MOVEMENT AND MUSCLE FUNCTION IN INDIVIDUALS WITH

VISUAL IMPAIRMENTS

by

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(Under the direction of Michael Horvat)

ABSTRACT

The purpose of this investigation was to assess movement and muscle function in adults with visual impairments compared to an age and sex matched control group. Fifteen Individuals with visual impairment (38.07 ± 13.40) and fifteen matched individuals without visual impairment (38.13 ± 13.16) performed mobility measures consisting of a NeuroCom Sit-To-Stand, NeuroCom Walk Across, NeuroCom Forward Lunge, Thirty Second Sit-To-Stand, and a Timed Up and Go. In addition an Isokinetic assessment of muscular strength, power, and work were conducted, along with root mean squared electromyography (rmsEMG) was used as an indicator of motor unit recruitment. The measures were compared across groups and the relationship between components of muscle strength and movement function was studied. Five of the twelve movement measures resulted in significant differences ($p < .05$) for the visually impaired group. Significant differences ($p < .05$) were found on all measures of muscular function, motor unit recruitment yielded no significant group differences. A high correlation was found between muscular function and movement. Based on the data analyses, it was concluded that individuals with visual impairment make adaptations in mobility in order to maintain stability, as seen by the speed of movement and length of movement as it pertains to the individuals' center of gravity. Strength, power, and total work are deficient when compared to sighted peers and are areas that are recommended for remediation.

INDEX WORDS: Visual Impairment, Movement, Muscular Function

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VISUAL IMPAIRMENTS

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DEDICATION

I would like to dedicate this dissertation to my future wife, Julie, who has walked with me through this process and helped me to grow both outside and inside the classroom. Even though no ones future is certain, I am confident that with our continued support and our ability to bring out the best in each other we are at the beginning of wonderful ride.

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CHAPTER 1

INTRODUCTION

The Center for Disease Control (2003) has estimated that approximately 1 million people over the age of 40 in the United States are blind. An additional 2.4 million individuals can be classified as visually impaired (20/200 or worse, 20 degree field of view or less) (Blasch, Weiner, & Welsh, 1997). Vision is essential for movement development and is a primary factor in orientation, and mobility as well as learning new motor skills (Sudgen & Keogh, 1990). Although the link between vision and movement has been emphasized; the underlying somatosensory mechanisms involved in initiating or compensating for movement when vision is restricted have not been extensively studied. In this context, compensatory strategies in processing sensory information when vision is reduced must be understood in order to develop efficient methods to improve physical functioning and motor efficiency.

One of the difficulties in understanding movement compensation is the lack of standardized assessment that are specific to individuals with visual impairment. Perceived outcomes may be visually biased or are not validated for use with individuals with visual impairments (Skaggs & Hopper, 1996). For example, a common conception is that balance is deficient in visually impaired when using tests such as a stork stand or balance beam walk, which are not common situations faced by individuals with visual impairments and are sight related. In contrast performance is not necessarily deficient in all environments or on other assessments indicating compensatory strategies are being utilized to maintain stability (Horvat, Ray, Ramsey, Miszko, Keeney, & Blasch, 2003).

Previous research has indicated that vision plays an essential role in development. Adelson and Fraiberg (1974) reported comparisons of congenitally blind and sighted infants indicated that blind infants during restricted in activities that involved mobility. Furthermore, infants with visual impairment progress similarly to sighted children, but then become deficient in movements such as reaching and crawling in which a visual stimulus is needed to initiate movement (Warren, 1977). These developmental lags affect the acquisition of motor skills early in life much the same way the lack of spatial awareness affects mobility later in life.

In order to develop movement efficiency visual, somatosensory (sensory stimuli from the skin), and vestibular perception (system in the inner ear that provides feedback on linear/rotary acceleration and tilt of the head) are used to provide feedback to maintain balance and initiate movement (Blasch, Weiner, & Welsh, 1997). The combination of these senses is required to produce efficient movement patterns and provide stability during ambulation or the performance of activities of daily living (i.e. movement efficiency) (Horvat et al., 2003). In order to function properly it is important that when one or more sensory systems do not function properly, other senses must compensate to provide feedback to maintain movement efficiency. Vision provides the greatest stimulus for movement exploration and plays a vital role in the development of spatial awareness and mobility. A case can be made that due to the impact that vision plays in early development and its role in spatial awareness it is possibly the most important of all of the systems utilized for movement efficiency. If vision is lacking the feedback mechanism needed to develop mature movement patterns must come from vestibular and somatosensory systems or become degraded.

For individuals with visual impairments the use of proprioception and vestibular information to establish movement patterns and body position is necessary for mobility and orientation. Spatial concepts are needed to maintain a base of support and center of gravity stability prior to initiating a movement (Pereira, 1990). Concurrently, an individual must respond to changes in the environment by modifying and self-correcting their movement. For example, when changes in terrain or obstacles are encountered the individual must modify their movements to accommodate these environmental variations. For individuals with visual impairments, the use of somatosensory and vestibular information to establish movement patterns and body position becomes much more important as compensatory modifications due to loss of vision. Orientation and mobility becomes dependent on using sensory information other than vision to initiate changes in the center of gravity and base of support prior to a movement in visually impaired individuals. These postural adjustments and balance responses can include changes in direction during ambulation as well as how quickly an individual moves or responds to a stimulus (Horvat et al., 2003). While deficiencies in mobility and balance have been noted for individuals with a visual impairment, there is a noted absence of viable information on the underlying processes associated with movement as well as how the muscle responds to movement. If movement difficulties begin in childhood and affect movement and activity levels, then the ability to move effectively may also be compromised by a lack of strength or power (Horvat, Ray, Croce, & Blasch, In Review). Although individuals with visual impairments have been described as consistently weaker than their sighted counterparts, it is not know whether these differences are consistent across isokinetic parameters including power, peak torque, or work. Furthermore it is not known if these deficiencies are due to a reduction in muscle mass or motor function.

To accurately gauge muscular strength, a single measure of static or isometric strength may not present an accurate picture of muscle function. Further, measures of static strength are specific to one angle and do not represent strength performance through a full range of motion. Other parameters such as maximum strength, peak torque, power, and total work may be more appropriate indicators of muscle function than static strength indices. For example, the limited studies on muscular strength and power in individuals with visual impairments have reported measures of static strength (Jankowski & Evans 1981; Short & Winnick 1986; 1988) however; no previous research has reported the use of isokinetic testing or adjusted peak torque to body weight to present a relative measure of strength with relation to physical function.

The ability to overcome balance and movement difficulties via the use of sensory, proprioceptive feedback and muscle activation has not been investigated in a visually impaired population. As previous research indicates that vision affects stability and movement efficiency, the need for quantitative systematic studies of muscle activation and motor function should be linked to tasks of daily living to further analyze how the visually impaired individuals respond to movement. It is essential to know how the muscle produces forces, the pattern of muscle activation and the use of other sensory information to fully understand the underlying component of movement efficiency for individuals with a visual impairment.

Statement of the Problem

Based on the scarcity of information on muscle activation, motor unit recruitment, strength, power, work and compensatory movement strategies for individuals with visual impairments this study was undertaken. Comparisons of muscle activation, strength measures and movement scores will be used to investigate differences between groups and they will also correlate to movement efficiency during functional tasks. It is hypothesized that there will be significant differences in muscle activation, muscle strength, power, and total work between visually impaired and sighted peers. In addition it is expected that components of strength and responses to movement will correlate significantly.

Purpose of the Study

The purpose of this investigation was to assess movement and muscle function in adults with visual impairments compared to an age and sex matched control group. Fifteen Individuals with visual impairment and fifteen matched individuals without visual impairment performed mobility measures consisting of a NeuroCom Sit-To-Stand, NeuroCom Walk Across, NeuroCom Forward Lunge, Thirty Second Sit-To-Stand, and a Timed Up and Go. In addition an Isokinetic assessment of muscular strength, power, and work were conducted, along with root mean squared electromyography (rmsEMG) was used as an indicator of motor unit recruitment. This is relevant as individuals with a visual impairment routinely score lower on balance/stability assessments compared to a non-visually impaired population. Also, the need to document compensatory strategies for movement and stability is needed to understand how individuals compensate for the lack of vision during movement. There is a noticeable lack of research on underlying movement differences for individuals with visual impairments. Moreover, no research has been uncovered that has identified the underlying muscular and strength mechanisms that can be incorporated into programs to improve mobility and physical function in individuals with visual impairments. Therefore, the purpose of this study will be to analyze patterns of muscle activation, strength characteristics, as well as identifying movement/mobility problems that exacerbate voluntary motor control of individuals with visual impairments.

Hypotheses

This study was designed to investigate the differences in muscle activation, strength characteristics, and mobility measures in individuals with visual impairments and their age and sex matched sighted peers. The following hypotheses were formulated between the response and explanatory variables:

I. There will be a statistically significant difference between individuals with visual impairment and their age and sex matched sighted peers in mobility tasks including: NeuroCom Sit-To-Stand, NeuroCom Walk Across, NeuroCom Forward Lunge, Timed-Up-and-Go, and the 30-sec. Sit-To-Stand.

II. There will be a statistically significant difference between individuals with visual impairment and their age and sex matched sighted peers on the ability to produce force as measured by peak torque, power and total work.

III. There will be a statistically significant difference between individuals with visual impairment and their age and sex matched sighted peers in rmsEMG median frequency, which is an indicator of muscle recruitment.

Justification for the Study

This work will provide information to understand underlying mechanisms needed to enhance physical performance (specific strength programs or mobility programs?). This study complements previous work completed at the Rehabilitation Research and

Development Center of the Veteran Affairs Medical Center in Atlanta, Georgia. It is the intent of this study to expand on earlier work and quantify mobility deficiencies and force production patterns in a sample of individuals with and without a visual impairment.

The Significance of the Study

This project will produce preliminary information about balance and strength as they relate to physical functioning and mobility. A review of the literature revealed little concerning the movement adaptations to vision loss in adults and changes that occur in functioning. In order to understand what specifics are needed in intervention programs we need to understand the basic components of information processing. There are several unanswered questions that will be addressed in the present study and include: without vision how is sensory information used in mobility? What variations for compensating strategies are employed by individuals with visual impairments?

Limitations of the Study

This study is limited to the range of functional activities able to be performed on the NueroCom Equitest (Clackamas, OR), University of Georgia Movement Studies Laboratory, and the Cybex Isokinetic Dynamometer (CSMI). The ability to generalize to the total population of visual impaired may be limited by factors such as age, age of onset of vision loss, amount of vision loss, duration of blindness, variability of the sample and sample size.

Delimitations of the Study

This study was limited to 15 participants diagnosed as legally blind and 15 age and sex matched sighted participants. All subjects were between the ages of 20-60.

Participants were healthy and free of any additional disabilities or musculoskeletal problems.

Definition of Terms

Box's M – Indices used to test for violation of the assumption of homogeneity of covariance (Norusis, 1988).

Effect Size - "The magnitude of an independents variable's effect, usually expressed as a proportion of explained variance in the dependent variables (Weinfurt, 2000 p. 274)."

Hotellings' Trace – "A multivariate test statistic used when there is one independent variable with only two levels (Weinfurt, 2000 p. 274)."

Legally Blind – 20/200 or worse, 20 degree field of view or less. All participants in the visual impaired category are fit the parameters of legal blindness.

Levene Statistic – Test statistic measuring homogeneity of variances between the groups.

Mobility – "moving safely, gracefully, and comfortably." (Blasch, Wiener, & Welsch, 1997, p.10)

Movement Efficiency – (movement + efficiency) Movement – "A change in place or position (Dictionary.com, 2003)." Efficiency – "The ratio of useful work to energy expended (Dictionary.com, 2003)." The ability to perform tasks of daily living in an expedient and mature manner. The combination of these senses is required to produce efficient movement patterns and provide stability during movement (Horvat, Ray, Ramsey, Miszko, Keeney, & Blasch, 2003).

Muscle Recruitment – is the ability of the muscle to activate motor-units (Enoka, 1988).

Muscular Endurance – "the ability of a muscle or muscle group to perform repeated contractions against a light (sub maximal) load for an extended period of time (Baechle, 1994)." The ability to recreate the force over multiple repetitions. Measured by the set at 270 deg/sec. for 20 repetitions on the Cybex Isokinetic Testing Dynamometer.

Muscular Strength – "The maximal amount of force that can be generated by a muscle or muscle group (Powers & Howley, 1997)." Maximum force generated. Measured on the Cybex Isokinetic Testing Dynamometer in Newton-meters.

Orientation – "knowledge of one's distance and direction relative to things observed or remembered in the surroundings and keeping track of these "self-to-concept" spatial relationships as they change during locomotion." (Blasch, Wiener, & Welsch, 1997, p.10)

Peak Torque – The force produced by muscular contraction in a joints range of motion (Perrin, 1993). Measured by an isokinetic testing device in Newton-meters.

Pearson r – Statistic reflection of the linear relationship between two variables.

Power – is the amount of time it takes for a muscle to apply force times distance of movement (Perrin, 1993). Measured by an isokinetic testing device measured in watts.

Total Work – is the amount of force produced times distance of rotation a muscle produces through a set of repetitions (Perrin. 1993). Measured by an isokinetic testing device in Newton-meters.

Wilks' Lamda – "A multivariate test statistic that expresses the proportion of unexplained variance in the dependent measures (Weinfurt, 2000 p. 274)."

CHAPTER 2

REVIEW OF LITERATURE

This chapter is a review of literature that pertains to testing procedures and issues related to mobility and strength that pertain to individuals with visual impairments. The purpose of this chapter is to state what is already known about individuals with visual impairments and to justify the equipment and procedures utilized for this study. This review is organized as follows: (a) background, (b) functional tasks, (c) isokinetic strength testing, (d) mobility measures, (e) strength characteristics, (f) electromyography testing and (g) summary of the review of literature.

Background

Fraiberg presents the most compelling evidence for movement difficulties in children with visual impairments (Adelson & Fraiberg, 1974; Fraiberg 1977). Based on this work, we can see that children display inadequate physical coordination/motor skills during the developmental years. Children with a visual impairment are passive and not active in seeking information and responding to interactions in the environment. Fraiberg (1977) indicated that children display either developmental assets or roadblocks to developing movement sequences.

Sighted children will reach, grasp, and manipulate objects that they see and are active information seekers. Children with a visual impairment are more passive and constrained unless they adapt to their environment. Hatton, Bailey, Burchinal, and Ferrel (1997) indicated that some movement difficulties might be due to fear, spatial disorientation, or parental overprotection.

Children with visual impairments also demonstrate problems in basic extending reaching and grasping skills that are precursors to moving in the environment. Visual objects generally provide the lure to initiate movement in young children, whereas children with a visual impairment must rely on sound to obtain directional and spatial information. This results in delays of self-initiated movements, such as rolling. Rettig's (1994) observations of interaction among children with visual impairments reveal that these children are lacking in play skills and spend most of their time playing alone unlike sighted children: 56% of blind children played alone, whereas sighted children spent only 14% of their time playing alone.

Functional Ability

The decrease in functional ability in older individuals can be caused by a number of factors. Balance decreases in the aging process, because of age-related physiological and sensory changes that accentuate the incidence of falls (Lord & Dayhew, 2001).

With the loss of vision, balance appears to be more diminished primarily because the loss of visual ability deleteriously affects the vestibular system via feedback from the visual system (Maeda et al., 1998). In addition, the poor mechanical efficiency and loss of physical functioning that accompanies inactivity results in reduced orientation and mobility and decreases in activities of daily living (Heyes, 1974).

West et al. (1997) indicated that adults with visual acuity worse than 20/40 demonstrate reduced functional status in overall balance and mobility tasks, while Wright et al. 1999 reported that difficulty with everyday tasks was greater in individuals with visual impairments as compared to individuals without visual impairments. In addition, Beggs (1991) reported that walking speed was deficient in visually impaired although no reasons were documented for this finding.

Stones and Kozyma (1987) concluded that balance is deficient in individuals with a visual impairment due to the loss of sensory input while Shindo et al. (1987) suggested that lower levels of physical functioning and strength compared to sighted individuals is a factor in reduced functioning.

Isokinetic Strength Testing

Isokinetic muscle strength is generally described in units such as peak torque (Nm) and or peak force (N). The intent of evaluating isokinetic strength is to determine the work capacity of a muscle group. Muscle dysfunction or weakness can manifest limitations in development and functional performance especially muscle strength and power in relation to movement efficiency. For individuals with visual impairments, muscular strength and power is necessary to maintain postural stability and make corrections in body sway, initiating loco-motor movements and regaining balance on unstable or unknown surfaces. In this context, muscular strength and power are functionally important for maintaining balance, stability and loco-motor activities as well as decreasing fall risk.

Isokinetic strength testing allows the researcher to analyze the participants' peak torque, power, and total work. The advantage of isokinetic testing over other forms of muscular assessment is its ability to test the muscle throughout the entire range of motion of a given skeletal joint (Perrin, 1993).

Even though isokinetic testing has been the gold standard for strength testing for over thirty years the majority of work has been done on high school and collegiate age sighted athletes (Perrin, 1993). Little work has been done to assess muscular strength throughout the full range of motion on visually impaired individuals.

Mobility Measures

For the purpose of this study a NeuroCom Equitest was utilized to measure multiple aspects of mobility. NeuroCom International has been producing and improving on balance and mobility equipment since its inception in 1984. Its products were originally developed by a grant supported by NASA to look at vestibular functioning in astronauts (NeuroCom, 2001). The use of NeuroCom technology is primarily used in medical disciplines, however, for the purpose of this study it will be used to assess mobility in the research setting. The NeuroCom Equitest has a battery of mobility measures that can be performed on its long force plate.

In addition to the NeuroCom two common methods of assessing mobility by practitioners were utilized. Assessment of lower leg strength and physical functioning has been accomplished using the 30-sec Sit-To-Stand measure and has been shown to be a valid tool to assess older adults (Csuka & McCarty, 1985; Rikli & Jones, 1999; and Seaman et al., 1991). The Timed-Up-and-Go has also been shown as a reliable way to assess the risk of falls and mobility concerns in individuals with disabilities (Bruckne, Herge, & Ogunkua, 2002).

Electromyography Testing

Electromyography (EMG) is one of the only noninvasive means to examine muscle function. EMG analysis serves as a way for researchers to observe the motor function in the muscle that could not be assessed without the use of technology and instrumentation (Cram, Kasman, & Holtz, 1998). For the purpose of this study, EMG was utilized to look at muscle recruitment (rmsEMG) at different speeds by the visually impaired and sighted participants.

Strength Characteristics

To maintain stability and balance, muscular strength and power are necessary components of function. Muscular strength provides the force necessary to generate power and maintain stability against gravity. Likewise, power allows for the generation of force across a continuum by maximizing speed of movement. Functionally, a minimal amount of muscular strength and power are essential for maintaining stability to control body sway, adjust to functional demands, or accelerating or decelerating muscle activation during physical activity. For individuals who are generally less efficient in locomotion and demonstrate higher energy expenditures due to inefficiency of motor coordination, rapid fatigue and power reduction can reduce the intensity of the activity (Kobberling et al. 1991). In contrast to individuals with visual impairment, a dearth of knowledge is available about the strength and power output for individuals with sight.

Previous research with individuals with visual impairments has focused on aerobic components of fitness in children and adolescents with little attention being given to muscular strength and power as it relates to function and movement efficiency in adults with visual impairments. For studies that did assess muscular strength, static strength was the measurement of preference due to ease of administration and transportability (Jankowski & Evans 1981; Short & Winnick 1986; 1988).

In children, Wyatt and Ng (1997) reported that congenitally blind children have weaker knee and hip extensors static strength than sighted children but when corrected for body weight only the hip extensors were weaker than sighted children. Jankowski and Evans (1981) also reported deficiencies in static hand grip strength, obesity and low tolerance for activity in children with visual impairments.

In adults, absolute static knee extension strength measures demonstrated no significant differences between sighted and visually impaired elderly subjects (Maeda et aI, 1998). From the limited research available it appears that developmentally, the lack of self-initiated movement and activity in children with visual impairments may not be sufficient to produce typical age-related developments in strength and power that coincide with movement efficiency.

Balance

Standing balance is diminished by loss of vision which affects the vestibular system via feedback from the visual system (Maeda et al, 1998). Since vision may not be available or restricted, other compensatory mechanisms must provide the sensory input that is used to initiate movement and complete the response.

Although it appears that vision is essential for balance, especially in children, the lack of vision does not explain movement difficulties that many visually impaired individuals may encounter (Stones & Kozma, 1987).

From a review of the literature on individuals with visual impairments, it is evident that movement is affected by the lack of vision and demonstrates a variety of ways that affect movement efficiency. For example, it is evident that the major movement differences will occur if balance is a primary component of the task (Pereria, 1990).

Some authorities attribute developmental lags in movement due to the deficiency in sensory modalities (Fraiberg, 1977; Warren, 1977), which is a limitation for children in attaining movement efficiency. Skaggs and Hopper noted individuals with visual impairments use the proprioceptive senses as a substitute for vision when completing balance tasks (1996).

Furthermore, Sleeuwenkoek et al. (1995) indicated that individuals with visual impairments walk stiffly and hesitantly as well as demonstrating balance difficulties. Pogrund and Rosen (1989) indicated that congenitally blind individuals demonstrate posture anomalies while a notable backward lean of the trunk. In older adults with visual impairments, the loss of balance and mobility presents a barrier for independence that is also associated with a fear of falling (Maeda et al, 1998).

Fitness

Levels of fitness are generally lower in individuals who are visually impaired. Any physical activity program should have as its aim to develop and to encourage an active and productive lifestyle. Compared to sighted individuals, people with a visual impairment are lower in cardiovascular endurance, although performance on muscular strength and endurance tasks such as pull-ups, squat thrusts, flexed arm hangs, and standing high jumps is comparable to that of sighted individuals (Buell, 1983; Hopkins, Gaeta, Thomas & Hill, 1987). Most individuals with a visual impairment will not meet age-expected norms for peers with normal vision in running and throwing events if they are limited in the opportunity to practice and develop these activities.

In a study by Kobberling, Janikowski, and Leger (1991), comparisons of habitual physical activity and aerobic capacity between sighted adolescents and individuals who were blind indicated that the maximal oxygen consumption was higher among sighted subjects. The authors subsequently recommended that all individuals, sighted and blind, require a minimum of 30 minutes of daily activity to attain and maintain their age-predicated aerobic capacity.

Shindo, Kumagai, and Tanaka (1987) also reported that low physical work capacity in young males with a visual impairment are due to a lack of physical activity and that mild training accentuates physical functioning and cardiovascular fitness.

Further, Blessing, McCrimmon, Stovall, and Williford (1993) found significant increases in cardiovascular fitness and decreases in body composition after training in individuals with visual impairments, while Ponchillia, Powell, Felski, and Nicklawski (1992) reported improved fitness in women who were blind, after engaging in aerobic activities.

The overall lack of fitness in visually impaired subjects appears to be related primarily to lack of physical activity and the understanding of the capabilities of individuals with visual impairments. Skaggs and Hopper (1996) challenged health care providers to afford opportunities to promote active lifestyles for individuals with a visual impairment and indicated that specific strategies for improving motor skills that are lacking.

Sudgen and Keogh (1990) indicated that experience in physical activity is limited in visually impaired individuals by rhythmical stereotypes “blindisms”, such as body rocking and hand slapping, which are socially inappropriate and limit the opportunities for useful and functional movement experiences. Because many skills require externally paced movements, low scores among individuals with a visual impairment may not be so much an indication of physical capability as of the lack of opportunity to compensate for their inexperience.

Summary

It has been documented that visually impaired individuals do not perform as well on measures of balance and mobility; however speculation exists as to the mechanisms of these deficiencies and how to remedy these problems. Furthermore little work has been done to study the components of strength and movement in adults individuals with a visual impairment. It is the purpose of this study to utilize the most effective equipment to analyze the underlying mechanisms which lead to mobility, strength, and power concerns in the visually impaired community. Based on the results of this study, specific areas of mobility and strength deficiencies can be identified so that practitioners can more efficiently develop programs that serve the needs of individuals with a visual impairment. In addition, specific components of strength can be analyzed to find which measures exhibit the strongest relationship to the movement difficulties, so that interventions can be incorporated to improve the needed component of strength.

CHAPTER 3

METHODS AND PROCEDURES

This chapter examines the methods and procedures used in this study. This chapter outlines the participants, setting, equipment and instrumentation, variables, data collection and procedures, experimental design, data analysis, and human subject concerns.

Participants

Fifteen individuals with a visual impairment and a matched sex and age sample of fifteen, individuals without a visual impairment were tested on the NeuroCom Equitest (NeuroCom International, 2001) and Cybex Norm Isokinetic (CSMII, Norwood, MA) system. The participants were recruited from organizations serving individuals with visual impairments in the Athens community and through affiliations with the Veteran Affairs Medical Center. During Cybex testing EMG data was collected on the medial/lateral quadriceps and medial/lateral hamstring. Inclusion criteria included: legally blind (20/200 or worse, 20 degree field of view or less), and able to ambulate without assistance. Exclusion criteria included: uncontrolled cardiovascular disease, neurological disorders, severe musculoskeletal disorders, severe dementia or terminal disease. Participants were assessed on several tests designed to measure motor efficiency, muscle activity, and strength.

Setting

The University of Georgia Movement Studies Laboratory and the Research and Development Center of the Veteran Affairs Medical Center in Atlanta, Georgia were utilized for data collection. The University of Georgia Movement Studies Laboratory is designated for research and directed by Dr. Michael Horvat. The Veteran Affairs Medical Center in Atlanta is dedicated to research in the field of aging veterans with a visual impairment, and emphasizes on the impact of low vision on the mobility and physical function of the aging veteran. Matching equipment was utilized at each site. This study was funded by a developmental project from the VA Medical Center.

Instrumentation and Equipment

The testing includes the use of the three following types of equipment 1) NeuroCom Equitest, 2) Cybex Isokinetic Dynamometer, and 3) Biopac Electromyography (EMG) analysis system (Biopac, Santa Barbara, CA). The NeuroCom Equitest force plate was used to test all participants in functional tasks (Table 3.1). The force plate measures 18" x 60" and contains four load cells. Force plate outcomes include measures of movement symmetry and variation, force production, movement timing, and distance measures (NeuroCom, 2001).

The Cybex Isokinetic Dynamometer was used to test lower-body muscle function. The Cybex Isokinetic Dynamometer isolates the lower body muscles about the knee to gather human performance data from the subjects. The Cybex Isokinetic Dynamometer screens for any strength deficits in visual impaired population as compared to the sighted population. Variables included in the analysis are peak torque at 90 degrees/second, power at 180 degrees/second, and total work at 300 degrees/second.

EMG signals were recorded during measures on the Cybex Isokinetic Dynamometer. Surface electrodes were placed over the muscles of the medial/lateral quadriceps and medial/lateral hamstrings while the participants performed the Cybex protocol. Simultaneous with the motion performed during the tests the output of each electrode was stored and analyzed for differences in muscle activation across all isokinetic measures (NeuroCom, 1992).

Variables

The dependent variables for this investigation include the 1) lower body strength assessment on the Cybex Isokinetic Dynamometer (strength, power, & total work), 2) the NeuroCom Equitest measures, which includes the outcomes listed in Table 3.1, 3) mobility measures (30-second STS & TUG), and 4) EMG analysis (root mean squared EMG (rmsEMG)) across Cybex Isokinetic Dynamometer measures. The participants were grouped based on their vision loss. The visually impaired and sighted participants were age and sex matched.

Data Collection Procedures

Data collection and procedures were explained to all participants and an informed consent form was signed prior to all data collection. Prior to data collection, participants completed 10 min. of stretching exercises for the quadriceps and hamstrings. Subjects then were seated on the Cybex with stabilization straps placed around shoulders, waist, mid-thigh, and ankle to eliminate extraneous movements and provide constant conditions across subjects (Dvir, 1995; Perrin, 1993). The axis of the dynamometer was aligned with the axis of the knee and the tibial pad was placed proximal to the medial malleolus. Torque values were recorded in Newton-meters (Nm) and corrected for the effect of gravity using the Cybex Isokinetic Dynamometer CSMI gravity correction protocol (CSMI, Norwood, MA). Participants then were tested at angular velocities of 90, 180 and 300 deg/sec. These speeds reflect a continuum from strength to power to endurance. Participants were then allowed 3-5 practice repetitions at each speed to become familiar with the procedures (Dvir, 1995). Participants performed a maximal effort for contraction of the quadriceps (knee extension) followed by a maximal effort of the hamstrings (knee flexion) for 6 continuous repetitions at 90 deg/sec, and 180 deg/sec, followed by 20 repetitions at 300 deg/sec A two-min rest period was given between each test velocity to minimize the effect of fatigue on torque production. Participants were then instructed to push or pull as fast as possible using strong verbal encouragement ("push fast and hard" or "pull fast and hard") during the test procedures. Peak torque was identified as the highest recorded value among the repetitions.

The NeuroCom Equitest was used to assess the participants during functional tasks. The Neurocom equitest system is used to objectively evaluate balance and postural stability under dynamic test conditions to reflect the activities of daily life (NeuroCom, 2001). Included in Table 3.1 are the functional limitation assessments measured in this study. All tests were consistent with the software protocols and prompts for each measure included in the NeuroCom software (NeuroCom Version 8.1).

Table 3.1 Functional Limitation Assessment (Neurocom International, 2001)

Test	**Population**	**What is measured**	**Deficits Addressed**
Sit to Stand (STS)	1) Geriatric 2) Movement Disorders/GVA	1) Execution Time 2) Rise Strength	1) Lateral and front/back weight control 2) Motor control 3) Postural Stability
Walk Across (WA)	1) Geriatric 2) Movement disorders 3) Amputees	1) Parameters of gait: Step width Step length Velocity	1) Motor Control 2) Balance 3) Safety
Forward Lunge (FL)	1) Sports Performance 2) Orthopedics	1) Distance 2) Contact time 3) Force 4) Force impulse	1) Strength/Power 2) Motor Control

		(work)	

* Outcome measures of interest

The testing protocols include the following (NeuroCom, 2001):

1) NeuroCom Sit to Stand (NSTS) – Participants were seated on a 17" box placed on the force plate. The participants were then instructed to "Go" and they stood up from the seated position without use of their upper body and remained still until the test ended (< 5 sec. after they rise). Execution time, rise strength, weight bearing symmetry and COG control were measured.

2) Walk Across (WA) – Participants were positioned in front of the force plate. They were instructed to "Go", with both a visual and audible prompt. The participant proceeded to walk across the force plate. Step width, step length and velocity were measured.

3) Forward Lunge (FL) – The participants were placed at the beginning of the force plate. The participants were then instructed to "Go" by a visual and audible prompt. The participants lunged forward onto one of their legs and returned to a stationary position. Six trials were performed, three for each leg. Distance, execution time, contact, force and force impulse were measured.

In addition to the NeuroCom measures traditional clinical measures of the 30-second Sit-To-Stand and the Timed Up and Go were performed. These measures are explained below.

4) Timed up and Go - The Timed Up-and-Go test was performed to assess functional balance and strength. The Timed Up-and-Go test is appropriate for use by clinicians because it is easy to administer, low cost, and is functionally relevant. It requires leg strength, balance, and mobility to complete the task. The following modified protocol was used. Participants are seated in a chair next to a wall and asked to stand from the chair without the use of their arms, to walk 3 meters while trailing the wall with their hand, turn around at the end of the wall, then return to a seated position in the chair. Velcro strips were attached to the wall approximately 12-18 inches from the chair to serve as a "warning" that the chair is close. Participants are asked to do this at a safe pace, but told that their time was recorded. Three trials were performed and the best of three trials was used for analysis. Time was recorded on a stopwatch to the nearest 0.01-second.

5) Clinical 30-second Sit to Stand – The participants performed the 30-second Sit-to-Stand using a 17" padded chair, without arm rests. The chair was positioned against a wall, so that it would not move, and the researcher was positioned to their side to assist the participant for safety (Weiner, Long, Hughes, Chandler, & Studenski, 1993). The participants were instructed to "Begin" and the participants rose to a full standing position and then returned to a seated position as many times as possible in 30-seconds. When

the time was up, if the participant was more than halfway to a full standing position then it was counted as a full repetition (Jones, Rikli, & Beam, 1999).

During all of the protocols listed above the procedures were explained and practiced by the participant before the measured trials. This allowed the participants full understanding of what was expected, therefore providing the participant with the best opportunity for successful trial completion.

Experimental Design

Sample size was determined based on associations with organizations in the Athens/Clarke county area that provide services for individuals with visual impairments. A convenient sample of 15 visually impaired and 15 age and sex matched sighted participants was utilized for this study. This number was approximated through availability of participants within accessible transportation range and interest in participating in research projects. The participants were matched according to age and gender as outlined by Huck and Cromier (1996).

Data Analysis

This study was designed to study differences between groups of visually impaired, with an age and sex matched sighted peers on components of mobility and strength. Statistical analyses were selected to detect group differences on a battery of tasks utilizing a NeuroCom Equitest, Cybex Isokinetic Dynamometer, and the University of Georgia Movement Studies Laboratory. The Forward Lunge the NeuroCom Equitest accounted for differences in height by displaying all measurements as a percentage of the participants' height. The NeuroCom Equitest also accounted for differences in weight during all three measures (Sit-To-Stand, Forward Lunge and Walk Across) by displaying the weight values as a percentage of body weight. All strength values on the Cybex Isokinetic Dynamometer were collected and reported as a percentage of the participants' body weight. These steps were taken to allow values from both male and female participants to be compared. Descriptive statistics (e.g., means, standard deviations) were calculated and reported in chapter 4.

In addition to between group differences a Pearson correlation was performed on all variables primarily to study which component of strength had the greatest relationship to mobility. Descriptive statistics (e.g., means, descriptive statistics, and correlation coefficients) were calculated and reported.

Sit-To Stand

The Sit-To-Stand test was performed on the NeuroCom Equitest. Participants performed three trials and the mean values from the trials were calculated. A non-equivalent two group MANOVA with three outcome variables was performed. The outcome variables consisted of weight transfer, rising index, and sway velocity.

Walk Across

A three trial Walk Across was performed using the NeuroCom Equitest force plate. The means of all three trials was used and a non-equivalent two group MANOVA with three outcome variables was performed. The outcome variables consisted of step width, step length, and step speed.

Forward Lunge

A forward Lunge was performed on the NeuroCom Equitest. Three trials were performed by each participant with each leg. All six trials were analyzed and the mean values for distance, impact index, contact time, and force impulse was analyzed using a non-equivalent two group MANOVA with four outcome variables was performed.

Timed-Up-and-Go

A Timed-Up-and-Go was performed by each participant and the mean value of three trials was compared using a one way ANOVA.

30 sec. Sit-To-Stand

A 30 sec. Sit-To-Stand was performed by each participant and the mean value of three trials was compared using a one way ANOVA.

Cybex Isokinetic Strength Test

A Cybex Isokinetic Strength Test was performed by all participants. 3 speeds were chosen to represent a strength spectrum from peak torque (90 deg/sec.) to power (180 deg/sec.) to total work (300 deg/sec.). Both extension and flexion values were analyzed using a non-equivalent two group MANOVA with six outcome variables was performed.

Electromyography Analyses

During the Isokinetic Strength Testing the participants were analyzed using a 4 site Biopac EMG system. The pads were placed as close as possible to the participants' motor end points and the rmsEMG median frequency was normalized using the participants' maximal voluntary contraction at 45 degrees of extension. Three non-equivilant two group MANOVA with four outcome variables was performed. Each of the three MANOVAS represented only one speed.

All analyses were conducted using SPSS® version 12.0 software. An alpha level of .05 was used for all analyses and in all MANOVAS the error rate was controlled for

Family-wise by dividing .05 by the number of dependent variables in the analysis (Green, Salkind, & Akey, 2000).

Human Subject Concerns

Minor muscle soreness may be evident during the Cybex testing. Stretching and warm-up procedures were strictly followed. The data including identifiers pertaining to each participant will remain confidential, with only the researchers having access to the information. The data was stored on the computers in the Movement Studies Laboratory at The University of Georgia. All data was removed at the conclusion of the study. The participants obtained a functional task evaluation and lower body strength assesment. They learned their individual task and strength assesment scores and how they scored in relation to age-related norms, when available. Before testing occured, all subjects recieved a full explanation of what was expected from them. The Institutional Review Board informed consent was explained and signed prior to participation.

CHAPTER 4

RESULTS

The statistical analyses for this study are presented in this chapter. Means and standard deviations are reported on performance measures. Multivariate and univariate analysis of variance were used to identify differences between the visually impaired and sighted groups on the measures of mobility and strength characteristics. When multivariate effects were identified a discriminate analysis was used as a follow-up procedure to the MANOVA (Huberty, 1994, p.27). Pearson r correlations were also performed between muscle function and mobility to determine essential components of strength that are correlated with movement. The assumption of independence for both the MANOVA and ANOVA was adressed by having each participant tested individually without any other participants being present during data collection. Other assumptions are addressed individually in each section where applicable. Defintitions of statitics used in this chapter are included in Table 4.1.

Table 4.1: Statistical Terms and Definitions.

Term	Definition

Hotellings' Trace – "A multivariate test statistic used when there is one independent variable with only two levels (Weinfurt, 2000 p. 274)."

Box's M – Indices used to test for violation of the assumption of homogeneity of covariance (Norusis, 1988).

Levene Statistic – Test statistic measuring homogeneity of variances between the groups.

Effect Size - "The magnitude of an independents variable's effect, usually expressed as a proportion of explained variance in the dependent variables (Weinfurt, 2000 p. 274)."

Pearson r – Statistic reflection of the linear relationship between two variables.

Wilks' Lamda – "A multivariate statistic that expresses the proportion of unexplained variance in the dependent measures (Weinfurt, 2000 p. 274)."

Demographics

A convenient sample of 15 visually impaired individuals were used and was matched to 15 sighted participants by age and gender. The demographic variables for this study are included in the following Table 4.2.

Table 4.2: Participants Demographic Data (M ± SD)

Group	Age (M ± SD)	Height (m) (M ± SD)	Weight (kg) (M ± SD)	BMI (M ± SD)
VI	38.07 ± 13.40	1.71 ± 10.82	91.47 ± 22.27	30.71 ± 4.65
NVI	38.13 ± 13.16	1.75 ± 9.44	81.38 ± 24.23	26.14 ± 5.77

VI = Visually Impaired
NVI = Sighted

Although participants were age and sex matched to eliminate variability in the subject population notable differences were evident in body weight and BMI. A one-way ANOVA was performed to determine significant between group differences (Cohen, 1988). The ANOVA's yielded no significant differences ($p > .05$) in weight or height, although individuals with visual impairment were approximately 10 kg heavier then their sighted counterparts. Signifcant differences between groups were apparent in BMI ($F_{(1,}$

$_{28)}$ = 5.69, p = .024) indicating individuals with visual impairment were higher. This issue of significant differeance on BMI was addressed by normalizing force measures by the participants body weight and length measures by the participants body height.

<u>NeuroCom Sit-To-Stand (STS)</u>

The NeuroCom STS consisted of three trials. During each trial the participant was instructed to stand from a seated position and hold that standing position for approximately five seconds. Weight transfer (WT) in seconds, rising index (RI) as a percentage of body weight, and sway velocity (SV) in degrees/second was measured during the STS movement. Each participant performed three trials and the mean score for each measure was utilized. The results were analyzed using a non-equivilant two group MANOVA with three outcome variables. A Hotellings' Trace was utilized to determine multivariate effect by assessing the effect of the dependent variables between the groups (Weinfurt, 2000). The Levene's statistic and Box's M test were also performed to ensure no assumptions were violated by assessing multivariate normality and homogeneity of the covariance matrices. Because the signifigance level was not below .05, no significant differences between groups were indicated, resulting in no violation of the MANOVA assumptions. Results of the MANOVA indicated no multivariate effect between groups (Hotellings' Trace = .057, ($F_{(3, 26)}$ = .491, p = .691) on WT, RI, or SV indicating that the STS motion is similar between both groups (Table 4.3, Fig. 4.1).

Table 4.3: NeuroCom STS Results.

Group	WT (sec.)	RI (% BW)	SV (deg/sec.)

	Mean +/- SD	Mean +/- SD	Mean +/- SD
VI	.41 +/- .22	22.56 +/- 11.44	3.96 +/- 1.23
NVI	.42 +/- .20	23.31 +/- 10.19	3.70 +/- 1.19

Partial eta squared was calculated to measure the effect of the dependent variables on the groups, (Partial eta squared = .05) which indicated a small to medium effect. Acording to Cohen's R squared indicies (1977) between groups and the combined dependent variables (Huck, 2000). Due to the fact that no multivariate effect occurred, a stepdown analysis or discriminant analysis was not performed (Weinfurt, 2000).

<u>NeuroCom Walk Across</u>

The NeuroCom Walk Across was performed by all participants. In this test each participant performed three trials and the mean values of those trials were used in the analyses. Step width (SW) in cm, step length (SL) in cm, and step speed (SP) in cm/sec were recorded and are included.

Between group differences were analyzed using a non-equivilant two group MANOVA with three outcome variables. Means and standard deviations were calculated on all data. A Levene statistic of homogeneity of variance was used to determine differences in group variability, which indicated no significant differences were evident between groups. A Box's M test was also performed to determine equality of covarience matrices, and resulted in significant differences between groups ($F_{(6, 5680)}$ = 15.4, p = .035), however due to equivalent group sizes, no procedure was utilized address this problem (Huberty, 1994, p.199). Significant differences were found between groups among the dependent variables (SW, SL, SP), Hotellings' Trace = .49, ($F_{(3, 26)}$ = 4.52, p = .014). Significant differences were found for step length ($F_{(1, 28)}$ = 12.20, p < .01) and step speed ($F_{(1, 28)}$ = 4.51, p < .05), with the sighted participants demonstrating longer stride length and greater step speed. In contrast no differences were apparent for step width between groups (p > .05). To control the Familywise error rate the level of signifigance (.05) was divided by the number of dependent variables analyzed (Green, Salkind, & Akey, 2000). A Partial eta squared = .3, indicated a large effect size between groups on the walk across test (Huck, 2000; Cohen, 1977). Table 4.4 includes the means and standard deviations for SW, SL, and SP.

Table 4.4: NeuroCom Walk Across

Group	SW (cm) Mean +/- SD	SL (cm) Mean +/- SD	SP (cm/sec.) Mean +/- SD
VI	17.33 ± 4.49	56.04 ± 17.29	87.31 ± 30.31
NVI	17.64 ± 4.33	75.59 ± 13.10	106.65 ± 18.01

As recommended by Huberty (1993, p.27) a follow-up descriptive discriminant analysis was also computed to determine which of the three variables that were measured by the NeuroCom Walk Across make-up a variable construct and how the variable(s) differ between groups. The overall Wilks' Lambda was significant, Λ = .67, $F_{(3, 26)}$ = 4.52, p = .014 indicating an overall difference on the components of the Walk Across between the visually impaired and sighted group. Table 4.5 displays the within-group correlations between the components along with the discriminant functions and the standardized weights of the Walk Across task.

Table 4.5 Standardized Coefficients and Correlations of Predictor Variables for the NeuroCom Walk Across

	Correlation Coefficient With discriminant function	Standardized coefficients for discriminant function
SW(cm)	.052	-.026
SL(cm)	.94	.85
SP(cm/sec)	.57	.34

The means for the discriminant functions are M = .68 for the sighted group and M = -.68 for the visually impaired group, indicating that the sighted group performed at a higher level on the measured components of the NeuroCom Walk Across. The structure r's indicate that SL (.94) has the strongest relationship, while SP (.57) has a weaker relationship, and SW (.05) has virtually no relationship. In this context step length is the strongest factor in this functional task; step speed plays a moderate role in performance while step width is not a factor in movement.

NeuroCom Forward Lunge

All participants performed three forward lunges with each leg requiring the participant to step out as far as possible and then return to the neutral position. The results of the three trials were recorded and means calculated for: lunge distance (LD) in percentage of body height, impact index (II) in percentage of body weight, contact time

(CT) in seconds, and force impulse (FI) in percentage of body weight per second. The results from the forward lunge assessment are included in Table 4.6.

Between group differences were analyzed using a non-equivilant two group MANOVA with four outcome variables. Means and standard deviations were calculated on all data and a Levene statistic of homogeneity of variance was used to determine differences in group variability. Results of the Levene statisitic indicated a violation of the assumption of equality of error variances on LD ($F_{(1,28)} = 7.93$, $p = .009$) and FI ($F_{(1,28)} = 4.36$, $p = .046$). According to Weinfurt (2000, p. 254), violation of the assumption of normaility results in a small effect on the alpha level (Stevens, 1986; Olson, 1974). Due to this violation the alpha level set for this analysis must be considered an estimate and the probability of signifigance may actually be larger than the value reported (Cochran & Cox, 1992, p. 91). A Box's M procedure was then performed to determine equality of covarience matrices, which resulted in significant differences between groups ($F_{(10, 3748)} = 3.95$, $p = .000$), however due to equivalent group sizes, no procedure was utilized address this problem (Huberty, 1994, p.199). There was significant group differences among the dependent variables between groups (Hotelling's Trace = .64, $F_{(4,25)} = 3.52$, $p < .025$). A partial eta squared = .36, was also applied and indicated a large effect size indicating between groups on the forward lunge (Cohen, 1977; Huck, 2000).

Table 4.6: Forward Lunge Results

Group	LD(%BH) Mean +/- SD	II (%BW) Mean +/- SD	CT (sec.) Mean +/- SD	FI (%BW/sec.) Mean +/- SD

VI	*42.35 ± 12.43	27.07 ± 12.86	1.52 ± .95	151.13 ± 90.86
NVI	*52.40 ± 5.87	23.49 ± 5.16	1.26 ± .50	125.24 ± 31.57

* indicates signifigance at $p < .05$

As recommended by Huberty (1993, p.27) a follow-up descriptive discriminant analysis was also computed to determine which of the four variables that were measured by the NeuroCom Forward Lunge make-up a variable construct and how the variable(s) differ between groups. The overall Wilks' Lambda was significant $\Lambda = .64$, $F_{(4,25)} = 3.52$, $p = .021$ indicating an overall difference on the four factors of the task that were measured. Table 4.7 displays the correlations between the components along with the discriminant functions and the standardized weights of the forward lunge task.

Table 4.7: Standardized Coefficients of the Forward Lunge Predictor Variables with the Discriminant Function

	Correlation coefficients with discriminant function	Standardized coefficients with discriminant function
	Function 1	Function 1
Distance	.71	1.19
Force Impulse	-.26	.84
Impact Index	-.25	-.79
Contact Time	-.24	-.73

The means for the discriminant functions are .73 for the sighted group and -.73 for the visually impaired group indicating a performance by the sighted group on the components measured by the forward lunge to be higher. The structure r's indicate that LD (.71) has the strongest relationship, while FI (-.26), II (-.25), and CT (-.24) all have virtually the same weaker relationship. Indicating that lunge distance is the primary difference in completing the forward lunge task.

Timed Up and Go (TUG)

All Participants performed three trials for the Timed Up and Go which consisted of each participant standing up from the seated position walking 2 meters and then returning to the seated position. The mean time (sec.) of the trials was recorded. A one-way ANOVA was used to analyze group differences. A Levene statistic of homogeneity of variance was used to determine between and within-group differences in group variability. The Levene statistic indicated no significant differences between groups (.05). Statistically significant differences were evident ($F_{(1, 28)} = 9.409$, $p = .005$) between the individuals with visual impairment and their sighted peers on the Timed Up and Go performance indicating that the individuals with visual impairment needed more time to complete the task of standing up, walking three meters, turning around, and return to the seated position. The mean Timed Up and Go (sec.) for the individuals with visual impairment group (7.99 ± 3.86) compared to an average time of 4.86 ± .84 for the sighted group.

30 sec. Sit-To-Stand (STS)

The 30 second Sit-To-Stand procedure consisting of one trial. Each participant was instructed to stand from the seated position and return to the seated position as many times as possible in thirty seconds with the total number of repititions used for analysis. A Levene statistic of homogeneity of variance were applied to determine between and within-group differences in variability. The Levene statistic indicated a violation of the assumption of equality of variances ($F_{(1, 28)} = 4.20$, $p = .026$). Due to this violation the alpha level set for this analysis must be considered an estimate and the probability of signifigance may actually be larger than the value reported (Cochran & Cox, 1957, p. 91). Based on the ANOVA significant differences were apparent between groups on the 30-second STS ($F_{(1, 28)} = 5.49$, $p = .026$) indicating a greater level of performance for the sighted group. In addition to the ANOVA results, based on the violation of the assumption of the equality of variances, a Welch test was performed and the results indicated a significant differences between groups ($t_{(25.5)} = -2.342$, $p = .027$). The mean repititions for the group with visually impairment was 16.87 +/- 5.94 repititions, as opposed to 23.00 +/- 8.22 for the matches in the sighted group (Fig. 4.1).

<u>Isokinetic Strength</u>

Strength was assessed with a Cybex isokinetic dynamometer installed with Humac software (CSMI, Norwood, MA). All participants performed six concentric repititions at 90 deg/sec, 180 deg/sec and 20 repititions at 300 deg/sec. The procedure recommended by Perrin (1993) were followed and subjects were stabalized using straps around the shoulders, waist, thigh, and ankle. Data was collected on peak torque (flexion and extension) at 90 deg/sec, average power per repitition (flexion and extension) at 180 deg/sec, and total work (flexion and extension) at 300 deg/sec. All strength scores were normalized by body weight and are reported as a percentage of BW, per the procedure recommended by Perrin (1993).

Between group differences were analyzed using a non-equivilant two group MANOVA with six outcome variables. Means and standard deviations were calculated on all data, while a Levene statistic of homogeneity of variance was used to assess differences in group variability, which resulted in no signifigant differences. A Box's M test was also performed to determine the equality of covarience matrices which did not result in significant differences between groups. Significant differences were found between groups for the dependent variables. Hotelling's Trace = .805, $F_{(6,23)} = 3.09$, p = .023. Partial eta squared = .45 which, according to Cohen's R squared indicies (1977), indicates a large effect size between the visually impaired and sighted groups (Huck, 2000). Table 4.8 presents the means and standard deviations for the dependent variables for the visually impaired and sighted participants. Included in figures 4.3, 4.4, and 4.5 are the group results for peak torque, power and total work.

Table 4.8: Group Strength Values

	VI M +/- SD			NVI M +/- SD		
Peak Torque (90 deg/sec)						
EXT (PT/BW)	124.47	+/-	38.25	172.07	+/-	41.80
FLX (PT/BW)	64.40	+/-	31.02	94.60	+/-	28.80
Power (180 deg/sec)						
EXT (PWR/BW)	176.13	+/-	53.09	237.47	+/-	64.73
FLX (PWR/BW)	89.93	+/-	46.92	154.40	+/-	53.22
Total Work (300 deg/sec)						
EXT (TW/BW)	1802.20	+/-	525.60	2590.80	+/-	673.57
FLX (TW/BW)	852.33	+/-	426.19	1603.60	+/-	604.50

* Peak Torque and Total Work measured in newtons
** Power measured in watts

Significant differences were found on all six strength variables and are reported in Table 4.9. Individuals with visual impairment were significantly lower in peak torque extension and flexion at 90 deg/sec; in extension and flexion power at 180 deg/sec and total work flexion and extension at 300 deg/sec. Familywise error rate was controlled by dividing the level of signifigance (.05) by the number of dependent variables analyzed (Green, Salkind, & Akey, 2000).

Table 4.9: Level of Signicant Group Differences between Visually Impaired and Sighted Groups.

Speed	Strength Characteristics	F and p-values
90 deg/sec	Peak Torque (EXT)	F = 10.59, p < .01
90 deg/sec	Peak Torque (FLX)	F = 7.54, p < .02
180 deg/sec	Power/Rep (EXT)	F = 8.05, p < .01
180 deg/sec	Power/Rep (FLX)	F = 12.38, p < .01
300 deg/sec	Total Work (EXT)	F = 12.78, p < .01
300 deg/sec	Total Work (FLX)	F = 15.48, p < .01

As recommended by Huberty (1993, p.27) a follow-up descriptive discriminant analysis was also computed to determine which of the six variables that were measured during the Isokinetic strength test make-up a variable construct and how the variable(s) differ between groups. A Box's M test was performed to determine covariance matrix homogeneity, which resulted in no significant result ($F_{(21, 2884)} = 38.68$, $p = .101$). The overall Wilks' Lambda was significant $\Lambda = .55$, $F_{(6,23)} = 3.09$, $p = .023$ indicating an overall difference on the six factors that were studied between the two groups. Table 4.10 displays the within-group correlations between the components along with the discriminant functions and the standardized weights of the strength analyses.

Table 4.10: Standardized Coefficients of the Isokinetic Strength Test Predictor Variables with the Discriminant Function

	Correlation coefficients with discriminant function	Standardized coefficients with discriminant function
	Function 1	Function 1
Peak Torque (90 deg/sec)		
EXT (PT/BW)	.69	.83
FLX (PT/BW)	.58	-1.17
Power (180 deg/sec)		
EXT (PWR/BW)	.60	-.61
FLX (PWR/BW)	.74	.15
Total Work (300 deg/sec)		
EXT (TW/BW)	.75	.55
FLX (TW/BW)	.83	1.14

The means for the discriminant functions are M = .73 for the sighted group and M = -.73 for the individuals with visual impairment, indicate greater muscular strength, power, and endurance by the sighted group. The structure r's indicate that TW flexion (.83) and extension (.75) have the strongest relationship followed by PW flexion (.74) and extension (.60) and PT flexion (.58) and extension (.58). This indicates that the muscle function in individuals with visual impairments was less efficient for total work and is also deficient in the ability to generate force and power.

Electromyography (EMG) Muscle Recruitment

EMG data was collected on all participants during the isokinetic strength test. Data were collected on the medial quadricep, lateral quadricep, medial hamstring, and lateral hamstring. The data was analyzed using a BioPac Acknowledge III software. The median frequency (MDF) of the root mean square (rmsEMG) as a measure of muscular activity and the wave form was normalized using a maximal voluntary contraction (Basmajin & DeLuca, 1985). Included in Figures 4.6 – 4.9 are the results from the three speeds (90 deg/sec, 180 deg/sec & 300 deg/sec) used during the isokinetic test.

Between group differences were analyzed using three separate non-equivilant two group MANOVA's with four outcome variables. Each MANOVA represented all four sites with the differences pertaining to the speed at which they were collected (90 deg/sec, 180 deg/sec, & 300 deg/sec). Means and standard deviations were calculated on all data. A Levene statistic of homogeneity of variance was used to determine differences in group variability. The Levene statistic indicated no violation of the assumption of normality for any of the three speeds. A Box's M test was performed to determine equality of covarience matrices, and indicated no violations of this assumption at any of the three speeds tested. No significant differences were found between groups for the EMG among the dependent variables on any of the three speeds ($p < .05$). Table 4.11 contains EMG means and standard deviations for each muscle at each Cybex speed.

Table 4.11: rmsEMG Group Comparisons

	Muscle Placement			
	MQ Mean +/- SD	LQ Mean +/- SD	MH Mean +/- SD	LH Mean +/- SD
90 deg/sec.				

Visually Impaired	98.4 +/- 29.5	105.8 +/- 25.8	91.8 +/- 32.3	88.3 +/- 38.2
Sighted	109.4 +/- 22.8	105.6 +/- 22.9	99.5 +/- 34.7	91.0 +/- 29.7
180 deg/sec.				
Visually Impaired	89.4 +/- 24.0	96.6 +/- 37.2	93.4 +/- 33.9	84.5 +/- 27.7
Sighted	109.1 +/- 23.4	93.6 +/- 26.9	102.7 +/- 31.5	90.5 +/- 36.2
300 deg/sec.				
Visually Impaired	87.3 +/- 30.5	93.6 +/- 41.2	88.9 +/- 32.9	91.5 +/- 26.3
Sighted	92.1 +/- 25.6	88.4 +/- 29.7	98.5 +/- 28.1	105.0 +/- 39.2

MQ – Medial Quadricep
LQ – Lateral Quadricep
MH – Medial Hamstring
LH –Lateral Hamstring

Even though no significant differences ($p > .05$) were indicated between groups, it is of interest to note that at 180 deg/sec. Hotelling's Trace = .379 ($F_{(4,25)} = 4.00$, $p = .08$) and the partial eta squared = .28 which indicates a large effect in muscle recruitment between individuals with visual impairment and sighted participants (Cohen, 1977; Huck, 2000). In addition to there being a multivariate effect approaching signifigance, it is also important to note that on 9 out of the 12 measures of muscle recruitment, the sighted group was more efficient based on the mean values in Table 4.11. Familywise error rate was controlled by dividing the level of signifigance (.05) by the number of dependent variables analyzed by each of the MANOVAS (Green, Salkind, & Akey, 2000). Due to the fact that no multivariate effect occurred, a stepdown analysis or discriminant analysis was not performed (Weinfurt, 2000).

Correlation Between Strength Measures and Mobility Tasks

A Pearson product correlation was used to test the relationship between the peak torque at 90 deg/sec, power at 180 deg/sec, total work at 300 deg/sec with mobility measures. Significant correlations were found between NeuroCom STS, NeuroCom

Walk Across (SL, SP), NeuroCom Forward Lunge (LD, CT), 30-sec. STS, and TUG. Table 4.12 presents the Pearson Product Correlation Matrix for the isokinetic strength results and the mobility outcomes.

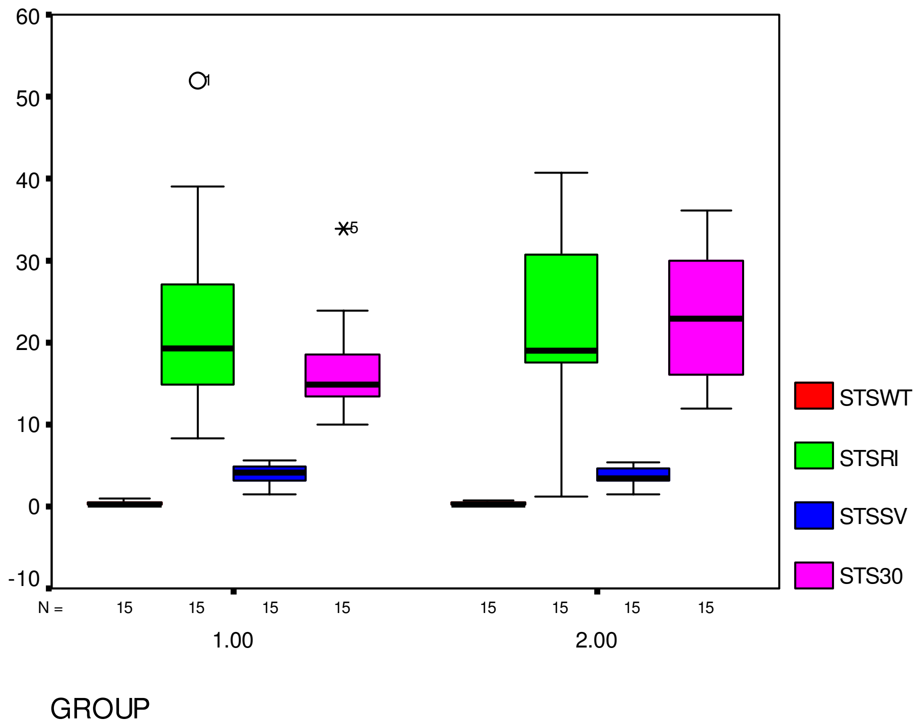
As indicated in Table 4.12 all strength characteristics Pearson r values correlated very highly with the mobility measures used in this study. Significant correlations were noted with the exception of the forward lunge distance and contact time. Figures 4.9 - 4.15 displays correlations between strength values and mobility measures. According to Cohen (1977) The pearson product r values from the walk across, timed up and go, and the 30-sec. sit to stand would all fall in the large effect size category.

Table 4.12: Pearson Product Correlations Between Strength Characteristics and Mobility Tasks between Visually Impaired and Sighted Participants.

Strength Measure	SL	SP	LD	CT	TUG	STS 30
Peak Torque 90 deg/sec						
EXT	.492	.569	.238	-.100	-.511	.538
	.006**	.001**	.206	.598	.004**	.002**
FLX	.631	.609	.221	-.092	-.519	.451
	.000**	.000**	.206	.598	.004**	.002**
Power 180 deg/sec						
EXT	.659	.441	.268	-.039	-.503	.533
	.000**	.015*	.152	.836	.005**	.002**
FLX	.657	.652	.337	-.132	-.596	.603
	.000**	.000**	.068	.487	.001**	.000**
Total Work 300 deg/sec						
EXT	.686	.399	.453	-.121	-.544	.653
	.000**	.029*	.012*	.524	.002**	.000**
FLX	.669	.562	.336	-.030	-.473	.541
	.000**	.001**	.069	.873	.008**	.002**

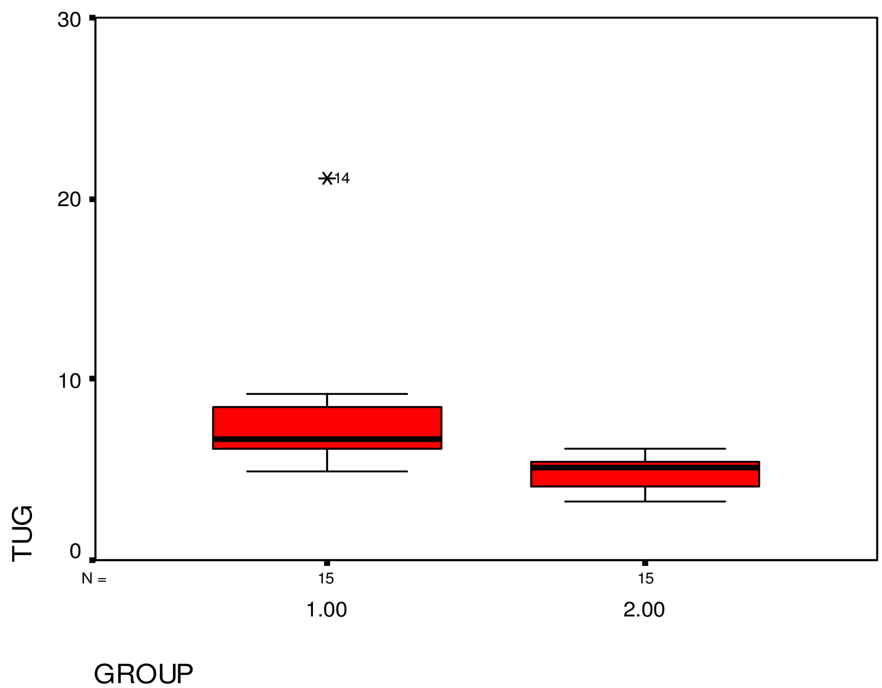
* Indicates signifigance at p < .05.
** Indicates signifigance at p < .01.

Figure 4.1 Visually impaired and sighted Sit-To-Stand Group Comparisons.



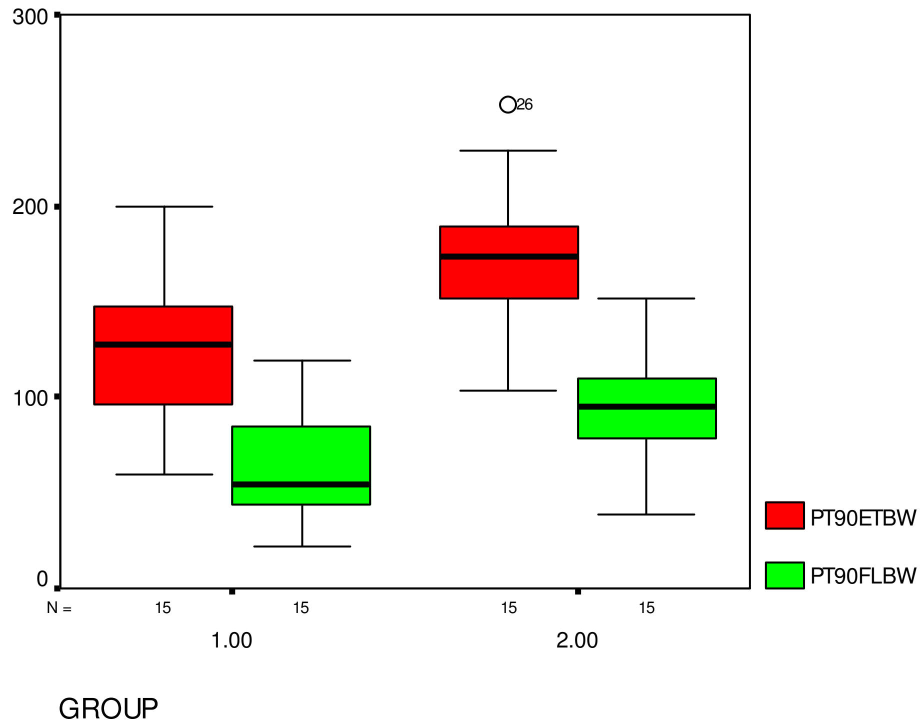
* Group 1 = Visually Impaired
Group 2 = Sighted Peers

Figure 4.2: Visually impaired and sighted Timed Up and Go Group Comparison.



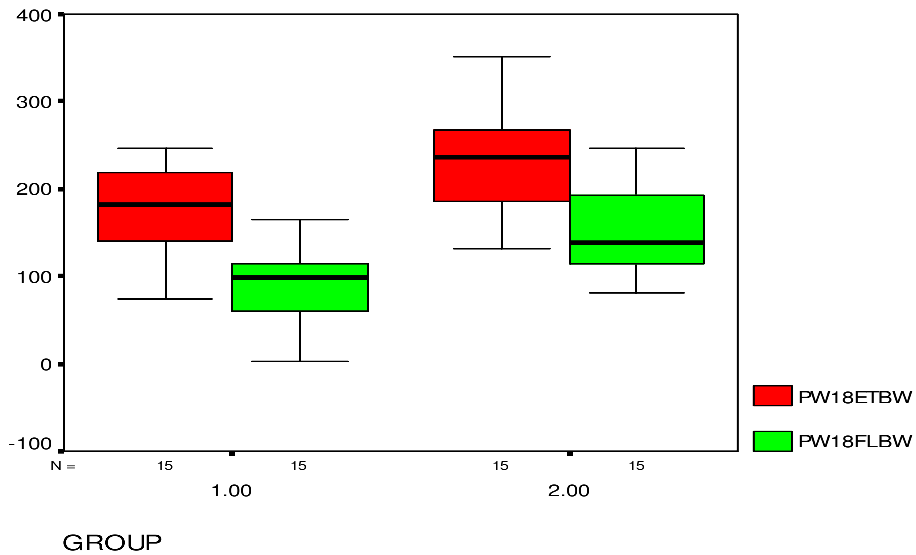
* Group 1 = Visually Impaired
  Group 2 = Sighted Peers

Figure 4.3: Visually impaired and sighted 90 deg/sec Peak Torque Group Comparison.



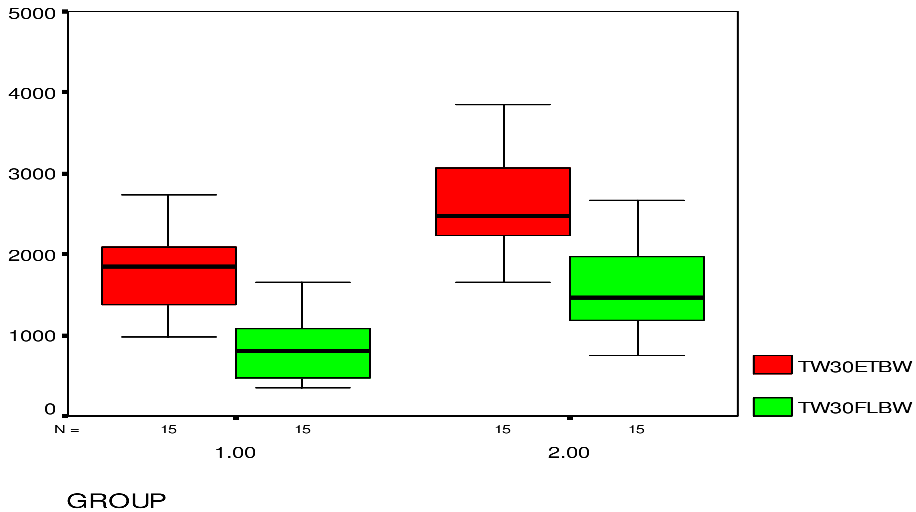
* Group 1 = Visually Impaired
Group 2 = Sighted Peers

Figure 4.4: Isokinetic Power Comparison between Visually Impaired and Sighted Groups.



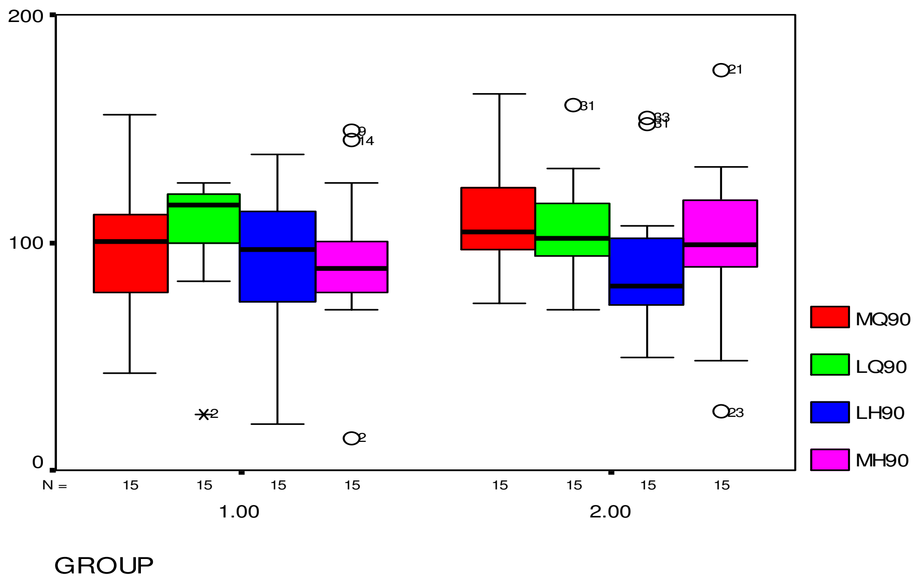
* Group 1 = Visually Impaired
Group 2 = Sighted Peers

Figure 4.5: Isokinetic Total Work Comparison between Visually Impaired and Sighted Groups.



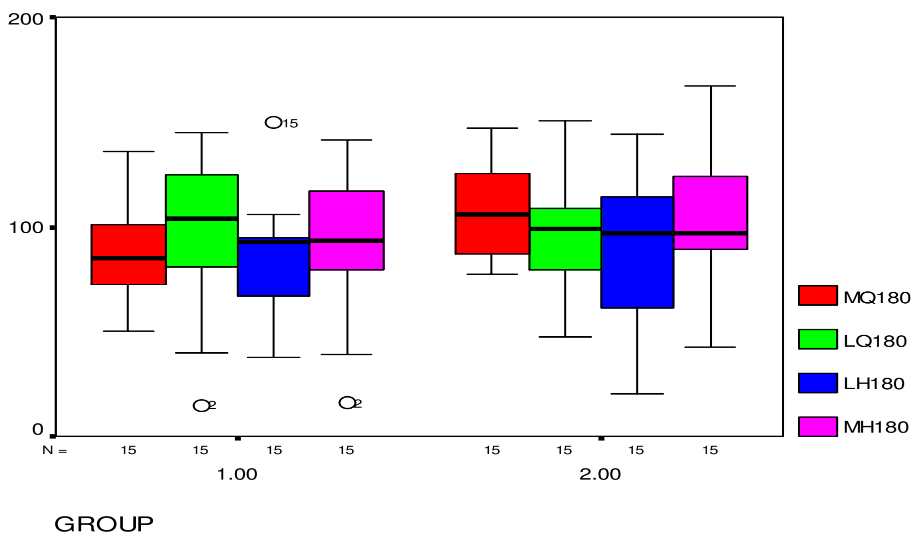
* Group 1 = Visually Impaired
Group 2 = Sighted Peers

Figure 4.6: Comparison of rmsEMG Muscle Recruitment at 90 deg/sec between Visually Impaired and Sighted Groups.



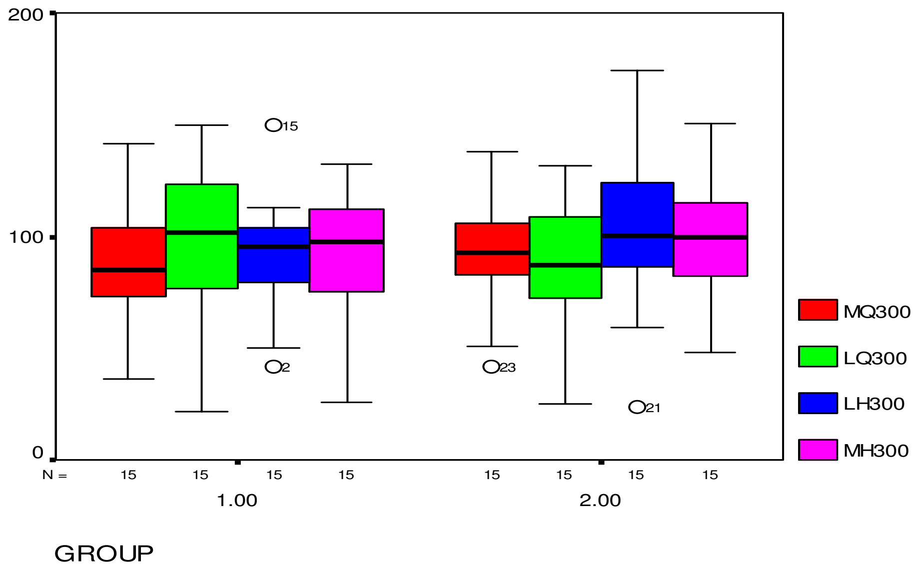
* Group 1 = Visually Impaired
  Group 2 = Sighted Peers

Figure 4.7: Comparison of rmsEMG Muscle Recruitment at 180 deg/sec between Visually Impaired and Sighted Groups.



* Group 1 = Visually Impaired
  Group 2 = Sighted Peers

Figure 4.8: Comparison of rmsEMG Muscle Recruitment at 300 deg/sec between Visually Impaired and Sighted Groups.



* Group 1 = Visually Impaired
Group 2 = Sighted Peers

Figure 4.9: Correlation between Performance on the Timed-Up-and-Go Result and Extension Power at 180 deg/sec.

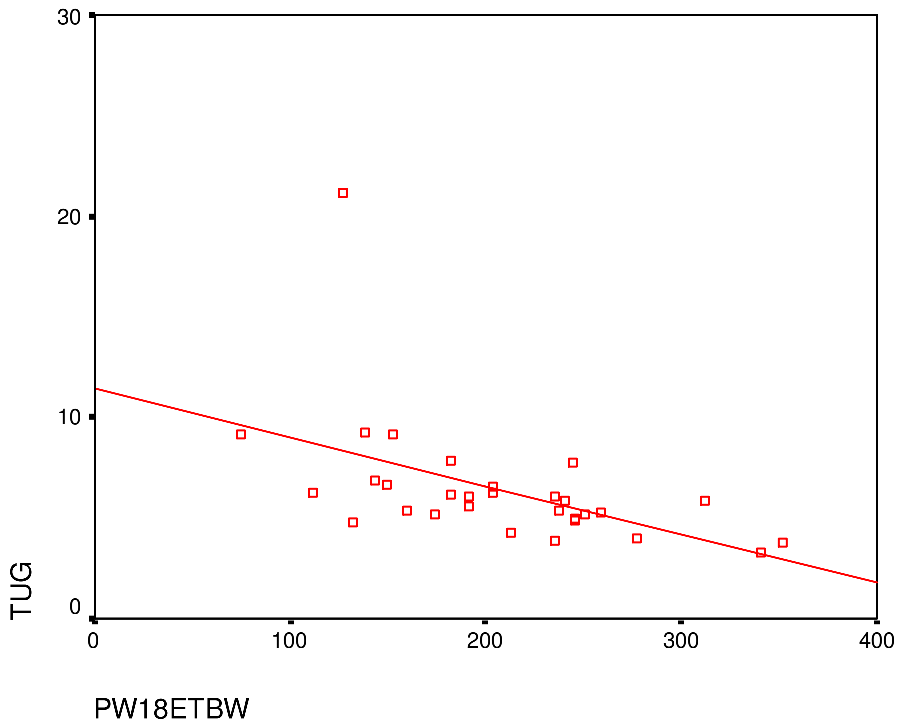


Figure 4.10: Correlation between Performance on the 30-sec. Sit-To-Stand and Extension Power at 180 deg/sec.

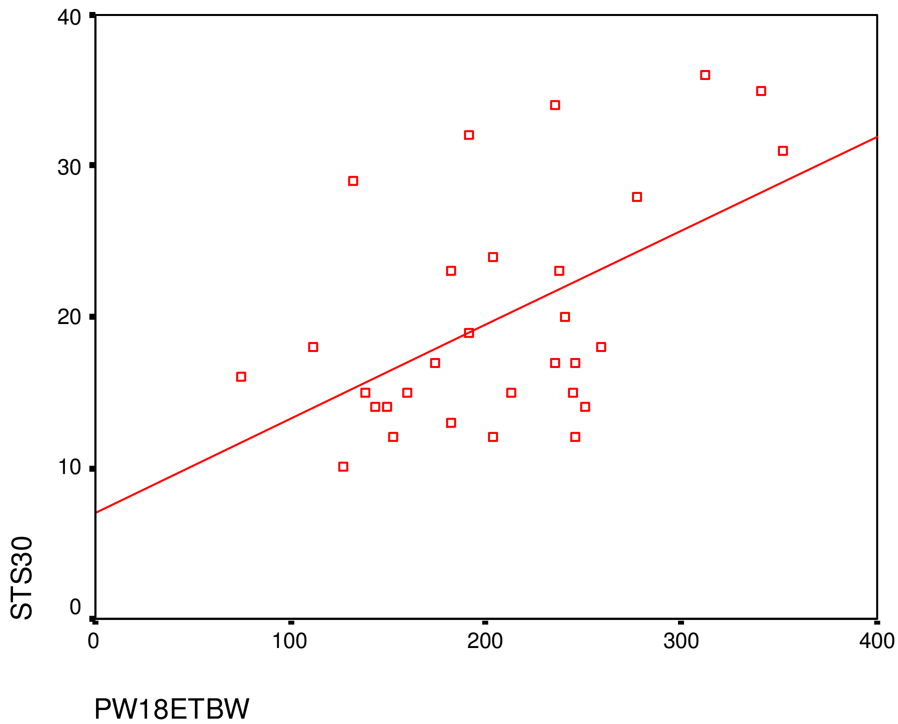


Figure 4.11: Correlation between 30-sec. Sit-To-Stand and Peak Torque Extension at 90 deg/sec.

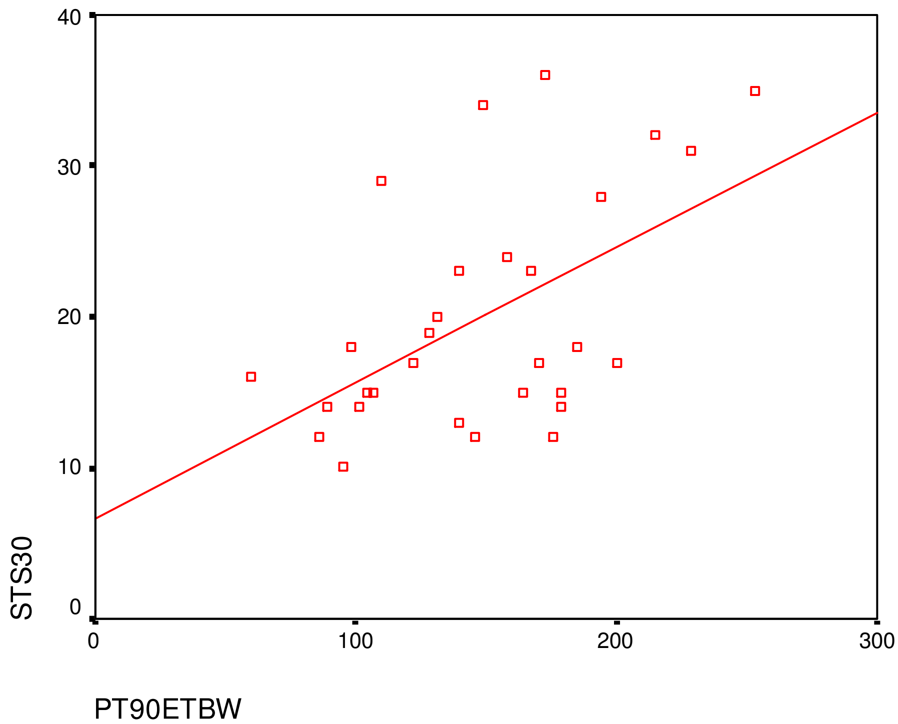


Figure 4.12: Correlation between Step Length and Extension Power at 180 deg/sec.

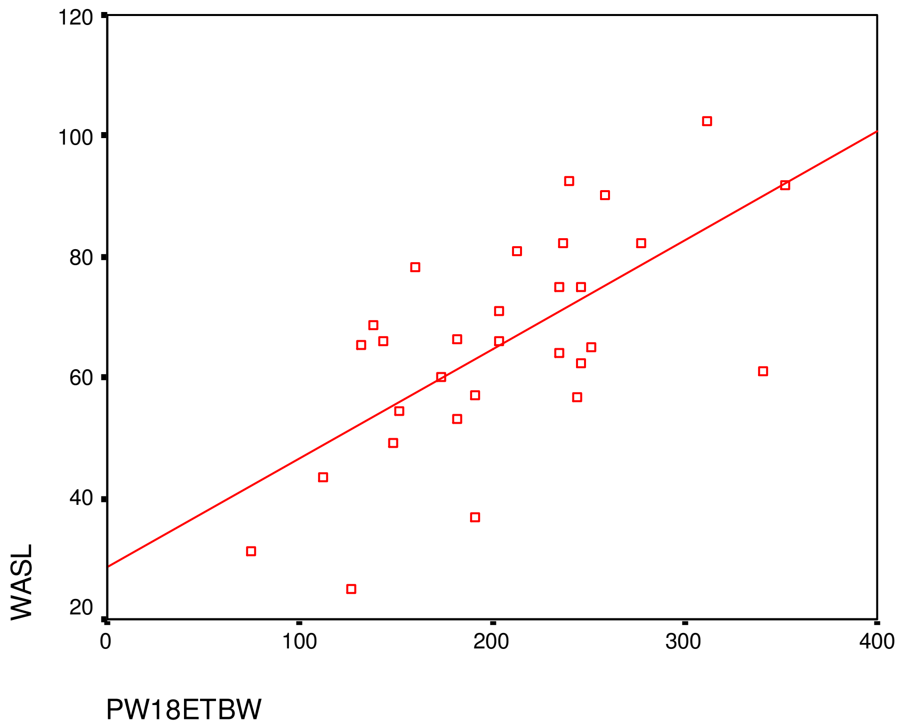


Figure 4.13: Correlation between Step Speed and Peak Torque Extension at 90 deg/sec.

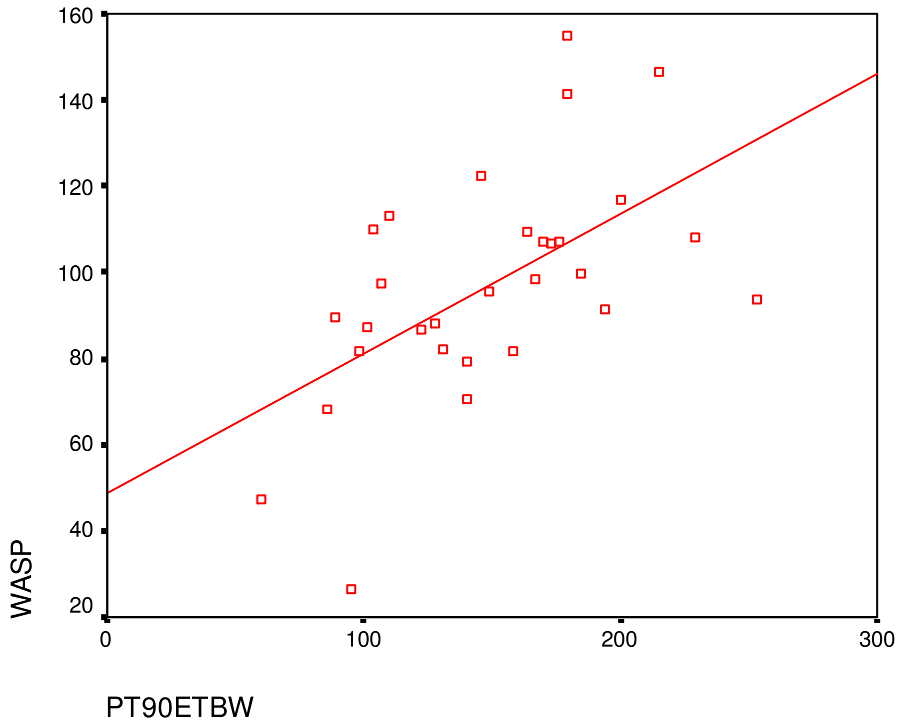
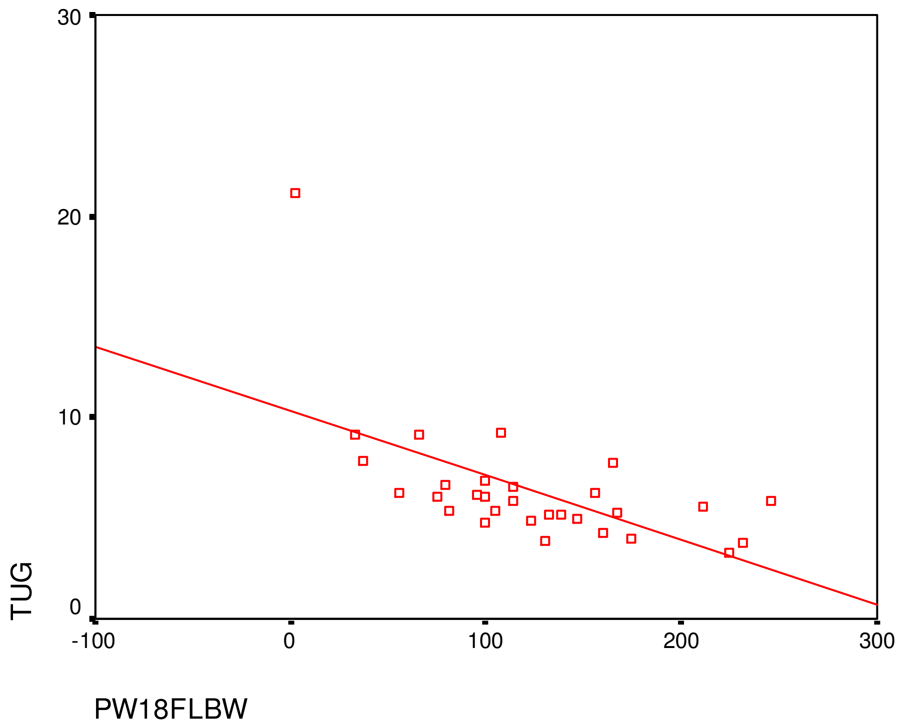


Figure 4.14: Correlation between Performance on the Timed-Up-and-Go and Flexion Power at 180 deg/sec.



CHAPTER 5

DISCUSSION

This study attempted to document performance characteristics of individuals with visual impairment and sighted individuals. Because of the lack of research on visual impairments little is known on balance, strength, and functional tasks in the visually impaired population. Based on the data from this study deficiencies are evident and the underlying mechanisms inherent in function could be identified in order to ultimately resolve those deficiencies. The purpose of this investigation was to assess movement and muscle function in adults with visual impairments compared to an age and sex matched control group; to identify differences and explore the role of muscle function as it pertains to movement.

The findings of this study provide some information on how individuals with visual impairments compare to sighted individuals on movement and strength characteristics. Previous research has addressed the notion that vision loss leads to difficulties in balance in sighted older individuals (Spirduso, 1995; Judge, King, Whipple, Clive, & Wolfson, 1995; Skaggs & Hopper 1996), contrary results indicated that individuals with visual impairments respond to restricted vision by adapting to use other strategies to compensate for reduced visual input (Horvat et al., 2003).

NeuroCom Sit-To-Stand (STS) & 30 Second Sit-To-Stand

Two STS assessments were used with each group resulting in contrasting results. The NeuroCom Sit-To-Stand revealed no significant differences between samples, indicating that individuals with visual impairment can rise efficiently based on the weight transfer in seconds, rising index as a percentage of body height, and sway velocity in deg/sec. Closer analysis reveals a slightly reduced performance on all three components measured. According to the NeuroCom (2001) the WT measures the time required to shift the center of gravity forward, the RI is the force exerted by the legs and SV is the control of the center of gravity over the participants base of support although statistically significant differences are not evident. Minimal differences are apparent especially in sway velocity. These results were similar to an earlier investigation in which the authors reported that under stable conditions individuals with visual impairment performed at the same level as their sighted counterparts on the Sensory Organization composite score (Horvat et al, 2003). In contrast during the 30-second STS, significant differences are evident in the number of trials completed. Performance suffers as the components of speed and muscular endurance are added to the task. Although the movement components of the task can be performed, the ability to perform the task quickly and repeatedly does present some questions regarding the strength and mobility of individuals with visual impairment. The ability to produce force and total work has been demonstrated to be lower in individuals with visual impairments and may provide a limitation in movement skills and stability movements in unstable environments (Horvat et al., 2003). Likewise the ability to maintain a stable posture and initiate a gait cycle is predicated on a level of strength necessary to overcome gravity. It seems that low scores in function may be the result of low levels of physical activity (as seen not only in their performance, but higher BMI) rather than strictly related to vision and is an area worthy of future studies.

NeuroCom Walk Across

During the NeuroCom Walk Across, several components of function were evaluated to determine the capabilities of individuals with visual impairment compared to their sighted counterparts. No difference in step width, however differences were evident in step length and step speed. From the context of gait and movement this is of particular interest for overall mobility. According to the NeuroCom (2001) the Walk Across is a functional assessment that includes SW, lateral distance as a measure of balance ability, while SL and SP measure overall gait ability. Balance ability as measured by SW seems to be consistent with sighted individuals and is probably a result of using the somatosensory and vestibular system (Horvat et al, 2003). Performance for individuals with visual impairment performance for SP also relates to older individuals, for example the mean age for this study was 38, while the performance data related to age, was in the 70-90 year old age groups. Lusardi, Pellecchia and Schulman reported that the overall comfortable gait speed for an individual between the age of 80-89 is 82 cm/sec and the individuals between the ages of 70-79 steped at a rate of 125 cm/sec (2003). The mean for individuals with visually impaired group in this study was 87 cm/second.

The findings from this study further represent that based on the SW scores visually impaired group does not suffer from deficiencies in dynamic balance, however mobility problems do exist. The Neurocom Operators Manual (2001) states that factors that influence gait are cognitive motor planning abilities, balance, conditioning, movement control, range of motion, and strength. Supported by the results of the walk across and the demographic data from the sample of visually impaired the focus of mobility concerns is conditioning of the participants which includes both flexibility and muscular strength.

NeuroCom Forward Lunge

The Forward Lunge is another functional test that measures strength, flexibility, balance, control, and coordination (NeuroCom, 2001). According to NeuroCom functional consequences of lunge performance relate to the ability to participate in activities that involve rapid muscular contractions and increases the risk of injury when quick loading occurs involuntarily. The NeuroCom Forward Lunge test yielded significant differences in LD which demonstares the cautious approach or adaptive response to movement that is seen in this population. Although not significant, a closer analysis demonstrate that CT, II, and FI indicating a slower movement and a larger weight shift, most likely due to the shorter stride. Also individuals with visual impairment took longer, even though significant differences did not occur. The individuals with visual impairment were more cautious in their movements and were reluctant to allow their center of gravity to move to far out in front of them and spent more CT out on their extended leg. This supports the findings that adaptations to mobility do occur with visually impaired and components of that adaptation are caution, unwillingness to compromise their center of gravity and a lack of muscular strength and flexibility.

Timed Up and Go (TUG)

The TUG is used to measure the ability to stand from a seated position, walk, turn around and return to a seated position. The results of the TUG revealed significant differiences between groups. The sighted participants were able to respond much faster while individuals with visual impairment performed the TUG in 7.99 seconds. According to Lusardi, Pellecchia and Schulman (2003) older participants in the age range of 60-69 performed the TUG task in 7.9 seconds and reflects the difficulty with fast paced movement that is seen in our sample of individuals with visual impairment. The timeliness of the total task takes significantly longer and demonstrates concerns for mobility are related to the speed required for movement. Specifically these findings support adaptations in movement is more cautious when vision loss occurs as individuals rely on other sensory systems to initiate and adapt to movement situations.

Isokinetic Strength & Electromyography (EMG) Muscle Recruitment

Perrin (1993) has indicated that normalizing peak torque relative to body weight enables a more relative comparison between populations of different body sizes. This was apparent in the age and sex matched sample, as greater performance is indicated in the sighted population in relative strength. Based on the isokinetic assessment included in this investigation, peak torque, power, and total work were significantly higher in sighted participants. Because of the dearth of research on isokinetic strength parameters, these results indicate that an essential component for function is lacking for individuals with visual impairment. A minimal amount of strength is necessary to promote function and independence as well as maintaining body posture and sway (Shumway-Cook & Wollacott, 2001).

When comparing data between groups the pattern of strength was similar. Participants developed greater peak torque during extension than during flexion. These results were anticipated and can be related to greater concentrated muscle volume of the muscle groups being tested.

It was also apparent that at a faster speed of 180 deg/sec and 300 deg/sec that power and total work was significantly higher in the sighted sample and also for males. Movement values were also higher during extension then flexion. From a purely functional point of view it is apparent that differences do occur in strength, power, and total work and could be rectified with a physical activity program. Since the EMG results are similar, the lack of strength and power may be more associated with inactivity than a lack of the ability to recruit muscle. Since individuals with visual impairment seem to trade efficiency for caution in movements, strengthening of the muscles of the lower extremity should be encouraged to promote orientation and mobility.

This study suggests that muscular strength and power are significantly lower in individuals with visual impairments compared to a matched sample of sighted participants. Although the mechanics of movements are consistent with sighted participants including H/Q ratio, the ability to generate force is lacking. However since the motor unit recruitment is similar it is indicated that specific interventions can improve strength and power as well as functional skills.

Correlation Between Strength Measures and Movement Tasks

The data from this study along with other work supports the relationship between strength and mobility, most sources indicate that strength is essential to maintain balance and stability as well as initiate and control movement. It is also indicated that significant correlations are apparent between leg strength and mobility measures, such as the Sit-To-Stand and the Timed-Up-and-Go, perhaps indicating that a lack of strength and power contribute to the lower level of function in individuals with visual impairments. For example, strength is essential to avoid falls and is a factor in maintaining posture and stability by correcting movements with the lower extremities, specifically the ankles and the hips. Overall weakness seems to generate cautious movements to avoid extending the body in an unstable position. This is evident in individuals with visual impairments and the elderly population who rely more on the hips (hip strategy) than the ankles (ankle strategy) to overcome stability problems (Horvat et al, 2003).

Although no research has been uncovered that utilized isokinetic testing of individuals with visual impairments for strength, power, and total work, it appears that they are deficient in generating a sufficient amount of force to overcome problems with mobility. The common restraint we see in movements may be related to reduced vision but also the lack of ability to produce an adequate amount of force.

Conclusions

From this study it is apparent that the literature is virtually non-existent on the physical and motor performance measures of individuals with visual impairment, especially in relation to functional tasks. Although most previous research documents balance difficulties in children this is an initial investigation into the capabilities and adaptation of adults with visual impairment. The capacity to respond adequately to changes in movement and stability are a combination of sensory and muscular factors and not dependent on one factor. Deficiencies in strength in conjunction with body weight may be an indicator of movement difficulties that can be remediated. A progressive physical activity program can be implemented to develop muscular strength and power; similar to responses seen in the elderly population that can be generalized to promote greater self-sufficiency and independence that are characteristic in inactive populations and are amendable to training. Likewise, children with visual impairments should be encouraged to be physically active, to promote overall development and stimulate movement experiences. From the limited research on static strength it is evident that deficiencies occur early in development and seem to continue throughout the life span (Leiberman & Mchugh, 2001). This lack of functioning provides rationale for activity programs that facilitate mobility but also provide the stimulus for developing strength and power in the lower extremities across the life span to promote functional development and independence.

Based on the findings of this study, individuals with visual impairments do display deficiencies in mobility, especially in more complex tasks and measures that included muscular endurance. In this context, participants with visual impairments were able to perform simple tasks related to mobility; however as the task became more physically demanding performance began to decrease such as in the 30-second STS, TUG and forward lunge. This is also evident in earlier work that demonstrated greater difficulty in responding to support surface changes when performing balance assessments (Horvat et al, 2003). For example, when the task becomes more difficult, an obvious shift occurred towards a hip dominant strategy to accommodate more stability. In addition it has also suggested that individuals with visual impairments make corrections after they feel a loss of balance that is reactive and a response to avoid falling in individuals with visual impairments adapt and trade efficiency for safety as they conditions become more challenging (Horvat et al, 2003; Sudgen and Keogh, 1990).

Several important findings were also evident between groups from the relationship between muscle function and mobility. 12 measures of mobility on the tasks of between group differences were found on 5 of 12 measures (Table 5.1).

Table 5.1: Group Differences in Mobility Measures

Significant group differences	Non-significant between group measures
Step Length	Sit-To-Stand weight transfer
Walking Speed	Sit-To-Stand rising index
Forward Lunge Distance	Sit-to-Stand sway velocity
Time up and go	Step width
30 – sec. Sit-To-Stand	Forward lunge impact index
	Forward lunge contact time
	Forward lunge force impulse

Deficiencies in mobility are not general consequences of visual impairments as measured by using the NeuroCom system, 30 second Sit-To-Stand, and Timed-Up-and-Go. However, individuals with visual impairments have more difficulties in mobility when the task became more complex. This appears to be an adaptive response to vision loss and a tendency to exercise caution in unfamiliar of difficult movements. It appears that function is based on the ability of the participant to produce adequate force to actively maintain stability and movement.

Reccomendations

Future work should investigate activities that increase functional strength especially activities that emphasize strength and power. Beyond muscle weakness other areas worthy of further study is the theory of inherent cautiousness, this is especially interesting due to the fact that the measures in this study did not put the participants in an unfamiliar, compromised, or previously unrehearsed position and yet differences were still evident. Lastly, future work should look at the difference in adaptations based on the length in blindness, due to the acknowledgment that these strategies should not be thought of negatively; in turn if the adaptation is viewed as compensation it should be taught to individuals with more recent visual conditions.

Reccomendations for Future Research

1. The effect of strength training on gait and mobility.

2. Orientation and Mobility Training and balance

3. Influence of Hamstring/Quadricep ratios on sway and stability

4. Exercise and activity interventions on overall health, mobility, and quality of life.

5. Analysis of adapted physical activity programs for individuals with disabilities.

6. Approach of adapted physical educators towards overall fitness for individuals with disabilities.

7. Analysis of opportunities for individuals with disabilies to participate in activity programs.

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APPENDIX A

INFORMED CONSENT

INFORMED CONSENT

I give consent for,____ to participate in the research titled "Balance, mobility in individuals with visual impairments". Mr. Christopher Ray (706) 425-0705 and Dr. Michael Horvat (706) 542-4455, Department of Physical Education and Sport Studies, at the University of Georgia are conducting the study. I understand that this participation is entirely voluntary; I can withdraw consent at any time without penalty and have the results of the participation, to the extent that it can be identified, returned, removed from the research records, or destroyed.

1. The following points have been explained.
a. The reason for the research is to develop an understanding of the components of balance and mobility in individuals with visual impairments.
b. The benefits that I may expect include the ability to develop appropriate interventions that may help visually impaired individuals to improve balance and mobility.

2. The procedures are as follows:

I will come to the Movement Studies Lab at the Ramsey Center on the campus of the University of Georgia for one 1 -hour time period. I will be required to wear a harness and the tests will be explained to my satisfaction. During the tests I will be asked to stand still for 20 seconds per trial. Approximately 24 trials will be performed with changing factors, which include floor movements; wall movements and trials with eyes open & closed. A short rest time between trials will be allowed if I need it. Additionally no more than 9 trials will be performed of on a Cybex isokinetic testing device. I will be instructed to kick forward and pull back with my dominant leg in a seated position at three settings. In addition to the tests on the NeuroCom and Cybex system I will perform a timed up and go along with a questionnaire on balance.

3. The discomforts or stresses that may be faced during this research include a possible loss of balance and muscle soreness which may occur during testing. To prevent injury I will be harnessed to prevent the risk of the participant actually falling and I will be instructed to stretch and warm-up on an exercise bike before any measurements will be taken.

4. No risks are foreseen.

5. The results of this study will be confidential, and will not be released in any individually identifiable form without my prior consent, unless otherwise

required by law. Code numbers will be used to conceal identities. The code list identifying names will be kept exclusive and secured.

6. The researcher will answer any further questions about the research, now or during the course of the project, and can be reached by phone at 542-4455.

____

Researcher

I understand the procedures described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____

Participant

____

Parent/Guardian

The Institutional Review Board oversees research at the University of Georgia that involves human participants. Questions or problems regarding your rights as a participant should be addressed to Christina Joseph, Ph.D., Institutional Review Board; Office of Vice-President for Research, The University of Georgia; 606A Graduate Studies Research Center; Athens, Georgia 30602-741 1; Telephone (706) 542-6514.