THE EFFECTS OF AN AQUATICS EXERCISE PROGRAM ON SIT TO STAND MECHANICS, FLEXIBILITY, AND BALANCE IN A GROUP OF ARTHRITIC WOMEN

By

Nicole E. Szajcz

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ABSTRACT

Arthritis is one of the most common chronic illnesses. It is an inflammatory condition that causes pain and stiffness in the joints. It presently affects approximately four million Canadians. As this illness progresses, it deteriorates the cartilage of a joint causing major limitation in activities of daily living due to decreases in strength, flexibility, and balance. The sit to stand movement is one of the most essential motor skills performed in daily life. This study was an attempt to find ways to improve functional ability within the arthritis population. The two purposes of the study was to examine the effects of an aquatics program on the mechanics of the sit-to-stand movement and on flexibility, balance, strength, and agility in arthritic patients. The aquatic program was based on the Arthritis Foundation YMCA Aquatic Program (AFYAP). One video camera was used to film the sit-to-stand movement so that a two-dimensional analysis on the Peak 5 motion analysis system could be performed. Participants were tested performing the side bend flexibility test, sit and reach test, one foot balance (eyes open) test, functional reach test, three tandem stance tests, six-minute walk test, sit-to-stand and walk test, and the five-timed repetitive stand test. There were five variables of the sit-to-stand movement that significantly changed on the post test. There was a decrease in the linear velocity of the center of mass, a decrease in the total range of motion of the hip, a decrease in the angle of the trunk and an increase of the angle of the hip at chair clearance, and a decrease in the angle of the hip at standing. All of the other sit-to-stand variables did not change significantly. The results of the physical performance tests indicated that there was a significant decrease in the distance reached on the functional reach test, and the side bend flexibility test to the right side. All other physical performance tests did not change significantly. Overall, the aquatics program did not improve functional ability within the arthritic subjects. However, many subjects felt that the program did help with stiffness. The aquatics did not improve the sit-to-stand movement. Aquatics exercise should be used as a way for arthritic individuals to cope with pain and stay active. Further research into the use of aquatics exercise as a treatment of arthritis is needed.

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CHAPTER 1

INTRODUCTION

Arthritis is one of the most common chronic illnesses. It is an inflammatory condition that causes pain and stiffness in the joints. It presently affects approximately four million Canadians. In the province of Manitoba, arthritis affects 150,000 men, women, and children (Canadian Arthritis Society, 2000). In Canada, it is suggested that the occurrence of arthritis will increase by one million per decade until at least the year 2031. The rapid increase of arthritic people is equal to about 100,000 people per year, 8,000 per month, 2,000 per week, or 300 per day developing arthritis (Canadian Arthritis Society, 2000). With the elderly population living longer, it is important to determine ways to improve functional capacity, quality of life and independent living. The Canadian Arthritis Society (2000) suggests that the number of people 65 years or more will shift from about 12 percent of the population to about 22 percent over the next 40 years. With this enormous increase in older individuals, it is essential that society find ways to cope with arthritis to reduce strains on the health care system and allow individuals to live more independent lives.

There are over 100 different types of arthritis. Two of the most common types are osteoarthritis and rheumatoid arthritis. Approximately 2.7 million or 1/10 of all Canadians suffer from osteoarthritis and 293,000 or 1/100 suffer from rheumatoid arthritis (Canadian Arthritis Society, 2000). Osteoarthritis occurs when the cartilage that surrounds a joint wears away, especially weight-bearing areas such as the hips and knees (Priest, 1992). Figure 1-1 shows a side-by-side comparison of a healthy hip and an osteoarthritic hip. Note some of the differences in the arthritic hip such as bone spurs, rough cartilage and narrowing of the joint space. Rheumatoid arthritis is the inflammation of the tissue around joints such as knees, wrists, toes, and fingers (Priest, 1992). If arthritis is not taken care of, it can lead to disabilities in mobility and severe pain.

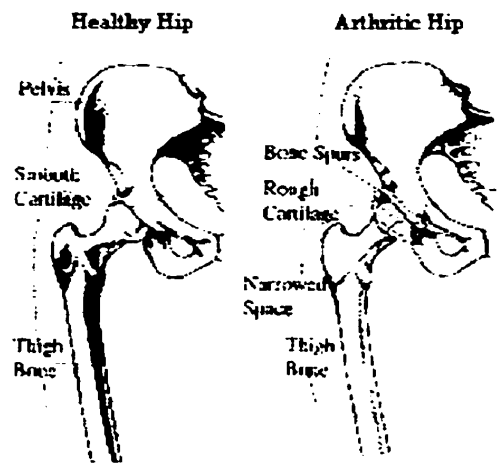

Figure 1-1. Comparison of a healthy hip to an osteoarthritic hip. (Phoenix Baptist Health and Arrowhead Community Hospital, 2000)

Moving from sitting to standing is one of the most essential motor skills that is performed in daily life. It is estimated that about 8% of people over the age of 65 that are not institutionalized have problems rising from chairs (Alexander, Schultz, & Warwick, 1991). Getting out of bed, rising from a chair, sitting in a bathtub, and using the toilet are examples of every day activities that involve the motion of sitting to standing. These activities are performed without leaving the home. Keeping this in mind, how can individuals survive in society living independently without being able to perform these daily physical functions?

A combination of four phases makes up the sit-to-stand movement (Millington, Myklebust, & Shambes, 1992). The movement begins in a sitting position, with the back against the chair. The flexion-momentum phase begins with the initial movement of the hips and trunk. The hips and trunk begin to flex causing the forward momentum of the upper body to increase. This forward momentum moves the center of mass more anterior in the body (Naumann, Ziv, & Rang, 1982). The momentum transfer phase begins when the buttocks leave the chair and continues until the forward momentum is transferred into forward and upward momentum. One of the most critical points of the sit-to-stand occurs during this stage and is called chair clearance. Chair clearance occurs at the instant the buttock leaves the chair and the body weight is no longer supported. The third phase, extension, starts as the knees begin to extend and ends when the trunk, hips, and knees are completely extended. Once the individual is in a standing position, the stabilization phase begins. During this phase, the anterior and posterior movements are balanced (Millington et al.,1992) primarily by the muscles of the legs and trunk. Performance of these four phases of a skillful sit-to-stand is directly related to muscle strength, flexibility and balance.

A study (Alexander et al., 1991) looking at the healthy, aging population found that muscle weakness and flexibility decreases are two of the major reasons for the susceptibility to seating problems. As individuals age, their muscle strength and flexibility decrease. This decrease in muscle strength impedes mobility and ease of rising from a chair. This causes individuals to become less active and consequently the decrease in muscle strength and flexibility continues. Elderly individuals who have arthritis are prone to similar standing up problems. In addition to that, they must deal with the pain, stiffness, and swelling of their deteriorating joints (Munton, Ellis, Chamberlain, & Wright, 1981). It has been estimated that forces on the knee are up to seven times the body weight when rising from a chair. These forces are extremely high for painful knee joints (Ellis, Seedhom, Amis, Dowson, & Wright, 1979).

Exercise has been documented in various studies as a way to improve physical function in individuals with arthritis (Anderson, 1996; DiNubile, 1997). Researchers have found that exercise such as walking programs, fitness classes, and flexibility and balance training are all beneficial (Ettinger & Afable, 1994; Kovar, et al., 1992; Minor, Hewett, Webel, Anderson, & Kay, 1989). However, forces during exercise on the lower extremities due to impact on the floor and muscles pulling across sore joints may actually cause more pain and inflammation in the joints of arthritis sufferers.

Current research has found that the most highly recommended type of exercise for arthritic individuals is aquatic programs (Danneskiold-Samsøe, Lyngberg, Risum, & Telling, 1987; Suomi & Lindauer, 1997). Unlike land-based exercise programs, the weight bearing impact is removed in aquatic programs due to the support of the water and body buoyancy. Water exercise allows the individuals to perform the same beneficial exercise, with much less pain. Specialized arthritis aquatics programs have been developed that focus on muscle strength, flexibility and balance. Programs are usually taught by a certified instructor in a heated pool in order to make the participants as comfortable as possible (AFYAP, 1996).

Purpose of the Study

The purpose of the study was to examine the effects of a 12-week aquatics program on the mechanics of sit-to-stand in arthritic patients. An additional purpose was to study the effects of a 12-week aquatics program on balance, flexibility, strength, and agility in arthritic patients. A subproblem was to examine the mechanics of the sit-to-stand in arthritic patients and compare the results to previous studies done on elderly, non-arthritic subjects.

Null Hypothesis

A 20-week aquatics program will not have an effect on the mechanics of the sit-to-stand. The 12-week aquatics program will not have an effect on balance, flexibility, strength, and agility. The mechanics of the sit-to-stand in arthritic patients will not be different from the sit-to-stand in healthy subjects of similar age reported in previous studies.

Rationale for the Study

As the incidence of arthritis increases, it is projected that approximately 6.5 million people will suffer from arthritis by the year 2031 (Canadian Arthritis Society,2000). Arthritis directly affects the joints of the body. Several studies (Messier, 1994; Messier, Loeser, Hoover, Semble, & Wise, 1992; Stauffer, Chao, & Györy, 1977) have been conducted on the effects of arthritis on walking gait and significant differences were found. Like walking gait, sit-to-stand is a core component of living independently. Activities such as using the bathroom, answering the door when sitting on the couch, and getting in and out of bed could be affected. Irregular mechanics of the sit-to-stand change the moments of the hip and knee joints (Fleckenstein, Kirby, & MacLeod, 1986; Rodosky, Andriacchi, & Andersson, 1989). This may cause an acceleration of the damage to these joints. This study will examine the mechanics of sit-to-stand in arthritic patients. It will also look at regular exercise as a medium to improve the mechanics of sit-to-stand. Improving the ease of sitting to standing will help individuals with arthritis live independently.

Limitations

1. All subjects were women therefore it is not possible to generalize the results to men.

2. Subjects were selected from persons who had memberships in the Wellness Institute at Seven Oaks General Hospital and volunteered to participate.

3. Chair height was not adjusted to fit each person; instead the same chair was used for everyone.

Delimitations

1. Attendance at the aquatics program, although mandatory, was not 100%.
2. Physical activity other than the aquatics program was not monitored.

Definition of Terms

Absolute Angle: The angular orientation of a body segment with respect to a fixed line of reference (Hall, 1995); for example the angle between a horizontal line and a limb segment.

Acceleration: The rate of change in velocity; it may be linear (change in linear velocity) measured in meters per second per second (m/s^2) or angular (change in angular velocity) measured in degrees per second per second (deg/s^2) (Hall,1995).

Arthro-opthalmopathy: A progressive genetic condition; deterioration and inflammation of the cartilage and connective tissue associated with the eyes and ears (less commonly in the bones and heart); as called Stickler Syndrome (Canadian Arthritis Society, 2000).

Center of Mass: The point around which the body's mass and weight are balanced in all directions (Hall, 1995).

Chondrocalcinosis: Chronic, recurrent attacks of pain and swelling in a single joint caused by the calcification of the cartilage; as called Pseudogout (Canadian Arthritis Society, 2000).

Concentric Contraction: The shortening of a muscle; muscle force is more than the resistance (Luttgens, Deutsch, & Hamilton, 1992).

Direct Linear Transformation (DLT): A method of transforming multiple two-dimensional views into three-dimensional data using a calibration tree (Peak Performance Technologies Inc., 1994).

Displacement: Change in position; it may be linear measured in meters (m) or angular measured in degrees or radians.

Eccentric Contraction: The contraction of a muscle during which the muscle lengthens and resists segmental motion (Kreighbaum & Barthels, 1990).

Knee to Heel Distance: Distance measured using the X-coordinates of joint position data from the heel and the knee; can be a positive or negative number.

Leighton Flexometer: A device for measuring range of motion; consists of a weighted needle attached to a 360° scale; when attached to a limb segment it measures angular displacement (Hall, 1995).

Moment: The turning effect produced when a force is exerted on a body or by a muscle that pivots about an axis; it is calculated by multiplying the moment arm by the force; usually measured in Newton meters (Nm) (Hay, 1993).

Moment Arm: The shortest, perpendicular distance between a force's line of action and an axis of rotation (Hall, 1995).

Momentum: It can be linear, where it is the product of mass (kg) and velocity (m/s); or it can be angular, where it is the product of the moment of inertia and angular velocity; It is a measure of the force needed to start and stop motion (Luttgens, et al., 1992).

Toe to Toe Distance: The distance between the tips of the toes; it is measured during phase 2, momentum transfer, of the sit-to-stand, the moment the buttock lifts off the chair.

Torque: The turning effect produced when a force is exerted on a body or by a muscle that pivots about an axis; it is calculated by multiplying the moment arm by the force; usually measured in Newton meters (Nm) (Hay, 1993).

Velocity: The rate of change in angular position; It may be linear (change in position) measured in meters per second (m/s) or angular (change in angle), measured in degrees per second (deg/s) (Luttgens et al., 1992).

CHAPTER 2

REVIEW OF LITERATURE

Introduction

This chapter will include a literature review of topics relevant to arthritis and the sit-to-stand movement as they relate to the present study. The review will contain (1) the anatomy of joints, (2) the definition of arthritis focusing on osteoarthritis and rheumatoid arthritis, (3) a kinematic description and mechanical analysis of the sit-to-stand movement including the phases of sitting to standing and muscle involvement, (4) a discussion on flexibility and methods of assessing flexibility, (5) a review on exercise and arthritis, (6) data analysis and (7) testing protocol.

The review on exercise and arthritis will discuss several studies that demonstrate the benefits of exercise. The main focus will be on aquatics exercise and the Arthritis Foundation YMCA Aquatics Program (AFYAP) due to the relevance in this study.

Anatomy of Joints

A joint is made up of two or more bones that are part of the body's skeleton. Joints can be fixed (e.g. sutures in the skull) or they can be movable (e.g. knee or hip). This review will focus on movable joints (AFYAP, 1996). Figure 2-1 shows the structure of a synovial joint.

The joint capsule surrounds joints, unites the articulating bones, and helps protect joints from dislocating. It is composed of two layers: the fibrous capsule and the synovial membrane. The fibrous capsule is the outside layer and is made up of irregular connective tissue. Irregular connective tissue consists mainly of collagen fibers, with a

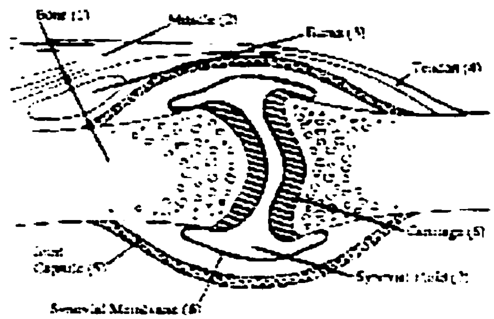

Figure 2-1. Structure of a joint (AFYAP, 1996).

few fibroblasts that are randomly arranged (Tortora, 1995). The fibrous capsule keeps the bones, articular cartilage, and synovial fluid connected. The synovial membrane is the inside layer of the joint capsule. It is composed of areolar connective tissue that has some elastic and reticular fibers and several kinds of cells such as fibroblasts, adipocytes, and macrophages. The synovial membrane secretes synovial fluid. Synovial fluid is used to lubricate joints and nourish the articular cartilage. The articular cartilage covers the articulating surface of the bones within a joint. The two main objectives of articular cartilage are: to spread the load of the joint over a wide area in order to lessen the stress at the contact point; and to decrease the friction and wear of the joint during movement (Moore & Dalley, 1999).

Several joints in the body contain specialized cartilage called fibrocartilage. It can be found in the knee and between the vertebrae. Fibrocartilage is the strongest type of cartilage and is found in the form of discs or partial discs. It is composed of chrondrocytes that are scattered within bundles of collagen fibers, which have been formed into a matrix (Tortora, 1995). The main roles of fibrocartilage are: to distribute loads of the surface, to improve the fit of oddly shaped articulating surfaces, to decrease the amount of translation between bones, and to protect, lubricate and absorb shock within the joint (Hall, 1995).

The joint capsule is aided by a number of structures. Ligaments are short, fibrous cords that are attached from bone to bone (AFYAP, 1996). They can be either extracapsular or intracapsular. Extracapsular ligaments lie outside of the joint capsule (e.g. collateral ligaments of the knee) and intracapsular ligaments are found within the joint capsule but outside of the synovial membrane (e.g. cruciate ligaments of the knee). Muscles and tendons surround the joints and assist with the movement of the joint depending on whether the fibers are lengthened or contracted (Moore & Dalley, 1999). These structures help protect the joint from abnormal movements.

The final structure that is shown in Figure 2-1 is the bursa. Bursa are located outside of the joint capsule and are not directly related to joints. The bursa actually is found at friction points for example between bones, muscle and tendons. It is a sac of synovial fluid and is used as a cushion to decrease the amount of wear on the muscles and tendons as they contact bone during movement (AFYAP, 1996).

Arthritis

It is estimated that approximately 4 million Canadians suffer from arthritis, with that number increasing everyday (Canadian Arthritis Society, 2000). Often in literature, rheumatism and arthritis are used interchangeably, however there is a difference between the two. Rheumatism is a general category that refers to ailments that cause pain to the supporting structures of the body such as bones, ligaments, muscles, tendons, and joints. Arthritis is a form of rheumatism that affects the joints (Lockshin, 1999). It is a general term that refers to over 100 different diseases. It is the inflammation of one or more joints that cause pain, stiffness, and swelling to the surrounding muscles and tissues. Over time arthritis becomes disabling due to its destructive nature. There is no known cure for arthritis (Tortora, 1995). The two most common types are osteoarthritis and rheumatoid arthritis. Figure 2-2 demonstrates the difference between a healthy joint, an osteoarthritic joint and a rheumatoid arthritic joint. Other examples of arthritis are juvenile rheumatoid arthritis, gout, and ankylosing spondylitis (Lockshin, 1999; Tortora, 1995).

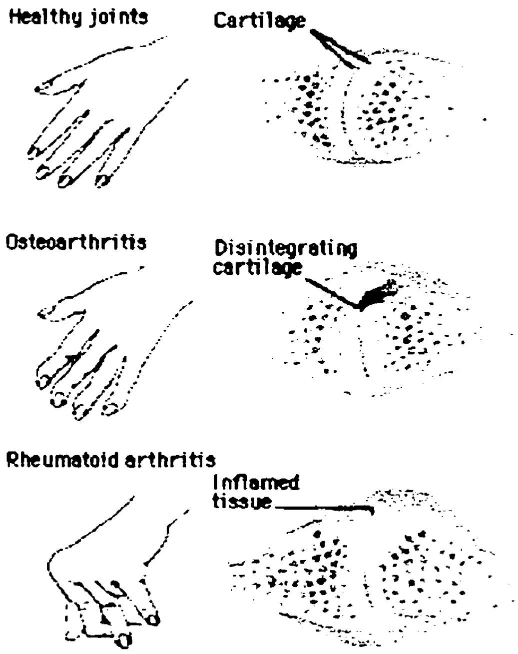

Figure 2-2. A comparison of a healthy, osteoarthritic, and rheumatoid arthritic joint (Lockshin, 1999).

Osteoarthritis

Osteoarthritis, the most common form of arthritis, occurs in people typically 60 years old or older and equally among the male and female population (Martin, 1994). It was formerly known as degenerative joint disease because it was primarily caused by the destruction of the articular cartilage in the body's joints (AFYAP, 1996). Osteoarthritis occurs apparently from the results of a combination of aging, joint irritation and wear and tear. Scientists have found that osteoarthritis has been linked to a particular gene, however other factors also affect whether a person is predisposed to developing the disease (Ross, 1997).

Osteoarthritis is a non-inflammatory, progressive disease that is characterized by the degeneration of the articular cartilage and subchrondral bone in a joint. As the cartilage wears away, new bone forms in its place in the form of bone spurs. These spurs reduce the space within the capsule and cause the joint to have restricted movement (Tortora, 1995). Figure 2-2 demonstrates the decrease in space of an osteoarthritic joint due to the decrease in articular cartilage and formation of spurs. It most often occurs in weight bearing joints such as the knees, hips and spine (AFYAP, 1996).

Rheumatoid Arthritis

Rheumatoid arthritis is another common form of arthritis. In general it most often strikes women between the ages of 20-40 but can also be found in men, children and the elderly (Lockshin, 1999). It is an autoimmune disease in which the body attacks its own cartilage and joint lining tissues. Symptoms of rheumatoid arthritis are swollen joints, severe pain, inflammation, low-grade fevers and reduced function of the joint. It commonly affects smaller joints in the hands and feet such as the proximal interphalangeal joints, and metacarpalphalangeal joint (Tortora, 1995). Over time rheumatoid arthritis begins to affect other, larger joints such as the elbows, knees and ankles. The cause of this particular type of arthritis is unknown, however it is believed that a genetic predisposition together with an environmental trigger plays a major role (Ross, 1997).

Rheumatoid arthritis begins with the inflammation of the synovial membrane. Over a period of time, the synovial fluid starts to thicken and nodules begin to form. Nodules attach to the articular cartilage surface of the bones and cause erosion. This erosion leaves the bone unprotected and new bone begins to build, until the joint becomes completely fused. Once the bone is fused, movement of the joint can no longer occur (Tortora, 1995). Figure 2-2 shows the crippling effects of rheumatoid arthritis. It normally develops bilaterally which means if the left wrist is afflicted, then the right wrist will also develop the disease (Ross, 1997).

Other Types of Arthritis

Osteoarthritis and rheumatoid arthritis are among the most common types of rheumatic diseases. There are a number of other types of rheumatic diseases that are less common but just as debilitating and are worth mentioning.

Juvenile rheumatoid arthritis is an autoimmune disease that affects children. The symptoms are similar to the adult version of rheumatoid arthritis, however most often it only affects a few joints and it does not normally continue throughout adult life. Some children are affected more severely, resembling the adult version. These children may not grow out of the disease (Tortora, 1995).

Gout is another type of arthritis found most often in middle aged males. It occurs in the form of attacks where the individuals may be affected for periods of time. Gout is caused by a build up of uric acid in the blood. The excess acid reacts with a form of salt and forms crystals. These crystals build up in the soft tissues and cause the irritation and deterioration of the articular cartilage. If left untreated, gout can cause the fusion and immobilization of a joint (Lockshin, 1999; Tortora, 1995).

Ankylosing spondylitis is an inflammatory disease that affects the fibrocartilage between the vertebra and the sacraliliac joint. It is normally found in males who are 20 to 40 years old. Symptoms of this disease are stiffness and pain in the lower back and hip region. Most individuals who suffer from this disease have a common rare blood type (Lockshin, 1999; Tortora, 1995).

Risk Factors for Osetoarthritis

There are a number of risk factors that increase the chances of developing arthritis. These factors can be separated into two different categories: controllable and uncontrollable. Controllable factors are ones that can be changed such as obesity and high intensity sports. Uncontrollable factors are ones that can not be changed such as congenital and developmental disorders, and genetics.

Obesity is a well-known risk factor for knee osteoarthritis. It is not known whether it is the cause or effect of osteoarthritis, although evidence suggests that obesity causes it (Oddis, 1996). As weight is gained, the forces on the lower extremities increase enormously. Experts believe that during walking, the forces on the knee are up to six times the body weight. Consequently, the amount of weight gained is multiplied by six and then added to the original forces on the knee (Martin, 1994). The force on the knee constantly increases as weight is gained. It causes deterioration of the cartilage in the knee from the pounding of the two bones, the femur and the tibia, together. As the cartilage gets more damaged, the joint becomes osteoarthritic (Ettinger & Afable, 1994).

Sport activities such as long distance running (hip and knee), baseball (shoulder and elbow), and football are demanding on the body. Repetitive stress and high force are put on the joints, which cause irreversible damage to the cartilage and other anatomical structures. It is notable that the risk of osteoarthritis is not increased by normal joint use (Oddis, 1996). Years of competing in sports may cause damage to the joints. Another factor is participating in a sport with an injury to a joint (normally competitive sports), which also increases the risk of developing osteoarthritis. Injury changes the mechanics of a joint, and this causes stress to anatomical structures which do not normally have those stresses. These stresses cause damage to the tissues of the joint, increasing the risk of osteoarthritis (Ettinger & Afable, 1994).

Genetics is an uncontrollable variable, which affects osteoarthritis. There are a number of types of arthritis, which have been linked by heredity for example Chrondrocalcinosis and Arthro-opthalmapathy. Chrondrocalcinosis (Pseudgout) is a recurring attacks of pain and swelling in a single joint caused by the calcification of the cartilage (Canadian Arthritis Society, 2000). Arthro-opthalmopathy (Stickler Syndrome) is a progressive genetic condition that causes the deterioration and inflammation of the cartilage and connective tissue associated with the eyes and ears (Canadian Arthritis Society, 2000). Although the genetics related to arthritis is not fully known, there have been studies that show links in three consecutive generations (Oddis, 1996). The cause of this particular strain of arthritis seems to have been a mutation of one amino acid for another.

The final risk factor (uncontrollable) is congenital and developmental disorders. A congenital and developmental disorder occurs when a joint does not form properly, or develops abnormally. Conditions such as hip dislocations and subluxation and acetabular dysplasia are examples of congenital disorders. They may cause unilateral arthritis in the joint involved. Congenital disorders usually cause premature osteoarthritis in girls and young women (Oddis, 1996).

Phases of Sit-to-stand

As people age their ability to perform physical functions changes. This is due to the natural aging process. When aging individuals become stricken with diseases and illnesses such as arthritis, their ability to live independently becomes threatened. The sit-to-stand movement has been analyzed by various researchers (Kotake et al., 1993; Kralj, Jaeger, & Munih, 1990; Millington et al., 1992; Naumann et al., 1982; Schenkman, Berger, Riley, Mann, & Hodge, 1990). These researchers have separated the movement into a number of phases.

Naumann et al. (1982) believed that the sit-to-stand could be separated into three phases. The first phase was flexion. During this phase the feet are planted on the floor and the spine, hips, knees, and ankles were flexed. The center of gravity shifted forward. The second phase, buttocks-off, began when the buttocks are lifted off the chair. The hips flex, the knees extend and the ankle dorsiflex as the center of gravity accelerated forward. Maximum shear and compressive forces at the knee are reached during this phase once the buttocks leave the chair. Extension is the final phase during which all the joints extend causing the center of gravity to shift backwards and upwards.

Kralj and associates (1990) used goniometers and force plates to study sitting down and standing up. They divided the movement of the sit-to-stand into four phases.

These phases were the initiation, seat unloading, seat off, and full knee extension. They described similar phases for sitting down.

Similar to Kralj and associates (1990), Millington et al. (1992) described three phases in rising from a chair. Phase one, weight shift, is characterized by the flexion of the trunk and pelvis, allowing the center of gravity to shift forward. Phase two, transition, involves the transition of the momentum from forward to upward. The third phase, lift, is the beginning of trunk extension and the continuation of knee extension.

There were six phases determined in a study by Kotake et al. (1993), however the first, seated in a chair, and final, stabilize in standing position, did not involve movements of the body, just stabilization. The second phase begins with flexion of the trunk. The buttocks leave the chair during this phase. The beginning of the third phase is marked by the hip joint achieving maximum flexion. The ankle joint achieving maximum dorsiflexion initiated stage four and stage five is standing. They felt that by splitting the sit-to-stand by distinct movements, it would be easier to recognize the different phases.

The phases that will be used to describe the sit-to-stand movement in this study were developed by Schenkman et al. (1990). Schenkman et al. (1990) used four phases to describe the sit-to-stand movement: flexion momentum, forward momentum, extension and stabilization. Figure 2-3 illustrates the four phases of the sit-to-stand with key events being pointed out.

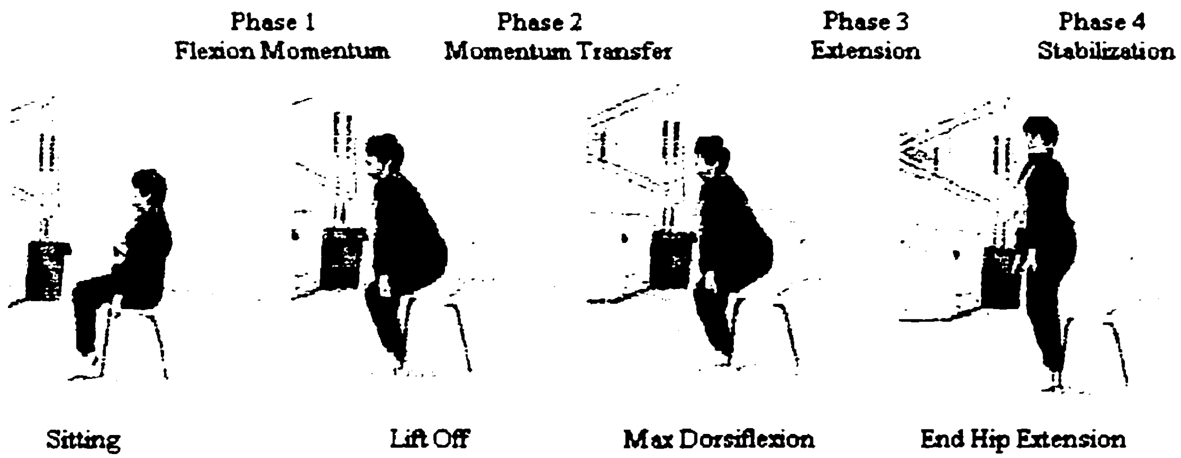

Figure 2-3. Four phases of the sit-to-stand movement.

Phase One - Flexion Momentum

The flexion momentum phase starts with the initiation of movement and ends just before the buttocks leave the chair. The momentum that will be described is angular momentum, which is calculated by the product of the moment of inertia and the angular velocity of the body. The moment of inertia is the body's tendency to resist acceleration and is calculated by the mass of the body multiplied by the distribution of that mass with respect to the axis of rotation (Hall, 1995). This phase is characterized by the trunk flexing and the pelvis rotating anteriorly (Schenkman et al., 1990). As these movements are occurring, the mass of the upper body and the velocity of the trunk flexion and pelvis movement generate the upper body momentum. The thighs, lower leg and feet do not move during this stage. The total body remains essentially stable throughout this movement because the center of gravity only changes slightly. The initial bony base of support is the ischial tuberosity and the posterior femur and the overlying tissues. These are the areas that are in contact with the chair. Maximum trunk flexion angular velocity, hip flexion angular velocity and neck extension angular velocity develop during the flexion momentum phase (Schenkman et al., 1990).

Muscles Active in Phase One

The main muscle groups that are involved with this phase are the erector spinae and hip flexors. The erector spinae (Figure 2-4) is the largest mass of muscle on the back. It is made up of three distinct groups: iliocostalis, longissimus, and spinalis

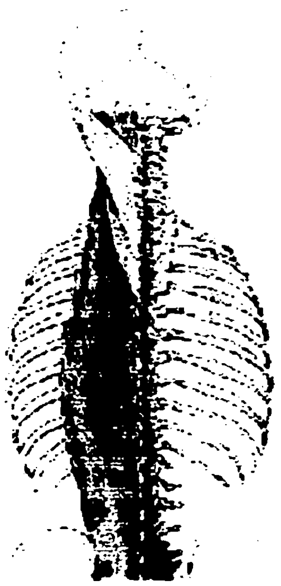

Figure 2-4. Erector spinae. (Riservati, 2000)

(Tortora, 1995). The iliocostalis group is located lateral to the other two groups. The three separate muscles of the iliocostalis (lumborum, thoracis, and cervicis) originate on the iliac crest, inferior six ribs, and the superior six ribs. They insert on the inferior six ribs, the superior six ribs and the transverse processes of the fourth to sixth cervical vertebrae (Moore & Dalley, 1999). The longissimus group is located between the iliocostalis and spinalis groups. The three muscles that belong to the longissimus group originate on the transverse processes of the lumbar vertebrae, fourth and fifth thoracic vertebrae, and the upper four thoracic vertebrae and articular processes of the last four cervical vertebrae. These muscles insert along the transverse processes of all thoracic and upper lumbar vertebrae and ninth and tenth ribs, the tranverse processes of the second to sixth cervical vertebrae, and the mastoid process of the temporal bone (Grays, 1991). The spinalis group is the most medially located group of the erector spinae muscle. The spinalis group also consists of three separate muscles: spinalis thoracis, spinalis cervicis, and spinalis capitus. The spinalis thoracis originates along the spinous processes of the upper lumbar and lower thoracic vertebrae and inserts along the spinous processes of the upper thoracic vertebrae. The spinalis cervicis originates along the ligamentum nuchae and the spinous process of the seventh cervical vertebrae and it inserts in the spinous process of the axis. The spinalis capitis arises and inserts in to the semispinalis capitis (Tortora, 1995).

The iliopsoas (Figure 2-5) consists of two separate muscles: psoas major and iliacus. The psoas major originates along the transverse processes and bodies of the

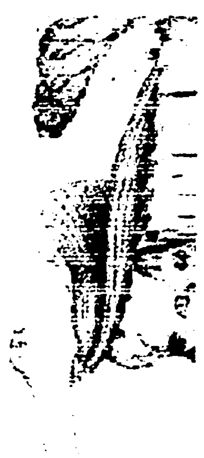

Figure 2-5. Iliopsoas. (Richardson, Teitz, & Graney, 2000)

lumbar vertebrae and inserts along the lesser trochanter of the femur. The iliacus originates along the iliac fossa and inserts into the tendon of the psoas major (Moore & Dalley, 1999).

The main action of the erector spinae is to extend the vertebral column. During the flexion momentum phase of the sit-to-stand, the erector spinae eccentrically contracts which controls the forward flexion of the trunk as gravity pulls forward. The abdominal muscles, rectus abdominis and the internal and external oblique, are only used to stabilize the trunk during the movement. This eccentric contraction allows the trunk to flex forward slowly. Both the erector spinae and the iliopsoas are used to achieve the anterior rotation of the pelvis. The erector spinae contracts causing the back of the pelvis to be pulled up. As this is happening, the iliopsoas pulls on the L1 –L5 causing hyperlordosis of the pelvis and anterior pelvic tilt. This results in a slight anterior rotation of the pelvis (Tortora, 1995).

Phase Two - Momentum Transfer

The momentum transfer phase starts directly after the flexion momentum stage ends at the point when the buttock leaves the chair. It ends when the ankle reaches maximal dorsiflexion (Schenkman et al., 1990). During this phase, the forward momentum of the upper body which was generated during the flexion momentum stage is changed into upward and forward momentum. Newton's Law of Conservation of Angular Momentum states that the total angular momentum of a rotating body remains constant unless acted upon by an outside (external) torque. Any change in momentum is equal to a torque applied over time, or angular impulse (Luttgens et al., 1992). To create upward and forward momentum during the sit-to-stand, from the forward momentum, an angular impulse must be applied. The impulse is generated by the strong concentric contraction of the hip extensors and knee extensors. This contraction also causes the lift off of the chair.

As the momentum of the upper body continues to move forward slightly and the feet become the only base of support, the center of gravity moves anteriorly. If the center of gravity remained further back, the individual would tend to be off balance, and fall backwards. Maximum moments of the hip and knee joints occur during the second phase (Schenkman et al., 1990).

Phase two develops by a sequence of events, starting with maximum hip flexion just after the buttocks leave the chair. Maximum trunk flexion during the sit-to-stand occurs at halfway through the momentum transfer phase and is followed by the maximum neck extension. Finally, maximum dorsiflexion is the last event of phase two (Schenkman et al., 1990).

Chair clearance, one of the major events of the sit-to-stand movement, happens at the beginning of the phase. It is the instant that the buttocks leave the chair and the feet are the sole base of support for the body weight. Several important measurements are calculated during this moment because the feet do not move after this point. Some useful measurements are toe to toe distance and knee to heel distance.

Muscles Active in Phase Two

During the momentum transfer phase, the erector spinae and the iliopsoas continue the action they were performing during the flexion momentum phase. The hip extensors concentrically contract to lift the buttocks off of the chair. The erector spinae eccentrically contracts until the trunk reaches maximal flexion. The iliopsoas continues to concentrically contract until maximum hip flexion (Tortora, 1995).

Neck extension is the result of the concentric contraction of the erector spinae. It is important in maintaining balance over the base of support because it keeps the center of gravity from moving too far anteriorly. If the center of gravity continued to move anteriorly the person would tend to fall forward (Moore & Dalley, 1999).

The hip extension is produced by two muscles, gluteus maximus and the hamstrings. Gluteus maximus (Figure 2-6) is the most powerful hip extensor. It

Figure 2-6. Gluteus maximus. (Richardson et al. 2000)

originates along the iliac crest, sacrum, coccyx, and the aponeurosis of the sacrospinalis. It inserts in the iliotibial band and lateral part of the linea aspera under the greater trochanter of the femur. The hamstring group (Figure 2-7) contains three muscles, biceps femoris, semitendinosus, and semimembranosus. Biceps femoris has two points of

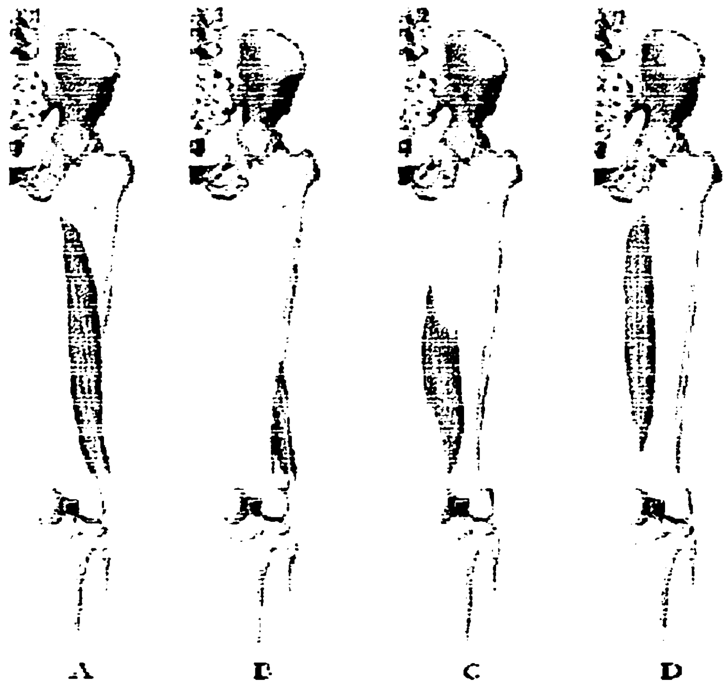

Figure 2-7. Hamstring. Picture A is the long head of the Biceps Femoris; Picture B is the short head of the Biceps Femoris; Picture C is the Semimembranosis; Picture D is the Semitendinosis. (Richardson, Tcitz, & Grancy, 2000)

origin, the long head originates from of the ischial tuberosity and the short head from the linea aspera of the femur. They both insert into the head of the fibula and lateral condyle of the tibia. Semitendinosus and semimembranosus both originate on the ischial tuberosity of the pelvis. However, semitendinosus inserts on the medial surface of the body of the tibia and semimembranosus inserts on the medial condyle of the tibia (Grays, 1991).

The final muscle group that is involved in the momentum transfer phase is the posterior compartment of the lower leg. The principal muscles that cause the ankle to dorsiflex are the gastrocnemius, soleus, and plantaris (Figure 2-8). These three muscles eccentrically contract allowing the ankle to dorsiflex. The gastrocnemius originates on the medial and lateral condyles of the femur and on the knee capsule. The soleus

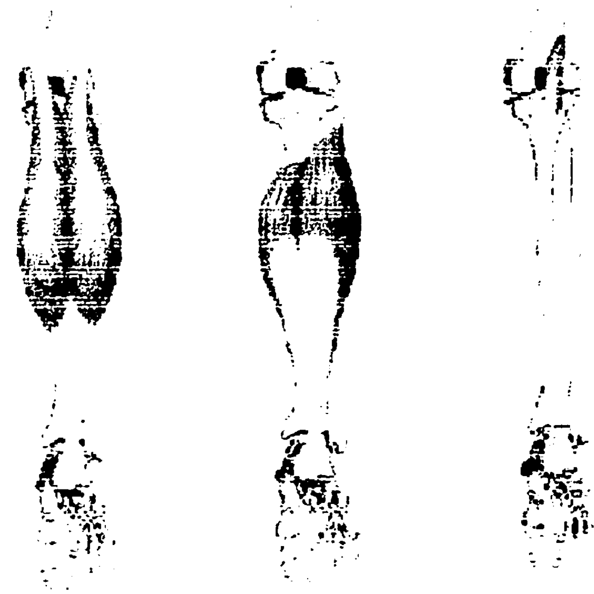

Figure 2-8. Picture A is the Gastrocnenius muscle; Picture B is the soleus muscle; Picture C is the plantaris muscle. (Richardson et al, 2000)

originates on the head of the fibula and the medial border of the tibia. The plantaris originates on the femur superior to the lateral condyle. All three of these muscles insert along the calcaneus via the Achilies tendon (Tortora, 1995).

Phase Three - Extension

The extension phase begins immediately after the point of maximal ankle dorsiflexion and continues until the first time the hips are completely extended. Complete hip extension is the point where the hip angular velocity equals 0 °/sec. During the extension phase the trunk extends, the hips extend, the knees extend, the ankles plantarflex, and the neck flexes. Trunk extension is the movement that occurs within the lumbar spine. Hip extension is the movement that occurs when the femur moves from a flexed position to a neutral position. The sequence of events is variable among individuals (Schenkman et al., 1990). Schenkman et al. (1990) found two common patterns among their subjects. The first pattern was that maximal knee extension occurred during the extension phase, which means prior to maximal hip extension. The maximal neck flexion did not occur until after the extension phase. The second pattern was that all three of the previously mentioned movements occurred during the extension phase. The order of the movements was maximal neck flexion, maximal knee extension and then maximal hip extension (Schenkman et al., 1990).

Muscles Active in Phase Three

The main movements during the extension phase are trunk extension, neck flexion, knee extension, and hip extension. The erector spinae concentrically contracts to extend the trunk. The hip extensor, gluteus maximus and the hamstrings continue to

Figure 2-9. Sternocleidomastoid. (Riservati. 2000)

concentrically contract. Neck flexion is produced by the sternocleidomastoid (SCM) (Figure 2-9). It originates along the sternum and clavicle and inserts along the mastoid process of the temporal bone. The SCM concentrically contracts bilaterally to cause the neck to flex into a neutral position (Moore & Dalley, 1999).

Knee extension is the result of the concentric contraction of the quadriceps. The quadriceps (Figure 2-9) muscle group consists of four separate muscles. The rectus femoris originates on the anterior inferior iliac spine of the pelvis. The vastus lateralis originates on the greater trochanter and linea aspera of the femur. The vastus medialis originates on the linea aspera of the femur. The vastus intermedius originates on the anterior and lateral surfaces of the body of the femur. All four muscles insert into the patellar tendon, which surrounds the patella anteriorly, and passes inferiorly to insert into the tibial tuberosity of the anterior tibia. (Tortora, 1995).

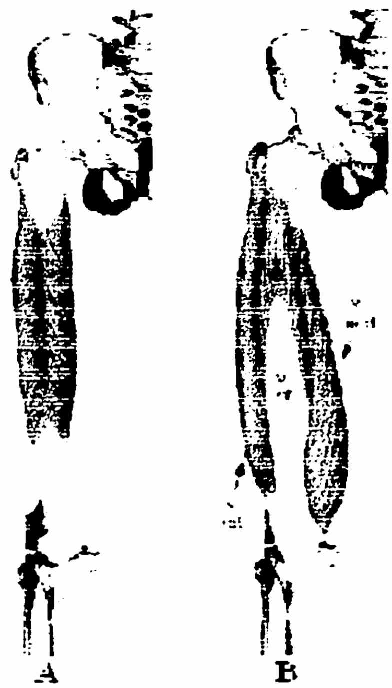

Figure 2-10. Picture A is the Rectus Femoris; Picture B is the Vastis lateralis, Vastis Intermediatis and Vastis Medialis. (Richardson et al. 2000)

The ankle returns to a neutral position by plantarflexing. Plantarflexion of the ankle is caused by the concentric contraction of the posterior superficial compartment of the lower leg. The three muscles in this group are the gastrocnemius, soleus, and plantaris (Grays, 1991), as described previously.

Phase Four – Stabilization

The final stage of the sit-to-stand movement is stabilization or upright standing position. Stabilization begins after maximal hip extension has occurred for the first time. It is the maintenance of the body in a standing position, with little movement. This phase was named stabilization because the main action of the muscles is to stabilize the body. Once the maximal hip extension occurs anterior and posterior movements or sway of the body occurs while standing (Schenkman et al., 1990). A number of muscles are used to stabilize the pelvis and trunk during this stage. The erector spinae and rectus abdominis and internal / external obliques work together to stabilize trunk sway. The quadriceps, hamstrings, and gluteus maximus stabilize hip movement. These muscles produce small contractions to stabilize the body from the force of swaying back and forth. This phase will not be examined in this study.

Maximum Joint Angles During the Sit-to-stand

The most important maximum joint angles during the sit-to-stand are the trunk flexion (movement within the lumbar spine), hip flexion (movement of the femoral head within the acetabulum), knee flexion, and ankle dorsiflexion. Two studies (Millington et al., 1992; Wheeler, Woodward, Ucovich, Perry, & Walker, 1985) reported measuring trunk flexion by using the trunk as one segment of the vector and using the thigh as the other segment. Millington et al. (1992) found that maximal trunk flexion range of motion in elderly individuals averaged about 84.9°. Wheeler et al. (1985) found the forward maximum trunk flexion averaged about 78.1° in elderly individuals and 75° in younger individuals. Nuzik, Lamb, VanSant, and Hirt (1986) measured the trunk flexion angle relative to the X-axis and found that maximum trunk flexion was 48.22°. Figure 2-11 demonstrates how these two different angles were measured. Another study by Ikeda, Schenkman, Riley, and Hodge (1991) found the trunk to pelvis angle was about 18.94° in

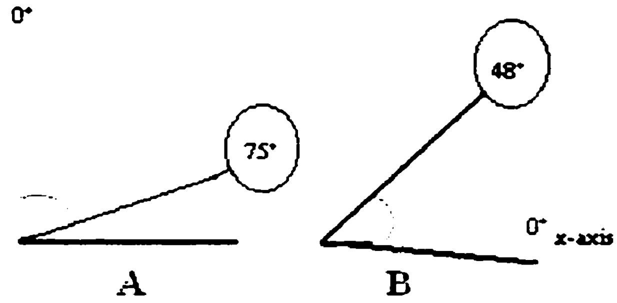

Figure 2-11 . Picture A demonstrates the angle that Millington et al. (1992) and Wheeler et al (1985), used to measure trunk range of motion. Picture B demonstrates the angle that Nuzik et al. (1986) used to measure trunk range of motion

young adults and 7.83° in older adults. The trunk to ground maximum angle was about 40.17° in young adults and 40.72° in older adults. It is difficult to compare these angles because they have not been measured the same method.

Maximum hip flexion is another important angle and in these studies (Ikeda et al., 1991; Naumann et al., 1982; Nuzik et al., 1986), it is measured the same as trunk flexion. Naumann et al. (1982) found that the maximum hip flexion angle was 110°. Figure 2-12 demonstrates the hip angle which was measured. Ikeda et al. (1991) measured maximum hip flexion in young adults to be 100.53° and in older adults to be 97.56°. Nuzik et al. (Nuzik et al., 1986) reported that maximum hip flexion was about 110.88° in normal adult studies suggest that maximum hip flexion is about 98 - 110° during the sit-to-stand. Figure 2-13 demonstrates the range of motion of the hip during the sit-to-stand. Maximum hip flexion occurs at the beginning of the phase 2 (Schenkman et al., 1990).

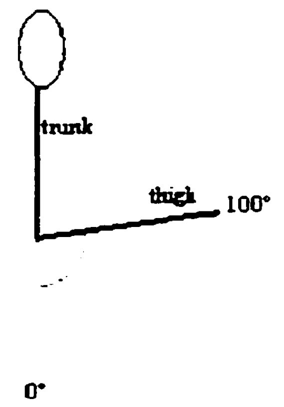

Figure 2-12. The hip angle that was measured.

The initiation of the forward, upper body thrust begins with increasing hip flexion. This movement causes the center of mass to shift forward, which creates an increase in the moment causing the hip to flex. This is the moment due to the body weight acting about the hip joint axis. As the hip flexing moment increases, the moment at the knee decreases. Therefore, with insufficient hip flexibility, the moment at the hip decreases and the moment at the knee increases (Rodosky et al., 1989). The increase in knee moment to compensate for the lack of hip flexion can cause acceleration in the deterioration of the knee joint in arthritic patients.

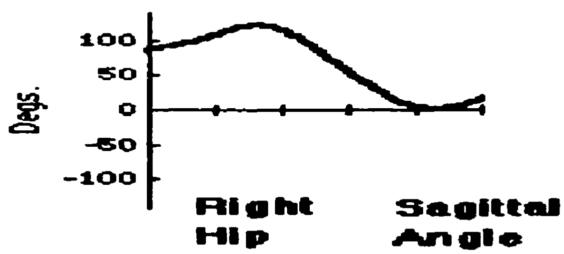

Figure 2-13. Graph of the range of motion of the hip during the sit-to-stand. Maximum hip flexion is at about 120°. (Kirtley, 2000)

Maximum knee flexion was reported by Naumann et al. (1982) to be 110°. This is the absolute angle with reference to the horizontal axis. Wheeler et al. (1985) found that maximum knee flexion was about 72.8° for older people and 75.5° for younger people. They measured the angle between the hip and knee segment and the knee and

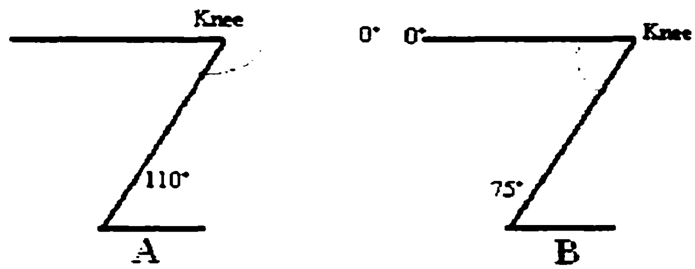

Figure 2-14 . Picture A demonstrates how Naumann et al. (1982) measured knee angle. Picture B demonstrates how Wheeler et al. (1985) and Millington et al. (1992) measured knee angle.

ankle segment. Measuring this same angle, Millington et al.'s (1992) study reported that maximum knee flexion occurred at 84.9°. To perform the sit-to-stand about 72-85° of knee flexion is needed. Figure 2-14 demonstrates how the knee angles were measured. Maximum knee flexion occurs at the beginning of phase one. Figure 2-15 is a graph of the range of motion of knee flexion. This graph uses the angle that is diagrammed in picture A in Figure 2-14.

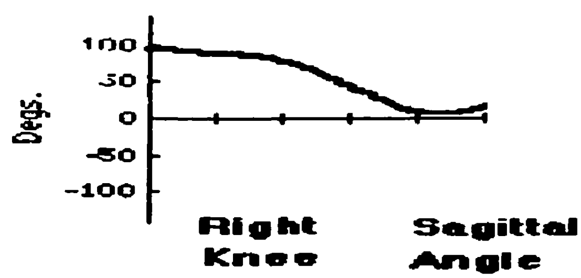

Figure 2-15. Graph of the range of motion of the knee during the sit-to-stand movement. (Kirtley, 2000)

Ankle dorsiflexion was not a common measurement. Two studies that measured maximal ankle dorsiflexion reported range of motion values between 27-30°. Ikeda et al.

(1991) found that young adults had more ankle dorsiflexion of 27.32° than older adults with 28.69°. Naumann et al. (1982) reported that maximal ankle dorsiflexion was 30°.

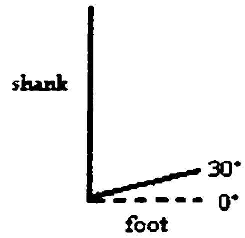

Figure 2-16. Demonstration of how the ankle range of motion was measured.

This suggests that ankle dorsiflexion of about 27-30° is needed in the sit-to-stand. Figure 2-16 demonstrates how the ankle angle was measured in the previously mentioned studies. Maximum dorsiflexion occurs at the end of phase 2 (Schenkman et al., 1990). The range of motion of the ankle during the sit-to-stand is shown in Figure 2-17.

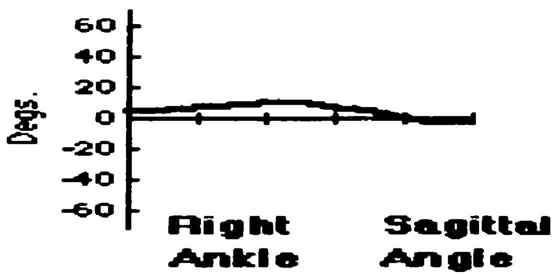

Figure 2-17. Graph of ankle range of motion. (Kirtley, 2000)

Ankle flexibility is very important in the sit-to-stand movement. As the chair clearance phase approaches, the ankles begin to dorsiflex and become maximally dorsiflexed at the point of chair clearance. If there is an insufficient amount of dorsiflexion, the forward momentum of the upper body will be restricted. The line of gravity will remain further back on the foot and this will create a problem transferring the momentum forward and upward. This momentum is needed to help lift the body upwards (Schenkman et al., 1990). Inadequate ankle flexibility will cause the individual to have the tendency to lean backwards as they try to stand up, possibly leading to a loss of balance.

Maximal angles are difficult to compare between studies because many studies do not describe in detail which angle they measured. It is the task of the researcher to attempt to determine which angle is being reported in other related studies.

Joint Angular Velocity during the Sit-to-stand

Two studies (Ikeda et al., 1991; Schenkman, O'Riley, & Pieper, 1996) will be used to compare the maximum angular velocities of trunk flexion, knee extension, and hip extension. Schenkman et al. (1996) found that maximum trunk flexion angular velocity occurred during Phase 1 of the sit-to-stand. It was calculated to be about 80 °/s when the chair height was set at 80% of knee to heel height (Schenkman et al., 1996). Ikeda et al. (1991) reported that maximal trunk flexion angular velocity was about 84.17 °/s in younger adults and 87.50 °/s in older adults. This study suggests that maximal trunk flexion angular velocity should be 80-88 °/s.

Schenkman et al. (1996) found that the maximal extension angular velocity of the knee should be about 160 °/s. This occurred during phase 3 of the sit-to-stand movement. Ikeda et al. (1991) found that younger adults had a maximal knee extension velocity of about 150.22 °/s and older adults had 156.50 °/s. Ideally, depending on chair height it has been found that maximal knee extension velocity is 150-160 °/s.

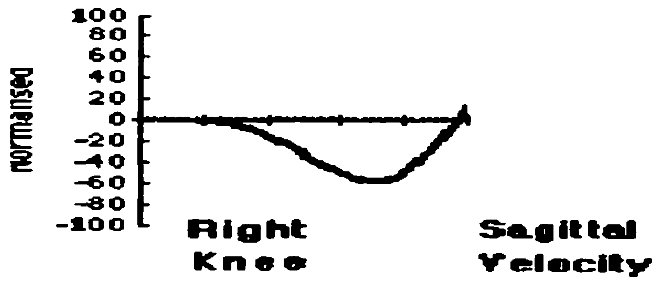

Figure 2-18. A graph of the angular velocity of knee extension. (Kirtley, 2000)

Figure 2-18 is a graph of the angular velocity of the knee during the sit-to-stand movement. The values that are reported in the graph have been normalised or transformed. This means that the data violated one or more of the assumptions required to carry out a parametric test, for example data must be normally distributed. If the data is not normally distributed (skewed), it can be transformed by using the logarithmic transformation. Logarithmic transformation uses the Log of x to transform the data. By transforming the data, it is measured on another scale without changing the placements of the data (Hassard, 1991). In this case, the graph used normalized values to change the scale to make it easier to view the path of the angular velocity.

At the beginning of the movement there is no extension of the knee therefore the velocity is zero. The angular velocity of the knee begins during the second phase. It continues to increase as the knee extends until about halfway through the third phase. Typically the knee extension is completed after hip extension is completed (Schenkman et al., 1990).

The maximal angular velocity of hip extension occurs between 155-175 °/s (Ikeda et al., 1991; Schenkman et al., 1996). Ikeda et al. (1991) reported that the younger adults had a maximal angular velocity of 161.94 °/s and the older adults had a maximum 155.50 °/s. Schenkman et al. (1996) stated that maximum hip extension was 175 °/s.

As the sit-to-stand is initiated, the angular velocity of hip flexion begins to increase. Hip flexion angular velocity peaks during phase one, about two thirds of the way through. The angular velocity decreases and reaches zero as the transition from flexion motion to extension motion. This occurs during the flexion momentum phase of the sit-to-stand. Maximum hip angular velocity occurs during phase 3 of the sit-to-stand. Normally it precedes maximum angular velocity of the knee extension. Figure 2-19 shows a graph of hip angular velocity. The graph uses normalized values. The maximum hip extension angular velocity is about three times the maximum hip flexion angular velocity.

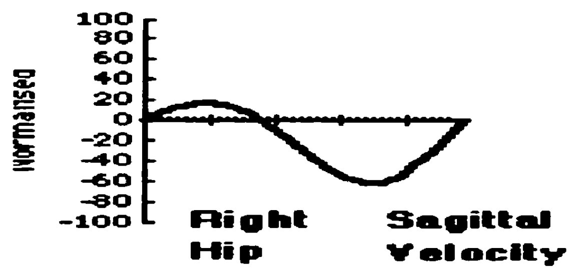

Figure 2-19. Graph of the angular velocity of the hip during the sit-to-stand. (Kirtley, 2000)

Ikeda et al. (1991) also reported the maximal angular velocities of hip flexion, neck extension, and neck flexion. Maximal angular velocity of hip flexion was 74.33 °/s in younger adults and 72.39 °/s in older adults. Maximal angular velocity of neck extension was 101.44 °/s in younger adults and 100.50°/s in older adults. Finally, maximal neck flexion angular velocity was 78.43 °/s in younger adults and 71.20 °/s in adults.

Moments during the Sit-to-stand

The moment (torque) about a joint can be calculated using Newton's second law of motion. It states that when motion is angular, the torque is the product of the mass moment of inertia and the angular acceleration of the segment being accelerated. Torque is also the product of the main muscle force accelerating a body part and the perpendicular distance of the force from the center of the joint. The most important moments that occur during the sit-to-stand movement are the hip and knee moments.

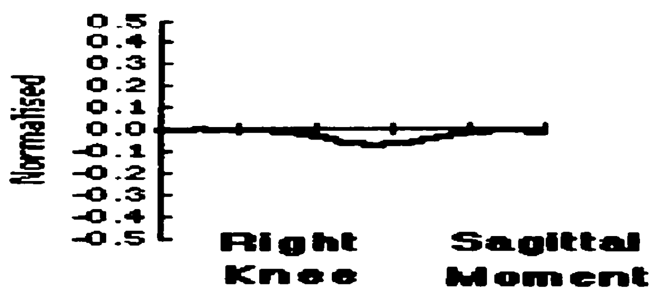

Figure 2-20. Graph of knee moment during the sit-to-stand. (Kirtley, 2000)

The moment at the knee becomes maximal during Phase 2 of the sit-to-stand. Figure 2-20 demonstrates the moment of the knee during the sit-to-stand. A positive value would be the result of a knee flexion moment and a negative value would be the result of a knee extension moment. The graph is measured in normalised units.

Knee extension begins at the end of Phase 1 at about the same time the buttocks are lifted off the chair. The knee extensors powerfully contract to help lift the buttock off the chair. As this contraction occurs, the angular acceleration of the knee joint increases. Knee extension moment is created by angular acceleration of the knee joint and mass of the upper body, arms, and upper legs. Maximal knee extension moment occurs about 2/3 of the way through Phase 2. From there it decreases until the knees are fully extended which happens during the Phase 3. Ikeda et al. (1991) found that young adults had a maximum knee torque of 19.17 Nm and older adults had a torque of 20.56 Nm.

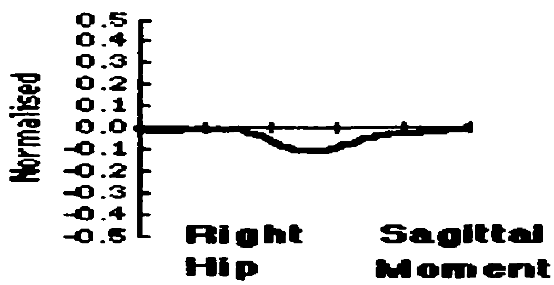

Figure 2-21. Graph of hip extension moment during the sit-to-stand. (Kirtley, 2000)

Peak hip extension moment occurs slightly before the peak knee extension moment during Phase 2 of the sit-to-stand. Figure 2-21 demonstrates the moment of hip extension during the sit-to-stand. The moment is reported in normalised values. Hip extension starts as a powerful contraction of the gluteus maximus and hamstrings to help lift the buttocks from the chair. The forward momentum changes into upward and forward momentum helping to increase the acceleration of the upper body and arms upward. The hip extension moment is created by the angular acceleration of the hip joint and mass of the upper body and arms. When the hip extensors powerfully contract during buttocks lift off, they cause an increase in the angular acceleration at the hip joint.

The maximum hip extension moment occurs just after buttock lift off. After the peak, the moment decreases until the hips are fully extended which occurs during Phase 3 of the sit-to-stand. Ikeda et al. (1991) found that maximum hip extension moment was 17.05 Nm for the young adults and 16.11 Nm for the old adults.

Knee range of motion directly affects the amount of torque that is applied to the hip during standing up. The less flexible the knees, the greater the amount of peak hip extension torque needed in order to stand up. Although the arms and upper body may often be thrown forward to help compensate, the hip joint is still stressed with the increase in torque (Fleckenstein et al., 1986). This accelerates the deterioration of the hip joint in patients with arthritis.

Chair Height

Chair height has been examined in several studies (Munro, Steele, Bashford, Hardy, & Britten, 1995; Rodosky et al., 1989; Schenkman & Riley, 1991; Weiner, Long, Hughes, Chandler, & Studenski, 1993). The mechanics of rising are altered when chair height changes because the body begins in a different position. Changing the chair height will affect the success of individuals with arthritis in the sit-to-stand movement.

Chair heights in the community have been found to be between 30-45 cm (Weiner et al., 1993). The average chair is about 42 cm high, with kitchen chairs generally being about 44 cm and living room chairs about 38 cm (Weiner et al., 1993). This study also found that as chair height rose from 43-56 cm, rising efforts decreased, and the number of successful rises nearly doubled. This indicates that higher chairs are easier for individuals. The following studies confirmed Weiner et al. (Weiner et al., 1993) findings and discussed reasons why this occurs.

Rodosky et al. (1989) looked at four chair heights set at 65, 80, 100, and 115% of the knee joint height. They studied the flexion-extension motion and moments at the hip, knee, and ankle while rising from the chair. The moments at the hip were found to change of about 12% between the four chair heights. The higher the chair, the smaller hip moment. The moments at the knee also changed significantly with the value nearly doubling from the highest chair to the lowest chair. They concluded that individuals with hip and knee problems should sit in high chairs and use armrests when rising because of the increase in moment on the knee joint. Moments at the ankle were found to be not affected in two studies (Burdett, Habasevich, Piscotta, & Simon, 1985; Rodosky *et al.*, 1989).

Schenkman and Riley (1991) found similar results with the added suggestion that decreasing chair height increases the difficulty in lifting the buttocks from the chair. A possible reason was that a greater forward momentum of the upper body was needed to overcome the decrease in chair height. They felt that the momentum of the upper body during the forward momentum phase was adjusted more than angular velocities at the hips and knees.

Due to the finding in the previously mentioned study, researchers developed a number of chairs such as the Eser Ejector chair that assist individuals in standing up. The Eser Ejector chair helps people rise by providing upward and forward forces to the body. These forces decrease the amount of upper body momentum needed to stand up (Munro et al., 1995). Munro et al. (1995) looked at height and the effects of the Eser Ejector chair on standing up. Similar to other studies, they found that seat height mainly affected the moment at the knee and the ranges of motion of the trunk and knee. The use of the Eser Ejector chair amplified the results of using a higher chair.

These studies suggest that higher chairs are easier to rise from. This is due to the decrease in moment at the knee joint, and the decrease in range of motion at the trunk and knee when rising from a higher chair.

Flexibility

Flexibility is the range of motion of a joint or series of joints in each plane of motion. It is divided into two categories: static flexibility and dynamic flexibility. Static flexibility is described as the range of motion a body segment can achieve when it is passively moved. Passive movement is when a tester moves a joint through its entire movement pattern. Dynamic flexibility is the range of motion through which a body segment can move while it is actively moving and is caused by muscle contraction. Static flexibility is a good indicator of relative tightness, and can help predict potential areas of injury. Flexibility tends to be joint specific, the range of motion of one joint can not be used as a predictor of another joint in the same person (Hall, 1995).

There are a number of structural and physiological factors that determine the flexibility of joints. The first and most important factor is the actual joint structure. The interfacing of the articulating surfaces within the joint can prevent excessive ranges of motion (Hubley-Kozey, 1991; Poole, 1993). For example, the humero ulnar joint (elbow) is restricted to flexion and extension in the sagittal plane with extension being limited by the olceranon process of the ulna and its groove (Hall, 1995).

The next factor in determining flexibility of a joint is the soft tissues that surround the joint. Muscle, tendons, fascia, ligaments, and skin all restrict the joint range of motion. When these tissues are not stretched on a regular basis, their extensibility decreases. Skin does not normally inhibit the range of motion of a joint unless there is some underlying problem such as disease. Ligaments and the joint capsule help stabilize a joint. The laxity of the ligaments and capsule should not be changed in order to increase flexibility (Hubley-Kozey, 1991). Research has found that looseness of ligaments in a particular joint have been correlated to an increase in injuries to that joint (Knapik, Jones, Bauman, & Harris, 1992). The soft tissue component that most affects the range of motion of a joint is the muscle tendon unit. These are the specific anatomical structures that are being stretched when training for flexibility. The ability of the muscle tendon structure to lengthen within the physical restriction of the joint is very important to flexibility (Hubley-Kozey, 1991).

The final factor that affects flexibility is tissue temperature. It has been found that tissue compliance is altered when it is exposed to different temperatures. The range of motion can be altered depending on whether the soft tissues are warm or cool. When special techniques were used to warm the muscle tendon unit they found an increase in flexibility (Hubley-Kozey, 1991). This suggests that when measuring range of motion of a joint it is important to warm-up and be in a room that is at normal room temperature.

Abnormal amounts of flexibility tend to increase the risk of injuries. People with extremely low levels of flexibility increase the chances of muscle, tendon and ligament tears if the joints go beyond the normal range of motion. If individuals have an excessive range of motion, their joints will tend to be lax. This will increase the occurrence of dislocating joints because of the decrease in stability. And finally, individuals who have unbalanced amounts of flexibility between their dominant and non-dominant sides of their body will also have an increased risk of injury (Knapik et al., 1992).

Methods of Measuring Flexibility

Over the years several procedures have been developed in an attempt to accurately measure flexibility. However, most of these procedures lack standardization of the following: uses of units of measurement, which angle was used (relative or absolute), amount of warm-up prior to testing, starting positions, whether the active or passive range of motion was measured, and external forces that were applied during passive movements. Flexibility can be measured using either indirect or direct methods (Poole, 1993).

Indirect Methods

Indirect methods of measuring flexibility most often involve the measurement of the linear distance between a segment and an external object, for example the back extension flexibility test. Individuals lie face down on a table with their hands placed behind their head and raise their chin as far off the table as possible. This test is scored by measuring the vertical distance between the chin and the table to the nearest centimeter (Poole, 1993). Though these tests are easy to administer, the results are difficult to interpret, due to the complexity of the movements involved. The movements are a combination of several joints, which make it hard to decide what exactly is being measured (Hubley-Kozey, 1991). Another limitation of indirect tests is that anthropometric proportions can greatly affect the results. This means that the result may not have been due only to the range of motion of a joint. For example, someone with extremely long arms may have a higher score on the sit and reach test than someone with short arms even though their trunk and hip flexibility is less. Subjects' results should not be compared for this reason. It is however, a good way to monitor flexibility over time within one subject (Poole, 1993). Two examples of indirect tests are the side bend flexibility test and the sit and reach. The procedures of administering these tests can be found in the methods section of this paper.

Direct Methods

Direct methods of assessing flexibility are performed by measuring the angular displacement between two adjacent segments or one segment and an external reference. The angular displacement is measured in degrees. Direct testing is a more valid method of measuring flexibility because the proportions of individuals do not affect it. It also results in a measurement of one specific joint, which allows you to compare the scores of many different subjects (Hubley-Kozey, 1991). Similar to indirect methods, within individual results can also be compared. There are several ways of calculating flexibility using direct methods such as the Leighton flexometer, goniometer, photography and videography, and radiography.

The Leighton flexometer (Figure 2-22) is the most reliable and accurate measurement of flexibility to date (Poole, 1993). It consists of a circular dial that rotates around an axis. The dial has a 360° scale marked on it and is weighted so that zero degrees opposes gravity when it is unlocked. There is also a needle that is weighted so that it also directly opposes gravity when unlocked. The flexometer can be strapped to any limb to get a measure of range of motion in a joint. The major limitation of the device is that the subject must move slowly through the range of motion or else the needle will sway back and forth and an accurate reading will be difficult (Poole, 1993).

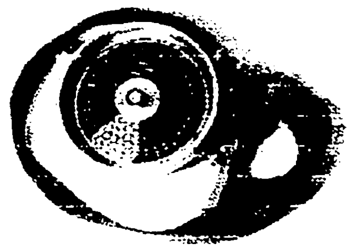

Figure 2-22. Leighton flexometer (Hubley-Kozey, 1991).

Bell and Hoshizaki (1981) used the Leighton flexometer to measure the range of motion of seventeen joints in males and females between the ages of 18 and 88. They used test retest to assess the reliability of the Leighton flexometer and found that the reliability coefficients ranged from r = .71 to .94. Only six of the seventeen joints tested had coefficients less than r = .88. They felt that these results were similar to other studies (Hupprich & Sigerseth, 1950; Leighton, 1942) that have used the Leighton flexometer and found coefficients of r = .89 to .99.

The goniometer (Figure 2-23) is a protractor-like device that has two arms attached to it that help identify the angle that will be measured (Hall, 1995). The point where the two arms intersect is aligned with the axis of the joint. The arms of the goniometer line up with the long axis of the bones of the limbs or segments that are involved. The goniometer has two major limitations. The first one is that it is difficult to locate the exact axis of the joint. This is especially difficult when there are more than two bones articulating within a joint. The second limitation is that it is difficult to keep the goniometer arms aligned with the bones of the limb throughout the range of motion (Poole, 1993). These limitations cause the results of tests measured with goniometers to be less reliable than other devices such as the Leighton Flexometer.

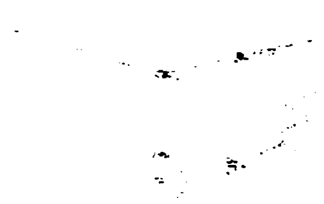

Figure 2-23. Goniometer (Hubley-Kozey, 1991).

Still photography and videography are techniques of measuring active range of motion. To perform still photography, a picture is taken and the static range of motion can be measured by marking the joint axis and drawing lines along the segments of the angle (Hubley-Kozey, 1991). Videography involves filming the individual while they perform the movement. Researchers can put the film on a monitor and pause it at the starting point of the range of motion. The joint axis and two arms of the vector are marked on a transparency. Then the film is forwarded to the end of the range of motion and the vectors are redrawn in the new position. These methods are good because they allow for a permanent record of the testing. The limitations are that the axis of the joint must be marked correctly and that the joint is only pictured in one plane. This means that care must be taken to prevent movements in the other planes that may change the results (Poole, 1993).

Flexibility in the Hip, Knee, and Ankle

Research has found that flexibility decreases with age (Bell & Hoshizaki, 1981; Roach & Miles, 1991; Sepic, Murray, Mollinger, Spurr, & Gardner, 1986) . This is mainly due to the change in fiber composition with increased hardening, or solidification in collagen fibers and the increase in the diameter of the fibers. These two characteristics reduce the extensibility of the fibers (ACSM, 1998). Maximum range of motion occurs at about the middle to late twenties in both males and females (Bell & Hoshizaki, 1981).

Hip Range of Motion

Hip movement occurs in the three different anatomical planes. In the sagittal plane hip flexion has been estimated to be approximately 140° and hip extension is approximately 15° (Nordin & Frankel, 1989). Data from a study by Roach and Miles (1991) reported that hip flexion in people between the ages of 25 and 39 was about 122° and that it was about 118° for people between the ages of 60 and 74. Hip extension was reported to be 22° for the younger group and 17° for the older group. The average amount of hip abduction is 30° and hip adduction is 25° (Nordin & Frankel, 1989). Roach and Miles (1991) found that their younger subjects (ages 25-39) had 44° of abduction and the older subjects (ages 60-74) had 39° of abduction. For the movements of hip internal rotation and external rotation the average amount of movement is 70° and 90° (Nordin & Frankel, 1989). Johnston and Smidt (2000) measured the active hip ranges of motions in normal daily activities. For example, to sit down, a maximum range of hip motion of 104° was needed in the sagittal plane, 20° in the frontal plane and 17° in the transverse plane. To tie a shoe with the foot on the floor, 124° is needed in the sagittal plane, 19° in the frontal plane and 15° in the transverse plane.

Knee Range of Motion

Knee movement occurs in the sagittal and transverse planes. The knee has about 140° of motion from full extension to full flexion. The movement in the transverse plane is maximal when the knee is flexed to 90°. In this position the knee can externally rotate to about 45° and internally rotate to about 30° (Nordin & Frankel, 1989). Roach and Miles (1991) found that the group of younger adults had 134° of knee flexion and the older adults had 131° while Bell and Hoshizaki (1981) reported values of about 130° for the younger adults and about 122° for the older adult group. In order to perform normal daily functions, Laubenthal, Smidt, and Kettelkamp (1972) found that the maximal amount of knee flexion was: 83° to climb stairs, 90° to descend stairs and 93° to sit.

Ankle Range of Motion

Plantarflexion and dorsiflexion occur at the talocrural joint. On average the movement of the ankle in the sagittal plane is about 45°. About 10-20° of this movement is dorsiflexion and about 25-35° of this is plantarflexion (Nordin & Frankel, 1989). Sepic et al. (1986) found that the range of motion for dorsiflexion in their study was 25° and for plantarflexion was 50°. Bell and Hoshizaki (1981) measured the total range of motion in the sagittal plane of the ankle to be about 65° in younger adults and 53° in older adults.

Arthritis and Exercise

Living independently is important in the elderly arthritic population. This makes it imperative that treatments for arthritis are found. These treatments should attempt to decrease the rate of the destruction of the joints and decrease pain and stiffness. To date, there are two recommended ways of treating arthritis: medication and exercise. Often medication is used to control the symptoms of arthritis such as swelling, inflammation, and pain of the joints. Medication does not help improve muscle strength, flexibility, balance, or the ability to live independently. To improve in these areas, in order to increase the quality of life of people with arthritis, exercise is the one of the best treatments (Canadian Arthritis Society, 2000). A number of studies (Ettinger et al., 1997; Fisher & Pendergast, 1994; Kovar et al., 1992) have examined the effects of exercise on arthritis.

Kovar et al. (1992) researched the effects of a supervised fitness walking program on knee osteoarthritis. The program was eight weeks long and involved 102 subjects. The six-minute walking test and the Arthritis Impact Measurement Scale were used to assess the subjects. The walking group increased the distance they walked in six minutes by 70m and they used less medication at the end of the study. The control group's distance decreased by 17m over the eight weeks and they had no change in their medication levels. These researchers concluded that arthritic individuals could participate in a walking program without worsening the pain or increasing the arthritis related symptoms of knee osteoarthritis.

Fisher and Pendergast (1994) studied 12 subjects over a three-month period of time. They were considering the effects of exercise on muscle strength and functional capacity in people with arthritis. Subjects participated in a one-hour physical therapy program developed specifically for each individual. After the hour of physical therapy, subjects participated in a half an hour to one-hour quantitative progressive exercise program. This program involved the subjects exercising on the same bench that they were tested on. Subjects performed knee extension and knee flexion exercises. They found that exercise improved the strength of their quadriceps by 29% and their hamstrings by 23%. The submaximal VO2 was significantly more and the systolic blood pressure was significantly less at the end of the three-month period. The researchers concluded that their exercise program improved muscle function, exercise capacity and functional performance. Finally, they felt that improving the muscle function caused increases in exercise capacity and aerobic fitness.

Ettinger et al. (1997) compared aerobic exercise, resistance training, and health education in 439 subjects with knee osteoarthritis. They found that the subjects in the aerobics group walked further on the six-minute walk test, and took less time to climb the stairs and perform the car task. The car task consisted of the time it took getting in and out of a simulated car. The resistance group also improved, but not as significantly, on all of those tests except the stair climbing. Both exercise groups reported that they had less pain than the health education group. They concluded that aerobic training and resistance training were effective ways of improving physical function in people with arthritis.

In conclusion, when people with arthritis participate in land-based exercise programs such as resistance training, walking, and exercise classes, improvements in muscle strength, aerobic capacity, physiological functions, and physical function have been reported.

Aquatics Exercise

Even though positive benefits have been seen in land exercise programs, they tend to cause pain, swelling and stiffness to the joints due to the impact of body weight on the deteriorating joints. In many cases the pain is so severe that individuals would rather not exercise. This creates a problem because besides medication, exercise is one of the most effective ways to treat arthritis (AFYAP, 1996). Research into methods for decreasing pain during exercise for arthritic patients has found that aquatics exercise programs are the most effective way to do so. Water provides a gravity reduced environment that, along with the buoyancy of the body helps support the body and reduces stress on the diseased joints (AFYAP, 1996; Levin, 1991). This allows individuals to participate in more activity without the pain. Aquatics exercise often decreases the pain and swelling in the joints (AFYAP, 1996; Levin, 1991; Templeton, Booth, & O'Kelly, 1996).

There are a number of studies (Danneskiold-Samsøe et al., 1987; Dial & Windsor, 1985; Simmons & Hansen, 1996; Templeton et al., 1996) that have evaluated aquatics programs as a treatment for arthritis. Templeton et al. (1996) studied the effects of an aquatics program on flexibility and functional status. Thirteen subjects with rheumatic diseases participated in an eight-week aquatic therapy program. A significant increase in range of motion was found in ankle dorsiflexion, hip abduction, shoulder flexion, and wrist extension. A decrease found in elbow extension was thought to have occurred due to a lack of exercises that worked on that particular movement. Subjects were also assessed by a functional status questionnaire. The results of the questionnaire found that subjects felt an overall improvement in their functional status and a decrease in pain and stiffness.

Danneskiold-Samsøe et al. (1987) tested the effects of an aquatics program on muscle strength and aerobic capacity in patients who suffer from rheumatoid arthritis. The program was eight weeks long and tested the isometric and isokinetic strength of the right knee extensors. They found that there was a 38% increase in the isometric strength of the knee extensors, the results being 88 Nm in the pretest to 121 Nm in the posttest. The isokinetic strength test resulted in significant increases at the lower angular velocities

(30 °/s and 60 °/s) and no difference at the higher angular velocities. Aerobic capacity was increased in all subjects.

Dial and Windsor (1985) found increases in the range of motion of the shoulder, elbow, wrist, hip and knee when their arthritic subjects participated in an eight-week water exercise program. They also found that improvements remained for at least one month after the posttest occurred.

There have not been many studies that tested the differences between land exercise and water exercise among people who have arthritis. Simmons and Hansen (1996) used a five-week aquatics program to compare land exercise, water exercise, water sitting and land sitting among arthritic subjects. The land-sitting group played cards in an activity room with supervised socialization. The water-sitting group sat in water and had supervised socialization. The land exercise and water exercise groups each participated in an exercise program (one on land and one in water). They used only one test, the functional reach test to compare the groups. The functional reach test measures dynamic balance in individuals. They found that over the five-week period, the water exercise group improved their distances the most out of the four groups. Land exercise came in second and water and land sitters were about even. After the programs, three participants in the water exercise class no longer needed to use walkers.

A study by Green (1993) involved a comparison of home exercise and hydrotherapy. The home exercises included five exercises that were designed to improve joint mobility and increase muscle power. The exercises worked on range of motion in hip flexion, extension, abduction, adduction, and rotation as well as some strength exercises for the hip. They found that daily exercise was a benefit, however it did not make any significant difference whether the person was in the home exercise group or the hydrotherapy group.

Arthritis Foundation YMCA Aquatic Program (AFYAP)

In an attempt to combat this disease and improve the quality of life in people with arthritis, the Arthritis Foundation created a specialized aquatics program for people with rheumatic diseases. The name of the program is Arthritis Foundation YMCA Aquatic Program (AFYAP). It is a recreational, warm water based program with the main goal of reducing pain and stiffness in joints, and increasing the range of motion of joints in individuals with arthritis. Certified AFYAP instructors teach the aquatic classes. Participants do not need to know how to swim to take part in the classes (AFYAP, 1996).

The recommended water temperature of the pool should be about 83-88 °F. Temperatures cooler than this may not allow participant's muscles and tissue to become warm enough to benefit from the exercise. Temperatures above this may be too high if the class is very active and could potentially cause cardiovascular problems (AFYAP, 1996).

There are a few guidelines that have been set in order to make the program as beneficial and comfortable as possible for the participants. Participants are encouraged to talk to their doctors prior to participating in the program. This is important because there may be some joints or exercises that their doctor might ask them to avoid. The exercises should be performed so that they do not harm the individual. The instructor should encourage participants to work at their own pace and to rest if they get tired. Classes should be about 30 to 60 minutes long and begin with a five-minute warm-up (AFYAP, 1996).

The AFYAP exercises are divided into 11 categories (A-K). Table 2-1 shows each category, what they focus on and sample exercises that would be performed.

Table 2-1. Summary of the Categories in the AFYAP program (AFYAP, 1996).

Category	Area	Sample Exercise
A	Walking	Walking Backwards, Marching
B	Breathing and Chest Expansion	Arms over Head, Deep Breaths
C	Neck	Chin Tuck
D	Trunk Stretching	Side Bend
E	Shoulder	Shoulder Shrugs
F	Elbow	Thumbs to Shoulder
G	Wrist and Finger	Palms Up/Down
H	Hip and Knee	Leg Swings, Squat
I	Ankle and Toes	Foot Circles
J	Lower Extremity and Abdominal	Bicycle
K	Games and Endurance	Hokey Pokey

A study by Suomi and Lindauer (1997) tested the effectiveness of the AFYAP program on muscle strength and range of motion in women with arthritis. The aquatic class was held over a six-week period, three times a week. Muscle strength was measured using isometric assessment on a specialized tester and ROM was measured using a 13-inch goniometer. They found that the exercise group had significant gains in muscle strength and ROM during hip abduction and adduction. There was no difference found between the exercise group and control group in muscle strength and ROM in shoulder abduction and adduction. They concluded that the AFYAP produced positive benefits in joints with arthritis, however the program may not be intense enough to increase muscle strength and ROM in joints that are not affected by arthritis. Suomi and Lindauer's (1997) study indicates that the AFYAP does indeed help achieve the goals it set out to do by decreasing pain and stiffness and increasing the range of motion of diseased joints.

Falls in the Elderly

Falling is the sixth leading cause of death and one of the major causes of institutionalization for older adults (Galindo-Ciocon, Ciocon, & Galindo, 1995). A study (Nevitt, Cummings, Kidd, & Black, 1989) looked at the risk factors for single and multiple falls and found that falling is twice as likely to occur in individuals who need help with daily activity, and persons with chronic conditions such as arthritis and Parkinson's disease. The incidence of falling also increases in individuals who use sedatives, have cognitive impairments, lower extremity disabilities, balance problems and abnormal gait patterns. Environmental factors such as tripping over objects, stairs, snow or ice also increase the incidence of falling. The reason arthritis is one of the major risk factors for falling is that if joints such as the hip and knee are affected, problems in gait patterns, and balance are affected (Tinetti, Speechley, & Ginter, 1988).

Tinetti et al. (1988) studied the risk factors for falls. Of 108 individuals who fell, they found that 76 were unsteady when sitting down, 61 could not stand on one leg, 77 were unsteady turning, and 75 became unsteady when a gentle push was given to the sternum. Unsteadiness was measured by standardized assessments of balance and gait. The following tests were used: standing from a chair, side by side standing with eyes open and closed, withstanding a nudge on the sternum, turning the neck, turning in place, standing on one leg, reaching up and bending over, and ability to walk faster. Each item was scored as normal or abnormal. Deficiencies in these patterns were associated with balance problems. Researchers also found that of 119 falls that occurred during mild activity, nine occurred when the subject was standing still, 13 occurred when the individual was performing activities of daily living, and 97 happened when walking.

Seventy-five falls were experienced when moderate activity was being performed; 39 when sitting down or getting up, 11 when bending over or reaching up, 20 when stepping down, and five stepping up. Only 12 falls occurred during activities such as climbing a ladder or playing a sport. This study suggests that most falls occur when performing normal daily physical functions.

Exercise, as discussed previously, is an effective treatment for arthritis with improvements in strength, range of motion, and balance. Numerous studies (Lord, Ward, Williams, & Strudwick, 1995; Shumway-Cook, Gruber, Baldwin, & Liao, 1997; Verfaillie, Nichols, Turkel, & Hovell, 1997) have found that exercise also decreases the risk of falling in individuals for these same reasons. Verfaille et al. (1997) found that resistance training with balance and gait training improved muscle strength, gait speed, and balance. They felt that this type of training would decrease the risk of falling in individuals. They also noted that resistance training alone did not improve balance and other gait parameters, and therefore would not decrease the risks of falling.

Shumway-Cook et al. (1997) performed a study on exercise and the risk of falling that confirmed the findings of Verfaillie et al. (1997). They tested the effects of a multidimensional exercise program on balance, mobility, and falls in older women. Significant improvements were found in the exercise groups in most of the tests. They also found that the exercise group who was more adherent reduced the risk of falling even more than the less adherent exercise group. Adherence was determined by percentage of classes the subjects attended. Fully adherent subjects attended the classes two times per week and exercised 5 to 7 days a week at home. Partially adherent subjects attended less than 75% of the classes and exercised less than 4 days per week at home. Home exercise was self-reported by the subjects.

However, not all studies have shown that exercise decreases the risk of falling. Lord et al. (1995) found that over a 12-month testing period, the exercise group and control group had similar percentages of individuals fall during the year. There was a difference in the type of falls that each group reported, however. A greater number of falls in the control group tended to be caused by a loss of balance or their legs giving way.

The incidence of falling increases in people with arthritis (Shumway-Cook et al., 1997; Tinetti et al., 1988; Verfaillie et al., 1997) due to lower muscle strength, range of motion, balance, and gait problems. It is important for people with arthritis to exercise because it decreases arthritic symptoms, increases strength and range of motion and decreases the risk of falling.

Video Analysis

As technology advances, new more accurate methods of analyzing skills have become available. Prior to the use of cinematography, biomechanical analysis of movement skills was performed by the naked eye. The naked eye records much less detail and can not be replayed in slow motion, reviewed, or freeze-framed. In the early 1980's, the most common method of movement analysis was high-speed film analysis. The high speed camera is capable of filming at rates of 1000 Hz or 1000 frames per second or more. It has some disadvantages however such as time and cost to process the film and the amount of time it takes to manually digitize the film. Another problem with filming is that 16 mm film is becoming more difficult to find in stores due to lack of use, cost of film, and cost of processing film.

More recently, researchers in movement analysis (Abraham, 1987; Angulo & Dapena, 1992; Kennedy, Wright, & Smith, 1989) have been using videotape analysis. A typical video camera films at a rate of 30 Hz or 30 frames per second. Cameras are available that film at higher frequency such as 200-300 Hz, however cost becomes a factor both in the camera price and the equipment that is needed to view the tape. Some advantages to video camera use are that the images are available immediately (little processing of the video is necessary), tapes are inexpensive and readily available, and cameras are easy to use. Abraham (1987) found that the resolution of video film was acceptable however it was limited to the number of pixels on the video monitor. Pixels are the very small divisions or elements that make up a picture on a visual display unit such as a video monitor. Most manual digitization studies use video monitors that have 512 x 512 pixels (Peak Performance Technologies Inc., 1994). The primary shortcoming of the standard video camera is that it only films at 30 frames per second. The video analysis software enhances the film to 60 frames per second. However, very fast movements are often not completely captured on the tape (Peak Performance Technologies Inc., 1994).

One of the first sit-to-stand studies (Jones, Hanson, Miller, & Bossom, 1963) was performed in 1963. Still photographs and photographs of moving subjects were used to examine the movement. The movement photographs were taken at a rate of 10 frames per second. Many studies on sit-to-stand mechanics now use the video taping methods to analysis the movement. Three studies (Carr, 1992; Hughes, Myers, & Schenkman, 1996; Lundin, Jahnigen, & Grabiner, 1999) used the technique of motion analysis that will be used in the present study. Studies (Ellis, Seedhom, & Wright, 1984; Pai & Rogers, 1990; Rodosky et al., 1989) that used high speed video cameras with capabilities of taping at up to 500 frames per second, found that 75-100 frames per second was the optimal taping speed of the sit-to-stand movement. For a slow movement such as the sit-to-stand, 60 frames per second will be adequate for accurate description of the kinematics.

Video taping methods have been shown to have a decrease in accuracy compared to the high speed filming methods. Angulo & Dapena (1992) found that error values for video methods were 11 mm, while they were 4 mm for filming methods. Kennedy et al. (1989) found the error values to be 5.8 mm for the video method and 4.8 mm for the filming method. This difference of 1 mm was found to be statistically different. However they concluded that the two methods were comparable in accuracy since the errors of the caliberated fields were only about .05% different.

Data Smoothing

Once the film data has been digitized, it is smoothed. Data smoothing is used to filter random amplitude noise that occurs at a constant frequency during digitizing. The preferred data smoothing technique for the sit-to-stand movement is the Butterworth filter. The Butterworth filter is a 4^{th} Order Zero Lag digital filter. This filter will be used because it is a good all-purpose filter used to filter out digitizing errors (Peak Performance Technologies Inc., 1994). A number of other studies (Carr, 1992; Hughes et al., 1996; Lundin et al., 1999) have used the Butterworth filter when studying the mechanics of the sit-to-stand. The cut off levels used in these studies ranged from 4 Hz to 6 Hz. Filtering the data gets rid of artifacts or unwanted signals and allows the analysis to be more accurate (Peak Performance Technologies Inc., 1994).

The Butterworth filter is a bandpass filter that passes some range of frequencies without distortion and suppresses all other frequencies. It makes forward and backward recursive passes through the data. Butterworth filtering is controlled by a filter parameter that is a cut off frequency. A frequency of 0 Hz means no filtering is done. As the frequency increases, less filtering is done (Peak Performance Technologies Inc., 1994). For example, a frequency of 2 Hz would result in more information being filtered out than a frequency of 7 Hz.

Physical Performance Testing

Sit and Reach

The sit and reach tests flexibility of the lower back and hamstrings. This test is measured on the floor or bench using a special apparatus that has a ruler that protrudes towards the subject. The subject places their feet against the apparatus, puts one hand on top of the other hand, and bends forward at the waist sliding the distance marker up the ruler. The tester makes sure that the subject's knees remain against the floor. Bravo et al. (1994) used a test retest to assess the reliability of the sit and reach test on elderly women. They found that the correlation coefficient was $r = 0.934$, meaning that they found the test to be very reliable. Shaulis, Golding and Tandy (1994) also tested the reliability of the sit and reach on older women and found similar results with the correlation coefficient to be $r = 0.979$. They found the correlation coefficient for older men to be very similar to women with $r = 0.970$.

Bravo et al. (1994) and Shaulis et al. (1994) found that the average scores of elderly women between the ages of 50 -70 was between 23.22 and 24.8 cm on the sit and reach test.

One Foot Balance

The one foot balance tests static balance. This test can be performed with eyes open or closed. This study will use eyes open because it is difficult for older, arthritic subjects to obtain a score on the test with their eyes closed. The subject stands with the non-dominant leg elevated, lower leg parallel with the floor and not touching the standing leg. Nevitt et al. (1989) tested the reliability of the one foot balance test on elderly subjects and found correlation coefficients of $r = 0.89$ to 0.96.

Hoeppner and Rimmer (2000) used the one foot balance with eyes open to test a control group and an exercise group of older adults. They found that the exercise group could balance for a average of 21.0 seconds and the control group for 7.0 seconds. This difference between the groups was significant.

Functional Reach Test

The functional reach test is a dynamic balance test. This test consists of an individual reaching forward with their dominant arm as far as possible (Duncan, Weiner, Chandler, & Studenski, 1990). The horizontal distance the hand moves is the score on the test. The individuals can reach using any technique as long as their feet do not move during the test. The inability to perform well on this test directly relates to daily life because individuals with low scores will not be as balanced as those who reach farther. Duncan et al. (1990) performed a test retest of the functional reach test and found that the correlation coefficient was r = 0.81. They concluded that the functional reach test is reliable. They also found that when they tested the functional reach as a measure of the margin of stability that there was a correlation coefficient of r = 0.71. This suggests that the functional reach test reflects the margin of stability, however, it is not a direct method of measurement. Clinically this test does measure characteristics that can be compared to the margin of stability (Duncan et al., 1990).

The functional reach was one of the tests Hoeppner and Rimmer (2000) used to assess the level of balance in self reported exercisers and non exercisers, who were between the ages of 65 and 95. They found that exercisers had significantly higher scores on the test with a mean value of 28.96 cm compared to the non exercisers who had scores of 21.34 cm.

Three Tandem Stance Test

The three tandem stance is a progressive static balance test (Verfaillie et al., 1997). There are three different foot positions that individuals must balance on for ten seconds each. The first position is the parallel stance where the feet are side by side with the toes lined up. The second position is the semi-tandem stance where the heel of one foot is lined up with the medial arch of the other foot. The final position is the tandem stance, where the heel of one foot is directly in front of the toes of the other foot. Each of the stances must be held for ten seconds, in order to progress to the next level. If the individual can not balance for the ten seconds, the test ends at that stage (Ostir, Markides, Black, & Goodwin, 1998). Nevitt et al. (1989) reported that in a test retest study of the tandem stance that the correlation coefficient was r = 0.71. This study demonstrates that the three tandem stance test is a fairly reliable test.

Binder, Brown, Craft, Schechtman, and Birge (1994) used the three tandem stance as one of the tests to examine the effects of a group exercise program on frail older adults. They found that the score significantly increased after an eight-week exercise program. This suggests that the participant's static balance may have increased due to the exercise program.

Six-Minute Walk

The six-minute walk is a test of cardiovascular capacity. During this test, individuals walk for six minutes and their distance is recorded. Guyatt et al. (1985) used the six minute walk to test if it was a useful method of measuring functional exercise capacity. They also studied whether this test was a suitable measure of outcome for patients with chronic heart failure. The test was administered six times over a 12 week period. They found that the test was highly acceptable to the patients, and produced stable results that were reproducible after the first two walks. They concluded that the six-minute walk was a good test to measure capacity in patients with chronic heart failure (Guyatt et al., 1985)

Arthritis studies (Ettinger et al., 1997; Kovar et *al*., 1992) have also used the six-minute walk to measure exercise capacity. Kovar et al. (1992) assessed the effects of supervised walking program on patients with osteoarthritis. The distance walked significantly increased in the walking group after the eight week walking program. The control group's distance decreased by 17 m. Another study (Ettinger et al., 1997) that compared aerobic exercise, resistance exercise, and health education also used the six-minute walk test.

Sit-to-stand and Walk Test

The sit-to-stand and walk test is used to assess agility in individuals (Bravo et al., 1994; Shaulis et al., 1994). Agility is the ability of the body or body parts to change direction quickly (Baumgartner & Jackson, 1995). The participant rises from a chair, walks around a pylon placed 3 meters (10 feet) to the right of the chair, and returns to the chair and sits down. This repeated for a pylon on the left. The stopwatch is stopped when the participants returns to the chair and is completely sitting (Bravo et al., 1994). Shaulis et al. (1994) tested the reliability of the sit-to-stand and walk by performing a test retest. They calculated the correlation coefficient to be $r = 0.959$. Bravo et al. (1994) found a similar correlation coefficient of $r = 0.859$, about 0.05 lower than Shaulis et al. (1994). Both experiments found that the sit-to-stand and walk test is reliable.

Five Timed Repetitive Stand

The five timed repetitive stand test is a measure of lower extremity strength. It is a field test that requires minimal instrumentation (stopwatch and an armless chair) (Bohannon, 1995). The participant begins in a sitting position and stands up five times as fast as possible. A variation to this test has the participant standing up ten times. A study by Newcomer, Krug, and Mahowald (1993) investigated the validity and reliability of the timed stand test on patients with rheumatoid arthritis. They found using a test retest experimental design in 16 stable patients that the correlation coefficient was $r = 0.882$. This value indicates that the experiment had a high degree of test retest reliability. To test the validity of the repetitive timed stand test, Newcomer et al. (1993) tested a control group and a rheumatoid arthritic group. They found that the presence of rheumatoid arthritis significantly affected the results on the timed stand test, with the time it took to perform the test increasing. Therefore, this test is both a reliable and valid measure of lower extremity strength.

Binder et al. (1994) used the timed stand test on a group of frail older adults who participated in a group exercise program. They found that participating in an eight week exercise program decreased the time it took the subjects to stand up five times by 27.4%.

CHAPTER 3
METHODS

Experimental Design

The research project consisted of eight steps beginning with subject recruitment for an arthritis exercise class by posters and word of mouth. Potential subjects members of the Wellness Institute and were screened over the phone. All subjects had a physical exam administered by the Wellness Institute and completed the pre test. The pre test consisted of a test battery that evaluated sit-to-stand mechanics, flexibility, balance, cardiovascular fitness, agility, and muscle strength. The group participated in a 20-week water exercise program.

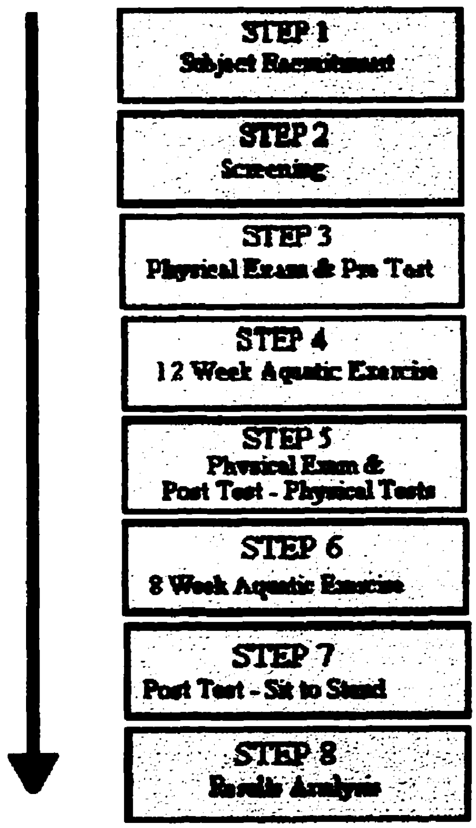

Figure 3-1. Flow chart of experimental design.

After 12 weeks, there was another physical exam of all of the subjects as well as the post test of the physical tests. The subjects participated in an additional eight weeks of the aquatics program after which the post test of the sit-to-stand mechanics was filmed. Originally the study was designed for a 12-week program, after which the physical performance data and sit-to-stand filming would be collected. However the film was damaged so a second film had to be taken eight weeks later. The results were then analyzed. Figure 3-1 summarizes the revised experimental design.

The design of the experiment was a within subject design, involving a comparison of the individual subject's score on the pre test and post test to see if there was any improvement or regression in the scores. The data were compared to see if the aquatics program produced any difference between the pre and the post test scores.

Subjects

The study involved a group of 19 females who have arthritis. Subjects were between the ages of 35 and 83 years old. They were members of the Wellness Institute at the Seven Oaks General Hospital and were recruited by posters located throughout the building and word of mouth. Subjects were cleared to participate in physical activity by their screening physical exam administered by the Wellness Institute. The group was limited to 19 subjects because the heated pool at the Wellness Institute accommodates only 18 subjects at one time. A small buffer of one person was allowed because all subjects did not attend every day and some subjects dropped out.

The investigator contacted each of the subjects one week prior to the first testing session. Consent forms and written descriptions of the testing procedure were given to the subjects (Appendix A) during a preliminary pool session. Included on the consent form was a description of the testing procedures, a confidentiality guarantee and note that the subjects could leave the study whenever they chose.

Height, weight and age of the subjects was measured at each of the two testing sessions. Body Mass Index (BMI) was calculated using the height and weight data, to compare body composition of the subjects to the norms of the general population.

Testing Procedure

All members of the Wellness Institute have a pre-activity screening. This screening consisted of a submaximal treadmill test, a sit and reach test, blood pressure, and medical history. This occurs before they are allowed to participate in any programs. This prevented us from having to administer any further screening procedures.

The pre and post tests were done at the Wellness Institute prior to the water exercise program. This location was chosen because it was convenient for the participants and it provided adequate space for the testing set up. All tests were administered by trained research assistants. The test results were recorded on data sheets (Appendix B) and then input into a computer. The calculated variables from the motion analysis system were also recorded on a data sheet (Appendix B).

Aquatics Program

The group participated in a 12-week aquatics program that began on September 19, 2000 at the Wellness Institute. The classes were 45 minutes in length, two days a week on Tuesdays and Thursdays from 12:00 PM to 12:45 PM. The program was based on the Arthritis Foundation YMCA Aquatics Program (AFYAP) (AFYAP, 1996). Subjects were requested to attend the program both days for the 20 weeks and attendance was recorded.

Two AFYAP certified instructors taught the aquatics class on alternating days one teaching the Tuesday class and one the Thursday class. The classes began with five-minute warm-up, followed by about 35 minutes of work out and a five-minute cool down period. The warm-up consisted of movements such as walking forward, walking backwards, marching, and side stepping (AFYAP, 1996). The warm-up allowed the muscles and joint tissues to increase their temperature progressively, decreasing the susceptibility to injuries such as strains and tissue tears (Luttgens et al., 1992) and reducing the sudden stress on the cardiovascular system. Figure 3-2 shows some sample warm up exercises.

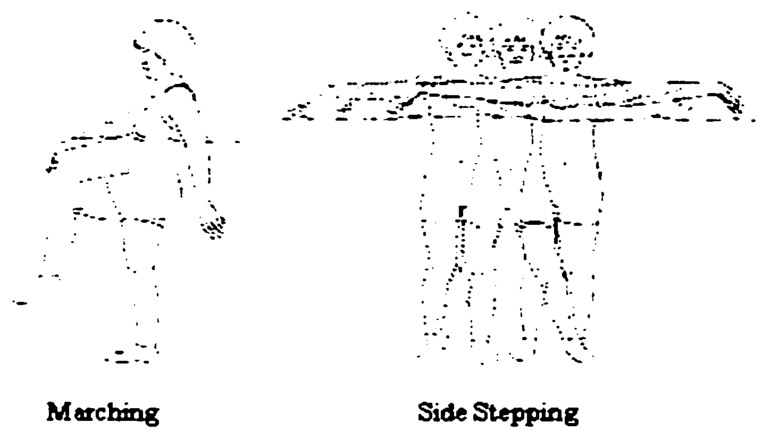

Figure 3-2. Warm up exercises (AFYAP, 1996).

The work out component helped increase or maintain muscle strength and functional endurance. It contained exercises from nine compulsory and two optional categories. The first category was walking. Exercises included in this category were walking backwards and marching. The second category was breathing and chest expansion exercises. It included movements with the arms overhead and hands behind head with the emphasis on taking deep breaths and exhaling slowly. The neck exercise category included movements such as chin tucks, looking over the shoulder, and head to shoulder. Trunk stretching consisted of movements such as side bending and hip rolls. Shoulder exercises had five sub categories (scapula, flexion/extension, abduction/adduction, internal/external rotation, and combined motions) and incorporated exercises such as shoulder shrugs, hug and pat back, shoulder circles, raise arms to water level, and move hands up spine. The elbow exercise group contained movements such as elbow chops, thumb to shoulders, and fingers to shoulders. The wrist and finger group had four subcategories (pronation / supination, wrist flexion / extension, finger flexion / extension, and thumb motion) and involved movements such as finger curls, thumb circles, prayer position, and palms up / down. There were four subcategories in the hip and knee exercise group (internal / external rotation, abduction / adduction, combined motions,

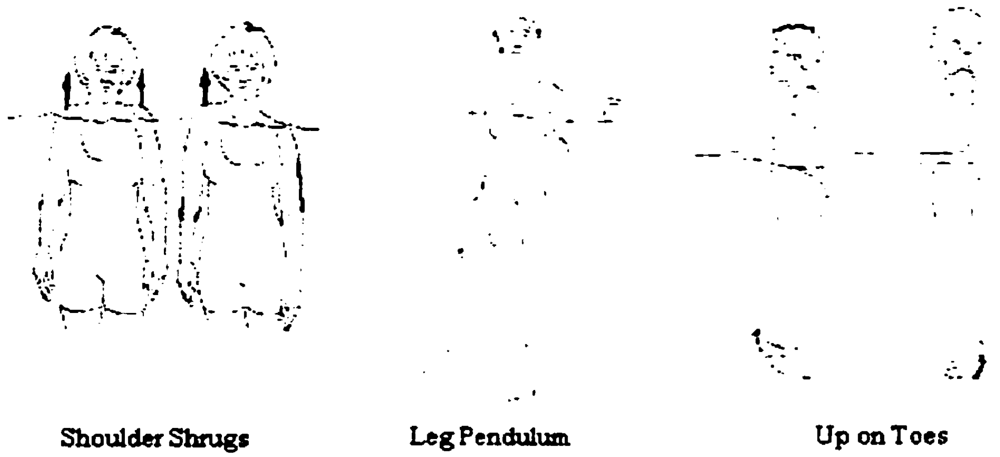

Figure 3-3. Work out exercises (AFYAP, 1996).

and stretching). Some sample exercises from the group were the quad stretch, squat, leg pendulum, leg circles, buttocks squeeze, and turn foot. The final compulsory category, ankle and toe exercises, had three subcategories (dorsiflexion / plantarflexion, inversion /

eversion, and toe flexion / extension). Exercises such as up on toes, foot circles, and foot pointing were included in this group. The two optional groups, lower extremity and abdominal exercises and games and endurance activities, were used to add variation to the class (AFYAP, 1996). Figure 3-3 shows some sample workout exercises.

The cool down component helped return the body temperature and heart rate to a resting level (Luttgens et al., 1992). The movements were mainly flexibility exercises that were performed slowly and gently. A sample cool down included five minutes of walking or marching and stretching such as the Achilles stretch, the quadriceps stretch, arm raises, and trunk stretch (AFYAP, 1996).

Biomechanical Analysis of the Sit-to-stand

Testing Procedure

The mechanics of the sit-to-stand were evaluated using video analysis. The subjects began the test sitting in a chair with no arm rests. At their own pace, the subjects stood up without the assistance of their arms. One video camera was used to film the movement in both the pre and post test. The Peak 5 (Peak Performance Technologies Inc., 1994) motion analysis system was used to analyze the sit-to-stand.

Filming Procedure

Filming of the sit-to-stand occurred on the infield of the indoor track at the Wellness Institute. Only one camera was used to film each of the subjects enabling a two-dimensional analysis. A Pansonic Digital 5100 video camera was used for the pre test and a Panasonic PV-5770A-K video camera for the post test. The cameras filmed at a speed of 30 frames per second, using a shutter speed of 1/500. The optimal shutter speed for filming would be 1/1000, however lighting conditions did not allow for that shutter speed.

The camera was placed so that sagittal view of the body could be taken as shown in Figure 3-4.

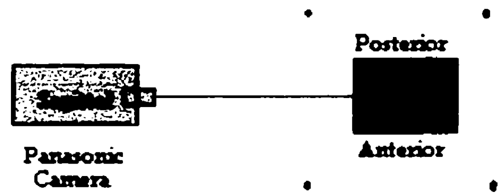

Figure 3-4. Camera set up for two-dimensional filming.

The camera was placed in a position that allowed the entire body and chair to be in full view. The Panasonic Digital 5100 was connected to a Panasonic SVHS AG-7400 portable VCR in order to record the filming. The system is diagrammed in Figure 3-5. The Panasonic PV-5770A-K had within camera recording capability, and therefore did not need to be attached to a portable VCR. The video films were encoded with a SMPTE time code generated by the time code generator, the Comprehensive Video Supply Corporation: Model # TCG-1000.

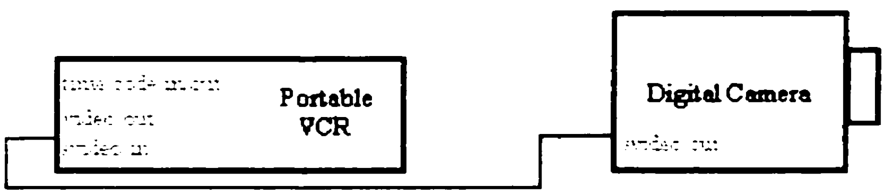

Figure 3-5. Schematic drawing of camera system configuration.

Once the camera was in place, the area of view was determined. This area was marked using four pylons. A meter stick was used to determine the scaling factor. The scaling factor was calculated in order to convert film distances to real life distances (Peak Performance Technologies Inc., 1994).

The meter stick was placed in the position where the chair was during filming. The camera was adjusted to ensure optimal data capture and the meter stick was filmed and removed. It was put back into the area of view at the end of data collection to ensure that the focus of the cameras was not altered during filming.

Testing Protocol

A chair without armrests, measuring 42.85cm (16.84 in) from ground to seat as shown in Figure 3-6, was used because it is the average chair height in the general population (Weiner et al., 1993). The chair was placed in the center of the area of view. The same chair was used for all subjects in order to mimic real life situations where most facilities only offer one size chair. Once the chair was in position, subjects were asked to stand in front of the chair at a comfortable distance. The investigator demonstrated and explained the sit-to-stand movement.

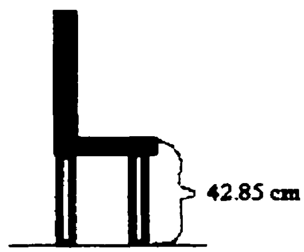

Figure 3-6. Measurement of the chair height from the ground to the top edge of the seat.

Each person sat down, paused and then stood up. Subjects were asked to perform the task twice at a comfortable pace without using their arms for assistance. They were asked to remain facing forward throughout the entire movement.

Film Analysis Equipment

The film was analyzed using a computerized video motion analysis system. The computer system used the software Peak 5 (version 5.2), which was purchased from Peak Performance Technologies (Peak Performance Technologies Inc., 1994). The Peak 5 system enhances the original 30 frames per second to produce 60 frames per second. The hardware of the Peak 5 system consisted of numerous components: a Sanyo GVR-S955 video cassette recorder, a Sony Trinitron PVM-1341 color video monitor, an ALR IBM compatible personal computer, a NEC MultiSync 2A computer monitor, a Hewlett-Packard LaserJet series II printer and a Hewlett-Packard 7475A plotter printer.

Spatial Model

A spatial model is a model of the human body that is made by assigning a number to each of the body joints or other landmarks. This model includes the points and their connections with other points that create a stick figure of the person or object that is being digitized. The spatial model is used to make calculations and position the center of mass. There were 22 points on the spatial model that was used in the experiment. Figure 3-7 shows the spatial model that was used. The experiment used the female values from Humanscale 1/2/3 (Diffrient, Tilley, & Bardagjy, 1978).

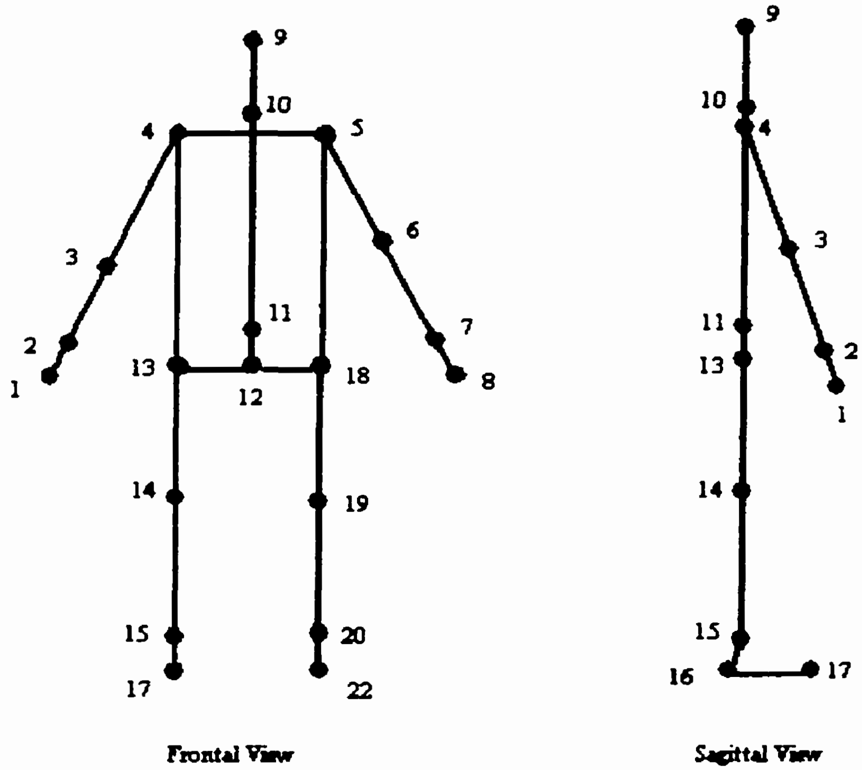

Figure 3-7. Spatial model used with digitized points numbered in the frontal and sagittal view.

Spatial Model Points
1, 8) Tip of middle finger (right and left)
2, 7) Wrist (right and left)
3, 6) Elbow (right and left)
4, 5) Shoulder (right and left)
9) Crown of head
10) Neck
11) L5/S1 Joint
12) Middle Hip
13, 18) Hip (right and left)
14, 19) Knee (right and left)
15, 20) Ankle (right and left)
16, 21) Heel (right and left)
17, 22) Tip of toes (right and left)

Data Analysis

Once the film data were ready to analyze, a two-dimensional project file was created in the Peak 5 motion analysis software. The project file contained all of the specific information about the project. It included information on how many and which video cameras were used, whether a reference point was used, which spatial model was used, how many and the names of the events throughout the movement, and it calculated the conversion factor from each camera. For each film, the meter stick was digitized in order to calculate the conversion factor. Each subject was digitized in the sagittal plane. The digitizing began at the frame before the subject's trunk moved away from the back of the chair. It continued until the subjects were standing upright and had not moved significantly for two frames. Every second frame was digitized.

Once the digitizing was complete, the raw data was smoothed using the data conditioner. The data conditioner allowed the digitized views to be filtered. Filtering the data helped to remove artifacts or unwanted signals and allowed the analysis to be more accurate (Peak Performance Technologies Inc., 1994). The data conditioner minimized the slight jittery movements of digitized points that resulted from digitizing errors. The data conditioner that was used was the Butterworth Filter. This filter was used because it is a good all-purpose filter (Peak Performance Technologies Inc., 1994). The filter was set at a cut off that filtered out small digitizing errors yet the curve remained very similar to the unfiltered curve. This point was 5 Hz, determined after the data had been digitized. Previous studies (Carr, 1992; Hughes et al., 1996; Lundin et al., 1999) have used cut off levels of 4-6 Hz while using the Butterworth Filter.

After the data were conditioned, the Peak 5 system calculated the linear displacement of the knees, toes, and heels, linear velocity the center of mass, angular displacement of the neck, trunk, hip, knees, and ankles, angular velocity of the hip, trunk, and knees. These calculations were made in the X, Y and resultant directions. The Peak 5 system also located and mapped the location of the center of mass of the body during the skill (Peak Performance Technologies Inc., 1994).

Calculated Variables

All variables were calculated using the film data from the sit-to-stand computed by the Peak 5 system. Toe to toe distance and knee to heel distance were measured using the data collected at the chair clearance frame of the sit-to-stand. The chair clearance frame was used because it was the point where the chair no longer supports the body and the feet were planted with little movement. Linear distances were reported in meters. All angular ranges of motion were calculated by subtracting the smallest angular distance from the largest angular distance and were measured in the sagittal plane. Angular distances were reported in degrees.

Toe to Toe Distance

Toe to toe distance is the distance between the left and right toes along the X-axis. This measurement has not been used in previous studies. A larger base of support may allow the subjects to have a more stable sit-to-stand movement (Hall, 1995). A greater distance between the feet creates a larger base of support. Over time, this distance should be smaller if balance was improved during the 12-week aquatics program. Figure 3-8 illustrates how the distance was measured.

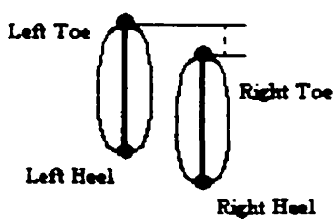

Figure 3-8. Toe to toe distance in the X direction; measured in meters.

Knee to Heel Distance

This distance was measured using the X-coordinates from the heel and the knee. If the distance was a positive number, the knees of the subjects were further ahead of their heel. If the distance was a negative number, the knees were behind the heel at chair clearance. This will result in a less stable movement because the line of gravity would be very close to the heels. Figure 3-9 shows how the knee to heel distance was measured. Wheeler et al. (1985) found that an older group of subjects with a mean age of 75 placed their foot further back than a younger group with a mean age of 24. They measured the distance slightly differently from this study. The front edge of the seat was used as the zero mark, and movement behind this point resulted in a negative result and movements in front of this point resulted in a positive result. Because estimating the location of the front edge of the chair was difficult, the knee to heel distance was used in this study.

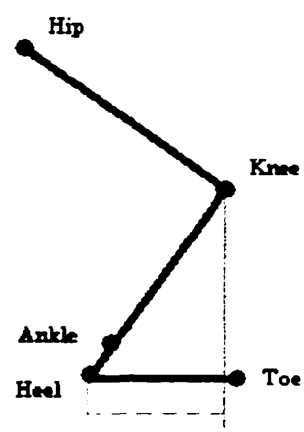

Figure 3-9. Knee to heel distance; measured in meters.

Range of Motion During the Sit-to-Stand (ROM)

During the sit-to-stand movement, a number of joint ranges of motion were measured, including the knee, hip, ankle, trunk, and neck.

To measure the ROM of the knee during the sit-to-stand movement, the relative angle was used. The ROM was calculated using the angular distance between the hip to knee segment and the knee to ankle segment. Figure 3-10 demonstrates which angle was used. This measurement was calculated for the right knee which was closest to the camera.

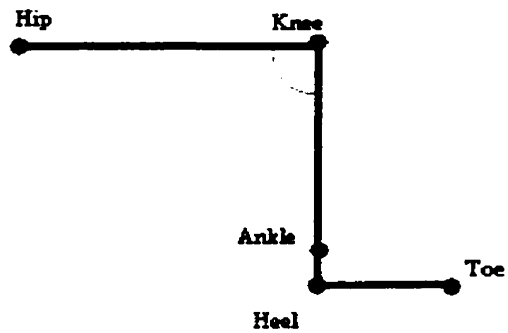

Figure 3-10. The angle measured to get the range of motion of the knee.

When finding the ROM of the hip, the angle between the knee to hip segment and the hip to shoulder segment was used. The ROM was measured as the amount of hip flexion. Figure 3-11 shows the angle that was used to measure the ROM of the hip. The right hip ROM was calculated.

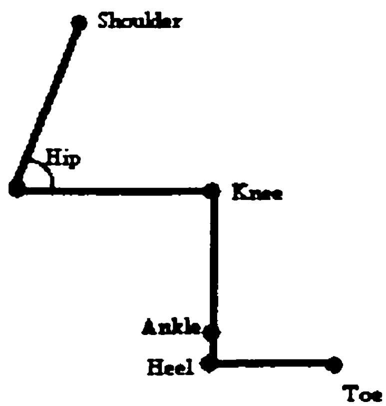

Figure 3- 11. The angle used to measure hip range of motion.

In order to obtain the true ROM of the ankle, the segment from the knee to the ankle was extended, until it passed through the heel to toe segment. The ROM was measured using the angle between the extended line and the toe to heel segment. Figure 3-12 shows how the ROM of the ankle was measured.

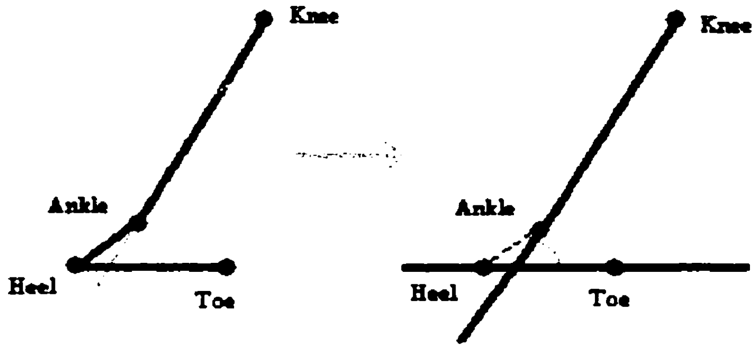

Figure 3-12. The angle used to measure ankle range of motion.

The trunk ROM was measured by using the angle between the neck to L5/S1 joint segment and the L5/S1 joint to the Y-axis segment. Trunk ROM included the lumbar spine flexion and extension. The total trunk ROM was the angle between these two lines. Figure 3-13 shows how the ROM of the trunk was measured.

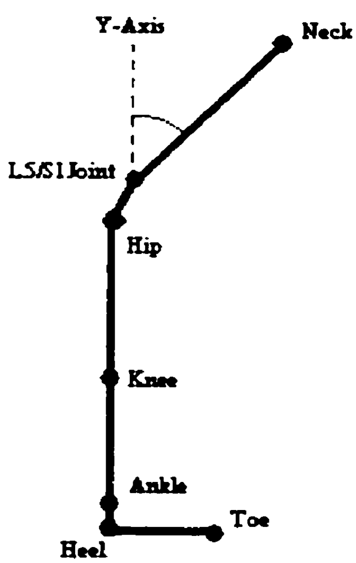

Figure 3-13. The angle used to measure trunk range of motion.

The neck ROM was calculated by extending the top of head to neck segment and connecting the neck to the Y-axis. The angle produced by these two lines measured neck flexion. Figure 3-14 demonstrates how neck range of motion was measured.

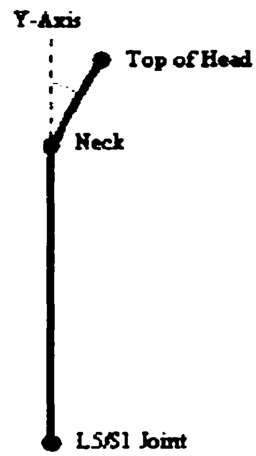

Figure 3-14. The angle used to measure neck range of motion.

Joint Angular Velocity of the Sit-to-Stand

During the sit-to-stand movement, a number of joint angular velocities were measured, including the trunk, hip, and knee. To measure the joint angular velocity of the trunk, the angle in Figure 3-13 was used. Angular velocity is the rate of change in angular position (Hall, 1995) and is measured in degrees/second. It was calculated by the number of degrees the trunk flexed or extended per second. Figure 3-15 demonstrates how trunk angular velocity was calculated.

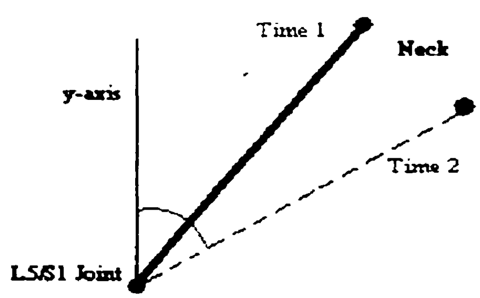

Figure 3-15. Trunk angular velocity.

Angular velocity of the hip was calculated using the angle shown in Figure 3-11. The angle consisted of the shoulder to hip segment and the hip to knee segment. It was the number of degrees the hip flexed or extended per second. Figure 3-16 demonstrates the measurement of hip angular velocity.

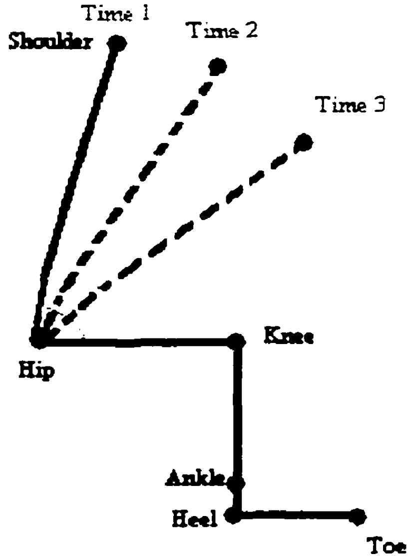

Figure 3-16. Hip angular velocity.

To measure knee angular velocity, the hip to knee segment and the knee to ankle segment were used. The same angle was used as in Figure 3-10. The angular velocity was the number of degrees the knee joint moved per second. Figure 3-17 demonstrates how knee angular velocity was calculated.

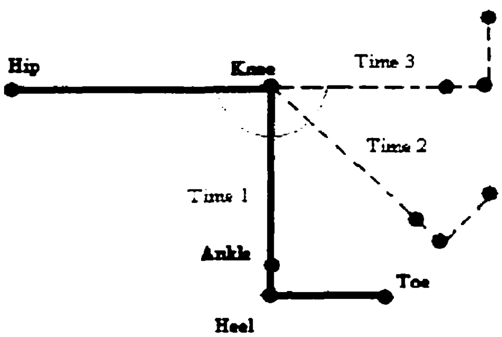

Figure 3-17. Knee angular velocity.

Flexibility Tests

Flexibility is the range of motion of a joint in each plane of motion (Hall, 1995). Studies (Bell & Hoshizaki, 1981; Roach & Miles, 1991) have found that flexibility decreases in persons with arthritis. Values are often 70-85% less than persons without arthritis at similar ages (Ekdahl & Broman, 1992). The two flexibility tests that were performed during this study were the side bend flexibility and sit and reach. These tests measured a combination of joints and muscles to obtain an overall estimate of flexibility.

Side Bend Flexibility

The side bend flexibility test is an indirect flexibility test used to quantify the amount of lateral flexion in the trunk which relates to the flexibility of the abdominal muscles (external and internal obliques), the erector spinae muscles, and the facet and intervertebral joints (Nordin & Frankel, 1989). It is important to have adequate and even side bend flexibility in order to reduce the risks of falls and injuries to the lower back. For a more stable movement, some people place their feet in an angled stance (one foot further ahead of the other) to make their base of support wider. In order to stand up with the feet in this position, some lateral trunk flexion is needed to compensate for the uneven amounts of knee and hip flexion.

Subjects stood with their backs and knees straight, arms hanging at sides, and feet together. A tape measure was attached with tape to their leg, with the tip of the middle finger positioned at zero. The tape was used to measure the distance, in centimeters, that the middle finger moves as the side bend occurred. The subjects were told to bend to the side, while the investigator watched to make sure that trunk flexion or extension did not occur. The feet of the subjects remained flat on the floor and knees were straight throughout the movement (Hubley-Kozey, 1991). The test was performed two times on each side (left and right). The score was the greatest distance reached to each side.

Sit and Reach

The sit and reach measured lower back and hamstring flexibility. The further the distance obtained on the test, the more flexible the lower back and hamstrings. This combination of flexibility is important during the sit-to-stand movement because it has been reported that older adults tend to flex the trunk more than younger adults in performing the movement (Kerr White, Barr, & Mollan, 1997). This trunk flexion compensates for the decrease in hip flexibility

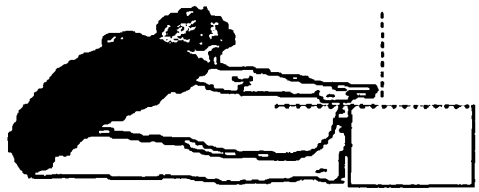

Figure 3-18. Demonstration of the sit & reach flexibility test (Tanji, 2000).

and helps increase the forward momentum of the upper body. This momentum increases the hip flexion moment and decreases the moment about the knee joint (Rodosky et al., 1989).

Sit and reach was measured using a Flexibility Tester Model # 001375, similar to Figure 3-18. The feet were placed so that they were perpendicular to the legs and a ruler protruded beyond the feet. On the ruler was a movable piece that was slid forward as the fingertips pushed it. The score on the test was how far the piece moved along the ruler.

Subjects removed their shoes, and sat with their hips flexed, and legs perpendicular to their upper body. Their feet were placed against the apparatus and their knees remained straight throughout the movement. One hand was placed on top of the other so that the hands were parallel and the subject stretched forward slowly, pushing the plastic piece as far along the ruler as possible. The subjects were reminded by the investigator to bend at the waist. The furthest distance reached by the subject, in centimeters, out of two trials was recorded.

Balance Tests

One Foot Balance Test (Eyes Open)

Ability to stand on one foot for a period of time is a test of balance ability. Balance is important in all daily activity including the sit-to-stand, and a lack of balance increases the risk of falls (Verfaillie et al., 1997). Tests in the elderly and arthritic populations have found that balance deteriorates as time passes (Verfaillie et al., 1997; Wegener, Kisner, & Nichols, 1997). The one foot balance tests static balance and is a good indictor of a general level of balance.

The one foot balance test can be performed with eyes open or closed. Eyes open was chosen for this study because some older adults have trouble balancing even for a second with their eyes closed. Subjects were positioned within an arm's reach of a wall to assist in regaining balance. One foot was lifted off the ground and the subjects balanced for as long as possible (Verfaillie et al., 1997). A stopwatch was used to time the number of seconds the subjects could balance. Any sudden movements in order to maintain balance, such as putting an arm out to counterbalance a fall or putting their foot down was considered to be loss of balance. The longest amount of time that the subject balanced on one foot was reported out of three trials.

Functional Reach Test

The functional reach tests dynamic balance in individuals. Often elderly individuals have a difficult time performing static balance tests such as the one foot balance and parallel balance tests (Duncan et al., 1990). Dynamic balance tests tend to be superior to the static balance test because they measure real life functions. The functional reach measures the horizontal distance an individual can reach forward without moving off balance. As an individual reaches forward, the center of mass moves further forward in the body and makes it more difficult to balance. Individuals who have low scores on the functional reach will have a difficult time living independently because of their reaching limitations. Poor balance in this area can lead to an increase in the incidence of falling. Investigators can use the functional reach test to quantify the amount of balanced reach a person has (Duncan et al., 1990; Hoeppner & Rimmer, 2000).

For this test, a ruler was attached to an adjustable tripod shown in Figure 3-19, and raised to the height of the acromion process for each subject. A line was placed on the floor a foot (12") from the end of the ruler. The test began with the subjects in a neutral upright position with their arms at their sides, the feet at the line on the floor, and the dominant arm closest to the ruler. The subjects flexed their dominant shoulder until it was parallel with the ruler and made a fist with their hand. The investigator measured the initial position of the fist using the head of the third metacarpal as a landmark. The subjects reached forward as far as possible without moving their feet or touching the ruler. The investigator measured the final position of the fist. The horizontal distance in centimeters from the initial position to the final position was the score on the test (Duncan et al., 1990; Hoeppner & Rimmer, 2000). Three trials were performed with the furthest distance used as the reported score.

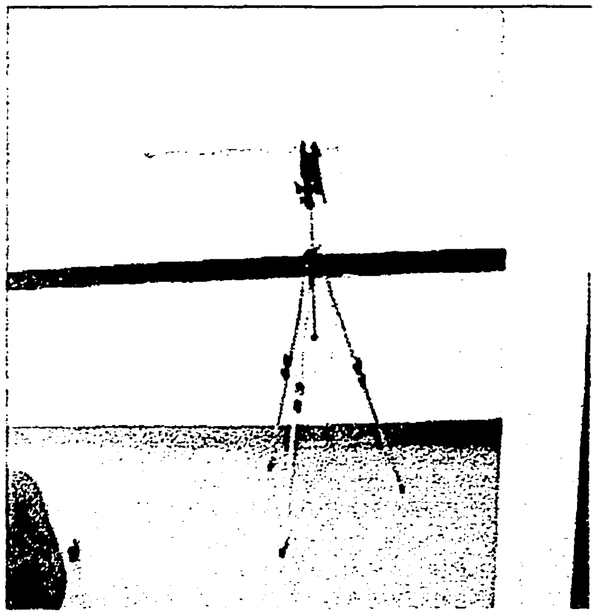

Figure 3-19. Set up for the Functional Reach test.

Three Tandem Test

The three tandem test is a progressive balance test that involves three different foot positions increasing in level of difficulty. The first position is the parallel stance where the feet are side by side, touching, and toes are parallel. The second position is the semi-tandem stance where the ball of one foot is at the heel of the other foot. The third position is the tandem stance where the heel of one foot is in front of the toe of the other foot. To advance to the next level, the prior position must be completed successfully. Each position is held for 10 seconds, starting with the parallel stance. If the subject can balance for 10 seconds in the first position they move on to the next position. This continues through the three positions until the subject can not balance for the ten seconds (Merrill, Seeman, Kasl, & Berkman, 1997; Verfaillie et al., 1997).

The final stage during sitting to standing, extension, occurs with the feet parallel and side by side. In order to maintain a stable extension phase, the subjects must have control and good balance. The three tandem test examines the ability of the subjects to stand balanced with their feet in different positions. Subjects who can balance through all three positions will be more stable during the extension phase of the sit-to-stand. This will help decrease the risk of falling during the sit-to-stand and other related activities.

The investigator explained the test to the subjects, and let them attempt to balance using the different foot positions. The subjects stood with their feet touching side-by-side and their toes even. A stopwatch was used to keep time in seconds, up to the allowed 10 seconds. The subjects were placed close to a wall so they could reach out to regain their balance. The time was stopped when a step was taken, or an arm extended to the wall. If the 10 seconds was reached, the subject continued the test with their feet placed in the semi-tandem stance. If the 10 seconds was reached in the second position, the subject repeated the test with their feet placed in the tandem stance. Two trials were performed if needed and the longest time balanced in the most difficult position was used as the reported score.

Other Test Protocols

Six Minute Walk

The six-minute walk examines the cardiorespiratory endurance of the subjects. Although the test is not directly related to the sit-to-stand, cardiorespiratory endurance does have an effect on daily living (Guyatt et al., 1985). Arthritic individuals who have poor cardiorespiratory endurance will have an increased disability because they may not be able to move around as much due to becoming "winded" (Bravo et al., 1994). The study tested to see if cardiovascular endurance improved after the exercise program.

The six-minute walk involved walking around the 139 meter indoor track at the Wellness Institute. The track was divided into eighths and the total distance walked was calculated at the end of six minutes in order to determine whether there was an improvement. Prior to walking, subjects were given instructions to walk at their own pace and to use the inside track. The subjects were told that they could stop walking at any point if the pain was too much, if they were too tired or for any other reason. Two subjects walked at one time, in order to allow the investigator to watch each person carefully. When the investigator said, "Go", the subjects began walking. The investigator used a stopwatch to keep track of the time and a distance sheet to record the number of laps (Appendix B). At the end of the six minutes, the subjects stopped and stood where they were until the investigator marked their distance. When the subjects stopped before six minutes elapsed, their specific time and distance walked was recorded. The time was measured in minutes and seconds and the distance was measured in meters.

Sit-to-Stand and Walk Test

The sit-to-stand and walk course tested the agility and balance of the subjects. Agility is the ability to change the direction of the body or body parts rapidly (Baumgartner & Jackson, 1995). Agility is important to sitting to standing because it measures the skill with which the subjects can stand up. Those who are less agile take a longer period of time to complete the course (Bravo et al., 1994). An example of an every day life activity that is directly related to the test would be rising from a chair to answer the door.

The sit-to-stand and walk test was performed using a chair and two pylons.

Figure 3-20

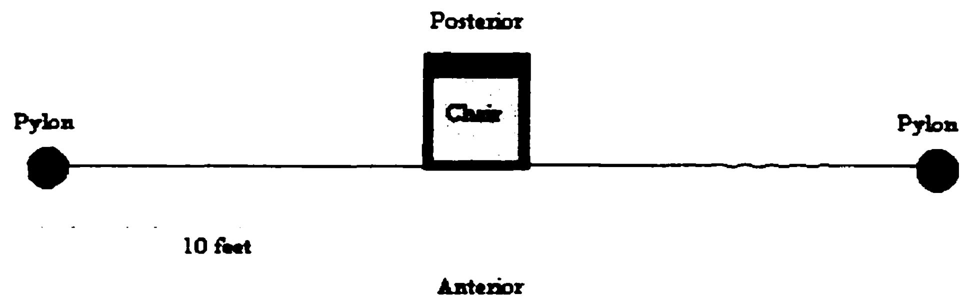

Figure 3-20. Set up for the sit-to-stand and walk test for agility.

shows the set up of the sit-to-stand and walk test. The two pylons were aligned with the front legs of the chair, ten feet away from each side. The goal of the test was to complete the course as rapidly and controlled as possible. The subjects started the test sitting in the chair. When the investigator said, "go", the subject stood up and walked around the pylon to the right. The subject circled the pylon, walked back to the chair, and sat down. This was repeated for the pylon to the left. The time was stopped when the subjects were completely sitting in the chair after circling both pylons (Bravo et al., 1994).

Five Timed Repetitive Chair Stands

The five timed repetitive chair stands test is a test of lower extremity strength (Messier, 1994). Lower extremity strength is important during a successful sit-to-stand because the muscles must produce a force that will overcome the weight of the body and gravity. If there is insufficient muscle strength, the body will have trouble during the extension phase. Subjects began this test sitting in a chair without arm rests. When the investigator said "go", the subjects stood up five times as fast as they could without using their arms. A stopwatch was used to keep the time in seconds.

Body Mass Index (BMI)

BMI is an indicator of body composition and can be compared to norms. It was used to analyze the weight (kilograms) relative to the height (meters) of the subjects. It was calculated by dividing body weight by height squared (Mahler, Froelicher, Houston miller, & York, 1995). A BMI of 20-24.9 kg/m^2 is the desirable range for adult men and women. A range of 25-30 kg/m^2 is where the obesity-related health risks begin. Any score above 40 kg/m^2 is considered to be morbid obesity. This means that the individual is at highest risk of developing obesity-related health problems (Mahler et al., 1995). This is an important variable for persons with arthritis as many suffer from obesity (Canadian Arthritis Society, 2000).

Evaluation by the Orthopaedic Surgeon

Prior to the first testing session each of the subjects completed a questionnaire about their arthritis (Appendix C). The main focus of the questionnaire was to locate which joints were affected by arthritis and to evaluate the patient's perception of the level of their disability. The evaluation of the subjects' arthritic joints was performed by an orthopaedic surgeon. The physician confirmed that the subjects had either osteoarthritis or rheumatoid arthritis and assessed the joints to ensure that they were able to participate in the aquatics program and the two testing sessions. The physician read the subject's medical history questionnaire prior to the evaluation. In the examination room, the subjects were asked which joints were most painful at the time. The physician examined those joints that were specified. Swelling, range of motion, deformities, and grinding of the joint were used to evaluate the subject's joint on the five-point scale. The physician rated the affected joints on a five-point scale; where one meant little damage and five meant severely damaged (Appendix C).

Only seven subjects received a pre and post physical evaluation from the physician. The most common joints that were affected by arthritis were the knees. Also reported as common was arthritis in the wrist, hands and fingers, hips, and ankles/feet. The joints were considered to be between slight - moderately to moderately damaged. After the 12-week intervention, the joints remained at the same level, for the most part. This is not surprising because the aquatics program was not focus on the function of the joints, just on how they felt.

The arthritic joints were assessed by two different variables. The first variable was the average rating of arthritis per person. This value was calculated by adding the rating of each joint that was evaluated by the physician and dividing by the total number of joints that were assessed per subject. The value that was found was considered to be the average rating of arthritis for the subject. The average rating of arthritis was compared for the pre test and the post test. The second variable was the individual joint rating of each joint that was affected by arthritis. This variable focused on each joint individually, pre test and post test.

The five-point scale was a good way to evaluate the joints quickly and easily without having to use expensive equipment, such as a x-ray machine. Although the use of rating systems are subjective, using a physician who has good knowledge in the area of arthritis helped keep the evaluations consistent. Two studies (Hakkinen, Hannonen, & Hakkinen, 1995; Stenstrom, Arge, & Sundbom, 1997) used the Ritchie articular index to assessed joint tenderness in subjects with rheumatoid arthritis. It was a four grade scale that combined to a maximum score of 78. Joints were assessed by palpation. Hakkinen et al. (1995) stated that the Ritchie Articular Index was a valid and reliable way to assess joint tenderness.

Statistical Analysis

After the data for the subjects were collected it was input into a data file. All statistical analyses were performed on an IBM ThinkPad computer using a statistical software package called StatView, version 5.0 for Windows (Abacus Concepts, 1994). A repeated measures ANOVA was used to compare the pre exercise tests to the post exercise tests for all, physical performance variables, sit-to-stand variables, and the joint evaluations. The significance was set at $p < 0.05$ confidence level because this is the acceptable level in most research (Hassard, 1991).

CHAPTER 4
RESULTS

Subjects

The subjects consisted of 19 females who participated in a water based arthritis exercise class. All subjects had been diagnosed with arthritis. Of those 19 subjects, 17 finished the 12-week portion of the aquatic programs, and 16 finished the 20-week portion and were filmed for the sit-to-stand. Two subjects dropped out of the experiment in the first 12 weeks due to medical reasons not related to the experiment. One subject dropped out after the first 12 weeks due to other commitments.

The means for the subjects' physical characteristics for pre and post test are reported in Table 4-1. The age of the subjects ranged from 35 to 83 years old with a mean of 65 years. The height of the subjects ranged from 142.50 to 169.00 cm. The range of the subject's weight was 61.60 to 121.20 kg with a mean of 80 kg. The mean BMI was 31.35 kg/m^2.

Table 4-1. Summary of the physical characteristics of the subjects.

Variables	Pre test		Post test		f value	p value
N=17	Mean	SD	Mean	SD		
Age (Yr.)	64.94	13.80				
Height (cm)	159.91	6.58	159.35	6.89	2.39	0.14
Weight (kg)	80.05	17.73	79.81	16.64	0.15	0.70
BMI (kg/m^2)	31.35	6.76	31.50	6.52	0.44	0.54

Attendance

Although attendance in the aquatics program was mandatory, subjects did miss some classes, due to illness or other appointments. The average attendance for the 12 weeks of the water exercise program was 76.47%. Of the 17 subjects, seven attended 86 - 96% of the classes, three attended between 76 – 86% of the classes, two attended 66 – 76% of the classes, two attended 56 – 66% of the classes, and three attended 44- 56% of the classes. Attendance ranged from 44% to 96%. Figure 4-1 summarizes the attendance at the aquatic classes over the 12-week period.

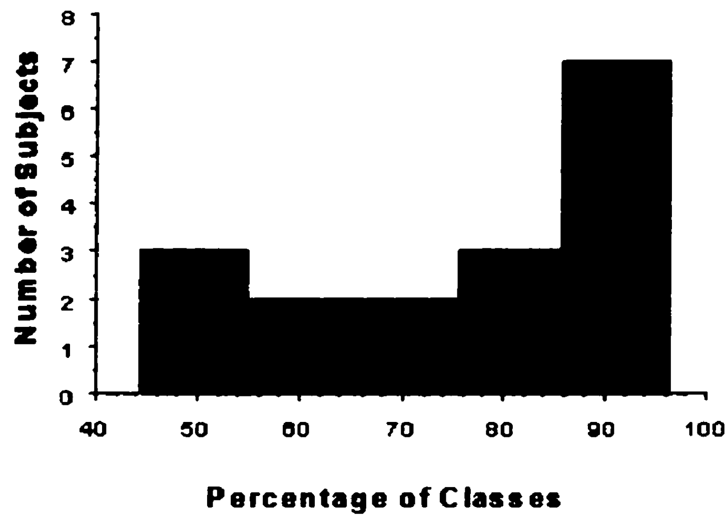

Figure 4-1. Aquatics class attendance.

Sit-to-Stand Variables

A summary of the comparison of the pre and post test results is included in Table 4-2. Graphs are presented for the variables that were significantly different between pre and post tests.

Table 4-2. Comparison of sit-to-stand variables between pre and post tests.

Variables	Pre test		Post test		f value	p value
N=16	Mean	SD	Mean	SD		
Time to full extension (s)	1.69	0.23	1.74	0.21	0.69	0.42
Time to chair clearance (s)	0.72	0.10	0.71	0.11	0.06	0.81
Time to max. d-flexion (s)	0.84	0.09	0.84	0.16	0.00	0.96
Toe to toe distance (m)	0.03	0.02	0.03	0.02	0.01	0.92
Knee to heel distance (m)	0.17	0.04	0.15	0.04	2.53	0.13
Velocity of C of M (m/s)	0.64	0.08	0.58	0.10	4.86	0.04*
ROM knee (deg)	80.71	6.86	73.90	11.49	4.22	0.06
ROM hip (deg)	106.43	9.01	86.40	10.61	29.85	0.001**
ROM ankle (deg)	9.73	2.45	8.80	1.46	1.79	0.20
ROM trunk (deg)	28.89	8.25	27.45	7.26	0.29	0.60
ROM neck (deg)	30.99	8.87	28.95	8.04	0.94	0.35
Velocity of trunk (deg/s)	150.69	45.33	159.91	63.05	0.51	0.49
Velocity of hip (deg/s)	137.27	25.68	136.50	24.34	0.01	0.94
Velocity of knee (deg/s)	166.14	30.16	157.26	31.32	0.50	0.49

$^*p<.05$, $^{**}p<.01$

Temporal Variables

Three different temporal variables were measured from the sit-to-stand film: the total time to standing, the time to chair clearance, and the time to maximum dorsiflexion. There were no significant differences between the pre and post tests for these temporal variables.

Linear Distances

The toe to toe distance between the right and left toes along the X-axis was not significantly different when the pre and post test was compared. There was also no significant difference between the means on the knee to heel distance.

Linear Velocity of the Center of Mass

The repeated measures ANOVA indicated that there was a significant difference for between the values found on the pre and post test. The maximum linear velocity of the center of mass decreased after the aquatics program. Figure 4-2 reports the mean scores for maximum linear velocity on the pre and post test. The mean maximum linear velocity of the center of mass was 0.643 m/s on the pre test and 0.584 m/s on the post test.

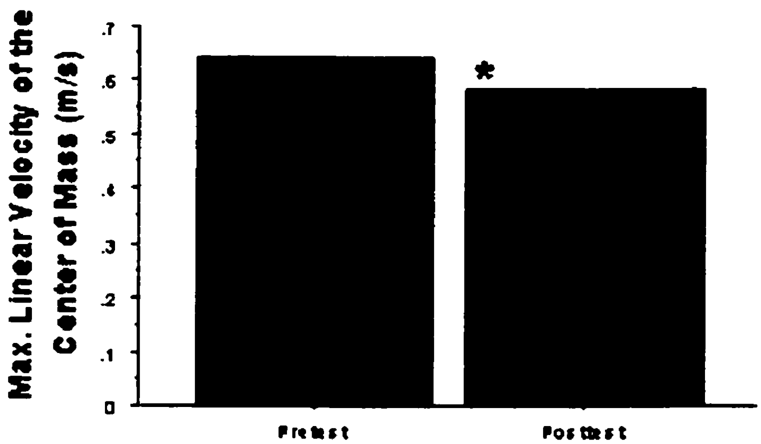

Figure 4-2. Comparison of the mean maximum linear velocity of the subjects between the pre and post test.

Total ROM of the Knee, Hip, Ankle, Trunk, and Neck

The ROM of the knee, ankle, trunk, and neck did not change significantly between the pre and post test. However, the ROM of the hip decreased significantly between pre test and post test. Figure 4-3 is a graph of the comparison of the pre and post test ROM of the hip. The mean ROM of the hip was 106.43 deg on the pre test and 86.40 deg on the post test.

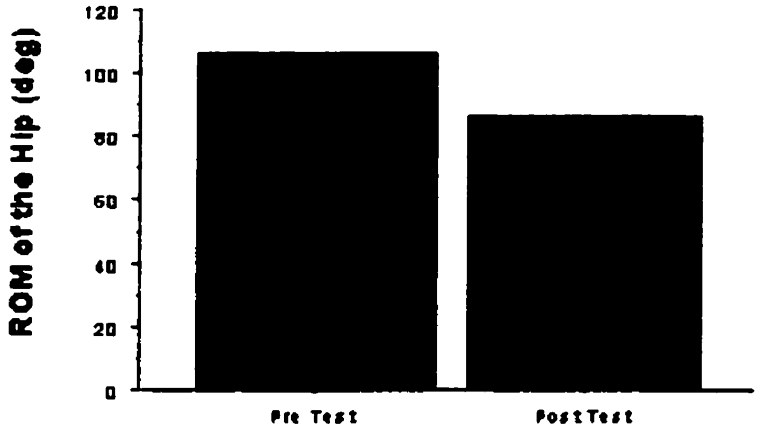

Figure 4-3. Comparison of the ROM of the hip between the pre and post test.

Angular Velocity of the Trunk, Hip, and Knee

The angular velocity of the trunk extension, hip extension, and knee extension were measured. There was no significant difference found in the knee, hip, or trunk angular velocity between tests.

Joint Angles During Sitting, Chair Clearance, and Standing

The repeated measures ANOVA performed on the angles during sitting, chair clearance, and standing is summarized in Table 4-3. Graphs are presented for the variables that were significantly different between the pre and post test.

Table 4-3. Summary of repeated measure ANOVA for the angle of the ankle, knee, hip, trunk, and neck during sitting, chair clearance, and standing.

Variables	Pre test		Post test		F value	p value
N=16	Mean	SD	Mean	SD		
Sitting						
Ankle (deg)	92.33	10.86	86.72	12.03	2.89	0.11
Knee (deg)	85.61	6.54	88.16	10.02	1.43	0.25
Hip (deg)	86.59	8.21	84.00	5.53	1.86	0.19
Trunk (deg)	5.48	8.85	4.46	8.54	0.17	0.69
Neck (deg)	191.39	7.75	189.08	9.00	0.69	0.42
Chair Clearance						
Ankle (deg)	106.17	5.91	107.18	6.36	0.50	0.49
Knee (deg)	105.80	7.71	105.97	8.78	0.01	0.92
Hip (deg)	71.58	9.32	77.47	7.95	12.62	0.003**
Trunk (deg)	15.97	8.24	8.33	10.65	14.82	0.001**
Neck (deg)	168.22	10.15	168.55	12.23	0.02	0.90
Standing						
Ankle (deg)	100.52	4.84	99.36	5.08	0.63	0.44
Knee (deg)	164.59	7.23	157.86	10.53	3.51	0.08
Hip (deg)	167.11	6.81	153.83	14.00	13.81	0.002**
Trunk (deg)	0.80	8.42	6.27	9.41	2.83	0.11
Neck (deg)	184.40	6.43	183.31	8.15	0.17	0.68

**p<.01

At sitting, there was no significant difference found in any of the joints. At chair clearance, there was no significant difference in the angles at the ankle, knee, and neck, between the pre and post test. However, there was a significant increase in the angle of the hip and decrease in the angle of the trunk. Figure 4-4 shows the comparison of the pre and post test mean angle of the hip and trunk at chair clearance. The mean value for the hip angle was 71.58 deg for the pre test and 77.47 deg for the post test. The mean value for the trunk angle was 15.97 deg for the pre test and 8.33 deg for the post test.

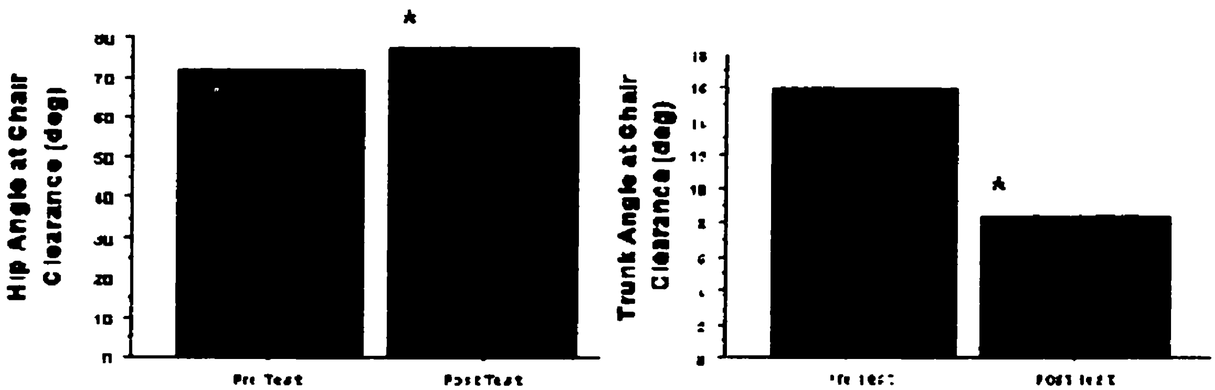

Figure 4-4. Comparison of the pre and post test hip and trunk angle at chair clearance.

During standing the repeated measures ANOVA indicated no significant differences between the pre and post test of the angles at the ankle, knee, trunk, and neck. However, there was a significant decrease in the hip angle at standing. Figure 4-5 illustrates the comparison of the pre and post test hip angle during standing. The mean angle during the pre test was 167.11 deg and the post test was 153.83 deg.

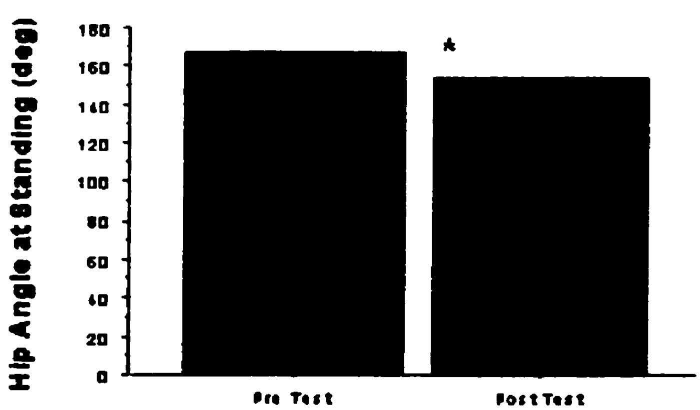

Figure 4-5. Comparison of the pre and post test hip angle during standing.

Physical PerformanceTests

A summary of the repeated measures ANOVA for the physical performance tests is reported in Table 4-4. Graphs are presented for the variables that were significantly different between the pre and post test.

Table 4-4. Summary of the comparison of the physical performance tests of the subjects.

Variables N=17	Pre test Mean	SD	Post test Mean	SD	f value	p value
L side bend (cm)	17.56	4.16	16.71	4.67	0.75	0.40
R side bend (cm)	17.48	3.23	15.88	3.71	5.37	0.03*
Sit & Reach (cm)	21.27	9.13	22.38	8.25	1.58	0.23
One Foot Balance (s)	16.17	17.17	14.25	14.23	1.01	0.33
Functional Reach (cm)	30.39	6.52	25.12	8.04	7.22	0.02*
Tandem Stance	2.94	0.24	2.94	0.24	0.00	1.00
6-Min Walk (m)	421.09	143.08	403.04	172.73	10.4	0.32
6-min walk (min)	5.50	1.12	5.14	1.66	1.93	0.18
Sit & walk (s)	23.72	8.72	23.27	6.10	0.16	0.70
5 timed stands (s)	16.16	4.77	17.02	4.95	1.46	0.24

*p<.05

Flexibility Tests

The two flexibility tests that were performed were side bend flexibility and the sit and reach. The repeated measures ANOVA indicated that there was no significant difference between the pre and post test of the sit and reach flexibility test. The side bend flexibility was measured both on the left side and the right side. There was no significant difference for the distance reached on the left side but the right side significantly decreased on the post test. Figure 4-6 shows a graph of the group means on the right side bend between the tests. The mean distance the subjects could reach to the right side was 17.48 cm on the pre test and 15.88 cm on the post test.

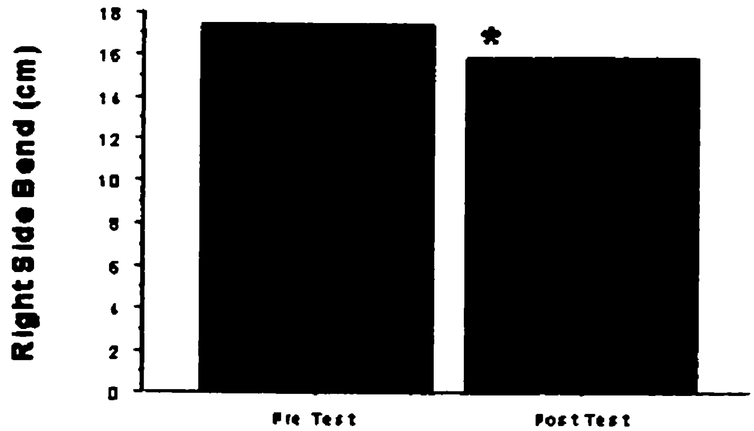

Figure 4-6. Comparison of the mean distance reached to the right side on the pre test and the post test.

Balance Tests

There were three balance tests performed by the subjects. These tests were the one foot balance test with eyes open, the functional reach test, and the three tandem stance test. No significant difference was found between the pre and post tests, for the one foot balance or three tandem stance test. However, the functional reach test declined significantly on the post test. Figure 4-7 illustrates the difference between the mean distance reached on the functional reach test on the pre and post test. The mean distance the subjects could reach on the pre test was 30.39 cm and on the post test was 25.11 cm.

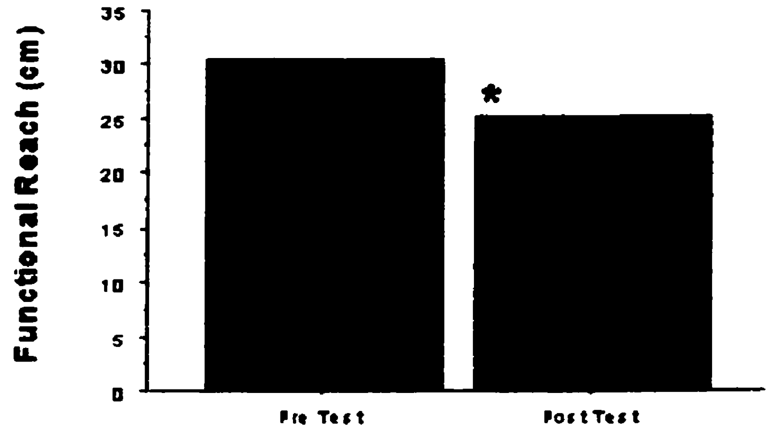

Figure 4-7. Comparison of the group mean for the pre and post test of the functional reach test.

Stand & Six Minute Walk Tests

The final three physical tests that were performed were the six-minute walk, the sit-to-stand and walk test, and the five timed repetitive stands. Two values were measured during the six-minute walk, the mean distance walked and the mean time out of the six minutes that the subjects walked. Neither of these means were significantly different when the repeated measure ANOVA was performed between the pre and post test.

There were also no significant differences found in the sit-to-stand and walk test mean scores or the five timed repetitive stand test mean scores following the exercise intervention.

Medical History Questionnaire

A summary of the medical history questionnaires is reported in Table 4-5. The questionnaires were completed by the subjects prior to the pre test. Three subjects (18.75%) stated they were employed full time and the remainder were retired or unemployed homemakers. Twelve subjects (70.59%) reported that they were involved in regular physical activity. When asked how far they could walk without pain, five subjects stated ¼ of a block, three reported ½ of a block, three said one block, and five stated three or more blocks.

Table 4-5. Summary of the medical history questionnaire responses.

Variable	%	Count	Variables	%	Count
Employed			**Using Medication for**		
Yes	18.75	3	Yes	64.71	11
No	81.25	13	No	35.29	6
Exercise			**Other Health Problems**		
Yes	70.59	12	High blood pressure	31.25	5
No	29.41	5	Diabetes	25.00	4
Walk without pain			Heart abnormalities	12.50	2
¼ block	31.25	5	High cholesterol	12.50	2
½ block	18.75	3	Other	18.75	3
1 block	18.25	3	**Personal Pain Rating**		
3 or more blocks	31.25	5	1-3	33.33	3
Arthritis Diagnosis			4-7	55.56	5
1 year	21.43	3	7-10	11.11	1
3 years	14.29	2	**Personal Restriction**		
6 years	14.29	2	1-3	0.00	0
10 years	35.71	5	4-6	66.67	6
30 years	14.29	2	7-10	33.33	3
Pain at Night					
Yes	70.59	12			
No	29.41	5			

The number of years the subjects had been diagnosed with arthritis spanned from one year to 30 years. Three subjects were diagnosed one year ago, two subjects were three years ago, two subjects were six years ago, five subjects were 10 years ago, and two subjects were 30 years ago. Twelve of the subjects indicated they had pain at night due to their arthritis. Eleven subjects indicated they used medication specifically for their arthritis to help control for pain and swelling. A number of the subjects reported other health comorbidities. Five subjects had high blood pressure, four subjects had diabetes, two subjects reported having heart abnormalities, two subjects had high cholesterol, and three subjects had other health problems such as circulation problems, hypothyroid, and osteoporosis.

The subjects were asked to rate how severe their pain was on an average day. They used a scale from one to ten, with ten indicating the worst pain they have ever felt. Three subjects indicated pain within the one to three range, five subjects reported pain between four and six, and one subject indicated pain between seven to ten. Subjects were also asked to rate the amount of restriction they had during daily life on a scale of one to ten, with one being very restrictive and ten indicating not much restriction. None of the subjects reported restriction in the one to three range. Six subjects reported ratings in the four to six range, and three subjects indicated restrictions in the seven to ten range.

Evaluation by Orthopaedic Surgeon

The evaluation of the arthritic joints of the subjects' pre and post test is summarized in Table 4-6. Only seven subjects received an assessment due to scheduling problems with the orthopaedic surgeon. In total eighteen joints were assessed and rated by the orthopaedic surgeon on a 5-point scale. An ANOVA test indicated that there was no significant difference between the joints, pre test to post test. The average rating of the individual joints during the pre test was 2.89 and for the post test was 2.33 so the subjects experienced a slight improvement over time. The average rating of affected joints for the seven subjects was calculated by adding the score of each joint assessed and dividing by the number of joints rated. There was no significant difference between the pre test and post test.

Table 4-6. Summary of the repeated measures ANOVA on the joints affected by arthritis and the average rating of affected joints for the pre test and post test.

Variables	Pre test		Post test		f value	p value
	Mean	SD	Mean	SD		
Individual Joints (N=18)	2.89	1.57	2.33	1.28	4.21	0.06
Average Rating of Affected Joints (N=7)	2.74	0.77	2.52	1.19	0.29	0.61

CHAPTER 5
DISCUSSION

Mechanics of the Sit-to-Stand

The first purpose of the study was to examine the effects of a 20-week aquatics program on the mechanics of the sit-to-stand in arthritic patients. It was hypothesized that there would be no significant difference in the performance of the sit-to-stand after the 20 weeks. There were five sit-to-stand descriptive variables that changed after the intervention, while the remainder did not change significantly.

Temporal Variables

The initiation of movement from the sitting position began the flexion momentum phase of the sit-to-stand. This phase continued until the point immediately before the buttocks left the chair. This phase took 0.72 s during the pre test and 0.71 s during the post test. As the buttocks were lifted from the chair, the momentum transfer phase began. It continued until the point directly before the ankles reach maximum dorsiflexion. The total time to maximum dorsiflexion was the same for the pre and post test (0.84 s). From maximum dorsiflexion to the end of hip extension, the extension phase occurs. During this phase the trunk, hips, and knees extended through their range of motion. The sit-to-stand finished at the end of this phase. The total time it took for the subjects to complete the sit-to-stand was 1.69 s during the pre test and 1.74 s during the post test.

There were no significant differences in the temporal variables between the pre and post test. The total time in the present study is less than in the study by Kerr et al (1997) in which the total time to stand up was 1.97 s for females between the ages 20.1 and 78.3 years. Their subjects were considered to be normal, as they did not have arthritis. Two studies (Wheeler et al., 1985; Yoshida, Iwankura, & Inoue, 1983) reported mean values for sit-to-stand ranging from 1.90 to 2.20 s for elderly subjects between the ages of 67 to 81 years without arthritis. Pai, Chang, Chang, Sinacore, and Lewis (1994) reported that it took their osteoarthritic subjects 2.44 s to stand up and it took their non-arthritic subjects 1.98 s to stand up. A possible explanation for the difference between the times in this study and the studies mentioned is that the present subjects with arthritis tended to not completely extend their hips and trunk upon standing. This may have been the result of stiffness and swelling of the joints. Fully extending these joints may have caused the subjects too much pain. Therefore, if the joints did not fully extend when the standing phase is reached, then the subjects would complete the sit-to-stand in less time.

Linear Distances

There were no significant differences between the pre test and the post test for the mean values of the two linear distances measured for the sit-to-stand. These two distances, the toe to toe distance and the knee to heel distance, were measured at the point of chair clearance during the second phase of the sit-to-stand. The toe to toe distance is illustrated in Figure 5-1B. This variable has not been used in previous studies. The mean toe to toe distance was 3 cm. This indicates that the subjects had their feet in a slightly staggered position, causing their base of support to become elongated instead of square. The staggered position of the feet helped move the center of gravity forward of the rear foot, allowing the subject a more stable sit-to-stand due to a longer base of support. During the angled stance, the center of gravity moves forward over the base due to the increased length of the base of support. Figure 5-1 compares the position of the center of gravity within the base of support for the square stance and the angled stance.

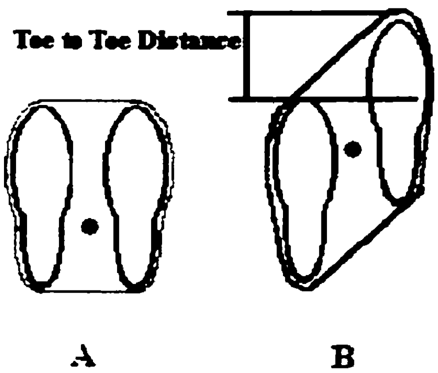

Figure 5-1. A demonstrates a square stance. B demonstrates a staggered stance. Note the position of the center of gravity is further forward on the rear foot in the angled stance.

The knee to heel distance was also not significantly different. The distance was measured at the moment of chair clearance during the second phase. As the knee joint became more flexed, more pressure on the joint occurred. As the joint flexes, the joint reaction force increases due to the change in pull of the quadriceps over the patella. There is a larger angle of pull of the patellar tendon and the quadriceps tendon when the knee is flexed than when the knee is extended. A larger angle of pull of the patellar tendon and the quadriceps tendon force the patella into the knee joint causing pressure on the joint (Nordin & Frankel, 1989). Joint pressure on arthritic joints causes pain. The more extended the knee is, the less pressure on the knee and the less pain. The mean knee to heel distance at post test was 15-17 cm. Figure 5-2 demonstrates how knee to heel distance was measured. In all cases, the knees were in front of the heels at chair clearance. If the knees were behind the heels at chair clearance, the line of gravity would fall behind the feet, and this would cause the individuals to be unstable backwards and

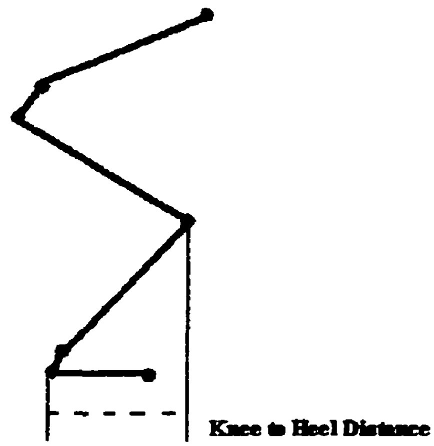

Figure 5-2. Knee to heel distance.

have difficulty in standing up. However, this position would result in less pressure on the knee because it is not in as much flexion. Figure 5-3 demonstrates the position of the line of gravity at chair clearance of one of the subjects during the sit-to-stand. Having the knees positioned in front of the heels helped subjects keep the line of gravity of the center of mass within the middle of the feet, allowing for a more stable sit-to-stand.

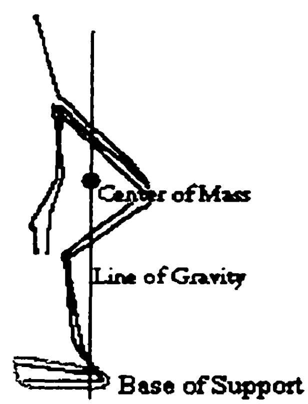

Figure 5-3. Demonstrates the position of the line of gravity at chair clearance of one of the subjects.

Linear Velocity of the Center of Mass

As the subject performed the sit-to-stand, peak linear velocity of the center of mass occurred as the trunk, hips, and knees extended to a standing position following chair clearance. This occurred during the third phase of the sit-to-stand, extension. As the powerful extension of the knees, hips, and trunk occurred, the center of mass traveled vertically. The peak linear velocity of the center of mass occurred at the point where the greatest distance was traveled within a short time period.

Following the aquatics program there was a decrease in the peak linear velocity of the center of mass. The linear velocity of the center of mass decreased from pre test to post test. The time for the sit-to-stand did not change significantly, therefore the average distance the center of mass covered per second decreased during the post test. As the subjects extended their trunk, hips, and knees, their center of mass did not travel as fast as it did during the pre test. The decrease may have resulted from a decrease in muscle force from the back extensors, the hamstrings, and the quadriceps. Another possible explanation for the decrease may be that a greater angular impulse was generated from the muscles. This suggests there was a greater force created over a smaller amount of time. Without testing the muscles specifically for activity, it is difficult to speculate on the exact cause of the decrease in the peak linear velocity of the center of mass from the pre test to the post test. A final explanation for the decrease in the linear velocity of the center of mass may be due to digitizing errors that can occur when manually digitizing body parts. These errors may produce variations in velocities.

Total ROM of the Joints

The total ROM from start to finish of the knee, hip, ankle, trunk, and neck did not change significantly between the pre and post test. In order to increase the ROM of the joints during the exercise program, the individuals may have had to put the joints into positions that caused pain. Increasing ROM does not affect the first two phases of the sit-to-stand, only the third phase, extension. In many cases, the pain of arthritis prevents individuals from fully extending joints even though individuals may be able to move the joint through a greater range.

The knee extension started at the beginning of the sit-to-stand movement during phase one. In five cases the knees flexed slightly before knee extension began. It continued until the knees were fully extended during phase three of the sit-to-stand. The knee ROM in the present study was compared to a previous study by Munro et al. (1998) that reported the kinematics and kinetics of elderly arthritic individuals and the use of ejector chairs. They reported the total displacement of the knee to be 74.3 deg. A study by Nuzik et al. (1986) describing the kinematics of the sit-to-stand in healthy, non-arthritic men and women found that the ROM of the knee was 83.25 deg. Kirtley (2000) reported that normal range of motion of the knee during the sit-to-stand was about 91.67 deg. The present study determined that the mean for the pre test was 80.71 deg and for the post test was 73.90 deg. When compared to normal subjects, the arthritic subjects had slightly less ROM in the knee. This may be due to the fact that 15 of the 17 subjects reported having knee arthritis which is the most common joint affected by arthritis. The 20-week aquatics program did not affect the knee ROM during the sit-to-stand. Figure 5-4 compares a graph of a normal range of motion of the knee to an arthritic knee.

In graph B, note that peak knee flexion occurs in phase one and that peak knee extension occurs during phase three. Graph A has a similar shape to Graph B however the scales are different. In Graph A, knee flexion is at the top and knee extension is at the bottom. In Graph B, knee extension is at the top and knee flexion is at the bottom.

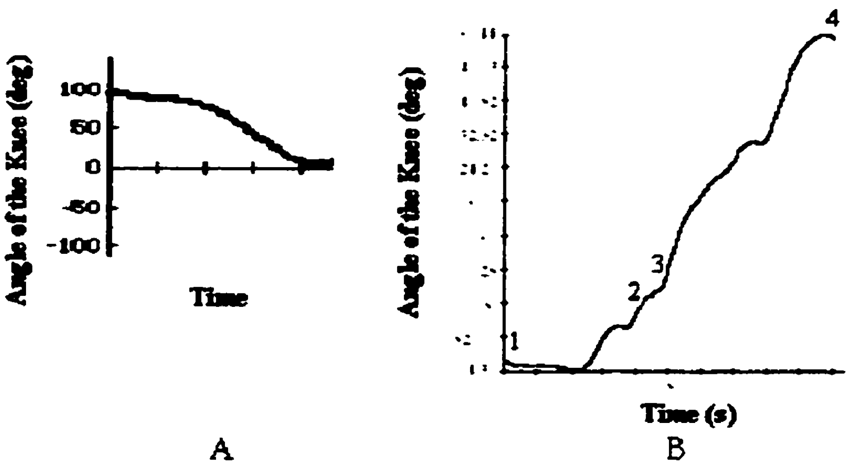

Figure 5-4. Comparison of the range of motion of the knee of a normal subject (A) versus and graph of arthritic Subject 1(B). In Graph B, the four phases of the sit-to-stand are marked.

Hip flexion started at the onset of the sit-to-stand during phase one. Maximum hip flexion occurred during the second phase just after chair clearance. Hip extension started at this point, and continued until the end of phase three. Maximum hip extension is the point at which phase three ends. The total ROM of the hip during the sit-to-stand in the present study was measured at 106.43 deg for the pre test and 86.40 deg for the post test significant differences. Pai et al. (1994) reported that patients with bilateral knee osteoarthritis had hip ROM of 95.4 deg while the control group's was 92.8 deg. The age range of Pai et al.'s (1994) subjects was 64 to 80 years. Kirtley (2000) reported normal hip ROM during the sit-to-stand was approximately 85.83 deg. The arthritic subjects tended to flex more at the hips when performing the sit-to-stand. This could be because arthritic individuals needed to move their line of gravity more forward in order to remain stable because the closer the line of gravity is to the middle of the base of support, the more stable an individual is. Also, a larger trunk angle will allow the muscles (back extensors and hamstrings) to contract through a larger ROM generating a greater force.

Ankle movement began about one-third through the first phase and ended at about halfway through the third phase. Maximum ankle dorsiflexion occurs at the end of phase two. The movement of the ankle was minimal during the sit-to-stand. As the ankle dorsiflexed, it assisted in the overall forward momentum of the body to lift off the chair. Ankle plantarflexion assisted in the upward movement of the body, into a standing position. The ankle ROM during this study was 9.73 deg during the pre test and 8.80 deg during the post test. Nuzik et al. (1986) found that the mean total ankle ROM in healthy subjects was 12.43 deg. The ages of their subjects ranged from 20 to 48 years old with a mean of 26.4 years. Kirtley (2000) stated that normal ankle ROM is about 15 deg throughout the sit-to-stand. Figure 5-5 illustrates a comparison between a graph of a normal ankle ROM versus the ankle ROM found during this study. In graph B, note that maximum ankle dorsiflexion begins at the onset of phase three. The curves are

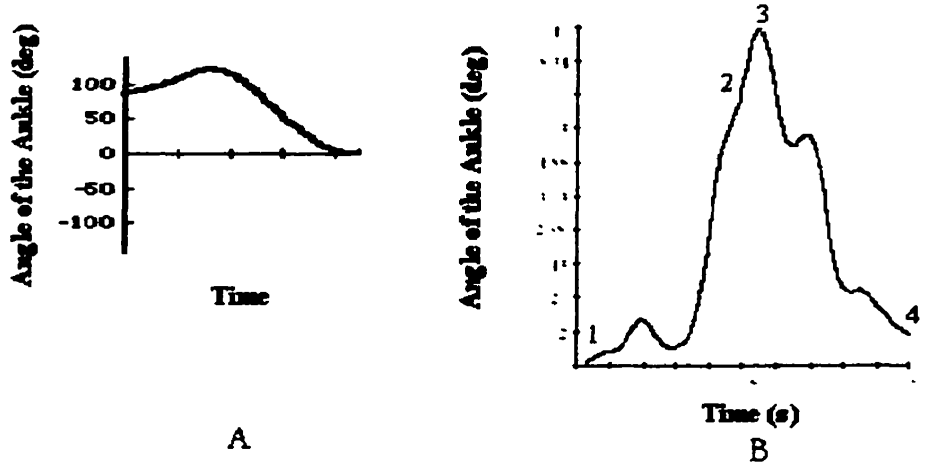

Figure 5-5. Comparison of a normal range of motion of the ankle (Kirtley, 2000) (A) versus an arthritic range of motion of the ankle for Subject 1 (B). In graph B, the four phases of the sit-to-stand are marked.

similar in that the peak ankle ROM occurs at approximately the same time during the movement. Graph A uses a different scale and average values, whereas Graph be is smoothed data from an arthritic subject from the present study. Note that the ROM of the arthritic subjects is less than the value Kirtley (2000) stated as normal. When Kirtley's (2000) values were compared to the scores in the present study, it was found that the ankle ROM was less in this study. However, the difference was only about 2.5 to 3.5 deg, which is not a large difference when comparing the present study to the values that Nuzik et al. (1986) reported.

Trunk flexion began at the onset of the sit-to-stand during phase one. It has two roles in the sit-to-stand. The first role is to generate forward momentum of the body, assisting in the lifting of the buttocks off the chair. The second role is to put the back extensors and hamstrings on a stretch. The stretch of these muscles assists in their powerful contraction to change the forward momentum to forward and upward momentum. Maximum trunk flexion occurred about halfway through phase two. Trunk extension ended after max knee extension, and before max hip extension during phase three (Schenkman et al., 1990). The mean ROM of the trunk in the present study was 28.89 deg in the pre test and 27.45 deg in the post test. Ikeda et al. (1991) reported the mean ROM of the trunk was 31.17 deg for the younger group and 41.56 deg for the elderly group.

Neck movement during the sit-to-stand begins during the first phase. As the hips and trunk flexed forward, the neck began to extend (Schenkman et al., 1990). The movement of the neck is thought to occur in order to maintain balance (Ikeda et al., 1991). If the neck did not extend, the weight of the head may cause an individual to fall forward as they lift off the seat since the weight of the head would be moving forward and downward. The neck begins to extend at this point in order to keep the head at a position with eyes facing forward. Maximum neck extension occurred during the second phase of the sit-to-stand. The mean ROM of the neck was 30.99 deg in the pre test and 28.75 deg in the post test. Ikeda et al. (1991) reported the mean ROM of the neck in the younger adults (age 25 to 36 years) to be 38.31 deg and in the elderly group (age 61 to 74 years) to be 19.56 deg. The values in the present study are slightly less than Ikeda et al.'s (1991) values for the younger adults and slightly more than the values for the elderly adults. A possible reason the values may vary is the age range of the subjects in the present study was broader (35 to 83 years) so the younger subjects will have a larger ROM and the older subjects will have a smaller ROM. Therefore, when the mean ROM is calculated, the value should fall somewhere between the values that Ikeda et al. (1991) found with the younger and older group separated.

Angular Velocity of the Trunk, Hip, and Knee

The sit-to-stand movement starts in the sitting position. The initial phase of the sit-to-stand is flexion momentum. The trunk and hips begin to flex forward. As this happens the neck begins to extend. Maximum hip flexion angular velocity occurs prior to maximum trunk flexion angular velocity. Both of these variables peak prior to the initiation of the second phase of the sit-to-stand, momentum transfer (Schenkman et al., 1990). At this point, the buttocks are ready to leave the chair. The second phase begins at the point the buttock leaves the chair, chair clearance. Hip flexion and trunk flexion continue through this phase. Maximum hip flexion occurs at about the one third of the way through the second phase and maximum trunk flexion occurs about half way through (Schenkman et al., 1990). This phase ends at the point of maximum ankle dorsiflexion. When maximum ankle dorsiflexion is reached, the third phase, extension begins. Trunk, hip, and knee extension begin during this phase. Maximum linear velocity of the center of mass occurs during this stage. The hips reach maximum angular velocity first. It occurs about half way through the extension phase. Next the knees reach maximum angular velocity, and then maximum trunk extension angular velocity. The knees reach full extension close to the end of the third phase. The trunk and hips then reach full extension (Schenkman et al., 1990). When the hip angular velocity equals zero, phase three is complete. Phase four of the sit-to-stand is stabilization. This is attainment and the maintenance of the standing position.

The peak angular velocity of the trunk occurred around the same time or slightly later than the peak angular velocity of the hip. Trunk angular velocity began as the trunk flexed forward during the first phase of the sit-to-stand. As chair clearance approached, the peak angular velocity of trunk flexion occurred. In three of the subjects, the peak trunk flexion angular velocity occurred at chair clearance. The flexion angular velocity decreased to zero until the trunk began to extend, so the movement changed direction. Trunk extension angular velocity began during the second phase of the sit-to-stand. The peak occurred during the third phase, generally immediately after the peak hip extension angular velocity.

The peak angular velocity of trunk extension in the present study resulted in a pre test value of 150.69 deg/s and a post test value of 159.91 deg/s. There was no significant difference between the pre and post test values. Ikeda et al. (1991) found the peak angular velocity of trunk extension to be 78.44 deg/s in the younger group and 71.20 deg/s in the older group. They did not indicate how they measured the trunk angle (what landmarks they used) but it was obviously different from this study because of the extreme difference.

Peak angular velocity of the hip occurred during the extension phase of the sit-to-stand. Hip angular velocity began as the trunk flexed forward during the first phase and peaked at about half way this phase. As the sit-to-stand continued, the angular velocity decreased until it reached zero (Schenkman et al., 1990). At that point, the hips began to extend. The peak angular velocity of hip extension occurred during the third phase of the sit-to-stand.

The peak hip extension angular velocity occurred before the peak knee extension angular velocity in all cases. The peak hip angular velocity during the standing movement calculated in the pre test was 137.27 deg/s, and for the post test was 136.50 deg/s. There was no significant difference between the pre and post test. Ikeda et al. (1991) reported the angular velocity of the hip to be 161.94 deg/s in the younger group and 155.50 deg/s in the older group. The younger group was 25 to 36 years old, and the older group was 61 to 74 years old. Ikeda et al. (1991) reported values for the elderly group about 18 deg/s faster than the values reported in the present study. This suggests peak angular velocities of the hip are less in arthritic subjects. A graph of hip angular velocity of one of the arthritic subjects is illustrated in Figure 5-6. Note that peak hip flexion angular velocity occurs before point one on the graph and that peak hip extension angular velocity occurs after point two.

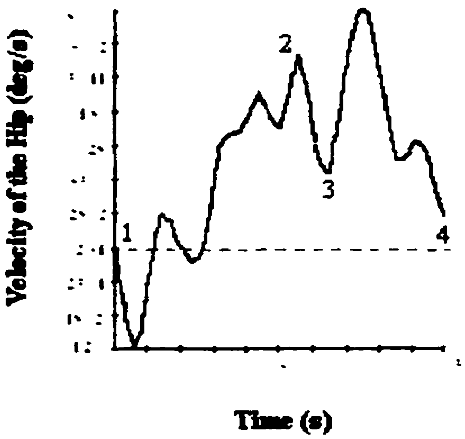

Figure 5-6. Graph of the angular velocity of the hip during the sit-to-stand for Subject 15. In the graph, the four phases of the sit-to-stand are marked.

Peak angular velocity of knee extension occurred during the third phase (extension) of the sit-to-stand. Angular velocity of knee extension began during the second phase (Schenkman et al., 1990). It continued to increase until the subject was about halfway through the third phase, where it began to decrease until the movement at the knee was complete (Ikeda et al., 1991).

The peak angular velocity of the knee did not significantly change between the two testing sessions. The present study found that the peak velocity of the knee was 166.14 deg/s during the pre test and 157.26 deg/s during the post test. Ikeda et al. (1991) tested young and elderly subjects that did not have arthritis. They reported that the young group had a peak velocity of 150.22 deg/s and the elderly group had a peak velocity of 156.50 deg/s. Schenkman et al. (1996) reported peak knee extension angular velocities for two non-arthritic groups, young (28.9 years) and old (67.3 years). They found that the younger group had peak velocities of 138.4 deg/s and the older group had peak velocities of 159.4 deg/s. Differences between the studies may be related to small digitizing errors that may produce slightly variations in velocities of manually digitized data. Therefore it can be assumed that the knee angular velocity in arthritic subjects does not differ from the knee angular velocity of elderly, non-arthritic subjects, at least in these two studies. A graph of the angular velocity of the knee for one of the subjects in this study is included in Figure 5-7. In the graph, note that the peak knee extension angular velocity occurs during phase three.

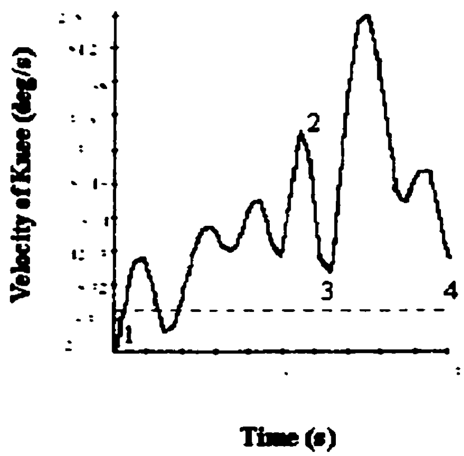

Figure 5-7. A graph of the angular velocity of the knee during the sit-to-stand for Subject 15. In the graph, the four phases of the sit-to-stand are marked.

Angles at Sitting, Chair Clearance, and Standing

Only three angles, hip angle at chair clearance, trunk angle at chair clearance, and hip angle at standing, differed significantly pre test to post test when comparing the joint angles at sitting, chair clearance, and standing. The aquatics program focused on increasing flexibility and range of motion. The standing angles should be most affected by an increase in range of motion. The angles at chair clearance may alter if strength is increased. An increase in strength in the back extensors and the hamstrings would decrease the angles at the hip and trunk. This is because stronger muscles would not have to contract through the same range of motion or be stretched as much in order to produce a particular muscle force. Since the same chair was used for the pre and post test, the angles at sitting remained the same. The ankle angle changed the most with a 5.61 degree difference between the tests, but was due to the fact that four subjects did not have their feet planted on the ground because the chair was too high for them. Depending on how they held their feet in the air, the angle would change. All other joints (knee, hip, trunk, and neck) did not differ more than 3.97 deg between the pre and post test.

The angle of the hip increased and the trunk decreased significantly at chair clearance. A number of studies (Kerr et al., 1997; Schultz, Alexander, & Ashton-Miller, 1992; Wheeler et al., 1985) have found that older adults tend to have a larger maximum trunk flexion during phase two of the sit-to-stand than younger adults. The larger trunk angle indicates that the subject has their trunk flexed more. A larger trunk angle at chair clearance created a more desirable position of the center of mass over the base of support and helped create more upward momentum. This suggests that the center of mass is located closer to the middle of the feet. Figure 5-8 illustrates the position of the line of gravity within the base of support. It is known that the closer the line of gravity falls to the edge of the base of support, the less stable the body is. Therefore, if the line of gravity is positioned close to the middle of the base of support during chair clearance, the body is more stable. A smaller trunk angle will cause the line of gravity to fall further back, towards the heels within the base of support. In an elderly individual, a small trunk angle makes it more difficult for them to balance as they rise. By increasing the angle of the trunk and hip, the individual helps reduce the possibility of falling backwards or of moving off balance.

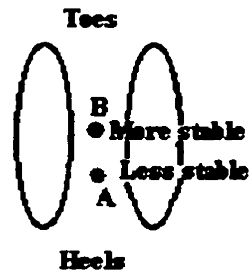

Figure 5-8. A is the position of the line of gravity within the base of support during chair clearance, which is close to the edge of the base of support and it less stable. B is the position of the line of gravity within the base of support during chair clearance, which is almost in the middle of the base of support and is more stable.

An increase in trunk angle and hip angle toward greater flexion will also increase the momentum of the upper body. As the trunk leans forward, the back extensors and hamstrings are lengthened. The increase in muscle length allows the concentric contraction of these muscles during phase three of the sit-to-stand to occur over a larger range of motion leading to an increase in force output. As well the muscle stretch stores elastic energy in the muscles which increases the contraction force. A greater force output will increase the momentum of the body to move vertically. This is key in the transfer of the forward momentum that was generated during phase one into forward and upward momentum that was generated during phase two of the sit-to-stand. The decrease in the trunk angle at chair clearance seen in the present study, suggests that individuals may have been in a less stable position as the base of support moved off the chair. The person will be less stable because the line of gravity is positioned further back in the base of support. As the line of gravity moves closer to the edge of the base of support, the subject becomes less stable. It also suggests that less upward momentum was needed to complete the sit-to-stand in the post test because the muscles did not contract through as large a ROM as in the pre test.

The angle of the hip during standing decreased during the post test. A study by Pai et al. (1994) reported that the mean angle of the hip when standing in knee osteoarthritic patients was 178.3 deg. The present study reported that the mean angle was 167.11 deg during the pre test and 153.83 deg during the post test. Pai et al.'s (1994) study reported a larger angle of the hip during standing by about 11 – 24 degrees. Hip angle was measured using the knee to hip segment and the hip to shoulder segment. The slightly lower values found during the present study may be due to the fact that the subjects in Pai et al.'s (1994) study were only reported to have knee osteoarthritis whereas many of the subjects in this study had arthritis in the ankles, hips, and lower back. All other angles did not significantly change during standing.

Observation of the video film revealed that during the pre test, most subjects moved into full hip extension at the end of the sit-to-stand. However, during the post test, the hip extension often stopped before the subject was in full hip extension. As the subject took a step after the sit-to-stand was complete, the hip continued to extend. A possible reason may have been that the subjects were not reminded by the investigator to stand up as far as they could prior to walking away. This decrease in hip angle was likely not a result of the aquatics program; instead it may have been a result of poor instruction by the investigator.

Physical Performance Tests

The second purpose of the study was to examine the effects of a 12-week aquatic program on physical performance of arthritic patients. It was hypothesized that there would be no change in balance, flexibility, strength, and agility. This hypothesis suggested that the aquatics program would allow the subjects to maintain these four factors without regression. The results of the study indicated that there was a significant decrease in two of the tests, the right side bend, and the functional reach, all other tests were not significantly different from pre test to post test.

The weight and BMI of the subjects were not affected by the 12-week aquatic intervention. An interesting finding was that the mean BMI for the subjects was slightly greater than 30kg/m^2. BMI is considered to be a good indicator of total body composition. The Panel on Energy, Obesity, and Body Weight (Mahler et al., 1995) standards for BMI is a scale which categorizes four different ranges of BMI and the related health outcome. A BMI of 20 to 24.9 kg/m^2 is the desirable range for adult men and women. A range of 25 to 29.9 kg/m^2 is considered grade 1 obesity, 30 to 40 kg/m^2 is grade 2 obesity and any score above 40 kg/m^2 is grade 3 obesity. When the mean from this study is compared to the Panel on Energy, Obesity, and Body Weight Standards, it rates at grade 2 obesity (Mahler et al., 1995). Three of the subjects were at a grade 3 obesity with a BMI above 40 kg/m^2. Since obesity health related risks are said to begin during the BMI range of 25-30 kg/m^2, it is apparent that the subjects involved in the experiment are indeed at a greater risk for developing such problems. A loss in weight would decrease BMI, and possibly help prevent further damage to the arthritic weight bearing joints. Unfortunately, the 12-week aquatic program did not alter the body weight of the subjects, nor was it one of the stated outcomes of the program.

The two flexibility tests that were performed were the side bend flexibility test, and the sit and reach test. The side bend flexibility test was performed both on the right and left side. The right side bend decreased between the pre and post test. One reason for these results may be that the subjects actually had a decrease in performance due to regression in the arthritis over the 12 weeks. Since arthritis is a progressive disease it is common to experience decreases in physical performance over a three-month period. Another possible reason may be that for this test different testers were used for the pre and post test.

There was a slight increase in the distance reached during the sit and reach test although it was not significant. The mean score on the pre test was 21.27 cm and on the post test was 22.38 cm. The mean scores on the sit and reach test were slightly higher than those found in a similar study comparing aquatics exercise to land exercise in arthritic patients (Minor et al., 1989) and to a study comparing osteoarthritis to rheumatoid arthritis (Minor, Hewett, Webel, Dreisinger, & Kay, 1988). Minor et al. (1989) reported scores of 20.4 cm in the aquatic exercise group, and 19.8 cm in the land exercise group. In a separate study, Minor et al. (1988) indicated that there was no significant difference on the scores on the sit and reach between individuals with rheumatoid arthritis (17.1 cm) and individuals with osteoarthritis (16.0cm). Although one of the Arthritis Foundations YMCA Aquatics Program's (AFYAP) (AFYAP, 1996) main goals was to increase the range of motion of the joints, the flexibility that was measured during the present study was not increased as expected. During the water classes shoulder ROM, as well as ankle, hand, and finger were focused on. When the sit and reach test scores were compared to a study by Bravo et al. (1994) on the reliability of the test in the elderly population (50 to 70 years old), it was found that the distance reached by subjects in the present study was slightly less. Bravo et al. (1994) reported mean scores of 23.22 cm and 23.36 cm, this is about 2 cm more than the values recorded during the present study. Bravo et al.'s (1994) subjects were women enrolled in seniors' exercise classes but these were not arthritis patients as were the current subjects.

The three balance tests that were performed were the one foot balance with eyes open, functional reach test, and the three tandem stance test. The one foot balance test with eyes open resulted in no significant difference between the pre and post test. Rikli and Edwards (1991) tested older non-arthritic women between the ages of 57 and 85 years old on the one foot balance test with the eyes open during their study on the effects of a three year exercise program. The mean time for their pre test was 37.95 s, for the year one test was 44.95 s, and the year 3 test was 42.76 s. Giorgetti, Harris, and Jette (1998) studied the reliability of the one foot balance test with eyes open. They had two groups of subjects: non-disabled and disabled. The mean age of the non-disabled group was 73.1 years and the mean age of the disabled group was 75 years. The time for the non-disabled subjects was 13.08 s by examiner one and 15.21 s by examiner two. The correlation coefficient was 0.75. The time for the disabled subjects was 8.53 s by examiner one and 9.48 s by examiner two. The correlation coefficient was 0.85. The mean time for the present study was 16.17 s on the pre test and 14.25 s on the post test. The time the subjects could perform the one foot balance actually decreased slightly from the pre test to the post test. The difference was about two seconds. The times of the arthritic subjects in this study were significantly less than the times reported by Rikli and Edwards (1991) on non-arthritic subjects. However, they reported that over the three year period, there was a significant difference in the scores on the one foot balance. This suggests that a 12-week aquatics program may not be long enough to find significant changes within the arthritis population on the one foot balance test. The times recorded during this study were longer than the times reported for the one foot balance by Giorgetti et al. (1998) for their non-disabled group. Their times reported for the disabled group are less than the times found in the present study. They did not indicate what type of physical disability their subjects had.

The functional reach test resulted in the subjects also experiencing a decrease in how far they could reach without losing their balance. Duncan et al. (1990) compared the functional reach by gender and for three different non-arthritic age groups (20 to 40 years, 41 to 69 years, and 70 to 87 years). They found that the youngest group reached the furthest with the men reaching 42.49 cm and the women reaching 37.19 cm. The middle group reached less with the men reaching 38.05 cm and the women reaching 35.08 cm. The oldest group had the lowest scores with the men reaching 33.43 cm and the women reaching 26.59 cm. The scores in the present study (30.39 cm for the pre test and 25.12 cm for the post test) were similar to Duncan et al.'s (1990) oldest group of women which reached slightly less than the present subjects. Hoeppner and Rimmer (2000) used the functional reach to assess the level of balance between self-reported exercisers and non exercisers without arthritis who were between the ages of 65 and 95. They found that exercisers had significantly higher scores on the test with a mean value of 28.96 cm compared to the non exercisers who had scores of 21.34 cm. In this study, the pre test mean score was 30.39 cm and post test score was 25.12 cm which is comparable to Hoeppner and Rimmer's (2000) group that exercised. The mean scores were different by 5 cm. This suggests that the subjects had a decrease in performance due to regression in the arthritis over the 12 weeks. Another suggestion is that for this test, different testers were used for the pre and post test. Overall, the functional reach test is a reliable measure of stability (Duncan et al., 1990). It can be easily performed at home or in a clinical setting and represents real-world function. The scores of the arthritic subjects were similar the non-arthritic subjects of Duncan (1990). Therefore age, not arthritis may have a greater effect on the distance subjects can reach on the functional reach test.

The three tandem stance test resulted in the mean of the pre test being similar to the mean in the post test. This test was performed with the eyes open with a possible maximum score of three, although it has been administered in other studies with eyes open only (Ostir et al., 1998), and with eyes open and closed (Binder et al., 1994). Almost all subjects could stand in each of the three positions for the ten seconds. Binder et al. (1994) used this test in their study, but performed the three positions with the eyes opened and closed making the possible maximum score six. The mean score they reported was 3.3 out of six. The mean score in the present experiment was 2.94 out of a maximum score of three. A study by Ostir et al. (1998) used the three tandem stance as a test of lower body functioning in older (65 to 99 years old) Mexican Americans without arthritis. Out of a total of 1281 subjects, 79% of the subjects obtained a score of three on the test, 13% of the subjects scored two on the test and 8% of the subjects scored one.

In a more subjective analysis the investigator observed that the subjects in the present study noticeably improved in balance in the pool. At the beginning of the aquatics program, most subjects needed to hold on to the side of the pool in order to maintain balance while performing certain balance exercises. By the end of the 12 weeks only the occasional subject reached for the wall. This balance that they attained in the pool did not transfer to land or was not measured by the tests selected. This tandem test needed to be performed with eyes both open and closed in order to distinguish a difference between the subjects. The mean score was 98% of the possible total in the present experiment. Binder et al. (1994) reported the mean score was 55% of the possible total and none of the subjects could stand in the third position (tandem stance) with their eyes closed for the ten seconds. In order to use this test to measure balance, it must be designed so that there is a difference between the individuals who are stable and those who are not. The test needs to increase in difficulty using protocol similar to that used by Binder et al. (1994) in order to produce valid results.

During the six-minute walk test, total distance walked decreased slightly, but not significantly during the post test. The mean distance walked during the pre test was 421.09 m and during the post test was 403.04 m. Messier et al. (2000) compared two exercise groups: a diet with exercise group and exercise only in arthritic subjects 60 years or older. They administered the six-minute walk and found the mean distance walked in six minutes was 429.16 m during baseline testing. After three months the exercise group walked 502.6 m and the exercise and diet group walked 518.2 m. During the final testing at six months the exercise group walked 523.6 m and the exercise and diet group walked 555.0 m. In a similar study, Ettinger et al. (1997) compared three groups: an aerobic exercise, a resistance exercise and a health education among individuals with knee osteoarthritis. The aerobic exercise group walked a mean distance of 459.33 m on the post test, the resistance exercise group walked 428.55 m, and the health education group walked 411.19 m. Kovar et al. (1992) tested the effects of supervised fitness walking in patients with knee osteoarthritis. The baseline mean distance walked was 381 m for the exercise group and 356 m for the control group. After the eight-week walking program the exercise group walked 451 m and the control group walked 339 m. The distance walked during the six-minute walk in those three studies is in the same range as the values recorded during the present study, however these studies found the exercise intervention improved walking performance and the current study did not.

Although heart rate was increased during the cardiovascular portion of the aquatic class, the program focused on range of motion. This is one reason why no difference was seen between the pre and post test when most of the studies using land exercise resulted in a significant increase in the distance walked during the six minutes. There was also no significant difference seen in the time the subjects walked. There may be three reasons for the findings. First, subjects participated in the aquatics program for only 12 weeks of non walking specific exercise, more time may be needed to find a significant result. Second, there may be a practice effect seen in the walking. Subjects may begin to pacing themselves through the test. Third, the previously mentioned studies all involved land exercise, not aquatic exercise. Therefore, the six-minute walk test may not be a good test to use when measuring the effects of an aquatics program on arthritic subjects, although it does provide an indication of cardiovascular fitness as well as daily function. Perhaps performing the six minute walk in the water or a different land test would better test the effects of the aquatics program on endurance. This would result in less impact on the hip, knee, and ankle joints due to the support of the body by the water.

There was a small decrease in the time it took to perform the sit-to-stand and walk test which was a measure of agility (Bravo et al. 1994). Most movements performed in the water were slow and relaxed, therefore agility was not a major focus in the AFYAP

(AFYAP, 1996). Bravo et al. (1994) administered a similar sit-to-stand and walk test in their study testing the reliability and validity of tests for elderly women without arthritis. The times in the present study for one complete circuit were 23.72 s for the pre test and 23.27 s for the post test. However a comparison of these two studies can not be done since Bravo et al. (1994) does not indicate how far from the chair they placed the pylons. In the present study, the pylons were placed 3.05 m from the chair on each side.

The five timed repetitive stands test measuring lower body strength and endurance produced a slight decrease in performance (Binder et al., 1994). There was not a significant difference found between the pre and post test. The mean time it took the subjects to stand five times during the pre test was 16.16 s and during the post test was 17.02 s. The AFYAP was not designed to specifically improve muscle strength, but to improve flexibility and cardiovascular fitness. A study by Binder et al. (1994) used this same test to measure the effect of group exercise programs on frail elderly (66 to 97 years old) adults. They reported that it took their subjects a mean time of 19.3 s to perform the five stands. This is about 3 seconds longer than the mean times reported in this study. A reason for this difference may be that Binder et al. (1994) used much older adults who had a history of at least one fall. Also, the height of the chair that was used was not mentioned. Therefore Binder et al. (1994) may have used a chair that was lower to the ground than the one that was used in the present study. This would result in a longer time to perform the five repeated stands.

A note worthy point was that many subjects complained about having a difficult day with their arthritis during the post test probably due to the -28°C weather outside. Cold, damp weather tends to make people feel their arthritis pain more than hot, dry weather (Canadian Arthritis Society, 2000). This does not mean that cold weather causes arthritis, only that joints tend to be more painful, and stiff if the weather is colder. Warmer, dry weather helps loosen the joints, and causes less pain (Canadian Arthritis Society, 2000).

Medical History Questionnaire

The medical history questionnaires that the subjects completed prior to the aquatics program provided some insight into the level of disability of the subjects. Several subjects stated that they had problems with daily activities such as walking, sitting down, standing up, housework, standing for periods of time, getting out of the bathtub, dressing, gripping objects such as cups and toothbrushes, lifting, reaching, walking up and down stairs, and driving. The occurrence of other health problems such as high blood pressure, diabetes, heart abnormalities and high cholesterol were listed as comorbidities among the subjects. Of the health problems listed, 29.4% of the subjects had high blood pressure, 23.5% of the subjects had diabetes, 11.8% of the subjects had heart abnormalities, 11.8% of the subjects had high blood pressure, and 17.6% had other health problems such as circulation problems, hypothyroid, and osteoporosis. More than half of the subjects indicated that they used medications to help control the swelling and pain of the arthritis. Generally, the length of time the subjects had arthritis spanned anywhere from one year to 30 years. Fourteen of the subjects had osteoarthritis and three of the subjects had rheumatoid arthritis.

There was a large range of disability among the subjects. Some of the less disabled subjects were not on medication, had only had arthritis for one or two years, and only had problems doing daily activities occasionally. Other more disabled subjects have already had a joint replacement, use canes or walkers to help with mobility, and have had arthritis for over 10 years. The younger subjects tended to have had arthritis for less than 10 years, and have fewer joints affected by arthritis than the older subjects. This could be due to the etiology of arthritis. Since arthritis, especially osteoarthritis is caused by the degeneration of the cartilage of weight bearing joints; the younger subjects have not had as much time to damage these joints.

The most common joint to be affected by arthritis was the knee, 88.2% of subjects in the study had arthritic knees, followed by the hands and fingers with 52.9% of the subjects, lower back (41.2%), and feet (41.2%). Other types of common arthritis the subjects reported were hip (35.3%), shoulders (23.5%), and elbows (11.8%).

Evaluation by Orthopaedic Surgeon

The orthopaedic surgeon rated the joints by examining how much swelling was present, what the ROM was, if there was any visible deformities present, and if there was any grinding within the joint. Overall, the group of seven subjects were assessed as having moderate arthritis. Swelling of the joint was observed in almost all of the subjects. Subjects with mild arthritis tended to have less swelling then subjects who had more severe arthritis. The surgeon observed a decrease in range of motion in subjects with moderate and severe arthritis but not in subjects with mild arthritis. Joint deformities were seen mostly in joints that had been rated as moderate to severely arthritic. Most joint deformities were found in the feet of the subjects at the metatarsalphalangeal joints. Grinding in the joint in occurred individuals with moderate and severe arthritis.

The orthopaedic surgeon asked subjects about their pain and about the effects of the aquatics exercise program on their arthritis. Pain was different in every subject, some did not have pain while other had severe pain. Generally subjects with mild arthritis indicated they had less pain then in subjects with more severe arthritis. Most subjects indicated that the aquatics program made their joints less painful, and helped them keep their ROM. However, the subjects with rheumatoid arthritis indicated that the aquatics program actually caused them more pain after each session even though they felt it was helping. Rheumatoid arthritis tends to involve more swelling and a increase in joint temperature. Therefore exercise in a heated pool would increase the joint temperature even more, and cause more swelling of the tissue. The orthopaedic surgeon suggested that these subjects should apply ice to their joints after the pool sessions.

CHAPTER 6
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The ability to perform basic activities of daily living is necessary to maintain independent living. Arthritis is one of the most common chronic illnesses that affects daily life activities and ultimately threatens independent living. The sit-to-stand is an essential part of life and functional ability. When it can not be performed effectively, individuals can no longer live independently. This study attempted to use an exercise program to improve the sit-to-stand movement as well as other activities of daily living.

Aquatic exercise reduces stress from the painful joints and may be beneficial to arthritic patients. The aquatic program used in the study was the Arthritis Foundation's YMCA Aquatics Program (AFYAP). This program focuses on decreasing pain and swelling in the arthritic joints as well as improving range of motion within the joints (AFYAP, 1994).

The first purpose of this study was to study the effects of an aquatics program on the mechanics of the sit-to-stand in arthritic patients. A two-dimensional motion analysis system (Peak Performance Motion Analysis System) was used to calculate the mechanical variables of the sit-to-stand. Significant changes between the pre test and the post test were found for five of the variables. There was a decrease in peak linear velocity of the center of mass, a decrease in the total range of motion of the hip, a decrease in the angle of the trunk and hip at chair clearance, and a decrease in the angle of hip extension during standing. These differences likely resulted because the subjects did not move fully into hip extension at the end of standing up.

The total time of the sit-to-stand was slightly faster in this study than most studies have reported in the past. This may be the result of the subjects not completely extending their trunk, hips, and when upright knees due to a decrease in range of motion of the joints and an increase in swelling, pain, and degeneration of the joints.

The second purpose of the study was to examine the effects of an aquatics program on physical performance measures related to flexibility, balance, strength, endurance, and agility. There were no significant improvements in any of the tests between the pre and post test. Two of the tests, the functional reach test and the side bend flexibility test on the right side resulted in a significant decrease in performance. Strength, endurance, and agility were not affected by the 12-week aquatic program.

Overall, the aquatics program did not improve the functional ability of the subjects that were tested during the study. However, subjects did suggest that they felt less pain after the aquatic program and their joints were less stiff. Aquatics exercise did not improve skill in the sit-to-stand movement. Perhaps exercise that uses the sit-to-stand as part of the program may be more useful in improving the sit-to-stand. Ideally, aquatics exercise should be used both as a treatment to improve functional ability, and as a way to cope with the pain and swelling of arthritis. Further research into the use of aquatic exercise as a treatment for arthritis is needed.

Conclusions

On the basis of this study the following conclusions appear justified:

1. An aquatics program significantly decreased the peak linear velocity of the center of mass and decreased the angle of the trunk at chair clearance during the sit-to-stand.

2. An aquatics program did not affect the timing of the phases of the sit-to-stand and the total time, the peak angular velocity of the knee, trunk or hip, and the total range of motion of the ankle, knee, hip, trunk, and neck.
3. The aquatics program did not affect the angle of the ankle, knee, hip, trunk, and neck, during sitting.
4. An aquatics program did not significantly affect flexibility, balance, strength, endurance, and agility of the subjects.
5. The three tandem stance test did not distinguish a difference in balance ability between subjects when it was performed with eyes open.
6. The evaluation by the orthopaedic surgeon using the five point scale was a useful method to evaluate the arthritic joints.

Recommendations

Future research should include the following:

1. Researchers should compare the mechanics of the sit-to-stand in osteoarthritic and rheumatoid arthritic subjects participating in aquatic exercise.
2. Researchers should compare the difference in the mechanics of the sit-to-stand between individuals who have mild to moderate arthritis, and those who have moderate to severe arthritis.
3. Researchers should use a control group that does not participate in the aquatics program in order to see if regression occurs in the control group within the three-month period.
4. Researchers should perform a three dimensional analysis of the sit-to-stand in order to investigate movement in all three anatomical planes and around all three axes.

5. Researchers should use a larger sample size to make the study more powerful, and use a random sample instead of a volunteer-based sample that may contain biases.
6. Researchers should study the effects of an aquatics program over a six-month, one-year, and two-year period to investigate the long-term effects of an aquatics program on arthritic subjects.
7. Subjects should perform the three tandem stance with eyes closed as well as eyes open to investigate whether this test will detect a difference in subject balance.

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APPENDIX A

Personal Consent Forms
Test Description

CONSENT FORM

Effects of an Exercise Program on Balance and Mobility Characteristics and Psychological Well-Being of Women with Arthritis

I HAVE READ THE DESCRIPTION OF THE STUDY, UNDERSTAND THE MEASUREMENT PROCEDURES INVOLVED, AND CONSENT TO PARTICIPATE IN THE STUDY

I ALSO UNDERSTAND THAT MY PARTICIPATION IN THIS STUDY IS VOLUNTARY, AND THAT I MAY WITHDRAW FROM IT AT ANY TIME WITHOUT PREJUDICE. ALL INFORMATION WILL BE KEPT CONFIDENTIAL AND MY RESULTS WILL BE RELEASED TO ME AT THE COMPLETION OF THE STUDY. I AM FREE TO QUESTION THE INVESTIGATORS AT ANY TIME ABOUT ANY ASPECT OF THE STUDY.

I UNDERSTAND THAT THE RESEARCH TEAM WILL RECEIVE ANY DATA COLLECTED DURING THE STUDY, INCLUDING CHANGES IN SOME OF MY FITNESS ASSESSMENT MEASURES.

I UNDERSTAND THAT PARTICIPATION IN THIS RESEARCH STUDY IS DONE AT MY OWN RISK, AND I HEREBY RELEASE THE UNIVERSITY OF MANITOBA, AND THE WELLNESS CENTER AT SEVEN OAKS HOSPITAL, THEIR AGENTS, OFFICERS, RESEARCH TEAM AND EMPLOYEES FROM ANY LIABILITY, WITH RESPECT TO DAMAGE OR INJURY (INCLUDING DEATH) THAT I MAY SUFFER FROM MY PARTICIPATION IN THIS RESEARCH STUDY.

DATE______________________ ____________________________

PARTICIPANT

DATE______________________ ____________________________

WITNESS

NAME:________________________________

ADDRESS:________________________________

PHONE NUMBER:________________________________

Arthritis Study 2000
Test Description

1. **Height:** A tester will measure the participant's height in centimeters.

2. **Weight:** A tester will measure the participant's weight in kilograms.

3. **Sit & Reach:**
Participants will sit on the ground/bench with their shoes off. They will place their feet in the marked spot on the sit and reach apparatus. Hands must be placed on top of each other, and move together throughout the reach. The participant bends forward, reaches with arms, and slides the marker forward until they can't go any further. The best score out of two trials is used.

4. **Side Bend Flexibility:**
The participant will be standing for this test, and will bend as far as possible to each side. The tester will ask the participant to hang their arms at their side and will put a piece of tape to mark the beginning hand position at rest (using the middle finger). The participant will then bend to the side and the tester will place a piece of tape at the spot to which the finger reached. A ruler will be used to measure the distance reached. The participants will perform two trials on each side and the best score will used.

5. **Sit to Stand Filming:**
The tester will explain the movement to the participant prior to the test. Participants will sit in a chair that is being video taped by two cameras. They will stand up at their own pace and remain facing forward throughout the movement. They will be asked to count to five once they are in the standing position before they leave the filming area. The sit to stand will be filmed once.

6. **One Foot Balance (eyes open):**
Participants will use their dominant leg for this test. The test will be done beside a support beam to use if balance is lost. The participant will keep their eyes open and lift their non-dominant leg by bending their knee. Arms maybe out to the side. The tester will begin timing the moment the leg is up. The tester will end the test when the participant grasps the pole or loses their balance and touches the floor with the other foot, which ever occurs first. The best score out of three trials will be used.

7. **Functional Reach Test:**
This test will be demonstrated to the participant prior to testing. The participants will stand with their dominant arm next to the ruler and their feet behind a line on the floor. The ruler height will be adjusted to their shoulder. Participants will be asked to raise their arm until it is flexed to 90 degrees. A fist will be made with their hand and the initial measurement will be recorded. The participants will lean forward, bending at the waist and reaching as far as possible. The final measurement will be taken. This test will be performed three times and the best score will be recorded.

8. **Three Tandem Test:**

The tester will explain this test to the participants prior to the testing. The participants will move through the three different foot positions before the test. To begin the test, the participants will stand with their feet side by side in a parallel position. The tester will time the subject balancing in this position up to ten seconds. If the participant passes the ten seconds, they will continue on to the next foot position. The second foot position is the semitandem stance. The heel of the participant one foot is lined up with the medial arch of the other foot. The participant will be timed in this position up to ten seconds. If this position is passed, the participant will continue to the final foot position, the tandem stance. The tandem stance is one foot placed directly in front of the other foot so that the heel of one foot is touching the toes of the other foot. This position is also held for up to ten seconds. In order to continue to the next stage the participant must pass the previous stage. Scores of 0, 1, 2,or 3 will be given depending on how many stages were successfully completed. Three trials will be completed for this test and the best score will be used.

9. **6-Minute Walk:**

A track will be used to walk around during this test. Participants will begin at a starting point and will walk around the track as fast as is comfortable possible for 6 minutes. If tired, participants may stop any time and their score will be the distance walked during that time. Participants remain in the stop they ended after the 6 minutes until their distance has been recorded. The total distance will be calculated in meters at the end of the 6 minutes.

10. **Sit to Stand and Walk Test:**

The tester will demonstrate this test. The participant will sit down on a chair. On the signal "Go", they will stand up and walk to the right, circle around a pylon, and return to the chair and sit down . The participant must be at a complete rest when the sit. They will then standup and walk to the left, circle around a pylon, and then sit down again. This is the end of the test. The tester will begin timing the participant as they begin to stand up, and will stop the watch when the person is in the final complete sitting position.

11. **Five Timed Repetitive Stand Up:**

The tester will explain this test. The participants will begin this test sitting in a chair. The tester will use a stop watch to time how long it takes for the participant to stand up five times in a row. The participants will begin when the tester says "Go", and will stand up five times as fast as possible. For participants who can not stand up five times, the number of times they stood up will be recorded along with the time it took. This test will be completed once.

APPENDIX B

Test Data Sheet
Sit To Stand Data Sheet
Six-Minute Walk Lap Sheet

Arthritis Study 2000
Test Score Sheet

Name:____ **Age:** _____________

Address: ____

Phone Number: _____________________

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1. **Height:** ___________cm

2. **Weight:** ____________kg

3. **Sit & Reach:** _________cm __________cm **Best Score:** _______cm

4. **Side Bend Flexibility:** Left _______cm ______cm **Best Score:** ________cm

   Right: ______cm ______cm **Best Score:** ________cm

5. **Sit to Stand Filming:** Yes No Subject Number _______#
   (Circle yes when filming is complete)

6. **One Foot Balance:** _________sec __________sec __________sec

   Best Score: _________sec

7. **Functional Reach Test:** _________cm __________cm _________cm

   Best Score: _________cm

8. **Three Tandem Test:** (Circle the score)

   Trial 1: 0 1 2 3 _______sec

   Trial 2: 0 1 2 3 _______sec

   Trial 3: 0 1 2 3 _______sec

9. **6 Minute Walk:** ___________m **Time Walked:** __________min

10. **Sit to stand and Walk Test:** ________sec

11. **Five Timed Repetitive Stand Up:** ________sec

SIT TO STAND DATA SHEET

Name: ______________________________

Subject #: ____________

Test Session: Pre Test / Post Test Group: Exercise / Control

Center of Mass Velocity: ____________

Toe to Toe Distance (Z): ____________

Toe to Toe Distance (X): ____________

Knee to Heel Distance: ____________

	Total Range of Motion (degrees)	**Maximum Angular Velocity (deg/sec)**
Ankle:	____________	____________
Knee:	____________	____________
Hip:	____________	____________
Trunk:	____________	____________
Neck:	____________	____________

Angles (degrees)

	Sitting	**Chair Clearance**	**Standing**
Ankle:	________	________	________
Knee:	________	________	________
Hip:	________	________	________
Trunk:	________	________	________
Neck:	________	________	________

SIX-MINUTE WALK LAP SHEET

Test Date: ______________________________

Name of Subject	1	2	3	4	5	6	7	8	9	10	Time Walked

APPENDIX C

Arthritis History Questionnaire
Five-Point Scale

Medical History Questionnaire
Arthritis Study
Submitted to
Dr. Peter MacDonald, Orthopaedic Surgeon

Name:________________________________

Address:________________________________

Phone:________________________________

Birth Date:________________________________

MHSC #:________________________________

1. Which of your joints are involved with arthritis?__________________

2. How long has each joint been involved?__________________

3. What is the order of severity of the joints involved?__________________

4. Have you had joint injury in the past? If yes, describe:__________________

5. Are you employed outside the home? If yes, does your arthritis affect your work? What is your job?__________________

6. Does your arthritis affect your activities of daily living? eg. walk, sit to stand, housework, etc? If yes, describe how:__________________

7. Did you exercise regularly prior to this program?__________________
If yes, describe:__________________

8. How far can you walk without pain? ie. 1/4 block, 1/2 block, 1 block, 3 blocks,__________________

9. Do you have pain at night? How often?__________________

10. Do you have pain at rest? Describe__________________

11. Do you take medications for your arthritis? If yes, list:__________________

12. Do you take any other medications? If yes, list:__________________

13. Do you have Diabetes, high blood pressure, heart or lung disease?__________________

14. Do you have any other medical illnesses?If yes, list:
____

15. Who is your family doctor?__________________

16. List any surgery that you have had:__________________

17. Are there plans for joint surgery?______________________________

18. On a scale of 1 to 10, how severe is your pain on an average day? (10 is the worst pain you have ever had)______________________________

19. On a scale of 1 to 10, how restricted is your joint function on an average day?(10 is completely normal)______________________________

Thank you for completing this questionnaire. The results will remain confidential and will be used only in the context of this study.

FIVE-POINT SCALE
Arthritic Joint Analysis

Name: ______________________________

Assessment Date: ______________________________

Group: Exercise Control

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1 = Slight damage
2 = Slight-Moderate damage
3 = Moderate damage
4 = Moderate-Severe damage
5 = Severe damage

Arthritic Joint: ______________ 1 2 3 4 5

Right / Left

Arthritic Joint: ______________ 1 2 3 4 5

Right / Left

Arthritic Joint: ______________ 1 2 3 4 5

Right / Left

Arthritic Joint: ______________ 1 2 3 4 5

Right / Left

Arthritic Joint: ______________ 1 2 3 4 5

Right / Left

Arthritic Joint: ______________ 1 2 3 4 5

Right / Left

Arthritic Joint: ______________ 1 2 3 4 5

Right / Left

Arthritic Joint: ______________ 1 2 3 4 5

Right / Left

APPENDIX D

Sit-to-Stand Raw Data
Physical Performance Raw Data
5-Point Scale Raw Data

Subject	Time to Full Hip Ext.		Time to Chair Clearance		Time to Max. Dorsiflexion		Lin. Vel. Of CM		Toe to Toe Dis.	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	2.00	1.70	0.80	0.63	0.90	0.80	0.62	0.57	0.06	0.05
2	1.73	1.57	0.80	0.70	0.80	0.73	0.50	0.43	0.01	0.08
3	1.90	2.03	0.67	0.87	0.90	0.93	0.61	0.51	0.01	0.02
4	1.77	1.67	0.73	0.67	0.87	0.80	0.51	0.59	0.02	0.02
5	1.70	1.53	0.90	0.53	1.00	0.77	0.61	0.73	0.00	0.02
6	1.47	1.50	0.76	0.73	0.87	0.83	0.68	0.59	0.05	0.02
7	1.80	1.60	0.70	0.63	0.80	0.73	0.64	0.73	0.01	0.02
8	1.53	1.57	0.67	0.60	0.73	0.63	0.65	0.48	0.01	0.01
9	2.03	2.00	0.87	0.77	0.93	1.30	0.61	0.51	0.09	0.03
10	1.57	1.87	0.53	0.60	0.60	0.67	0.70	0.79	0.03	0.04
11	1.80	1.83	0.83	0.70	0.90	0.77	0.72	0.51	0.03	0.04
12	1.70	2.20	0.60	0.93	0.83	1.03	0.59	0.53	0.03	0.00
13	1.33	1.67	0.63	0.80	0.83	0.90	0.69	0.67	0.02	0.04
14	1.60	1.90	0.60	0.83	0.77	0.87	0.73	0.55	0.03	0.04
15	1.20	1.53	0.70	0.63	0.83	0.73	0.78	0.56	0.01	0.00
16	1.73	1.57	0.73	0.73	0.80	0.90	0.65	0.62	0.03	0.00

Subject	Knee to Heel Dis.		ROM Ankle		ROM Knee		ROM Hip		ROM Trunk		ROM Neck	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	0.21	0.11	11.52	9.06	80.49	75.30	117.83	98.39	31.09	31.88	26.56	36.81
2	0.23	0.21	8.59	7.24	84.56	59.65	93.91	96.60	15.30	20.69	26.93	27.57
3	0.13	0.19	7.73	6.52	72.27	93.18	99.20	86.73	23.50	26.71	36.32	30.33
4	0.12	0.13	5.99	8.38	76.39	59.41	114.74	81.16	46.34	25.53	38.86	38.08
5	0.15	0.16	8.23	8.44	70.11	79.39	108.84	98.85	28.09	13.11	28.42	24.01
6	0.11	0.11	11.89	9.26	83.07	72.36	114.04	79.23	15.57	34.02	35.53	41.00
7	0.16	0.17	7.32	7.69	84.39	70.99	103.56	74.71	26.75	18.47	30.12	22.91
8	0.16	0.13	6.93	10.82	88.09	81.41	104.82	101.19	36.35	29.32	22.13	19.67
9	0.18	0.18	13.70	10.89	82.05	64.63	89.55	82.04	33.77	16.38	26.45	17.29
10	0.13	0.12	10.41	7.89	81.11	84.73	96.88	99.43	28.84	38.09	14.05	23.22
11	0.16	0.11	9.97	9.91	73.89	54.00	107.04	85.41	33.88	27.02	46.91	33.25
12	0.11	0.09	6.91	11.75	82.85	64.32	125.07	84.52	27.57	33.05	25.72	27.49
13	0.23	0.19	14.09	8.22	72.34	89.38	104.76	65.32	28.06	28.09	24.06	16.18
14	0.19	0.21	11.01	9.38	97.61	86.70	105.77	91.65	40.60	35.66	32.15	38.98
15	0.14	0.14	10.59	7.91	79.28	72.73	108.00	81.23	21.35	26.45	48.46	28.71
16	0.25	0.20	10.86	7.42	82.84	74.17	108.82	74.00	25.17	34.65	33.14	37.64

Subject	Ang. Vel. Of Knee		Ang. Vel. Of Hip		Ang. Vel. Of Trunk	
	Pre	Post	Pre	Post	Pre	Post
1	151.90	176.30	105.60	105.30	153.40	266.70
2	132.00	170.70	93.30	157.00	111.10	106.60
3	160.30	140.80	168.30	106.00	137.40	106.00
4	187.10	146.00	145.50	135.00	158.00	176.50
5	114.10	233.70	114.50	157.40	105.00	154.40
6	204.20	137.80	172.40	125.60	196.50	237.60
7	154.20	167.00	174.10	138.90	132.60	153.60
8	180.30	152.60	140.50	131.50	190.40	294.40
9	157.60	91.50	135.70	172.60	162.60	100.10
10	135.10	146.20	131.00	121.20	138.00	147.20
11	159.50	138.60	130.40	139.10	88.90	92.10
12	163.50	165.60	127.30	98.20	257.40	196.60
13	147.10	184.30	113.00	168.90	166.40	147.80
14	229.70	150.10	132.00	122.20	190.60	182.60
15	208.00	187.40	181.60	131.50	76.40	101.90
16	173.70	127.60	131.10	175.60	148.40	94.40

Subject	Angle at Sitting									
	Ank		Kne		Hip		Trunk		Neck	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	97.97	92.06	85.32	89.22	274.28	280.19	172.55	191.01	184.87	177.66
2	104.82	107.60	70.43	73.72	285.52	283.19	186.06	190.46	201.29	188.40
3	96.59	108.43	92.90	76.02	261.37	278.18	185.47	175.80	180.25	188.50
4	84.50	67.64	96.08	89.79	273.6	276.61	182.85	198.76	189.40	182.22
5	64.54	88.78	87.10	94.70	278.52	285.16	190.22	179.82	178.60	182.16
6	92.72	78.79	88.76	89.81	272.84	269.74	174.74	167.93	200.46	202.31
7	100.76	76.90	81.95	93.55	276.19	283.95	190.70	188.02	188.64	195.21
8	88.67	92.26	85.98	89.32	277.09	278.65	205.10	185.27	197.92	199.59
9	104.28	81.54	84.73	76.53	278.3	276.98	184.50	190.52	192.34	191.53
10	92.23	87.72	85.79	83.97	265.57	266.05	190.34	177.84	185.84	205.17
11	82.74	71.01	88.92	108.99	268.55	269.39	167.83	174.34	205.83	186.51
12	78.83	84.20	95.44	104.70	275.23	270.2	193.32	195.99	188.96	178.62
13	106.47	100.59	81.71	88.00	277.24	274.68	181.75	179.10	185.13	190.85
14	96.32	90.38	80.24	74.15	261.14	273.45	187.16	184.83	191.16	191.32
15	90.71	86.78	87.02	93.40	260.59	273.86	191.28	192.12	198.31	172.77
16	95.25	72.91	77.41	82.66	288.56	275.78	183.81	179.49	193.19	192.48

Subject	Angle at Chair Clearance									
	Ankle		Knee		Hip		Trunk		Neck	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	106.79	98.84	99.49	112.16	302.04	288.16	197.14	189.63	166.39	163.33
2	113.88	114.03	99.18	90.94	284.24	272.44	194.68	185.24	179.81	176.62
3	101.54	114.18	112.32	97.96	277.97	276.80	181.49	182.65	152.35	158.62
4	96.70	107.77	105.45	111.38	298.58	288.75	205.92	194.98	173.47	155.17
5	107.85	110.16	107.87	100.06	295.94	287.42	186.01	174.65	153.36	170.12
6	101.91	103.65	114.23	111.70	286.24	270.89	184.52	171.24	171.47	170.21
7	107.36	111.60	103.83	103.26	290.12	286.07	200.37	186.64	160.90	172.88
8	102.58	101.24	108.33	106.99	287.22	288.61	204.39	191.68	181.76	189.33
9	109.32	106.36	101.30	102.38	283.25	281	196.27	186.33	178.09	186.12
10	102.28	101.89	106.24	109.67	277.65	272.95	197.95	213.42	178.16	186.59
11	107.65	102.04	114.55	118.48	277.51	284.68	191.86	194.29	173.84	156.11
12	100.49	95.14	117.31	122.59	304.11	296.26	208.36	203.88	176.20	168.23
13	115.82	114.61	94.51	96.10	297.3	282.91	184.86	175.43	168.12	177.57
14	107.63	113.04	98.83	99.84	279.04	269.85	203.71	192.17	159.01	157.37
15	99.73	104.78	116.36	114.00	278.33	281.94	201.20	185.45	151.46	151.44
16	117.16	115.52	93.02	98.06	295.11	291.78	196.75	183.59	167.09	157.11

Subject	Angle at Standing									
	Ankle		Knee		Hip		Trunk		Neck	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	99.02	93.82	165.81	163.77	186.63	193.8	185.15	172.80	180.06	191.66
2	100.82	95.22	154.46	150.12	203.2	189.63	182.85	188.90	196.11	188.93
3	99.45	97.53	164.27	171.20	195.01	199.45	166.41	173.19	187.45	179.67
4	93.68	91.87	169.27	145.34	188.98	221.78	162.19	188.49	182.48	164.32
5	105.58	106.90	151.58	166.60	196.11	200.48	183.06	186.14	176.36	190.42
6	97.04	103.06	170.29	155.58	184.75	203.85	177.52	179.43	183.39	180.35
7	102.12	107.56	165.23	155.48	197.97	227.78	197.28	183.57	179.79	183.16
8	96.66	98.39	173.12	167.94	189.11	198.56	181.48	180.00	195.46	190.69
9	102.53	96.66	166.78	140.61	206.36	210.6	179.71	186.56	183.26	189.24
10	95.96	100.70	166.90	166.99	192.64	182.55	182.17	195.88	188.86	188.60
11	105.09	107.36	162.81	153.14	192.85	204.96	178.11	188.80	191.24	169.23
12	96.40	93.77	170.78	162.04	184.28	214.28	190.99	190.59	181.21	185.43
13	111.16	95.83	153.44	172.48	197.48	224.89	186.67	183.57	181.81	192.51
14	98.06	103.87	176.36	139.40	183.78	189.12	174.56	213.41	189.10	176.69
15	97.01	97.43	165.90	163.38	188.45	212.47	160.48	183.21	173.56	180.15
16	107.72	99.72	156.44	151.68	198.67	224.51	184.23	185.70	180.23	181.94

Subject	Age	Height (cm)		Weight (kg)		BMI (kg/m2)		Sit & Reach (cm)		L. Side Bend (cm)		R. Side Bend (cm)	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	69	166.50	165.50	122.70	121.90	44.26	44.50	18.00	23.00	19.00	12.00	18.50	11.00
2	83	158.80	157.00	70.50	71.40	27.96	28.97	19.00	22.00	15.00	13.00	15.50	13.00
3	64	161.50	160.50	61.90	61.60	23.73	23.91	42.00	40.00	11.00	21.00	16.00	18.00
4		155.50	155.00	75.80	76.90	31.35	32.01	26.00	23.00	19.00	18.00	16.00	16.00
5	72	159.50	158.00	80.00	82.80	31.45	33.17	17.50	21.50	21.50	19.00	19.50	16.00
6	40	164.50	163.00	77.30	75.80	28.57	28.53	31.50	22.00	17.50	13.00	16.00	13.00
7	40	162.00	162.00	75.70	76.30	28.84	29.07	32.50	35.00	25.00	26.00	23.00	24.00
8	77	159.80	158.00	103.60	105.40	44.49	42.22	16.50	15.00	17.00	10.00	15.00	13.00
9	68	164.30	162.00	67.70	69.60	25.08	26.52	12.50	15.50	10.50	11.00	15.70	14.00
10	35	161.00	165.00	73.00	72.80	28.16	26.74	9.50	11.00	17.00	16.00	14.00	14.00
11	76	144.50	142.50	71.00	70.70	34.00	34.82	34.00	37.00	14.60	16.00	17.00	13.00
12	67	156.40	156.00	109.30	108.00	44.68	44.38	25.00	25.00	18.40	14.00	18.50	16.00
13	66	167.00	167.00	71.70	70.60	25.71	25.31	19.00	24.00	17.20	20.00	23.00	19.00
14	75	168.50	169.00	72.60	71.60	25.57	25.07	16.00	20.50	23.00	24.00	20.00	21.00
15		148.30	148.00	63.90	62.80	29.05	28.67	14.00	14.00	18.00	15.00	18.00	13.00
16		166.10	165.50	83.10	85.80	30.12	31.33	17.50	18.00	23.00	22.00	21.00	22.00
17	64	154.20	155.00	71.00	72.80	29.86	30.30	11.00	14.00	11.80	14.00	10.50	14.00

Subject	One Foot Balance (s)		Functional Reach (cm)		Tandem Stance		Six Minute Walk (m)		Six Minute Walk (s)		Sit to Stand & Walk (s)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	25.00	13.00	26.20	14.50	3	2	382.25	139.00	6.00	2.00	28.00	31.00
3	14.00	6.00	30.00	32.50	3	3	139.00	34.75	3.00	1.00	30.00	32.90
4	13.40	20.00	32.70	35.50	3	3	556.00	556.00	6.00	6.00	17.[illegible]0	19.90
5	14.71	8.00	35.80	25.50	3	3	486.50	399.63	6.00	6.00	20.00	23.00
6	6.00	8.00	26.00	13.00	3	3	278.00	278.00	3.50	3.45	20.20	20.50
7	10.10	8.00	30.30	23.00	3	3	417.00	475.13	6.00	6.00	16.80	16.90
8	30.00	30.00	32.30	34.00	3	3	608.13	556.00	6.00	6.00	15.00	15.90
9	14.00	6.00	25.10	22.00	3	3	347.50	347.50	6.00	6.00	31.00	30.70
10	8.50	22.00	32.50	24.00	3	3	521.25	556.00	6.00	6.00	28.00	28.80
11	76.00	60.00	29.50	28.00	3	3	538.63	538.63	6.00	6.00	14.00	17.10
12	5.00	2.00	20.00	14.50	3	3	139.00	139.00	3.00	3.00	45.00	29.00
13	4.00	5.00	23.00	16.00	3	3	278.00	260.63	6.00	6.00	39.00	31.60
14	9.50	22.20	38.00	29.00	3	3	417.00	486.50	6.00	6.00	21.00	20.40
15	4.50	4.00	24.20	35.00	3	3	521.25	538.63	6.00	6.00	21.00	19.50
16	8.00	8.00	26.00	26.00	3	3	556.00	556.00	6.00	6.00	15.10	16.00
17	24.20	16.00	42.00	37.00	2	3	521.25	538.63	6.00	6.00	19.00	18.10
2	8.00	4.00	43.00	17.50	3	3	451.75	451.75	6.00	6.00	23.00	24.20

Subject	5 Timed Stands	
	Pre	Post
1	17.00	25.20
3	19.00	19.10
4	12.10	12.50
5	17.00	20.10
6	14.00	14.20
7	9.20	12.10
8	9.20	10.10
9	23.00	23.00
10	23.00	26.50
11	12.00	14.30
12	17.00	18.50
13	18.00	13.50
14	18.00	15.90
15	17.00	14.80
16	9.50	12.10
17	14.00	15.00
2	25.00	22.40

5-Point Scale Raw Data

	Average Arthritis	
Subject	Pre Test	Post Test
1	2.33	1.50
2	2.50	2.00
3	2.67	1.33
4	3.00	2.50
5	4.33	4.33
6	2.33	2.00
7	2.00	4.00

	Individual Joint Rating	
Joint	Pre Test	Post Test
1	1	1
2	5	3
3	1	2
4	2	4
5	1	1
6	1	1
7	5	4
8	5	4
9	2	2
10	3	1
11	3	3
12	2	1
13	4	4
14	4	4
15	5	3
16	4	2
17	1	1
18	3	1