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Comparison Of The Walking Performance At Two Different Speeds In Adolescents With And Without Juvenile Arthritis Using A Dual-Task Method

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DEDICATION

This work is dedicated to my family and friends, earthly and heavenly, who have helped me to embrace my dream.

I hope this makes you proud.

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ABSTRACT

Impairments associated with juvenile arthritis have the potential to restrict adolescents from walking efficiently to meet the demands of functional activities. Clinicians often rely on patient self-report to describe walking function. Few instrumented gait studies exist examining the differences in stride characteristics in children with arthritis compared to children without joint disease. The purpose of this study was to determine if adolescents with JA utilize similar efficient gait patterns as healthy adolescents when walking at self-selected and fast speeds, as well as when walking and performing a secondary carrying task. Twenty-four adolescents were age-matched and assigned to either a JA group (n=12) or control group (n=12) based on health status. Subjects completed the Children's Health Assessment Questionnaire to determine perceived level of function. Following one practice trial, five trials performed at each of the two speeds were recorded as subjects walked along a 4-meter x .5 carpeted computerized walkway for three randomized conditions (tasks): (1) single task walking, (2) walking while carrying a large ball, and (3) walking while carrying a bowl of water ¾ full for a total of 36 trials. Velocity, normalized velocity, cadence, step length, and double support time were measured using the GAITRite™ Gold software on a PC laptop. A two-way ANOVA with one repeated measure was employed ($p \leq 0.05$) to determine group and task differences. Post hoc analysis utilized paired-

samples t-tests ($p \leq 0.017$). A normalized change score was calculated to compare the increases in walking speed for each group. The adolescents with JA walked at slower velocities when compared with the control group under all conditions, even with velocity normalized to leg length. Although not significantly different, the values of the JA group resulted in an expected trend of shorter and fewer steps. No differences in the amount of time spent in double support were noted. Both groups of adolescents increased walking speed by similar percentages for all three conditions. These data suggest that the presence of arthritis in the lower extremities slows walking performance. Self-reports of disability may not capture the true levels of function for walking performance. The use of instrumented gait evaluation under single-task and dual-task conditions is supported by this study.

CHAPTER 1

INTRODUCTION

Juvenile arthritis (JA) encompasses a broad category of chronic childhood rheumatic diseases including juvenile rheumatoid arthritis, systemic lupus erythematosus, scleroderma, psoriatic arthritis, ankylosing spondylitis, and other connective tissue disorders (Davidson, Kutcha, & Petty, 2000). An estimated 290,000 children in the United States have JA, with adolescents comprising 36% of this population (Lindsley, 1999). While the pattern of joint involvement and the degree of severity may differ between each type of JA, the same inflammatory process, characterized by joint effusion and synovitis, occurs (Davidson, et al. 2000; Mier, Wright, & Bolding, 2000). Furthermore, this pathology may not only affect the joint but may also disturb the integrity of the ligaments, tendons, muscles, and bones (Skull, 2000).

The onset of inflammation in childhood has profound effects upon an adolescent's musculoskeletal development (Edwards & Murray, 1999), and may result in impairments including loss of joint motion, weakness, and joint instability or destruction (Skull, 2000). Since there is no cure, optimal management requires a multidisciplinary approach directed at suppression of inflammation, relief of pain, prevention of deformities, and preservation of functional ability. While assessment of clinical signs and symptoms directs the practitioner how to manage the adolescent's physical impairments, the

extent of the adolescent's ability to perform activities of daily living (ADL) must also be addressed. Approximately 30% of school age children with JA have been found to require assistance in their school routine (Wright, Lindsley, & Olson, 1992). For example, JA interferes with the ability to climb stairs, to arrive to and from classrooms in a timely manner, and to carry heavy books back and forth to school (Harrington, Kirk, & Newman, 1999).

An adolescent's daily routine requires the ability to walk effectively at school or home, and health care professionals must evaluate this important component of functional mobility. Clinicians frequently use observational gait analysis (OGA) to determine the quality of a walking pattern, i.e., identifying the presence of gait deviation(s), and to subjectively determine if disease-related impairments are affecting the ability to walk in a safe and efficient manner (Smidt, 1974). While this method of gait analysis is widely used, the OGA data correlate poorly to functional walking ability.

Measurement of temporal-distance parameters using instrumented gait analysis (IGA) provides quantitative information to best identify functional deficits (Holden, et al. 1984; Holden, Gill, & Magliozzi, 1986). Commonly measured temporal-distance elements of the gait cycle include velocity, cadence, step or stride length, and period of double support (Winter, 1991). Of these, walking velocity has been shown to be a valuable gait parameter to quantify because when velocity changes so do the other stride characteristics (Craik & Cutterer, 1995; Sutherland, 1997). Similarly, velocity is altered

when modifying either the cadence or the step length. Measurement of an adolescent's range of walking velocities and respective stride characteristics enhances clinical decision-making about the level of functional gait ability (Bohannon, Andrews, & Thomas, 1996) and the possible environmental factors that influence the walking pattern (Rose, Ounpuu, & Deluca, 1991). The IGA approach is widely accepted for evaluating healthy and physically impaired populations across the life span (Norlin, et al. 1981; Oberg, Karsznia, & Oberg, 1993; Winter, et al. 1990).

Impairments from JA often result in gait patterns consisting of reduced velocities and step lengths (Lindsley, 1999; Platto, et al. 1991). Lechner and associates (1987) noted 30 children and adolescents had reduced walking velocities, decreased cadences, and shorter step lengths when compared to a healthy control group. In contrast, Stiskal and Zipp (2000) reported that 4 children with JA demonstrated similar shortened step lengths, but walked with increased cadences to achieve walking velocities comparable to controls (Appendix A). Since the presence of joint impairment may account for the reduced step length, the ability to alter the cadence may explain the velocity differences between these two studies. Furthermore, only when the children with JA were asked to walk while also performing a secondary carrying task with a high attentional demand did Stiskal and Zipp describe reduced gait velocities, cadences, and step lengths akin to those reported by Lechner et al. (1987).

Background of the Problem

Arthritis is one of the more common chronic childhood diseases (Arthritis Foundation, 2001). Inflammation associated with JA can severely affect the musculoskeletal system and thus, management of the arthritis is directed at achieving optimal growth and development. Despite medical interventions, adolescents with JA frequently have unilateral or bilateral limitations in the hip, knee, and/or ankle joints (Davidson, et al. 2000; Mier, et al. 2000). These lower extremity contractures may inhibit the ability to move efficiently, and therefore affect the adolescent's level of disability.

Measurement of mobility and functional status for persons with rheumatological disease can be obtained in part from patient self-report measures. Self-reports are widely used to obtain functional information that might not be assessed directly in the clinical setting (Stratford and Binkley, 1999). The majority of these self-report data instruments are designed to identify problems encountered by the adult rather than the adolescent (Tucker, 1999). The Childhood Health Assessment Questionnaire (CHAQ) [Appendix B] is an internationally accepted parent or child self-report questionnaire to measure general functional status in eight domains, including walking (Singh, Brown, Fries & Goldsmith, 1994). One limitation of the CHAQ is that the questionnaire covers a limited number of activities and therefore the full extent of a child's disability and important functional problems in a

child's daily life may not be detected (Tucker, 2000). Therefore, this tool may be better suited as an adjunct to direct assessment of an adolescent carrying out necessary ADLs like walking in the setting in which the activity is normally performed (Davidson, et al. 2000).

Walking is a basic and essential activity of daily living. Clinical gait assessment is routinely performed on adolescents with JA to ascertain the quality of the gait pattern and quantify the stride characteristics. OGA focuses on the subject's walking strategy, specifically the degree of limping and asymmetry that may be seen as an attempt to minimize pressure on the inflamed joints (Davidson, et al. 2000; Mier, et al. 2000). In a study of 10 children with JA, Witemeyer and colleagues (1981) found that four children with "mild" JA demonstrated normal gait patterns characteristics, while three children with "severe" disease walked with "marked" gait deviations.

Alternatively, IGA provides objective information about the adolescent's stride characteristics and functional gait status. Dhenendran and colleagues (1980) suggested that 8 children and adolescents with JA walked with reduced pressure on their forefoot during the stance phase of gait due to pain and/or deformities. Lechner et al (1987) found decreased gait velocities, cadences, and stride lengths in a group of children and adolescents where the majority of subjects had JA affecting four or less joints within the body. However, Stiskal and Zipp (2000) found that 4 children with mild to moderate JA demonstrated similar gait velocities when compared to

healthy age and gender matched controls by increasing their cadence and not step lengths when presented with less challenging experimental walking conditions.

When walking at one's self-selected velocity, minimal attentional demands are required (Larish, Martin, & Mungiole, 1988). Attentional processes are challenged when performing two distinct but simultaneous tasks (Eichhorn, et al. 1998). For example, an adolescent must perform simultaneously walking between classes in a timely manner (primary task) while carrying textbooks or a backpack (a secondary task). The performance of the concurrent secondary task while walking has been found to slow self-selected velocities (Huang & Mercer, 2001). In small studies of older adults (Maher, Stiskal and Zipp, 2001), of young children (Zipp, Stiskal and Leonard, 2001), and of children with and without JA (Stiskal and Zipp, 2000), all subjects demonstrated reductions in gait velocities when secondary tasks that increased attentional demands were coupled with walking.

Walking faster than at one's self-selected velocity may also increase the attentional demands of primary walking task (Eichhorn, et al. 1998). An increase in gait velocity alters the cadence and step length (Borghese, Bianchi, & Lacquaniti, 1996). This new pattern may disrupt the level of efficiency found when walking at the self-selected pace (Jeng, et al. 1996). Oberg et al (1993) have reported the differences in velocity, step length and cadence values when walking at self-selected and fast speeds, in

adolescents and adults. These fast walking velocities in the healthy individuals have been found to be as great as 44% faster than self-selected walking speeds; however individuals with musculoskeletal impairments demonstrate much smaller increases in their fast gait velocities (Ayyappa, 2001). To date, no studies have reported the ability of children with JA to walk at faster speeds dictated by the demands of daily life.

Problem Statement

The impairments associated with JA have the potential to restrict adolescents from walking efficiently to meet the demands of functional activities. While there is a large body of research on the stride characteristics of young children as well as adults, there is a paucity of literature on the gait patterns of adolescents. The purpose of this study was to determine if adolescents with JA utilize similar efficient gait patterns as healthy adolescents when walking at self-selected and fast speeds, as well as when walking and performing a secondary carrying task.

The following questions were posed:

1. Do adolescents with and without JA demonstrate similar self-selected stride characteristics, specifically walking velocities, normalized velocities, cadences, step lengths, and double support times when:
    a. walking without carrying an object?
    b. walking and carrying a ball?

c. walking and carrying a bowl of water?

2. Can adolescents with JA increase their walking velocities in a manner similar to that of adolescents without JA when:

   a. walking without carrying an object?

   b. walking and carrying a ball?

   c. walking and carrying a bowl of water?

Definitions

Adolescence: period of human maturation, which occurs between the beginning of puberty and adulthood. Is divided into three subcategories: early, occurring between ages 10 and 14 years of age; middle, occurring between 15 and 17 years of age; and late, occurring from 18 years of age to the middle twenties

Bimanual coordination: preference for the two upper limbs doing the same thing at the same time

Cadence: the number of steps per unit time, expressed as steps/min.

Capacity sharing theory: the amount of attention needed to perform two simultaneous activities. As the amount of attention for one activity increases, there will be less capacity for the second task.

Double support: the period of time in walking when both feet are in contact with the ground, and expressed in seconds or as a % of the stride period

Dual-task paradigm: method used to determine the attentional demands of a particular task when two tasks are performed simultaneously.

Functional gait: the ability to ambulate during activities of daily living

Functional limitation: a level determined by the ability to perform task-oriented or functional motor activities

Gait cycle: the sequence of events that begins with one extremity continues until that event is repeated with the same limb

Gait velocity: the average horizontal speed of the body along the plane of progression measured over one or more strides periods; is reported in cm/second

Heel strike: initial contact between the heel and the ground

Instrumented gait analysis (IGA): technique involving quantitative analysis of walking performance obtained from instruments measuring walking performance including but not limited to a subject's stability and balance, velocity and control, symmetry and movement of the upper and lower extremities and trunk, deformities, and influence of assistive devices

Natural cadence: is the number of step per minute that the subject achieves when given instructions to walk naturally or freely as possible at a comfortable pace

Normalized Velocity: is obtained after dividing the average speed of walking by the average leg length and it is expressed in leg length per second

(LL/sec). The average leg length is computed (left leg length + right leg length)/2

Observational gait analysis (OGA): technique involving qualitative descriptions of walking performance from observations made of a subject's stability and balance, symmetry and movement of the upper and lower extremities and trunk, deformities, and influence of assistive devices

Performance: observable execution of a skill at a specific time and in a specific situation

Primary task: task of primary interest, which is performed and measured in the absence or presence of a simultaneous task using a dual-task paradigm

Secondary task: task added to the primary task in a dual-task paradigm

Self-selected cadence: number of steps per minute when a subject walks as naturally as possible

Self-selected velocity: qualitative descriptor of a subject's self-selected rate of forward progression

Speed: qualitative descriptor of the rate of progression during walking

Stance period: period of time when the foot is in contact with the ground, expressed in seconds or as a % of the stride period; is subdivided into several sub-events: weight acceptance, mid-stance, and push-off

Step length: the horizontal distance covered along the plane of progression during one step; is the distance measured form a point on one foot to the same point on the other foot, expressed in centimeters

Stride characteristics: the individual's basic walking capacity expressed as the combination of gait velocity, step lengths, cadence, and swing and stance times

Stride length: the horizontal distance covered along the plane of progression during one stride; is the distance covered from IC to IC of the same foot expressed in centimeters. Is equal to the sum of the two step lengths and is equal for both the left limb and the right limb if the person is walking in a straight forward line, even in the presence of marked bilateral step length asymmetry

Swing phase: period of time when the limb is swinging forward, out of contact with the supporting surface

Temporal gait variables: descriptors of gait including stance time, single-limb and double-support time, swing time, stride and step time, cadence, and speed

Temporal-distance measures: objective measures of the gait cycle include step/stride time and length, stance and swing time, period of double support, and base of support/stride width

Hypotheses

All adolescents will demonstrate a change in stride characteristics, at both self-selected and fast-walking speeds, when they perform a secondary

carrying task, i.e., walking and carrying either the ball or walking and carrying the bowl with water, compared to when they are walking without carrying an object. Adolescents with JA will exhibit slower walking velocities in each walking condition as compared to adolescents with no joint disease, and the adolescents with JA will not able to increase their walking velocities to the same extent as the adolescents in the control group. Lastly, adolescents with JA will exhibit stride characteristics consisting of increased cadence, increased double support times, and decreased step lengths as compared to the healthy group in all conditions.

Need for Study

Few instrumented gait studies have examined the functional limitations imposed by juvenile arthritis in adolescents. Pilot work by Stiskal and Zipp (2000) suggested that children and adolescents with JA obtain necessary gait velocities in select walking conditions by increasing cadence but not step length when the attentional demands are minimal. No additional studies have examined the influence of a carrying task on the walking patterns in children with JA. Similarly, no studies have investigated whether the adolescent with arthritis is capable of obtaining adequate fast gait velocities that may be necessary to meet school and home activity demands. Functional self-report tools may not be sensitive enough to determine the level of gait disability in adolescents and therefore information obtained from this study may help

physicians and other health care practitioners to identify more accurately the functional gait problems of this population.

CHAPTER II

REVIEW OF THE LITERATURE

This study is designed to investigate the changes in temporal-distance stride characteristics in adolescents with and without arthritis when walking at two different speeds and while performing a secondary carrying task. The review of the literature is divided into three sections. In the first section, an overview of JA is presented with an emphasis on the resulting physical impairments as a consequence of inflammation and their relationship to functional disability for the adolescent with JA. The second section presents a review of the human gait cycle and its stride characteristics. Issues of pathological gait for adolescents with arthritis and methods of gait assessment are illustrated. The third section contains a summary of motor control principles with an emphasis on the dual-task paradigm.

Juvenile Arthritis

According to the American College of Rheumatology (ACR), arthritis is defined as joint swelling or effusion, or as the presence of at least two of the following: decreased range of motion, warmth, and pain or tenderness with motion (Mier, et al. 2000). In children, more than 110 pediatric illnesses have been associated with an arthritic component (Singsen, 1991). Approximately

36% of children with JA are adolescents (Lindsley, 1999) and as many as one half of these adolescents will continue to have active arthritis for at least 10 years after date of onset (Martin & Woo, 1999).

One of the hallmarks of arthritis is inflammation, the complex response of the body to injury. In JA, the inflammatory process frequently leads to hypertrophic synovium and progressive destruction of articular cartilage from the various enzymatic reactions produced by the inflammatory cells (Mier, et al. 2000). Prolonged and/or uncontrolled inflammation may lead to weakening of the articular capsule, supporting ligaments, and soft tissue structures resulting in a reduction in the joint's biomechanical integrity.

Inflammation associated with JA may also shape skeletal growth and development (Mier, et al. 2000). Focal long bone growth problems, either overgrowth or undergrowth, are common since increased blood flow is a consequence of the inflammatory process (Davidson, et al. 2000). For younger children with JA, increased blood flow to the growth plates near the inflamed joint may produce bony overgrowth and a limb-length discrepancy of up to 2 or 3 centimeters (Mier, et al. 2000). In contrast, increased blood flow in older children with JA may accelerate bony maturation and early epiphyseal closure, resulting in a shortened limb segment (Edwards & Murray, 1999; Mier, et al. 2000).

While the progression of JA may differ based on age of onset or disease type, adolescents present with many of the same activity-limiting

musculoskeletal impairments: decreased range of motion, pain, and muscle weakness (Black, Murray-Weir, & Sanders, 2000; Skull, 1994). Joint instability and a concomitant decrease in the willingness to move further add to soft tissue restriction (Skull, 2000). A resultant contracture may develop as the inflamed joint assumes and maintains a position of greatest volume in an effort to reduce painful intrasynovial pressure.

As the child continues to grow, constrained joints may become more disabling and produce secondary, compensatory soft tissue restrictions within the same or the opposite limb (Edwards & Murray, 1999). For example, knee flexion contractures may result from hip disease as the child attempts to realign the body's center of gravity. The inability to tie one's shoelaces or to don and doff one's trousers due to loss of motion in both the hips and knees are representative of the challenges to the adolescent with JA (Edwards & Murray, 1999). Furthermore, these musculoskeletal problems may persist long after the inflammatory process goes into remission (Klepper & Skull, 2001).

Similarly, a frequent consequence of hip and/or knee joint contracture is leg-length discrepancy (Edwards & Murray, 1999). The soft tissue restriction at either joint reduces the amount of available range of motion needed to advance a lower limb during gait. For instance, the presence of limited knee motion has been found to markedly limit walking ability by reducing the adolescent's step length (Lindsley, 1999). The overall effect of a

shortened limb on the walking pattern may also cause the adolescent to transfer the bulk of weight-bearing force and time to the contralateral limb. This compensatory mechanism may induce additional lower limb inflammation and increase the risk for adaptive contracture in this contralateral leg.

Pain is a frequent, significant impairment associated with JA and pain on movement commonly occurs at the end ranges of motion (Klepper and Skull, 2001). Consequently, movement is avoided in an effort to control the discomfort and ultimately may result in adaptive contracture. Physiologic motions of hip extension, knee extension, and dorsiflexion are most at risk for adaptive losses. Less than full range in any of these motions places the adolescent at risk for loss of functional ability since end range, or near-to-end range, motions are necessary for upright stance and a normal gait pattern (Levangie & Norkin, 2001).

While inflammation severely compromises musculoskeletal maturation, children with JA tend to develop without neurological disability (Black, et al. 2000). However, the onset of arthritis before age six often prevents the child with arthritis from exploring the environment and may have an effect on the refinement of motor skills. Parental overprotection can also restrict a child's opportunities to explore the environment and further impede the development of skilled movement (Black, et al 2000; Giannini and Protas, 1992). For example, preschoolers with JA demonstrated lower gross motor performance

when compared with healthy, age matched children, limiting their ability to play at age-appropriate activities (Morrison, Bundy, & Fisher, 1991). Reduced activity levels over time may add to the musculoskeletal impairments and functional limitations imposed by the JA. Adolescents with JA have been shown to exhibit limited functional capacity, with decreased measures of peak isometric knee torque and reduced aerobic capacity (Giannini & Protas, 1991, 1992, 1993).

The complicated set of physical issues results in significant long-term functional limitations and handicaps for the adolescent with arthritis (Klepper, 1999). Therefore, the ultimate goal in the management of this chronic childhood disease is the optimization of growth and development to maximize the individual's functional ability. Comprehensive evaluation of the adolescent's physical status is necessary to determine the musculoskeletal impairments and functional abilities prior to designing an intervention program (Klepper and Skull, 2001). An individualized treatment program for an adolescent with JA may require a team of health care professionals to address patient and family needs. The medical management should focus on improving function, reducing deformity, and minimizing permanent joint damage. Rehabilitation services provided by physical and occupational therapists are designed to improve physical function through thermal agents, exercises, assistive devices, and patient and family education.

The school environment is an example of one setting in which the adolescent with JA may experience considerable difficulty with physical performance. Bartholomew and associates (1994) summarized the most frequent problems interfering with school: impaired mobility, late arrival, inadequate time between classes, poor stamina, poor fine motor skills, difficulty standing in line, and participating in physical education. Furthermore, adolescents with JA have difficulty sustaining an adequate level of performance during the school day due to the effects of pain, inflammation, and fatigue (Harrington, et al. 1999).

Despite an increasing demand for functional outcome measures in the school-based setting (Knutson, Schimmel, & Ruff, 1999), many of the functional assessment questionnaires and clinical testing methods used by clinicians do not address the needs of the adolescent with JA. Singh and colleagues (1994) published the CHAQ as a general tool designed to ascertain the impact of rheumatic disease on health-related quality of life in children. The 10-minute, self-report questionnaire is adapted from the adult version of the HAQ and attempts to identify the level of physical functional in the child with JA. The questionnaire addresses eight domains: dressing/grooming, eating, walking, arising from a bed in the morning, hygiene, grip, reach, and general activities. A disability index is calculated from the means of each of the eight functional areas.

Although the CHAQ is internationally accepted as the most useful pediatric arthritis disability tool available, the sensitivity of the questionnaire may be low. Martin & Woo (1999) summarized several studies and concluded that the distribution of self-rating scores is heavily biased toward the child experiencing no or very few problems. Furthermore, the scope of activities selected for the respondent to answer on the CHAQ is restricted and as such, conclusions about the depth of the functional consequences of JA may be underestimated (Kuchta, et al. 2000).

Gait

Gait cycle. Walking is one of the most difficult motor tasks for humans to learn, but once achieved walking becomes almost automatic (Winter, 1991). Walking is the natural means for a human to move from one location to another and to move the body forward so that the hands and head are free to perform their numerous functions. Forward progression is mostly a lower-extremity task coordinated to transport the body as a whole (Winter, 1992) through the production of alternating propulsive and retropulsive motions (Levangie & Norkin, 2001). The lower extremity muscles produce coordinated, rotatory movements amongst the multiple lower limb joint segments to accommodate walking on levels and stairs, through doorways, over obstacles, and across changing surfaces.

In order to achieve safe and efficient forward progression of the body, critical functions are performed during each gait cycle, independent of the gait speed (Winter, 1991). The first functions involve the maintenance of postural control and balance throughout the gait cycle. The head, arms, and trunk (HAT) constitute 75% of total body weight and must be balanced over one lower extremity as well as transferred from one lower extremity to the other during walking (Levangie & Norkin, 2001). Next, the foot must be controlled for safe ground clearance and brought forward for a gentle initial contact with the floor (Winter, 1991). Lastly, the body must generate the mechanical energy needed for forward progression while also absorbing mechanical energy for shock attenuation and decreasing the forward velocity of the body.

Normal gait is the translation of the body's center of gravity (COG) through space along a pathway requiring the least expenditure of energy (Perry, 1992). The human COG has just a small vertical and lateral displacement during walking (Inman, Ralston, & Todd, 1981; Malanga & DeLisa, 1998). Saunders, Inman, and Eberhart (1954, in Perry, 1992) described several biomechanical factors that reduce the displacement of the COG. These functions are called the six determinants of gait, whereby the pelvis, hip, knee, and ankle joints are controlled by the neuromuscular system to achieve an efficient and effective gait pattern with the constraints imposed the lower limbs (Inman, Ralston, & Todd, 1981; Perry, 1992; Winter, 1991).

Therefore, efficiency in walking depends of the amount of joint mobility as well as appropriate intensity and timing of muscle activity (Perry, 1992).

Because multiple muscles may cross over the same joints, the same limb movement may be achieved when different combinations of muscles are activated (Winter, et al. 1990; Winter, 1991). The preferred patterns of leg movement aim to minimize the exchange of mechanical energy between the lower limb and the HAT (Levangie & Norkin, 2001). These preferred coordinated limb motions, especially when performed at self-selected speeds, also allow the central nervous system (CNS) to modulate the walking pattern at a low conscious level (Winter, 1992).

Breniere (1996) theorized that normal gait is stable and has consistent stride characteristics when performed at a preferred walking speed and in an open environment without any obstacles or change in walking surface. However when walking faster than at a self-selected speed, increases in stride length and cadence occur (Borghese, et al, 1996; Bonnard, Pailhous & Danion, 2000). Any rise in cadence even while walking at a constant speed adds to the physiological energy of the walking (Jeng, et al. 1996). Furthermore, the increased cadence alters the natural efficiency of the coordinated limb motion. Therefore, the subject must increase attention to the walking task in order to adapt to this faster cadence (Winter, 1991).

Stride characteristics. Time and distance are basic measures of motion and therefore the gait cycle can be broken down into measurable

components. One stride lasts approximately 1 second when walking at a normal preferred gait speed. Stride can be broken down into left and right steps, although the two step lengths may not be of equal length (Winter, 1991). Low coefficients of asymmetry have been found for stride, stance, and swing when walking along a straight path (Blanc, et al. 1999). The body's attempt to maintain bilateral lower extremity movement symmetry during walking is a means to minimize energy costs (Jeng, et al. 1996).

Walking velocity, step/stride length, and cadence are considered the most basic of temporal-distance gait parameters since these stride characteristics depend on an individual's joint mobility, muscle strength, neural control, and energy level (Perry, 1992). Quantification of the stride characteristics facilitates clinical decision-making and establishes the level of gait disability. For example, velocity is the most important stride characteristic to measure when group differences between disabled and non-disabled subjects are studied (Sisto, 1998). Self-selected gait velocity across smooth surfaces averages 137 cm/sec, with males averaging 5% faster and females 6% slower (Perry, 1992).

Step length and cadence are two stride characteristics highly correlated with velocity (Andriacchi & Hurwitz, 1997) when gait velocities are within 80 to 200 cm/sec (Craik & Dutterer, 1996). To increase one's velocity, an individual may simply increase the size of the step lengths (Oberg, et al. 1993; Winter, 1991). Perry (1992) reported the average stride length is 141

centimeters. Additionally, altering the cadence will change gait velocity (Levangie & Norkin, 2001). Averages for natural cadences have been reported to vary from 101 to 122 steps/min, with only slight gender differences found (Winter, 1991).

When walking with a natural cadence, an individual spends 58-61% of the gait cycle in the stance (Winter, 1991). During this stance time, two periods of double support occur, and if perfect symmetry is assumed, each of the two double support times is 8-11% per stride (Winter, 1991). Furthermore, double support time has an inverse relationship with cadence, and is ultimately influenced by gait velocity (Winter, 1991). When cadence is less than 120 steps per minute, a higher gait velocity is achieved by increasing both stride length and cadence. In gait patterns with greater than 120 steps per minute, the step lengths become consistent and only the cadence can be increased to achieve faster gait velocities. As the cadence rises, the period of double support decreases until the cadence approaches 180 steps per minute, a period when the double support time disappears and running commences (Ayyappa, 2001; Perry, 1992).

These temporal-distance measures are affected by a host of factors including age, size and shape of bony components, joint mobility, and notably, gender (Perry, 1992; Levangie & Norkin, 2001). When walking at similar self-selected gait velocities as males, females demonstrate a small increase in cadence and a decrease stride length (Oberg, et al. 1994).

Additionally, women generally walk at slower velocities than men (Oatis, 1999), but no significant gender differences exist when the stride characteristics are normalized for leg length (Norlin, et al. 1981).

Healthy individuals possess a wide range of safe and comfortable walking speeds (Perry, 1992). A speed faster than the self-selected walking speed is needed in many instances as a response to externally paced environmental conditions (Magill, 1998). Walking to cross the street in the presence of a traffic light or reaching a new classroom within a fixed period of time may necessitate a change in natural walking velocity. Reference values for the stride characteristics at self-paced and fast speeds have been reported for adolescents and adults (Oberg, et al. 1993; Winter, 1991).

Gait in children and adolescents. There is a wide body of literature describing the development of gait patterns in children. Sutherland (1997) investigated the walking patterns of 309 children, 1-7 years old; Knutsen, Schimmel and Ruff (1999) studied 228 healthy children 6-13 years of age; and Norlin et al. (1981) evaluated the walking patterns of 230 children 3-16 years of age. By 7-8 years of age, all authors concluded that healthy children exhibit minimal variability in their self-selected velocity and natural cadence. Similarly at this age, velocity, cadence, and double support measures were found to be comparable to adult values (Norlin, et al. 1981).

Growth and central nervous system maturation is believed to control the development of gait up until age 4, and thereafter growth alone accounts

for the changes in stride characteristics. The stride characteristics correlate well with a growing child's physical stature (Rose-Jacobs, 1983; Sutherland, 1997). For instance, Beck and colleagues (1979) reported that children have a significant increase in stride length for each year of growth until 11 years of age, and after this age, changes are minor (Perry, 1992).

Pathological gait. An atypical gait pattern is any gait pattern that deviates sufficiently from one recorded from healthy subjects. Normal gait is complex, however pathological gait is even more complicated since deviations are often confounded with compensations (Rose, et al. 1991). When gait deviations result from musculoskeletal impairments, the central nervous system must have the capability of regulating the limb segments to compensate for the loss of function (Winter, et al. 1990). For example, limitation in one lower extremity joint can usually be compensated by increased movements at the joints above or below the impairment (Malanga & DeLisa, 1998). In the presence of more severe impairment(s), the resultant walking pattern becomes a mixture of normal and abnormal motions, with a concurrent increase in energy costs and compromised function (Perry, 1992; Malanga & DeLisa, 1998).

An adolescent with JA may be incapable of normal stride characteristics. The atypical gait patterns arise because of musculoskeletal impairments (Lindsley, 1999; Mier, et al. 2000). Loss of joint flexibility can result in lack of the necessary mobility on the side of a shortened limb.

Arthritis in the hip restricts full range of motion in all planes, resulting in decreased motion during the entire gait cycle; a knee flexion contracture produces a decreased heel strike on the involved side (Lindsley, 1999).

The adolescent with JA may develop a compensated gait pattern to avoid pressure on inflamed tissues (Davidson, et al. 2000). Arthritis pain may also compel the individual to shorten the step length (Gussoni, et al. 1990). Dhenendran and colleagues (1980) compared the foot pressures in 8 children with "Still's disease" (JA) to 11 children without joint disease. The data indicated that the children with arthritis walk more slowly than healthy children as a mechanism to reduce pain and minimize the risk of additional inflammation from destructive high impact weight-bearing forces. The subjects also utilized altered weight-bearing patterns, predominantly on the posterior and lateral aspects of the foot, to reduce the magnitude of weight-bearing on the medial foot.

Lechner et al. (1987) investigated the stride characteristics of two groups of children and adolescents: a group with JA, 4-20 years of age, and a healthy group without JA, aged 4-27 years. The investigators found the group with JA had slower velocities, decreased cadence, and shorter steps when compared to the healthy children. The authors suggested that the decreased step length is a result of joint stiffness and the reduced cadence may arise from any of the physical impairments slows the lower limb's ability to move fully quickly the gait cycle.

In a pilot study, Stiskal and Zipp (2000) examined the effects of performing secondary tasks on walking abilities in children with and without JA. The testing conditions were selected based on the taxonomy described by Gentile (1987) [Appendix C], and used in other research pilots (Zipp, et al. 2001; Maher, et al. 2001). The methodology included a single-task condition of control walking, and two dual-tasks conditions: walking with a backpack on one shoulder (low-attention task) and walking with a pitcher of water three quarters full (high-attention task). When presented with the high-attention task, both groups of children walked with significantly decreased gait velocities and cadences. Significant group differences were also reported as the children with JA demonstrated significantly slower gait velocities when performing the high-attention dual-task condition. Furthermore, the raw data from the JA group were at or below 100 cm/sec, values considered to be dysfunctional (Messier, 1994).

Stiskal and Zipp (2000) also found significant group differences for step length and cadence. Shorter step lengths were recorded for the JA group during all testing conditions, however raw data suggested a trend toward utilization of further reduced step lengths when the two dual task conditions were performed. To meet the demands of the walking conditions, the JA group utilized higher cadences for all but the high attention dual-task condition. The authors hypothesized that children with JA were able to maintain adequate velocities by increasing cadence and not step lengths to

meet the demands of task conditions. These increases in cadence and velocities are dissimilar to the results found by Lechner, et al. (1987), but are comparable to the results of Gussoni, et al (1990) for subjects with rheumatic hip disease. Accordingly, children with JA may achieve adequate velocities during self-selected gait by taking shorter and more frequent steps when given no or a low-attention secondary task; complicated carrying tasks may create constraints that limit the child with JA to walk functionally within his/her environment.

Gait analysis. In clinical practice, the simplest method of measuring walking performance is performed by observational gait analysis (OGA) (Perry, 1992; Sisto, 1998). This method requires the clinician to note the presence or absence of various components of the gait cycle. Qualitative descriptors are also employed to denote symmetry, timing, and spatial relations. However, these measures tend to be very subjective and may be reflective of a practitioner's experience and bias (Sisto, 1998). Fair to poor intra-tester and inter-tester reliability coefficients have been reported (Stuberg, et al. 1988; Eastlack, et al. 1991).

The literature supports the use of instrumented gait analysis (IGA) for clinical and research purposes (Perry, 1992). Temporal-distance measures including step length, stride length, velocity, cadence, period of double support, and normalized velocity are examples of the quantitative parameters obtained from this form of measurement. The IGA is quickly performed and

yields valuable objective results for clinical decision-making (Rose, et al. 1991). In addition to determining intervention strategies, IGA data allow the clinician to assess the impact of the impairment(s) during functional walking (Sisto, 1998). Stuberg and colleagues (1988) summarized the literature and reported fair to excellent test-retest reliability of the temporal-distance measures for various healthy and physically impaired populations.

Computerized gait mats are relatively new IGA systems to objectively measure both temporal and spatial gait parameters (Bontrager, 1998). The advantage to a computerized gait system is the absence of gait monitoring attachments or devices, lower cost, and portability. One commercially available gait mat is the GAITRite™, a 4 mm thick, carpeted mat with embedded pressure sensors which are arranged in an array of switches running both across and along the length of the mat (Bontrager, 1998; Cir Systems, 2001). As a subject walks along the mat, these switches close as the foot comes in contact with the mat and open again as the foot loses contact with the mat. This allows the computer software to determine the timing of the switches closing and opening. Comparing the subject's stride characteristics to the known geometry of the mat, the software can calculate the spatial/distance parameters.

Additionally, the software calculates a normalized gait velocity value to assist in determining group differences. Since limb length is more directly related to lower limb function than the overall height, Sutherland (1997)

advocates normalizing the velocity by dividing by the limb length. For data analysis, when the right and left step lengths are approximately equal, then one of the step length values can be used for comparisons. In the presence of unequal leg lengths, stride length instead must be used for analysis. This attention to leg length is necessary, especially when comparing similar-aged subjects with and without pathologies such as JA, in which leg length may be affected (Rose, et al. 1991).

Skilled Movement

Skilled motor performance requires an organized and coordinated neuromusculoskeletal system to successfully achieve a functional motor activity (Magill, 1998). Different tasks impose different constraints and thus influence the neuromotor processing, which coordinates the body and limb segments to meet the unique requirements of each activity (Gentile, 1992). The emerging movement strategy, therefore, is an interaction between the individual, the task itself, and the environmental context in which the task is performed. Consequently, functional ability is dependent on the individual's physical capacity to meet these task and environmental demands.

To analyze functional movement performance and skill level, Gentile (1992) developed a two-dimensional taxonomy, which incorporates three continua: the range of task variability, the degree of body stability, and level of upper extremity manipulation (Shumway-Cook & Woollacott, 2001). For

example, a task executed with static positioning, in a quiet environment, with nothing in the hands will require less motor skill than walking along a moving platform with multiple packages in the hands. By determining the performance components as well as the manner in which these continua interact with the others, the clinician can identify an individual's problematic movement characteristics (Magill, 1998).

Clinical practice entails the analysis of functional activities. A clinician may document solely on a patient's ability to successfully execute an activity, or chose to perform an in-depth evaluation of the movement strategy employed to achieve the activity. When analyzing gait, the clinician documents if a patient can walk a known distance or not, and also with what type of walking pattern, e.g., antalgic, slow, etc. While these two modes of evaluation provide useful information about the patient's walking pattern in one particular setting, the therapist cannot predict how well the patient adapts the gait strategy if the environment or the purpose of the task should change. Hence, goal-directed behavior should be analyzed by not only examining an individual component, i.e., musculoskeletal system, involved with the neuromotor processing, but also the relationships between the multiple systems of the human body (Shumway-Cook & Woollacott, 2001).

Dual-Task Paradigm. An individual's motor function results from the interaction of cognitive, perceptual, mechanical, and neurological mechanisms (Huang & Mercer, 2001). Recently clinicians have begun to

address the influence of cognitive factors, particularly attention, on an individual's functional ability. Attentional processes may be evaluated when individuals are asked to execute two tasks simultaneously, by evaluating an individual's ability to perform one primary motor task while simultaneously performing an alternative, secondary task (Wright & Kemp, 1992). This dual-task methodology examines the ability to divide attention between two distinct but simultaneously performed tasks (Ebersbach, Dimitrijevic, & Poewe, 1995; Eichhorn, et al. 1998).

Because the individual may shift attention between each of these two concurrently performed tasks, this approach is also referred to as the divided attention or "time-sharing" paradigm (Huang & Mercer, 2001). This paradigm has two assumptions: 1) central processing capacity is limited and 2) the restricted capacity must be divided between the two concurrent tasks (Huang & Mercer, 2001). In this dual-task methodology, the current performance of the primary task with a secondary task should not differ from the performance demonstrated in a primary task only condition (Wright & Kemp, 1992). Nonetheless, the capacity sharing theory states that when the amount of attention for one activity increases there will be less capacity for the simultaneous second task (Eichhorn, et al. 1998), and individuals often sacrifice primary task performance to successfully execute the additional secondary task (Huang & Mercer, 2001). If either of two tasks becomes more difficult to perform than the other, then the ability to divide attention

successfully between the two concurrent tasks declines (Ebersbach, et al. 1995; Eichhorn, et al. 1998).

In clinical practice, the dual-task paradigm can be used to investigate the attention demands of any functional motor task (Huang & Mercer, 2001). Wright and Kemp (1992) studied the attentional demands of walking with various assistive devices in 10 young to middle-aged adults with no physical or cognitive impairment and who were instructed to give priority to the walking task along 6.1-meter line taped along the floor. The secondary task was a reaction time between an auditory stimulus and the subject's vocal response. The authors concluded that walking with a standard walker was more attention-demanding than walking with a rolling walker or walking without an assistive device.

Another objective of the dual-task paradigm is to investigate the effects of divided attention on motor performance by instructing subjects to give equal priority to primary and secondary task performance. Two studies were performed to measure if postural control was influenced by secondary cognitive processing tasks (Malar and Wing, 1996; Shumway-Cook and Woollacott, 1997). Malar and Wing found increases in postural instability during the two of five dual-task conditions. Shumway-Cook and Woollacott also found that the addition of a cognitive secondary task produced an increase in instability for three groups of younger and older adults.

Like posture, walking at a comfortable and self-selected speed is said to be an automatic activity that does not require much concentration (Larish, et al. 1988). Nevertheless even highly practiced tasks of postural control and gait require some degree of attention (Huang & Mercer, 2001). Any change from the normal, self-selected characteristics of a motor activity, e.g., walking as fast as possible, may challenge the attention capacity sharing and change the gait pattern (Eichhorn, et al. 1998). Additionally, performing two concurrent tasks may also challenge the ability of an individual to maintain an effective walking pattern.

A small number of gait studies have investigated the effect of a second task on walking performance. Ebersbach et al. (1995) explored the influence of different concurrent tasks on stride time and double-support time in 10 healthy subjects between the ages of 25 and 42 years. Secondary tasks included performance of digit spanning (cognitive task), buttoning, finger tapping, and digit spanning combined with buttoning. Subjects were instructed to concentrate on the secondary task rather than the gait performance. The authors reported that stride times increased between single and dual-task conditions only during the fast finger tapping condition and double-support times differed between single and dual-task conditions only during the digit spanning with buttoning condition.

Likewise, Eichhorn and associates (1998) evaluated the walking performance to determine if the addition of a secondary task had a negative

effect on stride characteristics of a group of 9 young adults and a group of 9 older adults. Secondary tasks required subjects to respond to an auditory stimulus at a stationary baseline testing session and then during walking. Data indicated that both groups of subjects reduced walking velocity in response to a secondary stimulus, and older subjects demonstrated significantly slower reaction times while walking when compared to younger subjects.

Grabiner, Biswas, and Grabiner (2001) also studied younger and older adults to establish if age, walking speed, shoe condition, and performance on an attention-dividing tasks affected stride variability. In their first part of their experiment, the authors found no significant differences in stride when subjects walked with and without shoes. For the second phase, the authors required subjects to carry an 8-ounce cup placed in a saucer, with the cup filled with water to within 3 mm of the rim. The results suggested that variability in the gait velocities of both groups was significantly different when performing the secondary carrying task. Interestingly, the younger adults demonstrated significant increases in gait velocity variability between the baseline and secondary-task trials; whereas, the older adults demonstrated increases in stride width variability. These researchers concluded that these findings were consistent in other gait studies investigating aging and pathological conditions.

CHAPTER III

MATERIALS AND METHODS

Subjects

Twenty-nine children between the ages of 10 and 19 were recruited from flyers posted in cooperating physician's offices, pediatric rehabilitation centers, school districts, Arthritis Foundation-New Jersey Chapter offices and newsletters to participate. In this study, two locations were offered: the Functional Human Performance Center at Seton Hall University or the Pediatric Rheumatology office at Hackensack University Medical Center (Appendix D). The investigator interviewed all children interested in participating in the study and gathered demographic information to determine appropriateness for inclusion (Appendix E). The subjects represented a sample of convenience and met the following inclusion criteria: 1) weight of at least 40 pounds (Pascoe, et al. 1997); 2) attended a regular educational school program; 3) had no known cognitive impairments (Eichhorn, et al. 1998; Kramer and MacPhail, 1994); 4) had normal or corrected to normal vision; 5) had a leg length discrepancy of no more than 1.9 cm (Blanke and Hageman, 1989); 5) ability to walk a 8 meter distance without an assistive device; and 6) possessed no known neurological, cardiovascular or

pulmonary condition that may compromise the completion of the testing protocol (Bohannon, Andrews & Thomas, 1996; Kerrigan, Todd, & Della Croce, 1998). Of the 29 volunteers, four were dismissed and one subject did not meet matching criteria. One adolescent with JA was dismissed due to the presence of permanent internal fixation in the right ankle and one potential control group subject reported bilateral congenital hip dysplasia that continued to present with problems of pain and limited motion. Two other candidates were initially included in the study and later dismissed for safety purposes when each could not complete the walking task without excessive water spillage on self or the walking surface.

The 24 adolescents meeting the inclusion criteria were age-matched to within one and half years and assigned to either a JA group or control group based on health status (Appendix F). Sample size was determined from a previous study by Stiskal and Zipp (2000) [Appendix G]. Adolescents in the JA group had a diagnosis of arthritis for more than six months, with involvement in at least one lower extremity joint, but without severe systemic disease as measured with a CHAQ score of two or greater (Bacon, et al. 1991; Spraul and Koenning, 1994). Children in the control group were free of lower extremity pain on the day of testing and unresolved musculoskeletal problems affecting the lower extremities (Kroll, et al. 1989) and had a CHAQ score of zero.

Confidentiality was assured by assigning each subject a unique alphanumeric code. The study received approval by the Institutional Review Board of Seton Hall University and the Institutional Review Board of Hackensack University Medical Center (Appendix H). Subjects over the age of 18 and the parents of the subjects under the age of 18 signed a written consent form, and subjects under age 18 signed a written assent form (Appendix I). Depending on the testing venue, all subjects and parents completed the appropriate version approved by the respective institutional review boards.

Procedures

Leg Length Measures. While standing with footwear on, the investigator obtained bilateral measures of leg length, in centimeters. Using a steel tape measure placed against the subject's greater trochanter, a measure of the vertical distance between this bony landmark and the floor, bisecting the lateral malleolus was recorded (Cutlip, et al. 2000).

Walking Procedures. Subjects were required to walk a length of 8 meters (one trial); 2 meters before and 2 meters after the 4-meter GAITRite™ carpeted mat to ensure measurement of steady state gait (Cutlip, et al. 2000; Grabiner, et al. 2001). Prior to each testing condition, subjects practiced one trial of walking down the GAITRite to familiarize subjects with each of six experimental conditions (Ebersbach, et al. 1995; Cook, et al. 1997). Excluding practice trials, subjects performed a total of 30 gait trials: five trials

for each of six walking conditions. The number of walking trials was selected to ensure that a minimum of 20 steps is recorded for each condition (Grabiner, et al. 2001). A chair was placed adjacent to the walkway for subjects to sit during each 45-second rest period given between each walking trial, and for each 3-minute rest period given between each set of five trials (Fransen & Edmunds, 1999; Walsh, Woodhouse, Thomas, & Finch, 1998).

Three walking conditions were selected to represent a continuum of increasing skill difficulty and attentional demand. The simplest and most automatic was the single-task walking only condition, employed to establish baseline self-selected walking speed. To increase the motor difficulty involved with walking, two dual-task conditions (1) walking and carrying a plastic ball about 40" in circumference (low-attention task) and (2) walking and carrying a plastic bowl of water three-fourths full and approximately two pounds (high-attention task) were also performed (Magill, 1998).

The three different task conditions were randomized to control for fatigue and learning effects (Ebersbach, et al. 1995; Grabiner, et al. 2001). Subjects performed all three conditions at two different speeds: self-paced and fast (Appendix J). The subjects always performed first the randomized task condition at his/her self-selected speed for the one practice and all five data trials. Then, subjects repeated this same task condition by walking at his/her fastest speed, as comfortably and safely as possible without running,

for an additional one practice and five data trials (Grabiner, et al. 2001; Peterson, et al. 1993).

Subjects were instructed to use both hands to hold the two objects while walking to ensure bimanual coordination (Magill, 1998). Additionally, subjects were told the goal of each trial is to avoid dropping or spilling anything while walking (Ebersbach, et al. 1995). No other verbal instructions or feedback about the walking performance was given during the testing protocol (Grabiner, et al. 2001).

Instrumentation

Gait measures. The temporal and distance stride characteristics were measured using the GAITRite, a computerized portable walkway composed of imbedded pressure sensitive sensors arranged in a 48 x 288 matrix, with the spatial resolution of the walkway at 1.27 cm. (Cutlip, et al. 2000) and an active recording area is 61 cm x 3.66 m, with 12.7 mm spaces between adjacent switches (Cir Systems, 2001). The walkway was connected via a serial cable interface to an IBM™ personal computer installed with the GAITRite Gold software that calculated temporal and distance measures of gait at a sampling frequency of 80 hertz (Appendix K). Information from each walking trial was electronically stored in the software's data files.

The GAITRite's reliability has been established. Comparing kinematic gait parameters measured with the GAITRite and a video-based system

(Peak performance motus 3.1®), high correlation coefficients were found for all parameters measured with both systems (Cutlip, et al. 2000). Excellent intraclass correlation coefficients between paper-and-pencil measurements and the GAITRite were found for spatial measures, and excellent correlations for temporal measures between video-based systems and the GAITRite were found (McDonough, et al. 2001). Furthermore, the authors concluded that the GAITRite's measurements of step lengths and times were reliable when data is collected in the walkway center as well as left-of-center.

Dependent variables

The following measures were collected using the GAITRite Gold software: velocity, normalized velocity to leg length, cadence, step length, and double support time.

Data Analysis

Independent samples t-tests were employed to compare the ages and the leg length measures between the two groups of adolescents. Means and standard deviations were calculated from the demographic information provided by the adolescents with JA. A summary of joint involvement for the adolescents with JA was constructed to illustrate how arthritis affected each of the lower extremity joints.

All data collected on the GAITRite system were averaged for each subject from the five trials of each task condition at each of the two speeds (Grabiner, et al. 2001), with means and standard deviations presented in table format. To determine if adolescents with JA demonstrate different stride characteristics than healthy controls when performing single or dual tasks, a two-way analysis of variance (ANOVA) with one repeated measure was employed in this 2 x 3 (group x task) factorial design to determine differences between groups and between tasks (Marsh and Geel, 2000). The repeated measures design is based on the assumption of compound symmetry, such that the variances within each set of different scores will be relatively equal and correlated with each other (Portney & Watkins, 2000). For within group comparisons, if the Mauchly's Test of Sphericity for compound symmetry resulted in significant differences, the Greenhouse-Geiser correction to decrease the degrees of freedom was used to determine the F statistic and to control for type I error (Munro, 2001; Portney & Watkins, 2000). The overall alpha was set at 0.05 (Peterson, et al. 1993). Post hoc analyses for pair-wise comparisons between tasks were performed using the paired-samples t-tests (Portney and Watkins, 2000). A Bonferroni corrected alpha of 0.017 was employed for the planned comparisons of task differences to control for inflated Type I error (Green, Salkind, & Akey, 2000; Portney & Watkins, 2000). The Statistical Package for the Social Sciences (SPSS) software, version 11.0 for Windows (2002), was utilized for computations.

To investigate if each group of adolescents can change their gait velocity in similar manners, a change score (expressed as a percentage) was calculated by subtracting the faster velocity from the self-paced velocity and then this new value was normalized by dividing this by the absolute (original) value (Scull, 2000).

CHAPTER IV

RESULTS

Subjects and Demographics

Twelve adolescents with JA (4 males, 8 females) were age-matched within 1.5 years to a group of 12 adolescents (5 males, 7 females) with no known musculoskeletal disease (Figure 1). The ages for both groups of adolescents were analyzed using an independent samples t-test (Table 1). The ages of the adolescents with JA were not significantly different than the adolescents in the control group. The ages ranged from 11-19 years and 10-19 years for the JA group and control group, respectively.

Figure 1: Ages of Subjects by Group

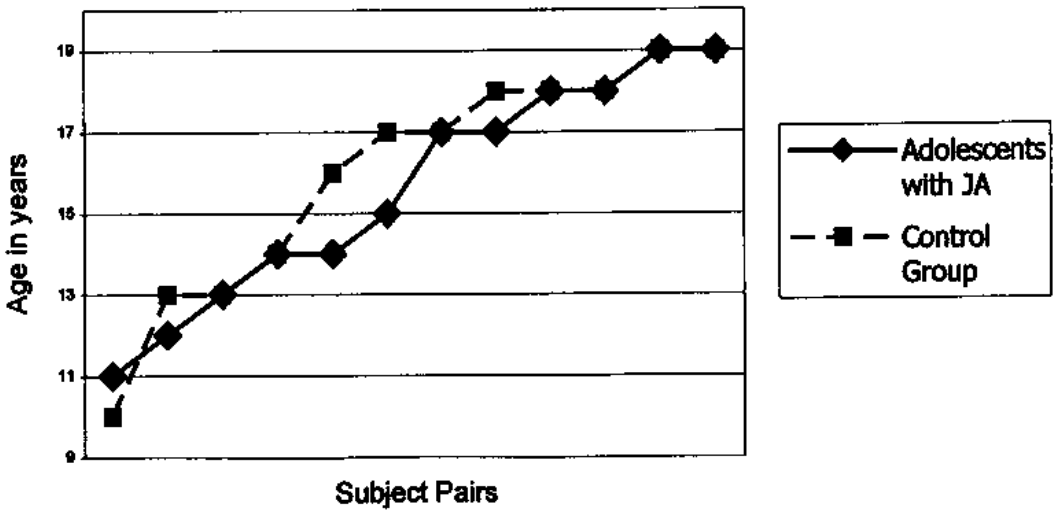


Table 1

Comparison of Age

Group *(ranges)*	Age (years) M (SD)	t	p
JA Group *(11-19)*	15.5 (2.71)		
Control Group *(10-19)*	16.0 (2.86)		
		-.439	.665

Means for each of the leg lengths for each group are presented in Figure 2. Right leg length ranged from 80.5 cm to 96 cm and 75.5 cm to 93.5 cm for the adolescents with JA and the control group, respectively; while the left leg length ranged from 79.5 cm to 95 cm and 76 cm to 93.5 cm for the adolescents with JA and the control group, respectively. The results of independent samples t-tests for leg length showed no significant differences between the bilateral lower extremities or between groups (Table 2). Since the means of right and left leg lengths were not significantly different for side or between groups, the right step length and right double support time were selected for all data analysis.

Figure 2: Comparison of Leg Length by Group and Side

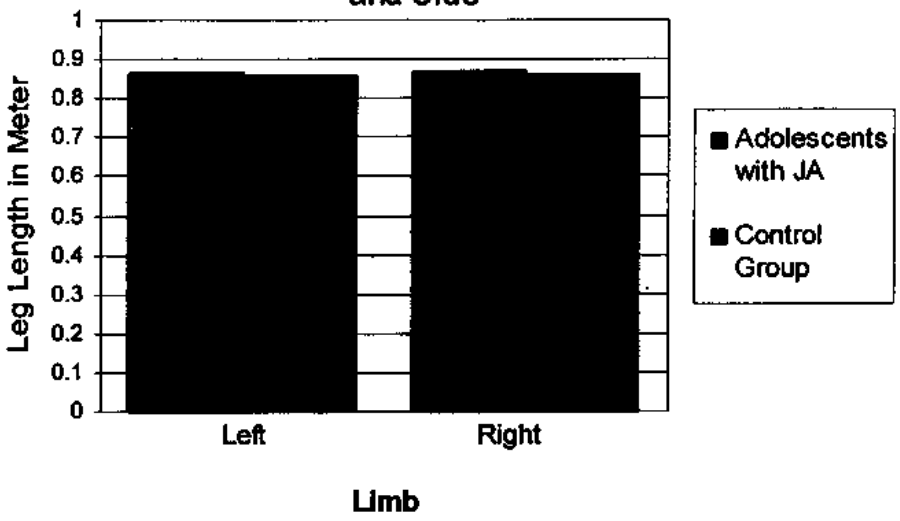


Table 2

Comparison of Leg Length Measures

Group	Right Leg Length (centimeters) M (SD)	t	p	Left Leg Length (centimeters) M (SD)	t	p
JA Group	86.79 (5.19)			86.53 (4.92)		
Control Group	86.01 (5.45)			85.78 (5.24)		
		.360	.722		.316	.718

The individual values and descriptive statistics for the JA group for the clinical characteristics of age, disease duration, CHAQ score, pain score, health status score, and joint count are presented in Table 3. Seven adolescents reported having a confirmed diagnosis of juvenile rheumatoid arthritis, two had a diagnosis of spondyloarthropathy, and three responded that they had "arthritis". The mean disability index score on the CHAQ of this sample population was 0.47, indicating that the subject population was highly functional.

Table 3

Demographic Characteristics of Subjects with JA

Subject	Age (years)	Disease Duration (years)	CHAQ Score (index)	Pain Score (cm)	Health Status (cm)	Joint Count (#)
1	11	3.0	0.375	3.0	1.4	8
2	12	1.5	0.375	6.8	4.0	5
3	13	7.0	0.375	1.1	1.3	1
4	14	10.0	0.375	2.8	2.8	8
5	14	0.7	0.375	5.5	5.2	3
6	15	2.0	0.625	6.1	4.3	4
7	17	6.0	0.875	2.5	3.0	6
8	17	3.5	0.75	3.0	0.0	4
9	18	1.5	1.00	4.0	0.5	3
10	18	3.0	0.125	3.5	2.5	4
11	19	1.5	0.125	4.0	1.0	7
12	19	9.0	0.25	4.0	0.0	4
Mean	15.58	4.06	0.467	3.86	2.17	4.75
SD	2.78	3.16	0.28	1.61	1.74	2.14

Presence of joint disease by region is displayed in Table 4. More than one-half of the subjects reported knee or ankle involvement and less than one-third reported hip or foot involvement. The most commonly involved joints were the right ankle and right knee; subjects reported the least involvement in the right foot and left hip.

Table 4

Frequency of Joint Involvement in the Lower Extremities

Side	Joint Region	# of Subjects
Right Leg		
	Hip	4
	Knee	10
	Ankle	10
	Foot	3
Left Leg		
	Hip	3
	Knee	8
	Ankle	7
	Foot	4

Stride Characteristics Under Single and Dual Task Conditions

Means and Standard Deviations. Summaries of these select descriptive statistics are presented for each of the following gait variables: velocity, normalized velocity, right step length, cadence, and right double support for each group of adolescents. The means and standard deviations when performing the single task condition and both of the dual task conditions at the self-paced speed are illustrated in Table 5.

Table 5

Comparison of Stride Characteristics at Self-paced Speeds by Group

Variable	Task Condition		
	Single Task Walking	Walking with Ball	Walking with Water
	Mean (SD)	Mean (SD)	Mean (SD)
Velocity (cm/sec)			
JA	124.94 (10.49)	124.28 (10.97)	89.78 (18.50)
Control	136.60 (10.13)	136.05 (13.02)	103.64 (19.07)
Normalized Velocity (LL/sec)			
JA	1.46 (.12)	1.46 (.15)	1.05 (.22)
Control	1.60 (.15)	1.59 (.18)	1.21 (.25)
Cadence (# steps/min)			
JA	108.53 (7.09)	109.78 (8.30)	99.58 (9.50)
Control	112.65 (6.44)	114.78 (6.53)	105.16 (10.31)
Step Length (cm)			
JA	68.28 (6.35)	68.87 (5.86)	54.41 (7.26)
Control	73.18 (5.29)	71.62 (5.87)	59.01 (6.89)
Double Support Time (%)			
JA	23.75 (1.48)	23.52 (1.58)	29.54 (4.60)
Control	23.07 (2.70)	23.33 (2.79)	28.04 (3.68)

Analyses of Variance. One factor (task) repeated measures ANOVAs, with a between subjects factor of group, were carried out on these dependent variables: velocity, normalized velocity, cadence, step length, and double support time.

Table 6 summarizes the between groups effects from each of the five repeated measures ANOVAs. Significant differences were found between the two groups of adolescents for velocity (F (1,22) = 8.65, p =. 008) and normalized velocity (F (1,22) = 5.32, p = .031). Although significance was not reached for cadence (F (1,22) = 3.27, p = .084) and step length (F (1,22) = 3.50, p = .075), the reduction of these stride variables by the adolescents with JA demonstrated a trend of less frequent and shorter steps when compared with controls. No significant differences between groups occurred for double support time (F (1,22) = .645, p = .430).

Table 6

Between Groups Effects for Stride Characteristics

Source	df	MS	F	p
Velocity	1,22	2780.094	8.645	.008*
Normalized Velocity	1,22	.350	5.323	.031*
Cadence	1,22	432.180	3.274	.084
Step Length	1,22	299.350	3.503	.075
Double Support	1,22	11.202	.645	.430

Note. * $p \leq .05$

A summary of the within-subjects results is presented in Table 7. Main effects for tasks ($p < .0001$) were found for all of the dependent variables at the self-selected speed. No significant interactions occurred between task and group for these gait variables.

Table 7

Summary of Univariate Tests on Task and Group for Each Gait Variable

	Main Effect: Task				Interaction: Task x Group			
	df	MS	F	p	Df	MS	F	p
Velocity[b]	1.549	11776.563	64.464	.000	1.549	11.917	.065	.896
Error	34.067	182.684						
Normalized Velocity[b]	1.542	1.621	66.982	.000	1.542	2.271	.094	.862
Error	33.927	2.420						
Cadence[b]	1.326	1019.019	19.874	.000	1.326	4.936	.096	.827
Error	29.163	51.273						
Step Length[a]	2	1520.228	91.44	.000	2	8.140	.490	.616
Error	44	16.625						
Double Support[b]	1.226	377.088	46.886	.000	1.226	4.324	.538	.505
Error	26.969	8.043						

Note. [a]Sphericity Assumed
[b]Greenhouse-Geisser correction

Results of the post hoc pair-wise comparisons indicated that the each of the tasks differed from each other for more than one dependent variable (Table 8). Significant differences ($p < .017$) between single task walking and walking with ball occurred for all gait variables; whereas differences between single task walking and walking with water were found only for step length and double support. Significant differences between the two dual task conditions (walking with ball and walking with water) resulted for normalized velocity and step length variables. All other t values approached but did not reach corrected significance, with p levels between .019 and .093.

Table 8

Results of Paired Samples T-tests

Gait Variable	Pair-Wise Correlations		
	Single Task Walking and Walking with Ball	Single Task Walking and Walking with Water	Walking with Ball and Walking with Water
	t	t	t
Velocity	.599*	.347	.461
Normalized Velocity	.704*	.476	.556*
Cadence	.830*	.431	.479
Step Length	.682*	.569*	.635*
Double Support	.786*	.517*	.420

Note. * $p \leq .017$

Velocity Changes

To determine if the adolescents with JA were capable of increasing their speed of walking, the mean velocity values for each group were compared to determine the differences between self-paced velocity and the fast-paced velocity. The change scores calculated represent the percentage

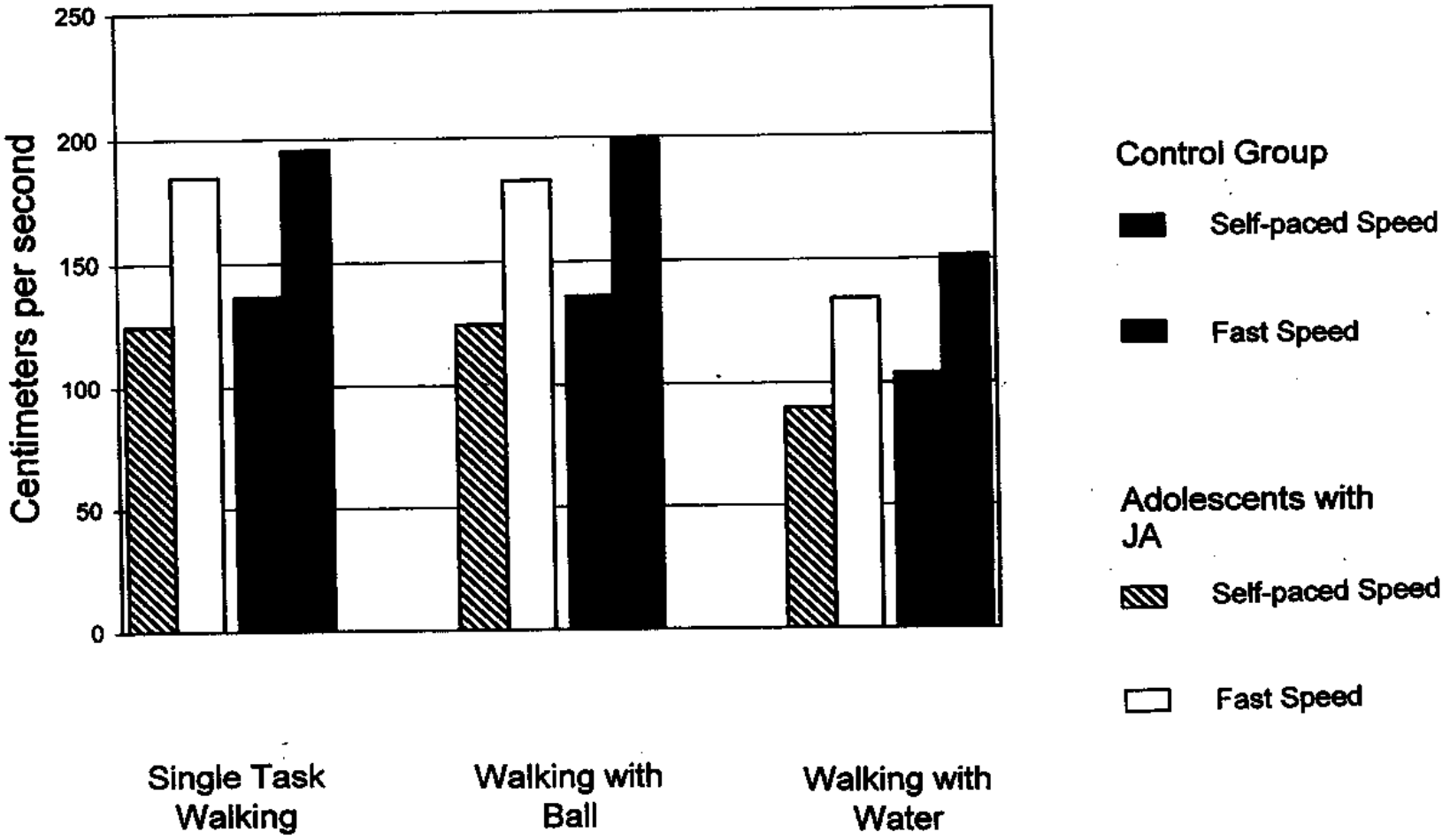
increases in the centimeter per second walking rate. Descriptive statistics for velocity at both speeds are presented in Table 9 and Figure 3. These values show that each group increased walking speed similarly. In the single task walking condition, the JA group increased their velocity 48% compared to 43% for the control group. For the dual task condition of walking when carrying the ball, a 46% change was recorded for each group of adolescents. For the walking when carrying the water, the JA group increased their velocity 50% compared to 48% for the control group.

Table 9

Comparison of Walking Velocities at Two Speeds by Adolescent Group

Condition	Task Condition		
	Self-paced Walking Speed (cm/sec) Mean (SD)	Fast paced Walking Speed (cm/sec) Mean (SD)	Percentage Change (%)
Single Task Walking			
JA	124.94 (10.49)	184.38 (21.56)	48
Control	136.60 (10.13)	195.03 (11.52)	43
Walking with Ball			
JA	124.28 (10.97)	182.48 (26.70)	46
Control	136.05 (13.02)	198.73 (14.69)	46
Walking with Water			
JA	89.78 (18.50)	134.51 (38.71)	50
Control	103.64 (19.07)	151.21 (24.88)	46

Self-paced and Fast Walking Speeds



Chapter V

DISCUSSION AND CONCLUSIONS

Two groups of adolescents, one with JA and another with healthy controls, were measured on their walking patterns during three different task conditions and at two different speeds. The tasks included a single task condition, i.e., walking with nothing held in the upper extremities, and two dual task conditions: walking while carrying a ball and walking while carrying a bowl of water. Five stride characteristics were recorded to examine the effects of these tasks on walking performance. The comparison of the self-paced gait variables under the three task conditions at the self-paced speeds is first discussed. The dual-task paradigm is the focus of the second section. The ability to increase speed of walking for each group of adolescents is presented in the third section. Therapeutic implications and study limitations appear in the subsequent two sections. Summary and conclusions are addressed last.

Self-paced walking speed

This study explored the differences and similarities in five stride characteristics between adolescents with and without JA as measured with a short computerized walkway. Although the subjects with JA who participated

in this study represented a sample of convenience, the inclusion criteria reflected greater experimental control for the influences of age and leg length on stride characteristics than in previous JA gait studies (Lechner, et al. 1987; Dhanendran, et al. 1980). The ages of the subjects with JA who participated in this study were dispersed throughout adolescence to control for gait maturation and to allow for comparison with published adolescent and young adult gait values. This study also utilized subjects from both sexes, with the number of females somewhat greater than males for both groups. This was important when comparing cadence rates between groups since females tend to have higher rates than males (Perry, 1992). Most subjects reported a JA diagnosis for greater than 3 years, arthritis affecting three or more lower extremity joints, and VAS scores of moderate discomfort and pain within the past week. When compared to the JA gait study by Lechner and associates (1987), this sample had similar knee joint involvement, greater ankle joint involvement, but less hip joint involvement.

Despite the subjects' reports of chronic and moderately painful disease activity, the CHAQ scores reflected minimal disability in this sample. Answers from this self-report questionnaire of physical disability are converted into an index score between 0 (no disability) and 3 (extreme disability). For this investigation, all adolescents with JA had CHAQ index scores of 1 or less. The self-reported health status VAS scores also reported from the CHAQ indicated that these subjects perceived they were in good health. While these

demographics are essential to the describe the sample JA group, as in similar JA gait studies, no attempt was made to control for the location of joint involvement, stage of arthritis, disease activity level, or pain. The author theorized that the presence of joint inflammation and pain would result in a predictably slower walking speed, one that is consistent with individuals who have joint impairments when compared with those without disease (Wall & Kirtley, 2001).

Velocity is the primary measure of walking performance. The adolescents with JA walked at slower velocities when compared with adolescents in the control group. The JA group also walked at slower velocities than the control group under each of the two dual-task conditions. When corrected for leg length, the adolescents with JA also demonstrated slower normalized gait velocities during the control walking and both dual-task conditions. These data suggest that despite similar ages and leg lengths as well as the perception of no to minimal physical disability, the presence of arthritis in the lower extremities slows the walking performance.

The means, 124 cm/sec and 136 cm/sec for the JA group and control groups respectively, in the single task walking condition are comparable to published values. Perry (1992) wrote that velocity averages 137 cm/sec for adults. In a review of young adult self-paced velocities, Bohannon, Andrews, and Thomas (1996) described mean values ranging from 126 to 150 cm/sec. Oberg and associates (1993) examined adolescents between 10-19 years of

age and reported mean speeds of 123 and 124 cm/sec, with standard deviations of 11 and 17 cm/sec for males and females, respectively. The JA group in this study had similar mean values to the subjects in the study by Oberg and colleagues, but the healthy subjects walked on average 12 cm/sec faster. These higher values are similar to those reported by Perry. The mean velocity of 89.78 cm/sec achieved by the JA group during the walking while carrying the bowl of water (high attention task) lies beyond two standard deviations from the mean self-paced velocity score reported also by Oberg et al., and into what Oberg defined as a slow speed category. This finding suggests that the JA group's walking speed while carrying water may be too slow and this may present as a functional limitation. However, none of these studies normalized velocities to leg length and therefore direct comparisons should be made with caution.

Gait velocity influences other gait parameters. Although not significantly different, the values of the JA group resulted in an expected trend of shorter and fewer steps when compared with the control group. These reduced cadence values, however, are consistent with normative values reported by Perry (1992) and Winter (1991). While step lengths recorded were longer than published normal scores (Oberg, et al. 1993), the smaller step lengths of the JA group when compared with the control group may be clinically important when considering functional walking tasks performed over longer distances. The mean difference in step lengths between groups was 5

centimeters despite task condition. When this reduced value is multiplied with numerous steps taken over a distance, the summative effect may account for additional reductions in walking velocity for adolescents with JA.

No significant differences in actual leg length between groups existed to explain this finding. Reasons for these stride deficiencies have been attributed to slowness in advancing the leg during the swing phase and to limitations in available range of motion (Lindsley, 1999). Shortened step length may be related to decreased hip extension and ankle plantar flexion range of motion at the end of the stance phase (Lechner, McCarthy, & Holden, 1987). When comparing the results of this study to the pilot study findings of increased cadence at similar velocities for children with JA compared to those without (Stiskal and Zipp, 2000), modifying cadence may be most effective strategy for this population to achieve functional velocities.

Gait deviations may result directly from weakness. In studies of other pathologies, researchers suggest that the shorter step length may result from a need to increase the double support phase and ultimately move to a more stable gait pattern (DeVisser, 1998). Diminished gait has also been identified with increased time spent in double support as a mechanism to increase stability or to reduce painful weight-bearing forces. The lack of a significant difference for double support time between the two groups in this study suggests that for the JA group's balance was not compromised nor was there a need to reduce joint loading forces. Since the adolescents with JA in this

study reported high incidence of knee and ankle arthritis at the time of the study, the shorter steps may be associated with loss of functional range of motion or joint stiffness. Further research is needed to determine if these factors account for the any of the variance in the stride characteristics.

Dual Task Design

This investigation focused on gait control under dual task conditions because skilled walking is a crucial prerequisite for many daily activities. Inclusion of these particular dual-tasks was aimed at mimicking daily activities confronting adolescents. During walking performance under a dual-task condition, stride characteristics of all adolescents changed when compared to the single task, baseline walking condition. In contrast to the single task walking, the walking velocities tended to decrease as the dual-task condition became more complex. The addition of either a low or high attentional motor task when walking appeared to force all subjects to modulate their velocity as well as other related stride characteristics. For both groups, the step lengths decreased and the time spent in double support increased as the complexity of the task increased.

These findings lend support to the assumption that the ability to attend to one task declines when a second task is added. All subjects chose to sacrifice walking performance to successfully perform the carrying tasks. These results are compatible with previous research (Maher, Zipp & Stiskal,

2001; Zipp, Stiskal, & Leonard, 2001). In the study by Stiskal and Zipp (2000), the authors reported that the addition of similar dual-tasks (walking with a backpack and walking with water) resulted in similar findings of slowed velocity and shortened steps for children with and without JA.

Individuals move through three stages of learning when performing a new skill (Eichhorn et al, 1998). Fitts and Posner (1967) postulated that during the second stage of motor learning a person still requires attention to the movement during the performance of the task, while in the third stage the motor skill is well defined and performed automatically (Magill, 1998). The data in this study suggest that both groups of subjects altered stride characteristics when presented with a carrying task while walking. Thus the subjects most likely were in the second stage of motor skill acquisition and their preferred gait pattern had not been come an automatic activity requiring little concentration (Larish, et al. 1988; Winter, 1992).

These results represent the first examples of research in which the role of dual task in the regulation of walking performance in adolescents with JA has been examined. The findings support the inclusion of dual tasks during clinical assessment of walking performance. The overall gait changes found with an addition of a second task, such as a carrying task, may assist health care providers in determining functional gait deficits. Since many school-based activities involve the transport of textbooks, cafeteria trays, and other equipment in two hands, one cannot assume the adolescent with JA is

capable of achieving an appropriate walking speed or demonstrating an effective gait pattern based on the analysis of single task walking only. At this time, no literature exists to support the use of dual task training to improve walking performance in this population.

Ability to increase speed

While research has shown that adolescents with JA walk slower, their ability to deviate from a preferred speed of walking has not been reported. This investigation evaluated subjects walking at their preferred and fastest, safest speed possible. Comparisons were made for velocity during each of three task conditions. It was hypothesized that there would be deficiencies in the JA group's abilities to increase walking speed in a similar manner to controls, indicating the JA group's limited ability to respond to environmental demands.

Both groups of adolescents increased walking speed by similar percentages for all three conditions. The increases in speed ranged from 43% to 50%, exceeding the 44% described by Appayya for healthy individuals (2001). Presentation of any of the dual tasks did not interfere with either group's ability to alter walking speeds from their self-paced speed. Thus, all subjects possessed the capability of consciously increasing their walking speed in all single and dual task conditions for short distances. However, while the JA sample could increase walking speeds in a similar pattern as the

control group, adolescents with JA demonstrated significantly slower overall walking velocities than the control group at both speeds.

This investigation's exploration of fast-paced speed values in addition to analyses at self-paced walking speeds is consistent with those few researchers who recognized the importance of maximum gait speed. Evaluating fast-paced speed is probably not emphasized in many clinical settings. Such fast speeds may be required of adolescents, however, when they need to safely cross streets or to walk at speeds externally regulated by other adolescents or adults. The available literature does not provide many values to compare with the results of this study. The speeds reported here were substantially higher than those published by Oberg, et al. (1993). Both velocity and normalized velocity reported here may be useful as a basis for which the gait of other adolescents with JA can be compared.

Clinical Applications

This information should be useful to clinicians who make judgments about the gait performance of adolescents with JA. The results of the self-paced gait speeds during the single walking condition are similar to those reported by Lechner, et al. (1987). From the perspective of rehabilitation, attention to the ability to walk while performing various tasks and at different speeds may be a therapeutic goal. Given the results of this study in which a high functioning group of adolescents with JA walked at significantly slower

velocities and with decreased step length and cadence than healthy controls, therapeutic attempts to rectify these deficiencies should be addressed. In the presence of shortened step lengths, practice of walking performance with attempts to increase step lengths should be made. By providing subjects with a physical goal or some form of feedback to increase the distance between each foot placement, these longer steps may result in faster gait velocities.

In proposing this strategy, there is the assumption that the newly adopted gait pattern would not result in increased joint pain. While the longer step lengths help to reduce potentially harmful vertical ground reaction forces, this spatial requirement requires greater use of the adolescent's available range of motion. As previously noted, motion toward the ends of the range are often the most limited and painful. Attempting to walk faster with longer steps may increase pain, resulting in a new or accentuated compensatory gait that can be more harmful to the lower extremity joints.

Treatment of these gait deficits, i.e., decreased velocity, cadence and step length, should also match personal physical performance goals. Environmental constraints, such as those presented in a dual-task strategy, should be included along with an emphasis on increasing both cadence and stride length. To date, it is unclear if changing the stride characteristics is an effective treatment strategy. While energy expenditure may be reduced with a gait pattern with fewer but longer steps, the current gait pattern may be organized to protect painful joints.

Bohannon (1997) reported that when individuals increase their gait speed, higher levels of muscle activity and larger joint moments are observed. Thus muscle force is essential to ambulation and maximizing strength should be included in a comprehensive rehabilitation program. To date there have been no known studies that have investigated this direct relationship to gait in adolescents with JA. Although the intensity of muscle force required for gait is submaximal, individuals may adjust their gait speed based on their strength so that they are able to maximize energy levels to meet the requirements of the task. The studies by Gianni and Protas (1991, 1992, 1993) as well as Klepper (1999) have shown that children with JA following muscle strengthening exercises can improve their aerobic capacity and walking endurance when measured with physical performance distance tests.

Limitations

The author recognizes that the JA sample consisted of highly active adolescents whose arthritis was well managed at the time of the study. Individuals reported participating in extra-curricular sports and physical activities. Many of the older adolescents were employed. As such, these subjects may be considered elite in terms of walking and functional ability. They also reflect adolescents who have benefited from the recent advances in medical and pharmacological management. While the previous studies on walking performance reported subjects with minimal joint disease or minor

functional disability (Lechner, et al. 1987; Dhanendran, et al. 1980), current trends in health care are redefining the traditional poor outcomes of this chronic disease. Care must be taken to describe the functional effects of the disease as well as the health and physical status. In this study, the adolescents with JA reported little disability on the CHAQ and health status VAS, yet walking speed was significantly slower than the average speed from the control group. This finding suggests the need to assess stride characteristics and not rely solely on the disability level obtained through standardized self-report tools. Instrumental gait analysis, using a simple portable computerized walkway, has the advantage of being a performance-based measure of disability that is not dependent on patient report or observer judgment.

In this study, the use of a shortened walkway may be a major limitation to greater generalizability. For each task condition and at each speed, six trials were recorded for a total of 36. This design attempted to insure that a minimum of 20 steps would be recorded for the data analyses of each condition and speed (Grabiner, 2001). While this number is supported in the literature, the walkway used is only 4 meters long, one-half of the usual 8 meters. Therefore, these subjects walked for shorter distances than subjects in other gait studies. The velocities demonstrated reflect average walking speed only for these shorter lengths. It is unknown whether this group could

maintain similar self-paced velocities or increase to the same degree to a fast-paced speed for longer distances.

The failure to find differences in the fast gait speeds obtained from the two groups may be due to the testing order. While the overall order of task conditions was randomized for each group, the conditions of speed were presented in a fixed order. Adolescents performed each task for six trials (one practice and five recorded) initially at their self-paced speeds, and then performed the same task condition at the fastest speed possible for an additional six trials. Subjects then repeated this self-paced/fast-paced order for the remaining two trials. While this design is similar to other studies investing self-paced and fast-speeds, this study also included walking at both speeds for three different task conditions. Subjects in both groups reported anecdotally that after walking fast they found that returning to a self-paced baseline walking speed was difficult.

Summary and Conclusion.

The purpose of this study was to determine if adolescents with JA utilize similar efficient gait patterns as healthy adolescents when walking at self-selected speeds, as well as when walking and performing a secondary carrying task. As hypothesized, adolescents with JA exhibited significantly slower walking velocities as compared to adolescents with no joint disease. The velocity was also significantly different between groups of adolescents

when the walking velocity was normalized to leg length. At these slower velocities, reduced step lengths and cadences of the JA group compared to the control group approached significance. No differences in the amount of time spent in double support were noted. Both groups of adolescents demonstrated similar abilities to increase walking speed. These results also demonstrated that all adolescents altered their stride characteristics at self-selected walking speeds when they perform a secondary carrying task, i.e., walking and carrying either the ball or walking and carrying the bowl with water, compared to when they are walking without carrying an object.

The obvious and subtle deviations found in this highly functioning JA sample raises awareness of the need to evaluate the walking patterns of adolescents with JA more closely. Self-reports of disability may not capture the true levels of function for walking performance. The use of instrumented gait evaluation under single-task and dual-task conditions is supported by this study. As Lechner and associates (1987) proposed 15 years ago, even a relatively minimal deficit in velocity, step length, or cadence may compromise physical performance and present a "handicap" to adolescents during more sophisticated gross motor activities that they may commonly encounter, such as carrying a cafeteria tray in school. With the emergence of earlier interventions and more aggressive drug therapy, health care providers still need to look beyond disease status to maximize the functional potential of these adolescents.

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Poster session presented at the annual Combined Sections Meeting of the American Physical Therapy Association, San Antonio, TX.

APPENDIX A

PILOT STUDY ABSTRACT

The following abstract was accepted for poster presentation at the 2000 Association of Rheumatology Health Professionals/ American College of Rheumatology 64th Annual Scientific Meeting.

EFFECTS OF PERFORMING SIMULTANEOUS DUAL-TASKS ON WALKING PERFORMANCE IN CHILDREN WITH & WITHOUT JUVENILE ARTHRITIS (JA). Doreen M. Stiskal & Genevieve Pinto Zipp. *Seton Hall University, SGME*

Introduction: Current motor control theories state that motor performance is influenced not only by the individual's neuromuscular skill, but also the task and the environment. All three conditions provide restraints to an activity, which then influences an individual's self-organized temporal and spatial movement pattern. While studies demonstrate that children with JA have slower gait patterns than children without joint disease, no studies have investigated how the JA gait patterns are effected by performing carrying tasks, which may require different various levels of concentration.
Purpose: This repeated-measures pilot study compared the effects of performing dual-tasks, requiring different attentional demands on walking abilities in children with and without JA.
Methods: Four children with juvenile arthritis (JA group), 7-16 years old, were age and gender matched with four children without any musculoskeletal impairments (control group). Each child walked (self-paced) along a 4 meter x .5 carpeted computerized walkway, a total of three trials each, for each of the three randomized conditions (tasks): (1) ambulation only (control), (2) ambulation carrying a clear plastic pitcher of water ¾ full (high attention), and (3) ambulation carrying a 13 pound weighted knapsack on one shoulder (low attention). Temporal-spatial gait parameters: gait time, velocity, cadence, step count, step length and time, heel-to-heel base of support and degree of toe out/in, were recorded using the GaitRite (Cir Systems) software on a Windows 95 PC. Multifactorial ANOVAs and Scheffe post hoc analyses were carried out, with a p value of $\leq .05$.
Results: Temporal-spatial gait parameters were significantly different for task as well as for groups of children. Control walking was significantly different than the walking with carrying a pitcher of water, a high attentional task. The JA group, as compared to the control group, utilized gait patterns which resulted in significantly different increases in step count, gait time, and cadence as well as decreases in step length and time, stride time, and velocity across all testing conditions.
Conclusion: This pilot study supports the existing literature, such that gait is influenced by constraints imposed by task as well as the biomechanical limitations of multi-joint pathology. Further information regarding the ability to successfully perform functional activities while walking is important for children with JA, within both the home and school settings.

APPENDIX B

CHILDREN'S HEALTH ASSESSMENT QUESTIONAIRE

(Adapted from Singh, G., Brown, B., Fries, J, and Goldsmith, D., 1994 in Tecklin, J.B. (Ed). Pediatric Physical Therapy, 3rd Ed. Philadelphia, Lippincott Company, 2001)

Health Assessment Questionnaire

In this section, we are interest in learning how your illness affects your ability to function in daily life. Please feel free to add any comment on the back of this page. IN the following questions, please check the one response which best describes your usual activities (averaged over an entire day) OVER THE PAST WEEK. If you have difficulty in doing a certain activity or are unable to do it because you are too young but NOT because you are RESTRICTED BY ARTHRITIS, please mark it as "Not Applicable". ONLY NOTE THOSE DIFFICULTIES OR LIMITATIONS THAT ARE OWING TO ARTHRITIS.

	Without Any Difficulty	With Some Difficulty	With Much Difficulty	Unable to Do	Not Applic-able
Dressing and Grooming					
Are you able to:					
➢ Dress, including tying shoelaces and doing buttons?	_____	_____	_____	_____	_____
➢ Shampoo your hair?	_____	_____	_____	_____	_____
➢ Remove socks?	_____	_____	_____	_____	_____
➢ Cut fingernails/toenails?	_____	_____	_____	_____	_____
Arising					
Are you able to:					
➢ Stand up from a low chair or floor?	_____	_____	_____	_____	_____
➢ Get in and out of bed or stand up in a crib?	_____	_____	_____	_____	_____
Eating					
Are you able to:					
➢ Cut your own meat?	_____	_____	_____	_____	_____
➢ Lift a cup or glass to mouth?	_____	_____	_____	_____	_____
➢ Open a new cereal box?	_____	_____	_____	_____	_____
Walking					
Are you able to:					
➢ Walk outdoors on flat ground?	_____	_____	_____	_____	_____
➢ Climb up five steps?	_____	_____	_____	_____	_____

Please check any AIDS OR DEVICES that your child usually uses for any of the above activities:

_____	Cane	_____	Devices used for dressing: button hook, zipper pull, long-handled shoehorn, etc.
_____	Walker	_____	Built-up pencil or special utensils
_____	Crutches	_____	Special or built-up chair
_____	Wheelchair	_____	Other (specify)

* Please check any categories for which your usually need help from another person BECAUSE OF ARTHRITIS

_____	Dressing and Grooming	_____	Eating
_____	Arising	_____	Walking

continued

	Without Any Difficulty	With Some Difficulty	With Much Difficulty	Unable to Do	Not Applic-able
Hygiene					
Are you able to:					
➢ Wash and dry your entire body?					
➢ Take a tub bath (get in and out of tub?					
➢ Get on and off the toilet?					
➢ Comb/brush hair?					
Reach					
Are you able to:					
➢ Reach and get down a heavy object, such as a large game or books, from just above your head?					
➢ Bend down to pick up clothing or a piece of paper from the floor?					
➢ Put a sweater over your head?					
➢ Turn neck to look back over shoulder?					
Grip					
Are you able to:					
➢ Write or scribble with a pen or pencil?					
➢ Open car doors?					
➢ Open jars that have been previously opened?					
➢ Turn faucets on and off?					
➢ Push a door open when you have to turn a knob?					
Activities					
Are you able to:					
➢ Run errands and shop?					
➢ Get in and out of car or school bus?					
➢ Ride bike or tricycle?					
➢ Do household chores (e.g., wash dishes, take out the trash, vacuum, do yardwork, make bed, clean room?					
➢ Run and play?					

Continued

Please check any AIDS OR DEVICES that you usually uses for any of the above activities:

_____	Raised toilet seat	_____	Bathtub bar
_____	Bathtub seat	_____	Long handled appliances for reach
_____	Jar opener	_____	Long handled appliances in bathroom

* Please check any categories for which you usually need help from another person BECAUSE OF ARTHRITIS

_____	Hygiene	_____	Gripping and Opening things
_____	Reaching	_____	Errands and chores

Pain

We are also interested in learning whether or not you have been affected by pain because of your illness.

- How much pain do you think you have because of your illness IN THE PAST WEEK? Place a mark on the line below to indicate the severity of pain.

No Pain — Very Severe Pain

0 — 10

Health Status

1. Considering all the ways that arthritis affects you, rate how you are doing on the following scale by placing a mark on the line.

0 Very Well — 10 Very Poorly

2. Are you stiff in the morning? _____ Yes _____ No
   If YES, about how long does the stiffness usually last (in the past week)?
   Hours/Minutes_____

Adapted from Singh G, Athreya B, Fries JF, Goldsmith, DP. Measurement of Health Status in Children with Juvenile Rheumatoid Arthritis. Arthritis and Rheumatism 1994; 37:1761-9.

APPENDIX C

GENTILE'S TAXOMONY OF TASK ANALYSIS

(Adapted from Magill, R.A., 1998.) Motor learning: Concepts and applications, 5th edition. Boston: McGraw-Hill).

APPENDIX D

RECRUITMENT FLYERS

VOLUNTEERS NEEDED
for the study:
"COMPARISON OF THE WALKING PERFORMANCE AT TWO DIFFERENT SPEEDS IN ADOLESCENTS WITH AND WITHOUT JUVENILE ARTHRITIS USING A DUAL-TASK METHOD"

AT SETON HALL UNIVERSITY
SOUTH ORANGE, NJ

The purpose of the study it to investigate how carrying objects effect walking patterns at two different walking speeds in adolescents with and without arthritis. This study is being conducted in partial fulfillment of Doreen Stiskal's dissertation for a doctoral degree in the Seton Hall University, School of Graduate Medical Education's Graduate Programs in Health Sciences

NEEDED: Children, 10 - 19 years old, with or without arthritis are invited to participate. Participants should have no history of neurological or cardiopulmonary conditions or orthopedic surgeries or recent injuries. Participants should be able to walk without assistance across a classroom at least 30 times, with rest periods. Participation is voluntary. Data collection will take place at Seton Hall University in the Functional Human Performance Lab, South Orange, NJ and should take no more than 1 hour. Participants will need to wear shorts, short sleeve shirt, and sneakers with laces during all data collection. Parent(s)/ Guardian(s) will be able to sit inside the classroom/lab during the project. All information will be kept strictly confidential

For more information or to answer any questions, please call or E-mail:

Doreen Stiskal, MS, PT (973) 275-2320 or STISKADO@shu.edu

VOLUNTEERS NEEDED
for the study:
"COMPARISON OF THE WALKING PERFORMANCE AT TWO DIFFERENT SPEEDS IN ADOLESCENTS WITH AND WITHOUT JUVENILE ARTHRITIS USING A DUAL-TASK METHOD"

AT HACKENSACK UNIVERISTY MEDICAL CENTER

The purpose of the study is to investigate how carrying objects effect walking patterns at two different walking speeds in adolescents with and without arthritis. This study is being conducted in partial fulfillment of Doreen Stiskal's dissertation for a doctoral degree in the Seton Hall University, School of Graduate Medical Education's Graduate Programs in Health Sciences, and in collaboration with the Department of Pediatric Rheumatology.

NEEDED: Children, 10 - 19 years old, with or without arthritis are invited to participate. Participants should have no history of neurological or cardiopulmonary conditions or orthopedic surgeries or recent injuries. Participants should be able to walk without assistance across a classroom at least 36 times, with rest periods. Participation is voluntary. Data collection will take place at Hackensack University Medical Center and should take no more than 1 hour. Participants will need to wear shorts, short sleeve shirt, and sneakers with laces during all data collection. Parent(s)/ Guardian(s) will be able to sit near and directly observe the project. All information will be kept strictly confidential.

For more information or to answer any questions, call or E-mail:
The study coordinator:
Doreen Stiskal, MS, PT (973) 275-2320 or STISKADO@shu.edu
Or

The Principal Investigator:
Dr. Yukiko Kimura, Chief of Pediatric Rheumatology 201-996-5306

APPENDIX E

INTERVIEW AND DATA SHEET

INTERVIEW AND DATA SHEET

Part A: Investigator will complete this section. She will ask the subject (and parent/guardian, if appropriate) the following and dismiss if subject meets exclusion criteria:

1. Subject Initials: _____ 2. Date of Birth:_____

3. Grade in School: _____
   Is this age-appropriate? *Yes* *No*

   If NO: THANK PARTICIPANT AND EXCLUDE

4. Gender: *Male* *Female*

5. Presence of JA: *Yes* *No* (if no, continue to Q6)

   a. If yes, type of JA: _____

   b. # years and months diagnosed: _____ years_____ months

   c. Lower extremity joint count:

Left	**Right**
___ hip	___ hip
___ knee	___ knee
___ ankle	___ ankle
___ feet	___ feet

   TOTAL NUMBER LE JTS INVOLVED:_____

6. Weight: _____lbs. Is this # > 40 LBS? *Yes* *No*

   If NO: THANK PARTICIPANT AND EXCLUDE

7. "Have you ever been told by a health care provider that you have less than adequate eye-site for daily activities, even when you are wearing glasses?" *Yes* *No*

   If YES to either: THANK PARTICIPANT AND EXCLUDE

8. "Have you ever had an injury or a problem in your legs that was treated by a health care provider?" *Yes* *No*

If yes: "Do you have this problem today?" *Yes* *No*

If YES: THANK PARTICIPANT AND EXCLUDE

10. "Are there any major problems that you know of with your heart, lungs, brain, spinal cord, or nerves in your lower legs?" *Yes* *No*

If YES: THANK PARTICIPANT AND EXCLUDE

11. Walking abilities:

    a. "Can you walk across the length of an average classroom without stopping or undue pain or fatigue?" *Yes* *No*

    b. "Can you walk this distance 30 times without assistive devices or orthoses, but with 3 minute seated rest periods?" *Yes* *No*

If NO: THANK PARTICIPANT AND EXCLUDE

Part B: Investigator will perform the following measures:

1. Leg lengths (in cm): Left _____ Right _____

Is there a difference > 1.9 cm between sides? *Yes* *No*

If YES: THANK PARTICIPANT AND EXCLUDE

2. Have adolescent complete the CHAQ.

Disability index score: _____ Pain rating from VAS: _____

Is the disability index > 0 in a healthy adolescent? *Yes* *No*
Is the disability index > 2 in an adolescent with JA? *Yes* *No*

If YES: THANK PARTICIPANT AND EXCLUDE

Is the pain value > 0 in a healthy adolescent? *Yes* *No*
Is the pain value > 7 in an adolescent with JA? *Yes* *No*

If YES: Is pain anywhere in the lower extremities? *Yes* *No*

If YES: THANK PARTICIPANT AND EXCLUDE

Verify the subject has met all inclusion criteria and confirm participant wishes to continue. If yes: assign a subject code #:

APPENDIX F

SUBJECT CODE AND CONDITION ORDER MATRIX

Twelve subjects in each group guarantees that the presentation of task conditions is counter-balanced to further eliminate error (Portney & Watkins, 2000). Six possible combinations of tasks exist, and as such, each combination will be utilized two times per group.

Subject Code	1st condition	2nd condition	3rd condition	Comments
JA1	Control walking	Walk with water	Walk with ball	
JA2	Control walking	Walk with ball	Walk with water	
JA3	Walk with ball	Control walking	Walk with water	
JA4	Walk with ball	Walk with water	Control walking	
JA5	Walk with water	Control walking	Walk with ball	
JA6	Walk with water	Walk with ball	Control walking	
JA7	Control walking	Walk with water	Walk with ball	
JA8	Control walking	Walk with ball	Walk with water	
JA9	Walk with ball	Control walking	Walk with water	
JA10	Walk with ball	Walk with water	Control walking	
JA11	Walk with water	Control walking	Walk with ball	
JA12	Walk with water	Walk with ball	Control walking	
CO13	Control walking	Walk with water	Walk with ball	
CO14	Control walking	Walk with ball	Walk with water	
CO15	Walk with ball	Control walking	Walk with water	
CO16	Walk with ball	Walk with water	Control walking	
CO17	Walk with water	Control walking	Walk with ball	
CO18	Walk with water	Walk with ball	Control walking	
CO19	Control walking	Walk with water	Walk with ball	
CO20	Control walking	Walk with ball	Walk with water	
CO21	Walk with ball	Control walking	Walk with water	
CO22	Walk with ball	Walk with water	Control walking	
CO23	Walk with water	Control walking	Walk with ball	
CO24	Walk with water	Walk with ball	Control walking	

APPENDIX G

POWER ANALYSIS

A sample size of 12 for each group was determined based on combination of statistical requirements and data acquisition (Macellari, Giacomozzi, & Saggini, 1999). Eta squared values from the 3 x 2 factorial pilot study by Stiskal and Zipp (2000) are presented below. Using the sample size determination tables for one-way ANOVA published by Cohen (1987) for studies with one degree of freedom to detect *f* by F test at a =. O5 level, a sample size between 7 and 21 is suggested to achieve a power of 80% for any of the variables of interest. No published tables are available to determine a recommended sample size for the repeated measures design. However, Munro (2001) reports that a repeated measures design generally reduces the error, therefore enhances the power of the analysis, resulting in the need for fewer subjects.

Eta squared values (η^2).

Dependent variables	Within factors (η^2)	Between subjects (η^2)
Velocity	.824	.767
Step length	.762	.645
Cadence	.499	.623
Task x interaction	--	.811

APPENDIX H

IRB APPROVAL LETTERS

SETON HALL UNIVERSITY

1 8 5 6

April 30, 2002

Doreen Stiskal-Galisewski
Graduate Medical Education
McQuaid Hall

Dear Professor Stiskal:

The Seton Hall University Institutional Review Board has reviewed the information you have submitted addressing the concerns for your proposal entitled "Comparison of the Walking Performance at two Different Speeds in Adolescents with and without Juvenile Arthritis using a Dual-Task Method." Your research protocol is hereby approved as amended through expedited review. The IRB reserves the right to recall the proposal at any time for full review.

Enclosed for your records are the signed Request for Approval form and the stamped original Consent Form. Make copies only of this stamped Consent Form.

The Institutional Review Board approval of your research is valid for a one-year period from the date of this letter. During this time, any changes to the research protocol must be reviewed and approved by the IRB prior to their implementation.

According to federal regulations, continuing review of already approved research is mandated to take place at least 12 months after this initial approval. You will receive communication from the IRB Office for this several months before the anniversary date of your initial approval.

Thank you for your cooperation.

Sincerely,

Mary F. Ruzicka, Ph.D.

Mary F. Ruzicka, Ph.D.
Professor
Director, Institutional Review Board

cc: MaryAnn Clark, Ph.D.

Office of Institutional Review Board
Presidents Hall
Tel: 973.275.2974 • Fax: 973.275.2978
400 South Orange Avenue • South Orange, New Jersey 07079-2641

THE DAVID & ALICE JURIST
INSTITUTE FOR RESEARCH

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Hackensack, N.J. 07601
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Affiliated with the University of Medicine and Dentistry of New Jersey

Member of the University Health System of New Jersey

August 19, 2002

LOUIS J. RAMAZZOTTO
Ph.D., CRA
Director

Yukiko Kimura, MD
Hackensack University Medical Center
Pediatric Rheumatology
30 Prospect Avenue
Hackensack, NJ 07601

Re: Protocol No: 02.02.081
Name: Comparison of the Walking Performance at Two Different Speeds in Adolescents With and Without Juvenile Arthritis Using a Dual-Task Method

Dear Dr. Kimura:

I have received confirmation of approval from the IRB for the above referenced protocol.

On behalf of the institution, I am issuing final approval for said protocol. You may accrue patients and commence your clinical trial. My staff and I are available should you require assistance.

Please be reminded that all modifications to the original approved protocol must first be reviewed and approved by the IRB prior to implementation.

Wishing you success in the conduct of your research, I remain,

Sincerely yours,

Louis J. Ramazzotto, Ph.D.

LJR/ml

Cc: Ronald Squillace, Chairman
Terry McKleman, RN
Cheryl Dubenezic, RN, IRB Manager

The David Joseph Jurist Research For Tomorrows Children Building

30 Prospect Avenue
Hackensack, N.J. 07601
201.996.2255
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Affiliated with the
University of Medicine and
Dentistry of New Jersey

Member of the
University Health
System of New Jersey

Institutional Review Board

August 12, 2002

Yukiko Kimura, MD
Hackensack University Medical Center
Pediatric Rheumatology
30 Prospect Avenue
Hackensack, NJ 07601

Dear Dr. Kimura:

Meeting Date: 9/11/02 **At: Hackensack University Medical Center**
RE: Our Study # 02.02.081
Protocol Title: Comparison of the Walking Performance at Two Different Speeds in Adolescents With and Without Juvenile Arthritis Using a Dual-Task Method.

The above referenced **Minimal Risk** study has been Approved via expedited review and will be presented to the full board on the date identified above, and the following actions taken subject to the conditions and explanation provided below.

Please be reminded that all modifications to the approved projects must be reviewed and approved by the Institutional Review Board below before they may be implemented. Any changes to this protocol must be suited for IRB approval before initiated.

All serious adverse events and unexpected adverse events must be reported to the Institutional Review Board within seven days.

Please do not make any changes to the IRB approved consent without approval of the IRB. Only the IRB stamped approved consent should be used.

It is necessary that you utilize the assigned protocol number in any and all communication submitted to the IRB Office, i.e., amendments, audits, etc.

DOCUMENT AND CORRESPONDENCE RECEIVED INCOMPLETE OR WITHOUT THE PROTOCOLO NUMBER WIL BE RETURNED.

FOR NEW APPLCIATIONS; RECEIPT OF THIS LETTER DOES NOT CONSITITUE PREMISSION TO BEGIN THE STUDY UNLESS AND UNTIL RECEIPT OF A SECOND LETTER, FROM THE DIRECTOR OF RESEARCH APPROVING THE PROTOCOL ON BEHALF OF THE INSTITUTION.

Internal #: New Application
Expiration Date: 8/3/03

On Agenda For: Expedited
Reason 1: **Reason 2:** New Study Expedited

Description: Date Received – 7/25/02; Reason Expedited – Appendix D (7) – Moderate exercise by healthy volunteers

IRB ACTION: **Approved**

Action Explanation: The protocol, consent and flyer was reviewed and approved via expedited review by Melvin Polkow, MD on August 9, 2002.

This study will be reviewed in one year.

Respectfully yours,

Cheryl Dubenezic, RN
IRB Manager

APPENDIX I

CONSENT AND ASSENT FORMS

COMPARISON OF THE WALKING PERFORMANCE AT TWO DIFFERENT SPEEDS IN ADOLESCENTS WITH AND WITHOUT JUVENILE ARTHRITIS USING A DUAL-TASK METHOD

Assent Form

I have been informed that Doreen Stiskal, who is a physical therapist and a student at Seton Hall University, is conducting this study. The study is to fulfill the requirements for completion of Ms. Stiskal's Doctor of Philosophy degree program at Seton Hall University, School of Graduate Medical Education in the Graduate Programs in Health Sciences department.

Purpose of Research
I am aware that the purpose of this study is to look at how walking and carrying objects may change the way children, with and without problems in their joints and muscles of their arms and legs, walk. We are doing this study to help physical therapists see if a child's walking ability changes when carrying objects. The results of this study will help doctors and physical therapists to identify more accurately the walking problems in children, with and without joint and muscle problems in their legs.

Duration
I am aware that I will be tested only one time (one session) for roughly 1 hour to in the laboratory called the Functional Human Performance Lab. This is located at Seton Hall University, South Orange, NJ. I am aware that I will need to wear shorts, t-shirt, and sneakers with the laces tied. The session includes approximately 15 minutes of introduction and questioning. Then, the walking procedures will take approximately 45 minutes, with rest periods given after each time I walk.

Procedure
I am aware that I will be questioned about my health and medical history, including questions if I have arthritis or other problems with the muscles and joints. I understand that I will be given a questionnaire, named the Children's Health Assessment Questionnaire, to answer about my ability to walk, dress, groom, etc.

I am aware that the lengths of each of my legs will be measured in standing, with my clothes and shoes on, with the researcher placing a tape measure from the outside of my hip bone toward the floor. I am aware that I will be asked to walk across a computerized walkway, called the GAITRite™ mat. It

is a flat rubber mat that measures almost three feet wide and fifteen feet long. It is connected to a computer. In the mat are small sensors that are sensitive to pressure from your feet. When you step on the mat, it measures and records your foot's contact with the floor. This sends a picture and a signal to the computer about how you move your feet over the mat. I have been told that no pulse or shock (electrical current or any other output) will be given to me.

I understand that I walk across the mat on the floor for a total of 36 times. I know that I will first be asked to walk 6 times like I normally do, and then 6 more times as fast as I can safely walk while I also do the following:

a) carry nothing,
b) carry an large ball in two hands, and
c) carry a plastic bowl of water 3/4s filled

I also understand that I will be asked to sit and rest after each time I walk, in a chair that is placed next to the mat.

Refusal or withdrawal from participation.
I am aware that participation in this study is purely voluntary and that I have the right to say that I do not want to participate, and that I can stop participating at any time.

Deciding to take part in this study is entirely up to you and your parent/guardian. If you do take part in this study project, you or your parent/guardian may stop at any time. Also, the tester has the right to stop you from finishing this study.

Anonymity
All information collected from me and my testing session will be given a code, and my name will not be told to anyone. The only paperwork that will have both my name and number will be this informed consent form. My information will be kept in locked files in the Functional Human Performance Laboratory and only the researcher, Ms. Stiskal will know my information based on my special code. If the information collected from this study is used in a paper or in teaching, my name will not be used. No one will know who I am or what my name is.

I understand that my anonymity will be protected by assigning my data sheets with an unique number. This document as well as data collection sheets will be kept in a locked cabinet in the Functional Human Performance Lab at Seton Hall University.

Access to data

The only persons with access to forms and data collected in this project will be Doreen Stiskal, PT, and Dr. MaryAnn Clark, PT, EdD, who is the research advisor. Names of any participant in this study will be maintained confidential and will at no time be made public.

The data from the study will be kept in a locked cabinet for 3 years and then destroyed.

Risks and discomfort
There is no risk of getting hurt or injured from the physical therapist measuring your leg, from any of the two objects, or from walking on the mat. The distance you will walk for each test is similar to walking across a classroom. You will rest between each walking test, and you may end the session at any time. I understand that the walking assessment involves no greater risk of pain or discomfort that normally would be associated with a walking and carrying objects as I normally do during the school day.

I understand that the risk of pain or discomfort from walking 36 times for a distance of 24 feet is similar to walking the distance from a parking lot into my school (864 feet).

Should I experience moderate increase or changes in pain or discomfort I will alert the researcher and I will be referred to the local community hospital or care center or to my primary care physician.

Benefits
I understand that participation in this study likely will not have any direct benefit to me. The major potential benefit from this study will be after the completion of the study, when data have been analyzed and performance compared between the individuals with and without juvenile arthritis (JA). Information gathered can be of potential benefit in identifying and designing rehabilitation for adolescents with JA.

Request for Information
I understand that I at any time can request more information about the study. Doreen Stiskal, PT is available at telephone number 973-275-2320 to answer any of my questions or concerns.

If during the study or at a later time I wish to discuss my participation with a person not directly involved in the study I am aware that the research advisor Dr. MaryAnn Clark, PT, EdD, is available at 973-275-2894.

Institutional Review Board

This project has been reviewed and approved by the Seton Hall University Institutional Review Board for Human Subjects (IRB). The IRB believes that the research procedures adequately safeguard the subject's privacy, welfare, civil liberty and rights. The Chairperson of Seton Hall University Review Board may be reached at 973-275-2974.

In the event of injury
The Department of Health and Human Service requires that you be advised to the availability of medical treatment if a physical injury should result during the research procedures. No special medical arrangements have been made for your participation in this project. If you are a registered student of SHU you are eligible to receive medical treatment at the University Health Service. If you are not a registered student at the University, immediate medical treatment is available at usual customary fees at the local community hospital or care center or at your primary care physician's office.

Resources
In the event you believe that you have suffered any injury as a result of the participation in the research program, please contact the Chairperson of the IRB (phone number 973 275-2974) who will review the matter with you and your parent, and identify any other resources that may be available to you.

Copy of Assent Form
I am aware that I will receive a copy of this assent form. I am also aware that my parent/guardian has reviewed and signed a parental consent form.

I have read the material above, and any questions I asked have been answered to my satisfaction. I agree to participate in this activity, realizing that I may withdraw without prejudice at any time.

_____ _____
Signature of Participant Date

_____
Name of participant

_____ _____
Parent's Signature Date

_____ _____
Researcher's Signature Date

Assigned number:

COMPARISON OF THE WALKING PERFORMANCE AT TWO DIFFERENT SPEEDS IN ADOLESCENTS WITH AND WITHOUT JUVENILE ARTHRITIS USING A DUAL-TASK METHOD

Parent Consent Form

I have been informed that this study is being conducted by Doreen Stiskal, who is a physical therapist and a student at Seton Hall University. The study is to fulfill the requirements for completion of Ms. Stiskal's Doctor of Philosophy degree program at Seton Hall University, School of Graduate Medical Education in the Graduate Programs in Health Sciences department.

Purpose of Research

I am aware that the purpose of this study is to look at how walking and carrying objects may change the way children, with and without problems in their joints and muscles of their arms and legs, walk. We are doing this study to help physical therapists see if a child's walking ability changes when carrying objects. The results of this study will help doctors and physical therapists to identify more accurately the walking problems in children, with and without joint and muscle problems in their legs.

Duration

I am aware that my child will be tested only one time (one session) for roughly 1 hour to in the laboratory called the Functional Human Performance Lab. This is located at Seton Hall University, South Orange, NJ. I am aware that my child will need to wear shorts, t-shirt, and sneakers with the laces tied. The session includes approximately 15 minutes of introduction and questioning. Then, the walking procedures will take approximately 45 minutes, with rest periods given after each time my child walks.

Procedure

I am aware that my child will be questioned about his/her health and medical history, including questions if my child has arthritis or other problems with the muscles and joints. I understand that my child will be given a questionnaire, named the Children's Health Assessment Questionnaire, to answer about my child's ability to walk, dress, groom, etc.

I am aware that the lengths of each of my child's legs will be measured in standing, with my child's clothes and shoes on, with the researcher placing a tape measure from the outside of my hip bone toward the floor. I am aware that my child will be asked to walk across a computerized walkway, called the GAITRite™ mat. It is a flat rubber mat that measures almost three feet wide and fifteen feet long. It is connected to a computer. In the mat are small sensors that are sensitive to pressure from your child's feet. When your child steps on the mat, it measures and records your child foot's contact with the floor. This sends a picture and a signal to the computer about how your child moves his/her feet over the mat. I have been told that no pulse or shock (electrical current or any other output) will be given to my child.

I understand that my child will walk across the mat on the floor for a total of 36 times. I know that my child will first be asked to walk 6 times like my child normally does, and then 6 more times as fast as my child can safely walk while my child also does the following:

a) carry nothing,
b) carry an large ball in two hands, and
c) carry a plastic bowl of water 3/4s filled

I also understand that my child will be asked to sit and rest after each time my child walks, in a chair that is placed next to the mat.

Refusal or withdrawal from participation.
I am aware that participation in this study is purely voluntary and that my child and I have the right to say that I do not or my child does not want to participate, and that my child or I can stop participating at any time.

Deciding to take part in this study is entirely up to you and your child. If you do take part in this study project, you or your child may stop at any time. Also, the tester has the right to stop my child from finishing this study.

Anonymity
All information collected from your child and your child's testing session will be given a code, and your child's name will not be told to anyone. The only paperwork that will have both your child's name and number will be this informed consent form. My information will be kept in locked files in the Functional Human Performance Laboratory and only the researcher, Ms. Stiskal will know your child's information based on your child's special code. If the information collected from this study is used in a paper or in teaching, your child's name will not be used. No one will know who your child is or what your child's name is.

I understand that my child's anonymity will be protected by assigning my child's data sheets with an unique number. This document as well as data

collection sheets will be kept in a locked cabinet in the Functional Human Performance Lab at Seton Hall University.

Access to data
The only persons with access to forms and data collected in this project will be Doreen Stiskal, PT, and Dr. MaryAnn Clark, PT, EdD, who is the research advisor. Names of any participant in this study will be maintained confidential and will at no time be made public.

The data from the study will be kept in a locked cabinet for 3 years and then destroyed.

Risks and discomfort
There is no risk of getting hurt or injured from the physical therapist measuring your child's leg, from any of the two objects, or from walking on the mat. The distance child's will walk for each test is similar to walking across a classroom. Your child will rest between all walking tests, and you or your child may end the session at any time. I understand that the walking assessment involves no greater risk of pain or discomfort that normally would be associated with walking and carrying objects similar to what my child normally does during the school day.

I understand that the risk of pain or discomfort from walking 36 times for a distance of 24 feet is similar to walking the distance from a parking lot into my child's school (864 feet).

Should my child experience moderate increase or changes in pain or discomfort, my child or I will alert the researcher. I will be referred to the nearest community hospital or care center or to my child's primary care physician.

Benefits
I understand that participation in this study likely will not have any direct benefit to me. The major potential benefit from this study will be after the completion of the study, when data have been analyzed and performance compared between the individuals with and without juvenile arthritis. Information gathered can be of potential benefit in identifying and designing rehabilitation for adolescents with JA.

Request for Information

I understand that I may request more information about the study. Doreen Stiskal, PT is available at telephone number 973-275-2320 to answer any of my questions or concerns.

If during the study or at a later time I wish to discuss my participation with a person not directly involved in the study, I am aware that the research advisor Dr. MaryAnn Clark, PT, EdD, and she is available at 973-275-2894.

Institutional Review Board
This project has been reviewed and approved by the Seton Hall University Institutional Review Board for Human Subjects (IRB). The IRB believes that the research procedures adequately safeguard the subject's privacy, welfare, civil liberty and rights. The Chairperson of Seton Hall University Review Board may be reached at 973-275-2974.

In the event of injury
The Department of Health and Human Service requires that you be advised to the availability of medical treatment if a physical injury should result during the research procedures. No special medical arrangements have been made for your participation in this project. If you are a registered student of SHU you are eligible to receive medical treatment at the University Health Service. If you are not a registered student at the University, immediate medical treatment is available at usual customary fees at the local community hospital or your child's primary care physician's office.

Resources
In the event you believe that your child has suffered any injury as a result of the participation in the research program, please contact the Chairperson of the IRB (phone number 973 275-2974) who will review the matter with you, and identify any other resources that may be available to you.

Copy of Consent Form
I am aware that I will receive a copy of this consent form. I am also aware that my child has reviewed and signed an assent form.

I have read the material above, and any questions I asked have been answered to my satisfaction. I agree to participate in this activity, realizing that my child may withdraw without prejudice at any time.

_____ _____

Parental Signature Date

_____

Name of participant (Child)

_____ _____

Researcher's Signature Date

Assigned number:

COMPARISON OF THE WALKING PERFORMANCE AT TWO DIFFERENT SPEEDS IN ADOLESCENTS WITH AND WITHOUT JUVENILE ARTHRITIS USING A DUAL-TASK METHOD

Participant Consent Form

I have been informed that this study is being conducted by Doreen Stiskal, who is a physical therapist and a student at Seton Hall University. The study is to fulfill the requirements for completion of Ms. Stiskal's Doctor of Philosophy degree program at Seton Hall University, School of Graduate Medical Education in the Graduate Programs in Health Sciences department.

Purpose of Research

I am aware that the purpose of this study is to look at how walking and carrying objects may change the way children, with and without problems in their joints and muscles of their arms and legs, walk. We are doing this study to help physical therapists see if a child's walking ability changes when carrying objects. The results of this study will help doctors and physical therapists to identify more accurately the walking problems in children, with and without joint and muscle problems in their legs.

Duration

I am aware that I will be tested only one time (one session) for roughly 1 hour to in the laboratory called the Functional Human Performance Lab. This is located at Seton Hall University, South Orange, NJ. I am aware that I will need to wear shorts, t-shirt, and sneakers with the laces tied. The session includes approximately 20 minutes of introduction and questioning. Then, the walking procedures will take approximately 40 minutes, with rest periods given after each time I walk.

Procedure

I am aware that I will be questioned about my health and medical history, including questions if I have arthritis or other problems with the muscles and joints. I understand that I will be given a questionnaire, named the Children's Health Assessment Questionnaire, to answer about my ability to walk, dress, groom, etc.

I am aware that the lengths of each of my legs will be measured in standing, with my clothes and shoes on, with the researcher placing a tape measure from the outside of my hip bone toward the floor. I am aware that I will be asked to walk across a computerized walkway, called the GAITRite™ mat. It is a flat rubber mat that measures almost three feet wide and fifteen feet long. It is connected to a computer. In the mat are small sensors that are sensitive to pressure from your feet. When you step on the mat, it measures and records your foot's contact with the floor. This sends a picture and a signal to the computer about how you move your feet over the mat. I have been told that no pulse or shock (electrical current or any other output) will be given to me.

I understand that I walk across the mat on the floor for a total of 36 times. I know that I will first be asked to walk 6 times like I normally do, and then 6 more times as fast as I can safely walk while I also do the following:

a) carry nothing,
b) carry an large ball in two hands, and
c) carry a plastic bowl of water 3/4s filled

I also understand that I will be asked to sit and rest after each time I walk, in a chair that is placed next to the mat.

Refusal or withdrawal from participation.
I am aware that participation in this study is purely voluntary and that I have the right to say that I do not want to participate, and that I can stop participating at any time.

Deciding to take part in this study is entirely up to you. If you do take part in this study project, you may stop at any time. Also, the tester has the right to stop you from finishing this study.

Anonymity
All information collected from me and my testing session will be given a code, and my name will not be told to anyone. The only paperwork that will have both my name and number will be this informed consent form. My information will be kept in locked files in the Functional Human Performance Laboratory and only the researcher, Ms. Stiskal will know my information based on my special code. If the information collected from this study is used in a paper or in teaching, my name will not be used. No one will know who I am or what my name is.

I understand that my anonymity will be protected by assigning my data sheets with an unique number. This document as well as data collection sheets will be kept in a locked cabinet in the Functional Human Performance Lab at Seton Hall University.

Access to data
The only persons with access to forms and data collected in this project will be Doreen Stiskal, PT, and Dr. MaryAnn Clark, PT, EdD, who is the research advisor. Names of any participant in this study will be maintained confidential and will at no time be made public.

The data from the study will be kept in a locked cabinet for 3 years and then destroyed.

Risks and discomfort
There is no risk of getting hurt or injured from the physical therapist measuring your leg, from any of the two objects, or from walking on the mat. The distance you will walk for each test is similar to walking across a classroom. You will rest between each walking test, and you may end the session at any time. I understand that the walking assessment involves no greater risk of pain or discomfort that normally would be associated with a walking and carrying objects as I normally do during the school day.

I understand that the risk of pain or discomfort from walking 36 times for a distance of 24 feet is similar to walking the distance from a parking lot into my school (864 feet).

Should I experience moderate increase or changes in pain or discomfort I will alert the researcher and I will be referred to the local community hospital or care center or to my primary care physician.

Benefits
I understand that participation in this study likely will not have any direct benefit to me. The major potential benefit from this study will be after the completion of the study, when data have been analyzed and performance compared between the individuals with and without juvenile arthritis (JA). Information gathered can be of potential benefit in identifying and designing rehabilitation for adolescents with JA.

Request for Information
I understand that I at any time can request more information about the study. Doreen Stiskal, PT is available at telephone number 973-275-2320 to answer any of my questions or concerns.

If during the study or at a later time I wish to discuss my participation with a person not directly involved in the study I am aware that the research advisor Dr. MaryAnn Clark, PT, EdD, is available at 973-275-2894.

Institutional Review Board
This project has been reviewed and approved by the Seton Hall University Institutional Review Board for Human Subjects (IRB). The IRB believes that the research procedures adequately safeguard the subject's privacy, welfare, civil liberty and rights. The Chairperson of Seton Hall University Review Board may be reached at 973-275-2974.

In the event of injury
The Department of Health and Human Service requires that you be advised to the availability of medical treatment if a physical injury should result during the research procedures. No special medical arrangements have been made for your participation in this project. If you are a registered student of SHU you are eligible to receive medical treatment at the University Health Service. If you are not a registered student at the University, immediate medical treatment is available at usual customary fees at the local community hospital or care center or at your primary care physician's office.

Resources
In the event you believe that you have suffered any injury as a result of the participation in the research program, please contact the Chairperson of the IRB (phone number 973-275-2974) who will review the matter with you, and identify any other resources that may be available to you.

Copy of Consent Form
I am aware that I will receive a copy of this consent form.

I have read the material above, and any questions I asked have been answered to my satisfaction. I agree to participate in this activity, realizing that I may withdraw without prejudice at any time.

_____ _____
Signature of Participant Date

_____
Name of Participant

_____ _____
Researcher's Signature Date

Assigned number :

HACKENSACK UNIVERSITY MEDICAL CENTER

Consent Form

Title of Protocol

COMPARISON OF THE WALKING PERFORMANCE AT TWO DIFFERENT SPEEDS IN ADOLESCENTS WITH AND WITHOUT JUVENILE ARTHRITIS USING A DUAL-TASK METHOD

The word "you" in this consent form signifies "you or your child."

Who is conducting this study?

Principal Investigator: Yukiko Kimura, MD

Co-Investigator and Coordinator: Doreen Stiskal, PT

Sponsor: Hackensack University Medical Center

Why have I been asked to take part in this research study?

You have been asked to take part in this study because you have juvenile arthritis (JA), or are a healthy volunteer without arthritis. It is up to you to decide whether or not to take part in this study. Please read this entire consent form. This consent form may contain words that you do not understand. Please ask the study doctor or the study coordinator to explain any words or information that you do not clearly understand. You may take home an unsigned copy of this consent form to think about or discuss with family or friends before making your decision.

Why is this study being conducted?

This study is being conducted to look at how walking and carrying objects may change the way children, with and without problems in their joints and muscles of their arms and legs, walk. We are doing this study to help physical therapists see if a child's walking ability changes when carrying objects. The results of this study will help doctors and physical therapists to

identify more accurately the walking problems in children, with and without joint and muscle problems in their legs.

How many people will participate in this study?

Approximately 24 children will be studied (12 with arthritis and 12 without).

What is involved in this study?

You will need to wear shorts, t-shirt, and sneakers with the laces tied. The session includes approximately 15 minutes of introduction and questions. Then, the walking procedures will take approximately 45 minutes, with rest periods given after each time you walk.

Procedure:
You will be questioned about your health and medical history, including questions if you have arthritis or other problems with the muscles and joints. You will be given a standard questionnaire, named the Children's Health Assessment Questionnaire, to answer about your ability to walk, dress, groom, etc.

The lengths of each of your legs will be measured in standing, with your clothes and shoes on, with the researcher placing a tape measure from the outside of your hip bone toward the floor. You will be asked to walk across a computerized walkway, called the GAITRite™ mat. It is a flat rubber mat that measures almost three feet wide and fifteen feet long. It is connected to a computer. In the mat are small sensors that are sensitive to pressure from your feet. When you step on the mat, it measures and records your foot's contact with the floor. This sends a picture and a signal to the computer about how you move your feet over the mat. No pulse or shock (electrical current or any other output) will be given to you.

You will walk across the mat on the floor for a total of 36 times. You will first be asked to walk 6 times like you normally do, and then 6 more times as fast as you can safely walk while you also do the following in a random order:

a) carry nothing,
b) carry an large ball in two hands, and
c) carry a plastic bowl of water 3/4s filled

You will be asked to sit and rest after each time you walk, in a chair that is placed next to the mat.

How long will I be in the study?

There will be one session for roughly 1 hour at Hackensack University Medical Center.

What are the risks involved in this study?

There is no risk of getting hurt or injured from the physical therapist measuring your leg, from any of the two objects, or from walking on the mat. The distance you will walk for each test is similar to walking across a classroom. You will rest between each walking test, and you may end the session at any time. The walking assessment involves no greater risk of pain or discomfort that normally would be associated with a walking and carrying objects as you normally do during the school day. The risk of pain or discomfort from walking 36 times for a distance of 24 feet is similar to the risk from walking the distance from a parking lot into your school (864 feet).

Are there benefits to taking part in the study?

Participation in this study likely will not have any direct benefit to you. The major potential benefit from this study will be after the completion of the study, when data have been analyzed and performance compared between the individuals with and without juvenile arthritis (JA). Information gathered can be of potential benefit in identifying and designing rehabilitation programs for adolescents with JA.

What other treatment options are there?

You may choose not to participate in the study.

How will information about me be kept private?

Your identity and participation are confidential to the extent permitted by law. All information collected from you and your testing session will be given a code, and your name will not be told to anyone. The only paperwork that will have both your name and number will be this informed consent form. Your information will be kept in locked files in the Functional Human Performance Laboratory at Seton Hall University, and only the researcher, Ms. Stiskal will know your information based on your special code. If the information collected from this study is used in a paper or in teaching, your name will not be used. No one will know who you are or what your name is.

Your anonymity will be protected by assigning your data sheets with an unique number. This document as well as data collection sheets will be kept

in a locked cabinet in the Functional Human Performance Lab at Seton Hall University. The only persons with access to forms and data collected in this project will be Doreen Stiskal, PT, and Dr. MaryAnn Clark, PT, EdD, who is the SHU research advisor. Names of any participant in this study will be maintained confidential and will at no time be made public. The data from the study will be kept in a locked cabinet for 3 years and then destroyed.

What are the costs?

Taking part in this study will not add costs to you or your insurance company. In the case of physical injury resulting from participation in the study, treatment determined by a physician will be made available to you. This care will be billed to you/your insurance company in the usual and customary manner. There will be no monetary compensation by Hackensack University Medical Center.

What are my rights as a research participant?

Your participation in this study is purely voluntary and you have the right to say that you do not want to participate, and that you can stop participating at any time.

Deciding to take part in this study is entirely up to you and your parent/guardian. If you do take part in this study project, you or your parent/guardian may stop at any time. Also, the tester has the right to stop you from finishing this study.

Who can I call if I have questions or problems?

For questions concerning this research project and/or research subjects' rights, you should call Louis J. Ramazzotto, PhD, Director of Research at Hackensack University Medical Center at 201-996-2879 or The Institutional Review Board Office at 201-996-2255. In the event that medical assistance is required, you are instructed to call Dr. Kimura at 201-996-5306.

Where can I get more information?

Doreen Stiskal, PT is available at telephone number 973-275-2320 to answer any of your questions or concerns. If during the study or at a later time you wish to discuss your participation with a person not directly involved in the study, you may contact the research advisor Dr. MaryAnn Clark, PT, EdD, at 973-275-2894.

Conflict of Interest

There is no conflict of interest.

Consent

- I have read or it has been explained to me and I understand the information in this consent form. All my questions have been answered to my satisfaction. I consent to participate in this study.
- I understand that I will receive a signed and dated copy of this consent form for my records.
- By signing this consent form I have not waived any of the legal rights which I otherwise would have as a participant in a research study.

I hereby consent (to have my child/ward consent) to participate.

_____
Person Obtaining Consent

_____ _____
Signature of Person Obtaining Consent Date

_____
Subject's Name or Legally Authorized Representative

_____ _____
Signature of Subject (If participant is 9 years old or older) Date
Or Signature of Legally Authorized Representative

_____
Parent/Guardian's Name If Participant is a Minor

_____ _____
Signature **Date**

A witness is someone who has no connection with the clinical trial. A witness is only required in cases where the subject cannot read or is not able to understand the consent document. By signing the consent form, the witness attests that the information in the consent form and ant other written information was accurately explained to and apparently understood by the subject or the subjects legally acceptable representative and that the informed consent was freely given by the subject or the subjects acceptable representative. In cases where this does not apply N/A should be placed in the witness section.

Witness (someone not connected to this research project) _____ *Date:*_____

Witness Identification: (nurse, friend, receptionist, etc.) _____

APPENDIX J

DATA COLLECTION FLOW SHEET

DATA COLLECTION FLOW SHEET

1. Provide the appropriate informed consents and assents and answer any questions from subject and/or parent.

2. Complete interview form.

3. Create subject file in software program using subject code #, DOB, and leg lengths.

4. Instruct subject in the walking procedure.

5. Allow one practice pass prior to each new condition, and at each speed.

6. Verify order of conditions.

7. Begin data collection for 1st condition at self-selected speed and mark memo box on data file: Instruct subject to walk and avoid dropping anything if a dual-task condition and to walk at his/her normal speed.

    a. Trial # 1SS ____
    b. Trial # 2SS ____
    c. Trial # 3SS ____
    d. Trial # 4SS ____
    e. Trial # 5SS ____

8. Provide a seated 3-minute rest period.

9. Repeat this condition but at the subject's self-selected faster speed. Instruct subject to walk and avoid dropping anything if a dual-task condition and to move at a rate that is safe and comfortable.

    a. Trial # 1FS ____
    b. Trial # 2FS ____
    c. Trial # 3FS ____
    d. Trial # 4FS ____
    e. Trial # 5FS ____

10. Provide a seated 3-minute rest period.

11. Begin data collection with second task. Instruct subject to walk and avoid dropping anything if a dual-task condition and to walk at his/her normal speed.

a. Trial # 1SS ____
b. Trial # 2SS ____
c. Trial # 3SS ____
d. Trial # 4SS ____
e. Trial # 5SS ____

12. Provide a seated 3-minute rest period.

13. Repeat this condition but at the subject's self-selected faster speed. Instruct subject to walk and avoid dropping anything if a dual-task condition and to move at a rate that is safe and comfortable.

a. Trial # 1FS ____
b. Trial # 2FS ____
c. Trial # 3FS ____
d. Trial # 4FS ____
e. Trial # 5FS ____

14. Provide a seated 3-minute rest period.

15. Begin data collection with second task. Instruct subject to walk and avoid dropping anything if a dual-task condition and to walk at his/her normal speed.

a. Trial # 1SS ____
b. Trial # 2SS ____
c. Trial # 3SS ____
d. Trial # 4SS ____
e. Trial # 5SS ____

16. Provide a seated 3-minute rest period.

17. Repeat this condition but at the subject's self-selected faster speed. Instruct subject to walk and avoid dropping anything if a dual-task condition and to move at a rate that is safe and comfortable.

a. Trial # 1FS ____
b. Trial # 2FS ____
c. Trial # 3FS ____
d. Trial # 4FS ____
e. Trial # 5FS ____

18. Provide a 3-minute seated rest period and answer any final questions of the subject and /or parent.

19. Ensure all files are saved and appropriately coded in subject's electronic gait file.

APPENDIX K

GAITRITE DISTANCE AND TEMPORAL MEASURES

(adapted from: CIR Systems, Inc.,2001. www.gaitrite.com)