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THE EFFECTS OF FUNCTIONAL ACTIVITY ON POSTURAL CONTROL AND LOWER LEG STRENGTH OF ANKLE FUNCTION

By

Phillip H. Andre

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ABSTRACT

THE EFFECTS OF FUNCTIONAL ACTIVITY ON POSTURAL CONTROL AND LOWER LEG STRENGTH OF ANKLE FUNCTION

By

Phillip H. Andre

The lateral ankle sprain has been researched and identified as one of the most prevalent injuries incurred by physically active individuals. Many risk factors have been named, including postural control and lower leg strength. This study examined the effects of functional activity on the body by measuring these two factors.

Fourteen subjects (7 males, height = 178.54 ± 6.88 cm, weight = 82.02 ± 7.02 kg, age = 24 ± 2 years; 7 females, height = 165.84 ± 5.82 cm, weight = 59.31 ± 6.60 kg, age = 22.86 ± 3.14 years) volunteered to be participants. Subjects performed pre-activity testing that involved measures of postural control and lower leg strength. This was followed by an intense functional activity session that included a series of runs, jumps, and push-ups. Participants then performed post-activity testing that retested their postural control and lower leg strength.

A series of paired t-tests revealed significant decreases in postural control from pre-activity testing to post-activity testing for all three variables (path length, velocity average, area 95). T-tests for strength also revealed significant differences. Invertors, dorsiflexors, and plantar flexors all experienced decreases in peak torque.

Females sustained significant decreases in all three postural control variables. Males experienced these decreases in only the variables of path length and velocity average. When results from the strength testing were divided into male and female groups, no significant differences were found from pre-activity testing to post-activity testing.

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Chapter 1

INTRODUCTION

Injuries are accepted as being common in the world of physical activity. For years, the physically active have had complaints concerning particular injuries. From football to basketball, soccer to baseball, and track to ice hockey, people involved in many types of physical activity have seen and experienced the effects of injury. Epidemiological studies [1-7] documented the variety of injuries seen in these activities in both men's and women's sports.

All regions of the body are susceptible, with certain injuries being more common in some activities than in others. Among all sports, lower body injuries are seen in a wide array of circumstances. Specifically, lateral ankle sprains are one of the most common injuries experienced in the lower extremity [1-7].

The current study focused on possible factors that may predispose the body to incur a lateral ankle sprain. A review of the current literature identified many possible risk factors, both intrinsic and extrinsic [8-10]. Intrinsic risk factors for the lateral ankle sprain include anatomic foot types, history of previous sprains, postural control, lower extremity muscle strength, and ankle joint laxity [8-10]. Postural control can be defined as maintaining the center of gravity within the base of support through a dynamic integration of internal and external forces [11]. Extrinsic risk factors include athletic shoes, taping and bracing techniques, and the nature of the activity [8-10]. In cases when the lateral ankle sprain does occur, it generally occurs during functional activity in combination with the internal and external risk factors. Functional activity can be defined as total body exercises that mimic actions seen in sports, where the individual is not reaching complete muscular fatigue.

In earlier studies, functional activity and its effects on the lower body have not been tested. Many of the previous studies exercised the musculature through the process that is known as isokinetic and/or isotonic exercise [11-18]. Isotonic refers to a dynamic activity in which the muscle length changes through concentric and eccentric contractions. Isokinetic refers to a type of isotonic activity in which there is a constant speed and a varying resistance throughout the range of motion [19].

The specific muscles used in the experiments previously noted were the dorsiflexors, plantar flexors, evertors, and invertors of the ankle. They were exercised until a pre-determined level of fatigue had been achieved. Different parameters were then used to examine the effects of the muscle fatigue and how it compared to pre-fatigue measurements of muscle strength. Although these exercises worked the muscles until fatigue, they are not functional activities typically seen in a practice and/or game setting. During functional activity, the body may not reach full muscle fatigue, yet the lateral ankle sprain still occurs in this setting.

The current study attempted to bring about a scenario that was closer to a game/practice situation by having the subjects perform functional activities. It was believed this would yield better results as to how postural control and lower extremity strength are affected during functional activity as opposed to exercises that induce fatigue. Although it is obvious that other factors are involved in a lateral ankle sprain (playing surface, joint laxity, foot type, shoes, etc.), functional activity was the main focus of the study at hand.

STATEMENT OF THE PROBLEM

Numerous studies have been conducted examining the effects of fatigue on the body[11, 12, 14, 15, 17, 18, 20, 21]. Most have used isokinetic exercises to induce fatigue to the musculature, and have not used functional activity in their testing protocols.

STATEMENT OF THE PURPOSE

The purpose of this study was to examine the effects of functional activity on the lower extremity through the measured variables of postural control and lower extremity strength.

SIGNIFICANCE

Little research exists concerning functional activity and how it affects the body. Although the body may not reach complete fatigue during functional activity most studies still document the effects of fatigue. Therein lies a need to study the effects of functional activity because the lateral ankle sprain occurs in this type of setting. Postural control and lower extremity strength are two factors that are said to have an impact on the prevalence of the lateral ankle sprain[8-10]. Results of this study may identify how these factors are affected by functional activity. Those results may in turn offer insight into how the potential for the lateral ankle sprain may be affected by the functional activity that was performed.

RESEARCH HYPOTHESIS

It was hypothesized that subjects' maximum force exertion would decrease from the pre-activity testing to the post-activity testing. The functional activity performed by the subject would cause less force to be produced by the muscles when compared to pre-activity tests.

It was also hypothesized that the measure of postural control would decrease from pre-activity testing to post-activity testing, indicating a decreased ability to control one's posture. The area covered by the center of pressure during postural control testing was hypothesized to increase from pre-activity to post-activity testing resulting in increased postural sway.

Chapter 2

LITERATURE REVIEW

EPIDEMIOLOGY

Lateral ankle sprains are common injuries associated with the participation of athletics. A number of factors are thought to be related to their occurrence, including lower leg strength and postural control. Specifically, it is detriments and changes seen in these two factors that are believed to be a main cause for the injury.

Multiple epidemiological studies [1-3, 5]have found high rates of occurrence for the lateral ankle sprain. Meeuwisse et al. [1]researched injuries in Canadian collegiate football players. Among the results, it was found that the lateral ankle sprain was one of the most common specific injuries. Starkey [2] found similar results in his study of participants in the National Basketball Association. He examined injuries and illnesses that had occurred over a 10-year time period. It was found that the most frequently occurring orthopaedic injury was the lateral ankle sprain. It accounted for a total of 9.4% of all orthopaedic injuries[2].

Powell and Barber-Foss [3] conducted a study in which it was found that ankle injuries accounted for a high-percentage of total injuries in many sports, including boys' and girls' basketball, football, boys' and girls' soccer, field hockey, and girls' volleyball. Messina et al.[4] found similar results in their study on the incidence of injury in Texas high school basketball players. They found that, among both boys and girls, the ankle was the most commonly injured area and the sprain was the most commonly occurring injury. Sallis et al.[5] studied and compared sports injuries in men and women. Among the numerous results, they found that the ankle was the most common site for injury in both men and women in the sports of basketball and soccer.

Schulz et al. [6] studied the incidence of injury in competitive cheerleading and found the lateral ankle sprain to account for over 21% of all injuries. A similar result was found by Dubravcic-Simunjak et al., [7] who concluded that the lateral ankle sprain was the most common acute injury in elite figure skating.

These epidemiological studies found similar conclusions concerning the ankle; when compared to other body parts, the ankle incurred a high percentage of injuries during athletics. The lateral ankle sprain was found to be one of the most commonly occurring injuries.

LATERAL ANKLE SPRAIN

A lateral ankle sprain is an injury involving one or more of the ligaments located on the lateral side of the ankle[22]. These ligaments are the anterior talofibular ligament, calcaneofibular ligament, and posterior talofibular ligament. The lateral ankle sprain is one of the most common injuries in all of sport and plagues a variety of athletes each season. For many, the lateral ankle sprain is an acute injury. In more severe cases, it can become a chronic injury for the athlete. The injury typically occurs during excessive supination of the rearfoot about an externally rotated lower leg following contact of the rearfoot during gait or landing from a jump[22]. These movements place a large level of stress on the lateral ankle ligaments[22]. When one or more of these ligaments becomes disrupted, it places an increased level of stress on the remaining ligaments and tendons that must now improve upon their own contribution to the static and dynamic support of the ankle.

There are a number of different factors that are capable of increasing the probability of an occurrence of the lateral ankle sprain[8, 9, 19]. These include intrinsic factors such as previous history of injury, joint laxity, foot type, lower leg strength, postural control, and biomechanical errors, such as over pronation and over supination. Extrinsic factors are field/ court conditions, shoe type, and taping /bracing techniques.

POSTURAL CONTROL AND THE LATERAL ANKLE SPRAIN

Numerous studies [8, 10, 23] have been conducted and found that deficits in postural control contribute to the occurrence of the lateral ankle sprain. Others [24-26] have found the reciprocal of this and concluded that sustaining a lateral ankle sprain elicits decreases postural control. There is also literature [10] that suggests the opposite, that deficits in postural control do not increase the chances of incurring a lateral ankle sprain.

Lateral Ankle Sprains Contributing to Deficits in Postural Control

Rozzi et al.[24] looked at the effect of balance training on people who were defined as having functionally unstable ankles. It was found that deficits in postural control can be caused by the lateral ankle sprain. A total of 26 subjects participated, half were placed in an experimental group and half were placed in a control group. The experimental group consisted of those individuals who had functionally unstable ankles, as defined by experiencing at least 2 lateral ankle sprains and who had currently given a self-report of the ankle feeling unstable. The control group was healthy and had no prior history of ankle sprains. All subjects were initially tested on the Biodex Stability System, a balance platform that can assess and train individuals. After testing, the subjects were placed in a 4 week-long (3 days/week) balance-training program on the same Biodex apparatus. At the end of the training, subjects were re-tested. The researchers found that initial assessment revealed poor balance of the experimental group in comparison to the control group, meaning that postural control capabilities were less for those subjects who had a history of lateral ankle sprains.

After training, both groups made significant improvements in their balance skill level. The results of this study indicate that deficits from injury can be improved with proper training.

Another study, performed by Hertel et al.[25], examined postural control after the occurrence of an acute lateral ankle sprain and found postural control deficits in the injured leg when compared to the uninjured leg. Seventeen subjects were used in the study, all of whom had sustained an acute lateral ankle sprain. After an initial evaluation, all subjects were placed in the same rehabilitation program. Postural control measures were then taken unilaterally for both legs through the use of a force plate. These measures were taken on the first day after full weight bearing, during the second week post-injury, and during the fourth week post-injury. On day one, there was a significant impairment of postural control of the injured ankle in comparison to the uninjured ankle. Measures taken during the second week yielded similar results. During the fourth week, differences were only found in the sagittal plane, demonstrating an improvement in postural control. These findings show that postural control was decreased following the occurrence of the lateral ankle sprain.

Goldie et al.[26] studied the effects of inversion ankle injuries on postural control. It was found that the affected leg experienced deficits in postural control when compared to the unaffected leg. A total of 48 subjects who had sustained a lateral ankle sprain within the past two years were used for the study. They were divided into two equally sized groups. The first group, the untrained subjects, consisted of those people who had not received balance exercises during rehabilitation. The second group, the trained subjects, had the benefit of receiving balance exercises during the course of their rehabilitation. Both groups were then tested for postural control deficits with the use of a Kistler force platform system. It was found that the injured leg in only the untrained group had a significant deficit in postural control when compared to the uninjured leg. One possibility for this result is that the other group had received balance training with their rehabilitation, thus improving their postural control. A similar finding to Hertel et al. was found in that postural control was affected by the occurrence of a lateral ankle sprain.

Deficits in Postural Control Contributing to the Occurrence of a Lateral Ankle Sprain

Gefen [23] analyzed fatigue related foot injury mechanisms in his subjects while they engaged in intense marching. The two specific mechanisms were subtalar joint collapse caused by loss of dynamic stability in the medio-lateral direction and loss of the muscles' ability to reduce impact loads to the bone. One result found that lateral ankle sprains were most likely to occur during times of impaired postural control. Four subjects were used in a simulated marching exercise that was performed on a treadmill. All four subjects maintained a constant speed of 8km/hr for a total distance of 2km. One of the primary findings following the march was abnormal lateral deviation of the subjects' center of pressure. The center of pressure changes were found to be significant and indicated a loss of postural control as a result of the simulated marching. Gefen concluded that this was an optimal time in which an ankle sprain might occur. He found that as the muscles continued with activity, the body's ability to control posture decreased, specifically in the medial/lateral direction. Due to the inversion mechanism that causes a lateral ankle sprain, it was concluded that the ankle was most susceptible an injury at this time.

In a review written by Beynnon et al.[8], researchers examined a number of predictive factors for lateral ankle sprains that had been presented in previous literature, including postural control. Three studies came to the conclusion that decreases in postural control lead to a higher risk of sustaining a lateral ankle sprain. One of the studies, by Tropp et al.[8], used a force plate to measure changes in an athlete's center of pressure. It was concluded that higher values in postural sway indicated a decrease in postural control, and an increased risk of suffering an ankle sprain. In Watson's study[8], postural control was measured through the use of a single-leg stance. Those who could not maintain a single-leg stance for 15 seconds were characterized as having poor postural control and an increased risk for ankle sprains. This characterization proved true when these subjects incurred a higher amount of ankle sprains. Another study, performed by McGuine et al.[8], used a NeuroCom Balance Master to measure postural sway in high school basketball players. It was found that athletes who were discovered to have decreases in postural control had experienced a higher number of ankle sprains.

A similar study was conducted by Riemann[10], who researched past literature to illustrate a possible link between chronic ankle instability caused by lateral ankle sprains and postural instability. He asks the question, "Is postural control disrupted in patients with chronic ankle instability?" Initially citing Freeman et al.[10], it appears as though chronic ankle instability does cause impairment to postural control. Tropp et al.[10] expanded on these ideas through the use of more concrete instrumentation methods, as opposed to the observation and self-reports of Freeman's subjects. Studies from other researchers soon followed and echoed the same conclusions that had been found by Freeman and Tropp: Chronic ankle instability has a significant effect on postural control.

Later studies began finding contrasting results. Researchers like Baier and Hopf [10] and Isakov and Mizrahi [10] failed to find any significant relationships between postural control and lateral ankle sprains. In addition, Bernier [10] also failed to distinguish a difference in postural control between healthy and injured groups. Riemann[10] concluded with discussion about a link between chronic ankle instability and postural control, stating that, if it becomes accepted that postural control becomes impaired during injury, it becomes important that future research focus on the factors within the postural control system itself.

Beynnon et al.[8] had repeated the experiment by McGuine et al.[8] with collegiate athletes in the sports of soccer, lacrosse, and field hockey. Opposite results were found in that no correlation between ankle sprains and postural control were seen.

Many studies have established relationships between postural control and the lateral ankle sprain, while some literature had not. Rozzi et al., Hertel et al., and Goldie et al.[24-26] all found deficits in postural control following a lateral ankle sprain. When rehabilitated properly following the injury, the severity of these decreases was lessened. In Beynnon's literature review[8], research conducted by Tropp et al., Watson, and McGuine et al. all concluded that a lack of postural control leaves the subject more susceptible to incurring an ankle sprain. With this information, it would seem helpful to design programs whose goals specifically focus on increasing an athlete's postural control. This may help reduce the frequency of the injury.

It may be concluded from previous research that the occurrence of the lateral ankle sprain causes detriments in postural control to the injured leg. Results have supported this by showing comparisons between injured and uninjured legs. Conflicting results have been found regarding the notion of whether a decrease in postural control causes a higher risk of incurring a lateral ankle sprains. Some researchers believe that postural control detriments cause a higher rate of lateral ankle sprains while other researchers do not believe this to be true.

LOWER LEG STRENGTH AND THE LATERAL ANKLE SPRAIN

Strength Training Decreasing Deficits from Lateral Ankle Sprains

In a study by Mattacola and Lloyd[27], the effects of a 6-week strength and proprioception training program on dynamic balance measures yielded positive increases in the dynamic stability of individuals who had incurred deficits from first-degree lateral ankle sprains. Three subjects who had previously sustained this injury took part in the study. Over the course of 6 weeks, subjects trained 3 days/week. Exercises were performed to strengthen the dorsiflexors, plantar flexors, invertors, and evertors of the foot. In addition, proprioception training also took place. Testing occurred with the use of a dynamic balance board. The results indicated that all three subjects showed improvement in dynamic balance. The researchers attributed this improvement to the participation in the training program. This particular study shows a positive relationship in which an increase in strength and proprioception yielded an increase in dynamic stability, meaning deficits in dynamic stability from lateral ankle sprains can be regained through training.

Docherty et al. [28] studied the effects of strength training on strength development and joint position sense in functionally unstable ankles and found that a 6-week training program positively increased the values for each variable. Twenty subjects were used for the study, all of whom had a history of at least 3 lateral ankle sprains in the last 5 years. At the time of the study, all subjects were completely asymptomatic. They were then divided into 2 equal groups, a control group and a training group. The unstable ankle for each subject was then tested for dorsiflexor and evertor muscle strength, as well as joint position sense for the invertors, evertors, dorsiflexors, and plantar flexors. Strength testing required the use of a dynamometer. The joint position testing used a custom designed electrogoniometer. Once baseline measures were taken, the experimental group began the training procedure. This consisted of 6 weeks of resistance training for the invertors, evertors, dorsiflexors, and plantar flexors through the use of an elastic band. Overall, the results revealed better post-training scores for the experimental group than for the control group. Specifically, strength increased for all 4 motions and joint position sense was significantly better for inversion and plantar flexion, illustrating that strength training is beneficial to individuals with functionally unstable ankles.

Strength Deficits from Lateral Ankle Sprains

In a study by Baumhauer et al.[9], researchers performed a prospective study of ankle injury risk factors and found discrepancies in strength ratios in laterally sprained ankles when compared to uninjured ankles. One of the factors being examined for this study was isokinetic strength. One hundred and forty-five college athletes were enrolled as subjects. In those athletes who had sustained lateral ankle sprains, all had demonstrated strength ratio differences for the invertors and evertors in the injured ankle that were greater then those displayed by the uninjured group. Similar ratios were found for the plantar flexors and dorsiflexors between the injured and uninjured legs. This study shows that muscular strength ratios were found to be greater following the occurrence of a lateral ankle sprain.

In a study by Willems et al.[29], researchers examined muscle strength and proprioception in subjects with a history of lateral ankle sprains and found a lower level of evertor muscle strength. A total of 87 subjects were used, all of whom had their muscle strength tested through the use of a Biodex System 3 Dynamometer, which tested isokinetic strength values for the invertors and evertors. Among some of the different results, it was found that subjects who had sustained lateral ankle sprains showed significantly lower levels of evertor muscle strength, demonstrating that there is a relationship between the lateral ankle sprain and evertor muscle strength.

The results from these studies indicate a relationship between muscular strength and the lateral ankle sprain. Those subjects who had a history of injury also demonstrated a decrease in muscular strength in the involved leg when compared to the uninvolved leg or healthy subjects. Others have found that individuals characterized as having chronic ankle instability may experience higher degrees of muscle imbalances in the lower leg then healthy individuals. These deficits can be reversed through strength training of the lower leg as exercises were found to be helpful in reducing these deficits and in regaining some imbalances that had been lost from postural instabilities.

RELATIONSHIPS BETWEEN FUNCTIONAL ACTIVITY AND POSTURAL CONTROL

Postural control has been identified as an intrinsic risk factor for the occurrence of lateral ankle sprains[8, 9]. Some researchers [8, 10, 23] have found that deficits in the control of posture are linked with injury. Yet, few researchers have studied how functional activity can affect postural control. Instead, they have examined the relationship between fatigue and postural control, finding that fatigue of lower extremity muscles causes decreases in the ability to control one's posture[11, 12, 14, 21, 30].

Muscular Fatigue and Postural Control

In studies by Lundin et al. and Ochsendorf et al.[12, 14], the effects of dorsiflexor and plantar flexor fatigue on unilateral postural control resulted in deficits after fatigue had been induced. Subjects' postural control was tested through the use of a force plate which was then followed by the plantar flexors and dorsiflexors being fatigued through isokinetic and isometric contractions on a dynamometer. Ochsendorf et al. [12] defined fatigue as being 3 consecutive repetitions performed below 50% of the maximum peak torque recorded for plantar flexion while Lundin et al. [14] defined it as 5 sets of 15 repetitions of concentric-eccentric contractions and 4 isometric contractions. One of the results found in both studies was that postural sway values were significantly greater for the post-fatigue measures when compared to the pre-fatigue measures, meaning there was a decrease in the subject's ability to control his posture after his plantar flexors and dorsiflexors had been fatigued. Lundin et al. [14] additionally found that their subjects' deficits were mostly in the anterior-posterior direction. Johnston et al. [13] found similar results in their study when they examined the effects of lower extremity muscular fatigue on motor control performance. Following isokinetic fatigue that included the dorsiflexors and plantar flexors, significant increases were found in balance test score values that examined postural control. These increased values demonstrate that significant decreases in postural control were found following the fatigue protocol.

In a study by Yaggie and McGregor [11] on the effects of isokinetic fatigue on postural control, it was found that postural control significantly decreased immediately after the completion of a fatigue protocol. Subjects used in this study balanced unilaterally for a total of 25 seconds on an AMTI force platform. Once this was completed, the Cybex 6000 Isokinetic Dynamometer was used to fatigue the evertors, invertors, dorsiflexors, and plantar flexors of the dominant foot. Fatigue was expressed as 3 consecutive repetitions performed at below 50% of the subjects' maximum joint torque. Subjects were then re-tested on the force platform immediately after the exercise, and at 10 minutes, 20 minutes, and 30 minutes post-fatigue. The researchers found that postural sway measures were significantly greater immediately following the fatigue protocol. This means that postural control capabilities significantly decreased immediately after the fatigue protocol. When tested at 10, 20, and 30 minutes post-fatigue, unilateral balance returned to normal.

Adlerton and Moritz[20], and Vuillerme and Nougier[30] each studied the effects of calf-muscle fatigue on standing balance and found conflicting results. Following fatigue that involved one-legged heel raises, Adlerton and Moritz [20]saw no significant changes from pre-fatigue balance measurements to post-fatigue balance measurements, indicating that postural control had not been significantly affected. Subjects in this study were first asked to balance on one foot on a strain gauge force plate. They concluded that compensatory mechanisms took over once fatigue had set in to the muscle. In the study conducted by Vuillerme and Nougier, [30] they found decreases in postural control following fatigue. Following a sustained isometric heel raise it was found that postural sway increased significantly indicating that a decrease in postural control had taken place.

Davis and Grabiner [21] found postural control to be most affected in the mediolateral direction when they examined the modeling effects of muscle fatigue on unilateral postural control. In this experiment, a subject was compared to a "rigid body" that was anchored to a support by a hinge. In other words, the subject is an inverted pendulum whose only movement can occur at the ankle when the hips and knees are locked in position. The subject's muscles were then compared to springs that became less rigid with structural fatigue. Through the use of this theoretical setup, conclusions were drawn with the application of biomechanical equations. It was found that before fatigue, joint stiffness is greatest in the frontal plane. Secondly, fatigue reduces muscle stiffness. Finally, postural sway is most affected in the mediolateral direction as fatigue approaches, which will decrease the ability to control posture.

The research that has been presented studied the variable of postural control and how it is affected by fatigue. Most of the fatigue protocols took place on an isokinetic dynamometer or utilized other non-functional methods. In 6 out of the 7 studies [11-14, 21, 30] decreases in postural control were found following fatigue of the musculature. Detriments in postural control are identified as a possible risk factor for the injury of the lateral ankle sprain, which occurs when people are performing functional activities and not taking their bodies to a defined level of fatigue. Although fatigue research is beneficial, little is known as to what happens to the body as it continues with functional activity. Therefore, studies including functional activities should also be examined.

Functional Activity and Postural Control

In Gefen's study[23] on foot injury mechanisms, one of the primary findings was an abnormal lateral deviation of the subjects' center of pressure following a simulated march. The center of pressure changes were found to be significant when compared to pre-activity measurements and indicated a loss of postural control as a result of the simulated marching. This study demonstrated that deficits in postural control could be caused by functional activity without the introduction of muscle induced fatigue.

Rowe et al.[31] found mediolateral postural control decreases following exercise after examining the effects of a 2-hour cheerleading practice on dynamic postural stability, knee laxity, and hamstring extensibility. The measuring of dynamic postural stability was carried out by the Biodex Stability System. The results found that mediolateral movement increased after the 2-hour cheerleading practice, indicating a decrease in postural control had been incurred by the subjects. Changes that occurred in other movement planes failed to reveal any significant changes between pre-practice and post-practice measures.

Many studies have looked at the relationship between postural control and muscular fatigue. Most have found that as fatigue sets in, postural control decreases[11, 12, 14, 21, 30]. Yet, few have incorporated functional activity. Because postural control is known as a possible risk factor for incurring the lateral ankle sprain, it would be beneficial to examine it in a functional setting. From the small amount of literature that did examine this type of setting, it can be seen that postural control deficits were found when compared to results of pre-activity testing. With the functional activity settings that lateral ankle sprains are occurring in, it is important that different types of activity be tested and analyzed.

RELATIONSHIP BETWEEN MUSCULAR STRENGTH AND FUNCTIONAL ACTIVITY

Muscular strength is another measurement variable that was used when examining the effects of functional activity on the body. In addition to postural control, deficits in lower leg strength are known as risk factors for the occurrence of a lateral ankle sprain. Some studies[15, 17, 18] have focused on taking the body to muscular fatigue in non-functional settings. Results from these studies found that muscles were producing less force post-fatigue when compared to pre-fatigue measures. In these studies no functional activity was used. Those studies [23] that have included functional activity have found that force production decreases over a prolonged period of time.

Muscular Strength and Functional Activity

Gefen's study [23] involving intensive marching studied the effects of a 2 kilometer march. Subjects marched at a speed of 8km/hour while EMG electrodes monitored signals from lower leg muscles. Muscles that were most significantly affected by the test protocol were the peroneus longus and gastrocnemius. Both muscles had experienced prominent decreases in their force durations when data from the beginning of the activity was compared to data at the end of the activity. This indicated that functional activity had significantly affected these muscles.

Muscular Strength and Fatigue Testing

Trappe et al.[15] assessed characteristics of calf strength and found decreases in force production following fatigue. Fatigue of the calf musculature was induced through the use of a torque velocity device. The device first tested the strength of the muscles through the use of isokinetic and isometric measurements. Fatigue of the calf muscles was accomplished by performing a total of 30 maximal isokinetic contractions. Upon completion of the contractions, it was found that an average of a 61% decrease in muscle force had resulted when post-fatigue tests were compared with pre-fatigue tests. Pasquet et al.[16] found similar results when they looked at muscle fatigue during concentric and eccentric contractions. Researchers examined the ankle dorsiflexors and made use of an ergometer that allowed isokinetic movement to take place. In addition to a loss of muscle force following fatigue, it was also found that concentric contractions caused a greater loss of force then did the eccentric contractions.

Christina et al. [17] studied the effects of muscle fatigue on vertical ground reaction forces and motions of the ankle joint during running and found a decrease in force production during running following isokinetic fatigue. In this study, subjects were first asked to run on a treadmill at a set speed of 2.9 meters/second. Once completed, dorsiflexors of the lower leg were fatigued through the use of the Elgin leg/ankle exerciser. After fatigue had occurred, the subjects were placed back on the treadmill for running. The same procedure was then repeated two weeks later. This time the invertors were the muscles being fatigued. The researchers found that fatigue of the dorsiflexors and invertors resulted in a decrease in the amount of force being produced during the running sequence. The lack of force that was caused by the fatigue could be detrimental to controlling posture.

Kawakami et al.[18] found decreases in torque when they conducted a study on fatigue responses of the triceps surae muscles during repetitive maximal isometric contractions. A total of 9 subjects were used, all of whom performed a series of 100 isometric contractions using the ankle plantar flexors. This occurred in both full knee extension and 90 degrees of knee flexion. During the study, surface electrodes recorded activity for the gastrocnemius and soleus. It was found that both muscles experienced decreases in torque. Plantar flexion performed in total knee extension produced a greater force and also experienced a more rapid decrease in torque when compared to plantar flexion performed in 90 degrees of knee flexion.

The studies previously presented have all demonstrated that muscular strength is affected by fatigue. Although this seems to be an obvious result, much of this research is still based on non-functional activities. In these scenarios, protocols have made use of different series of isokinetic or isometric contractions. Those studies that did mimic a more functional setting did so without taxing the entire body or involving different movements. Most sports involve movements and skills that utilize an athlete's entire body. Because of this, more research using functional activity should be conducted. By studying the effects that these activities have on muscles, more can be learned about which skills and sports are more strenuous on specific muscles, and could lead to more injury.

Much of the literature that has been discussed did not focus on the type of activity in which the lateral ankle sprain was occurring. Because the injury occurs during functional activity, it would be helpful to implement this into a study and identify the affect it has on variables such as postural control and lower leg strength. In an attempt to learn more of this relationship, the current study examined the effects of functional activity on the body through measuring changes in postural control and lower leg strength, two variables believed to be risk factors for lateral ankle sprain.

Chapter 3

METHODS AND ANALYSIS

SUBJECTS

Subjects for this study were 14 individuals (7 males, height = 178.54 ± 6.88 cm, weight = 82.02 ± 7.02 kg, age = 24 ± 2 years; 7 females, height = 165.84 ± 5.82 cm, weight = 59.31 ± 6.60 kg, age = 22.86 ± 3.14 years). All participants exercised on a regular basis (3 times a week or more). All subjects were injury free at the time of the study and had no previous history of surgery or ankle injury to their dominant leg.

MATERIALS

The functional activity session took place in a gymnasium. All other testing took place in an athletic training research laboratory. Strength testing for the lower leg musculature was measured with the use of the Biodex System 3 Pro isokinetic dynamometer (Biodex Medical Systems, Shirley, NY). Postural control testing took place on the Accusway Plus System force plate (Advanced Mechanical Technology Inc., Watertown, MA).

PROTOCOL

Sequence

Subjects were given an orientation about the research being conducted. At the end of the informal meeting, the subjects read and signed the informed consent form as regulated by University Committee on Research Involving Human Subjects (UCRIHS) (see Appendix A). A date and time was then set for the session to take place.

At the beginning of the session, each subject read and completed the Paffenbarger Physical Activity Questionnaire (see Appendix B), which assessed each subject's level of activity. Next, the subject's postural control was tested to gather pre-activity data.

Postural control testing was immediately followed by strength testing of the plantar flexors, dorsiflexors, evertors, and invertors of the subject's dominant leg while the subject was seated in the Biodex System 3 Pro. Subject #1 always began with eversion/inversion while subject #2 always began with plantar flexion/ dorsiflexion. This alternating progression continued throughout the entire study. Following pre-exercise testing, subjects were then escorted to the gymnasium for the functional activity protocol.

After completing the exercise protocol, each subject was immediately taken back to the research laboratory to participate in the post-activity testing of postural control and dominant leg strength. These were measured in exactly the same manner as were the pre-activity measurements.

Postural Control Testing

The AMTI Balance Program software was used in conjunction with the Accusway Plus System force plate to measure each subject's center of pressure. Using the software, subject information was recorded into the program before testing began. Three trials of 30 seconds were then selected for the testing of the study. Zeroing of the platform then took place just before the subject was asked to balance. All balancing was performed on the dominant leg while focusing on an "X" that had been placed at eye level on the wall approximately 2 feet in front of the subject. Both arms were folded across the chest while the non-dominant leg was held in 90 degrees of knee flexion. Subjects were given a 5 second countdown to the start of the balance test. After 30 seconds had passed, the subject was asked to step down from the force plate. The data were saved and the process was repeated 2 more times.

Strength Testing

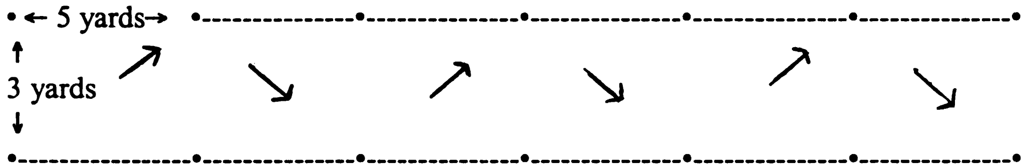
All strength testing took place on the Biodex System 3 Pro isokinetic dynamometer. Subject information was first programmed into the computer. One of two protocols was then selected for the first test (eversion/inversion @ 60 degrees/sec or dorsiflexion/plantar flexion @ 60 degrees/sec). The subject then sat in the testing chair and performed 3 sets of 10 repetitions at maximum effort for the protocol. The data were saved and the second of the two 60 degree/sec protocol was selected for the same subject. The testing chair was modified appropriately for the testing to take place. Following this session, the tests were performed again at 120 degrees/sec. Eversion/inversion testing always began with the dominant foot placed in full eversion. Dorsiflexion/plantar flexion testing always began with the dominant foot in full dorsiflexion.

Functional Activity

The functional activity session began with a warm-up of jogging 4 laps around the entire gymnasium (.25 miles). Upon completion of these laps, the subject was given 5 minutes to stretch in any manner he or she felt comfortable. During this time, the principle investigator again explained the exercises that were to be performed. The following is a list of the exercises, which were performed at a maximal speed by each subject:

1) 1 set of 15 push-ups,
2) 1 set of 30 2-footed stationary jumps to maximum height,
3) 1 set of 4 straight-forward sprints (90 feet each), and
4) 1 set of 4 "zigzag" sprints (cutting back and forth between 7 orange cones set at 3 yards wide and 5 yards long, see Figure 1)

Figure 1: Set-up For Zigzag Sprints



The sets listed above make a complete circuit. During a circuit, no time is allowed for rest between the different exercises. Each subject was asked to perform 4 complete circuits, with each being completed in less than 1.75 minutes. Between each of the circuits, the subject was given a 1 minute rest. The order in which the subject performed each circuit remained constant. Between subjects, the order was completely randomized.

STATISTICAL ANALYSIS

Three separate paired t-tests were used to analyze the dependent variables of postural control (path length, velocity average, and area 95). These variables were defined as:

Path length: the distance the center of pressure travels as it moves along the surface of the force plate beneath the sole of the foot during a test of standing balance

Velocity average: the speed and direction in which the center of pressure moves during a standing balance test (path length/unit time)

Area 95: displays 95% of the points that fit into an ellipse that were recorded during the standing balance test

Comparisons were made by examining data obtained from control testing (pre-activity test) and pairing it with data obtained from the experimental testing (post-activity test). Results were calculated for the total subject group and also for male and female subject groups. The same analysis was performed for lower leg strength. The paired t-test was again used to analyze the dependent variable (peak torque). This variable was defined as:

Peak torque: the highest recorded torque output at any point during a repetition.

Eight separate pairings were made, all of which compared data of pre-activity trials to post-activity trials. The pairings were eversion at 60 degrees/sec., inversion at 60 degrees/sec., plantar flexion at 60 degrees/sec., dorsiflexion at 60 degrees/sec., eversion at 120 degrees/sec., inversion at 120 degrees/sec., plantar flexion at 120 degrees/sec., and dorsiflexion at 120 degrees/sec.

The level of significance was set at $p < .05$ for all of the statistical analyses. Analyses were performed with the use of the SPSS 10.0 (SPSS Inc., Chicago, IL) statistical software package.

Chapter 4

RESULTS

PHYSICAL ACTIVITY QUESTIONNAIRE

Results from the Paffenbarger Physical Activity Questionnaire revealed no significant differences in the activity levels of the subjects. All subjects exercised at least 3 times/week, participating in such activities as running, biking, swimming, and resistance training. Other physical activities performed by the subjects included team sports such as basketball and soccer. The duration of these activities lasted for at least 30 minutes.

POSTURAL CONTROL

Statistically significant differences from the pre-activity testing to the post-activity testing were found in all three variables (see Table 1). Path Length (P=.000) had an increase in its mean value from 44.71 to 47.01 inches and represents an increase in the movement of the center of pressure and a decrease in postural control. Testing demonstrated an increase (P=.000) in the velocity average mean value from 1.49 to 1.57 inches/sec. An increase in velocity is an indication that postural control is declining. Finally, it was found that Area 95 increased (P=.039) in its mean value from .7991 to 1.0838 inches squared. This variable also demonstrates that a deficit in postural control has occurred.

Table 1: Comparison of Mean Postural Control Variables: Pre vs. Post-Activity

Postural Control	Pre	Post
Path Length (inches)	44.71	47.01
Vel. Avg. (inches/second)	1.49	1.57
Area 95 (square inches)	0.8	1.08

Statistically significant differences were also found when the results were broken down by sex (see Tables 2 and 3). In females, path length (P= .019) increased in its mean value from 43.97 to 47.27 inches. Velocity average (P= .019) increased from 1.47 to 1.58 inches /second. Area 95 (P= .027) saw an increase in its mean value from .80 to 1.06 square inches. All of these changes demonstrate that deficits in postural control had occurred.

Statistically significant differences in males were found for the variables of path length and velocity average. Path length (P=.013) increased in its mean value from 45.44 to 46.74 inches. Velocity average (P=.014) saw an increase in its mean value from 1.51 to 1.58 inches/second.

Table 2: Comparison of Mean Postural Control Variables in Females: Pre vs. Post-Activity

Postural Control	Pre	Post
Path Length (inches)	43.97	47.27
Vel. Avg. (inches/second.)	1.47	1.58
Area 95 (square inches)	0.8	1.06

Table 3: Comparison of Mean Postural Control Variables in Males: Pre vs. Post-Activity

Postural Control	Pre	Post
Path Length (inches)	45.44	46.74
Vel. Avg. (inches/second)	1.51	1.58

STRENGTH

Peak torque was a variable that was used as in indicator of strength (see Table 4). There was a significant difference found between pre-activity and post-activity testing of peak inversion torque at 60 degrees/sec. (P= .005). The average of the peak torque decreased from 17.86 to 14.05 ft-lbs. Plantar flexion and dorsiflexion at 60 degrees/sec. also experienced significant differences. Plantar flexion decreased (P=.005) from a mean value of 46.82 to 30.34 ft-lbs. Dorsiflexion decreased (P=.000) from 14.56 to 13.27 ft-lbs.

At 120 degrees/sec., inversion showed a significant decrease (P=.014) in strength from a mean value of 13.39 to 11.89 ft-lbs. Plantar flexion decreased (P=.001) from a mean value of 25.20 to 20.82 ft-lbs. Finally, dorsiflexion at 120 degrees/sec. decreased (P=.000) from a mean value of 12.71 to 11.06 ft-lbs.

Results from eversion tests performed at 60 degrees/sec. were not found to be statistically significant (P= .870). In addition, eversion tests performed at 120 degrees/sec. were also not found to be statistically significant (P= .407).

Table 4: Comparison of Mean Strength Variables: Pre vs. Post-Activity

Peak torque (ft-pounds)	Pre	Post
Inversion 60 deg/sec	17.86	14.05
Planter Flexion 60 deg/sec	46.82	30.34
Dorsiflexion 60 deg/sec	14.56	13.27
Inversion 120 deg/sec	13.39	11.89
Planter Flexion120 deg/sec	25.2	20.82
Dorsiflexion 120 deg/sec	12.71	11.06

When results from the strength testing were divided into male and female groups, no significant differences were found from pre-activity testing to post-activity testing.

Chapter 5

DISCUSSION

Lateral ankle sprains are one of the most common injuries in all of sport[1, 2, 4, 5]. Two factors that are believed to have an effect on this occurrence are postural control and lower leg strength[8, 9, 18]. The purpose of this study was to examine the effects of a functional activity intervention on postural control and lower leg strength. After approximately 20 minutes of intense exercise, significant increases were seen in the postural control variables of path length, average velocity, and area 95, indicating that postural control had incurred a deficit. In addition, significant decreases were seen in strength for the motions of inversion, plantar flexion, and dorsiflexion at 60 and 120 degrees/sec after the intervention of functional activity. No significant strength differences were seen for the motion of eversion at 60 and 120 degrees/sec.

POSTURAL CONTROL

The results of this study support the hypothesis that the subjects' postural control would decrease from pre-activity to post-activity testing. There was an overall increase in center of pressure measurements after subjects had completed the functional activity session. Path Length, which is a measure of the actual distance of the path for the duration of the trial, increased in length from an average of 44.71 inches to 47.01 inches. Velocity Average is a measure of the path length per unit time. A lower velocity implies greater postural control, while a higher velocity demonstrates a diminished ability to manage one's posture. When comparing pre-activity and post-activity values, an increase was seen after the functional activity session had been completed. Mean scores increased from an average of 1.49 in/sec to 1.57 in/sec. Area 95 is a measure of the area of the 95th percentile ellipse. This is the area where 95% of the recorded points reside. A significant increase was seen, with mean scores rising from .80 in. sq. to 1.08 in. sq. This indicates that there was an increase in the area of the measurement of the center of pressure. All three of these findings indicate that postural control had diminished from the pre-activity measurements to the post-activity measurements.

When the data was broken down by sex, only two of the postural control variables for males were significant. These were path length and velocity average. No significant changes were seen in the variable of area 95. This comes in contrast to the female group, who experienced significant changes with all three variables. The changes seen in the variables of path length and velocity average displayed greater differences then those seen by the males (see Tables 2 and 3). This information gives an indication that the female group exhibited greater deficits in postural control when compared to the male group.

In a study conducted by Gefen[23], the researcher found that there was an increase in the lateral deviation in the subjects' center of pressure after performing functional exercise. This finding comes in contrast to the current study, in which differences in medial-lateral displacement were primarily medial. These differences may be attributed to the fact that the functional exercises used were not the same. Gefen used a steady 2-kilometer march while this study used a full-speed circuit training routine.

In the study conducted by Rowe et al.[31], researchers tested subjects before and after a 2-hour cheerleading practice session. The variables looked at in this study were anterior knee laxity, hamstring extensibility, and postural control. Among the many results, it was found that medial displacement of the center of pressure during postural control tests increased following physical activity. This is similar to findings of the current study.

STRENGTH

Overall, the strength results of this study supported the hypothesis that the subjects' maximum force exertion would decrease following the functional activity. Following the exercise session, strength values showed significant decreases in most categories. The average of the peak torque was the variable used to measure lower leg strength for all muscle groups. At 60 degrees/sec., inversion decreased in its mean value for the peak torque. It dropped from 17.86 to 14.05 ft-lbs. Plantar flexion also experienced a decrease, dropping from an average value of 46.82 to 30.34 ft-lbs. Finally, dorsiflexion had its average peak torque drop from 14.56 to a value of 13.27 ft-lbs.

Significant differences were also seen when each muscle group was tested at 120 degrees/sec. The mean inversion torque decreased from 13.39 to 11.89 ft-lbs. Plantar flexion also experienced significant differences, with the average peak torque decreasing from 25.20 to 20.82 ft-lbs. Finally, the values for dorsiflexion also decreased after the exercise session, dropping from 12.71 to 11.06 ft-lbs.

No significant differences were seen for eversion at 60 or 120 degrees/second after exercise had been induced. This implies that the exercises used in this study did not have a large effect on the evertors.

Gefen's [23] study was not in complete agreement with findings of the current study. Gefen, who used a treadmill to imitate a 2-kilometer intensive march, found significant decreases in force in the peroneus longus and lateral belly of the gastrocnemius. Although in the current study significant decreases in peak torque were seen in the plantar flexors, no significant differences were found in the evertors at either speed. These differences may be attributed to other evertors of the lower leg compensating for the peroneus longus.

Contrasting activities between Gefen's[23] study and the current study may also have caused different outcomes to occur.

CLINICAL IMPLICATIONS

Ankle sprains occur in a functional setting in which multiple variables are involved. Of these variables, lower leg strength and postural control are two that have been previously researched, but seldom in a functional activity setting. Placing the subjects in a functional activity protocol similar to a game or practice situation yielded effects on strength and postural control that were more consistent with what was being experienced during athletic competition. The functional activity protocol that was used in this current study was one that was challenging for all subjects. All participants verbally explained that the program was both physically and mentally taxing to the body.

Incorporating functional scenarios into research studies can help clinicians understand more of the effects that athletic events have on strength and postural control. From the findings, preventative programs can then be developed that will help the athlete reduce the risk of injury.

Based on the findings of this current study, more closed chain functional activities should be incorporated into the final stages of personal rehabilitative programs. Plyometric training programs could improve the athlete's speed, agility and balance. Circuit training programs involving a mixture of cardiovascular, strength, and speed training would also be beneficial. Both circuit training and plyometric activities can be designed to mimic the specific sport in which the athlete is involved, allowing the athlete to better acclimate to their specific activity, and providing a safer return to play with a lower chance of future injury.

FUTURE RESEARCH

Future research in this area has many possibilities. One area of particular interest lies in the progression of the functional activities being used. The next step may alter the activities in the duration or types being used. Instead of incorporating a variety of activities as the current study did, the next area of research could focus on imitating one sport, so that more accurate data might be found for that particular group of athletes. To take the idea one step further, tests could be completed at different points of time throughout a practice, or perhaps even a game. Data from this research could possibly reveal when athletes' postural control and strength are at their weakest. This last idea, however, may be limited by a coaching staff's rules and regulations.

Another direction would be to identify differences between males and females. The current study identified differences in postural control finding that females had exhibited greater deficits following functional activity. No significant results were found when data from strength testing was broken into male and female groups. Future studies would require more participants and would most likely use athletes of the same sport to possibly achieve more accurate results. By learning more about the possible gender differences, preventative programs can be designed with more of the athlete's special needs in mind.

These are but two possibilities in which research on this topic could lead. As seen from the current study, activities that athletes are participating in today have an affect on their bodies, causing detriments in postural control and lower leg strength to occur as the activity continues. These detriments that are being experienced by the body predispose the athlete to a higher risk of incurring the lateral ankle sprain. With the high prevalence of this injury in the world of athletics, it is important that proper rehabilitation programs be implemented and more research be conducted involving functional activity.

APPENDIX A

Effects of Functional Activity on Strength and Postural of Ankle Function

Subject Consent Form

For questions concerning this study, please contact:

Kavin Tsang, Ph.D., ATC
Principle Investigator
Department of Kinesiology
Michigan State University
105 IM Circle
East Lansing, MI 48824
517-353-2010
ktsang@msu.edu

For questions concerning your rights as a research participant, please contact:

Peter Vasilenko, Ph.D.
Chair Person
Committee on Research Involving Humans
Michigan State University
202 Olds Hall
East Lansing, MI 48824
517-355-2180 or 517-432-4503 (fax)
crirb@msu.edu

Dear Subjects:

A study entitled, "Effects of Exercise on Strength and Postural Control of Ankle Function" is currently being researched and tested. This study is being conducted because there is an interest in learning more about the risk factors associated with the lateral ankle sprain, specifically strength and postural control. By choosing to participate in this study, you will play a vital role in helping to attain this knowledge.

The study will involve you taking part in a total body exercise program. This will be run at maximal exertion. Therefore, appropriate athletic clothing is required (shorts, T-shirt, sneakers, etc.). The program will consist of a series of sprints, jumps, and push-ups. Before this takes place, strength and postural control will be tested through the uses of a Biodex machine and a force plate. Data collected from these tests will provide information on muscular strength and postural control. Following the exercise program, you will be tested again on the same apparatus. The total amount of time for this test should take no longer than one hour.

Certain criteria must be met in order to participate in the study. You must be between the ages of 18 and 30. You must exercise regularly exercise at least 3 times a week. You also must have no prior history of surgery to the lower extremity. Finally, you must be free from injuries to the lower extremity.

If you are injured as a result of you participation in this research project, Michigan State University will assist you in obtaining emergency care, if necessary, for your research related injuries. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. As with any medical insurance, any costs that are not covered or in excess of what are paid by your insurance, including deductibles, will be your responsibility. Financial compensation for lost wages, disability, pain or discomfort is not available. This does not mean that you are giving up any legal rights you may have. You may contact Kavin Tsang Ph.D., ATC at 517-353-2010 with any questions.

All personal identities and information collected during the study will remain confidential and will be replaced and analyzed through the use of individual identification numbers. Participants will remain confidential at all times. **Your privacy will be protested to the maximum extent allowable by law.**

In order to participate, your written consent must be provided in the spaces provided below. **Your participation is completely voluntary and you are free to discontinue at any time without penalty.** Any discontinued data will not be used in the study.

Any questions concerning this study may be directed to Phillip H. Andre, ATC, Graduate Assistant. Questions regarding your rights in the research study may be directed to Peter Vasilenko, Ph.D., Michigan State University's chair of the Committee on Research Involving Human Subjects.

INFORMED CONSENT:
This section indicates that you are giving your informed consent.

I agree to participate in this study as described above

____
Participant Name

______________________________ ____/____/____
Participant Signature

APPENDIX B

Paffenbarger Physical Activity Questionnaire

1. How many city blocks or their equivalent do you normally walk each day?

   ____blocks/day (Let 12 blocks = 1 mile)

2. What is your usual pace of walking? (Please check one.)

   a. ____ Casual or strolling (less than 2mph) b. ____ Average or normal (2 to 3 mph)

   c. ____ Fairly brisk (3 to 4 mph) d. ____ Brisk or striding (≥4 mph)

3. How many flights or stairs do you climb up each day? ____ flights/day (Let 1 flight = 10steps.)

4. List any sports or recreation you have actively participated in during the past year. Please remember seasonal sports or events.

Sport/Recreation	Number of Times/year	Average Time/Episode Hours	Minutes	Years Participation
a				
b				
c				
d				
e				
f				

5. Which of these statements best expresses your view? (Please check one.)

a___ I take enough exercise to keep healthy. b ___ I ought to take more exercise.

c___ Don't know

6. At least once a week, do you engage in regular activity akin to brisk walking, jogging, bicycling, swimming, etc. long enough to work up a sweat, get your heart thumping, or get out of breath? ___ No Why not?__________ ___ Yes How many times/ week? ___ Activity: _________________

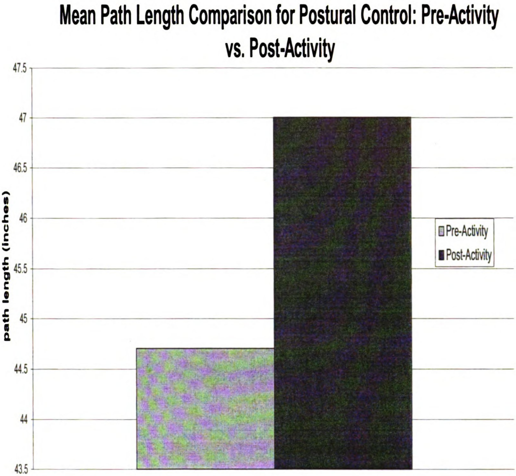
7. When you exercise in your usual fashion, how would you rate your level of exertion (degree of effort)? (Please circle one number.)

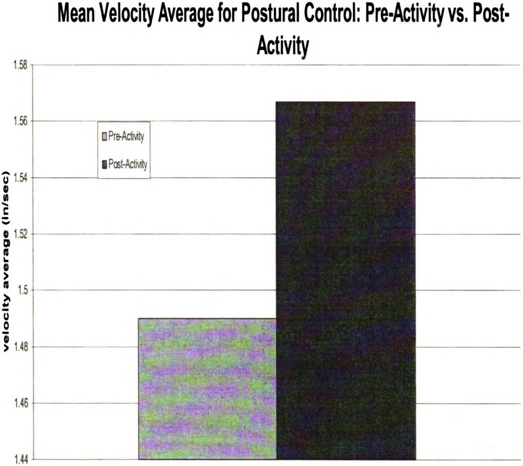
0 (Normal), .5 (Very, very weak. Just noticeable), 1 (Very weak), 2 (Weak), 3 (Moderate), 4 (Somewhat strong), 5 (Strong, heavy), 6, 7 (Very strong), 8, 9, 10 (Very, very strong)

8. On a usual weekday and a weekend day, how much time do you spend on the following activities? Total for each day should add to 24 hours.

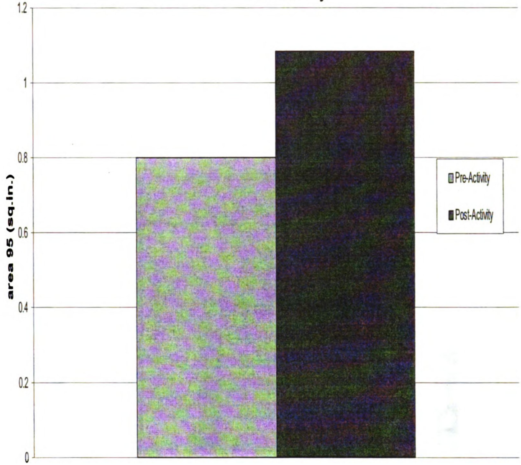
	Usual weekday	Usual weekend day
a. Vigorous activity (digging in the garden, strenuous sports, aerobic dancing, sustained swimming, brisk walking, heavy carpentry, bicycling on hills, etc)	________	________
b. Moderate activity (housework, light sports, regular walking, golf, yard work, lawn mowing, painting, repairing, light carpentry, ballroom dancing, bicycling on level ground, etc.)	________	________
c. Light activity (office work, driving car, strolling, personal care, standing with little motion, etc.)	________	________
d. Sitting activity (eating, reading, desk work, watching TV, listening to radio, etc.)	________	________
e. Sleeping or reclining	________	________

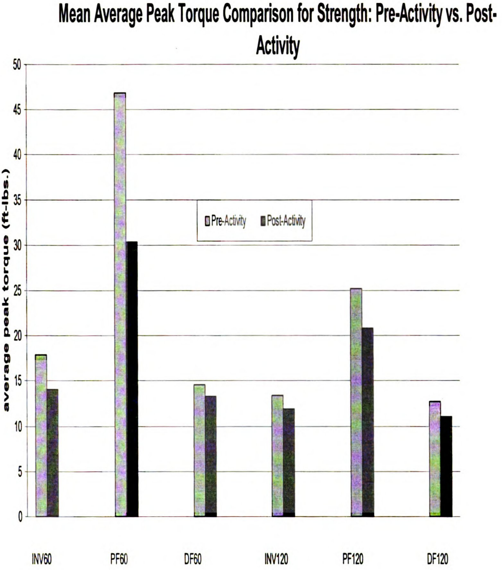
APPENDIX C


Mean Path Length Comparison for Postural Control: Pre-Activity vs. Post-Activity
47.5
47
46.5
46
45.5
45
44.5
44
43.5
path length (inches)
Pre-Activity
Post-Activity

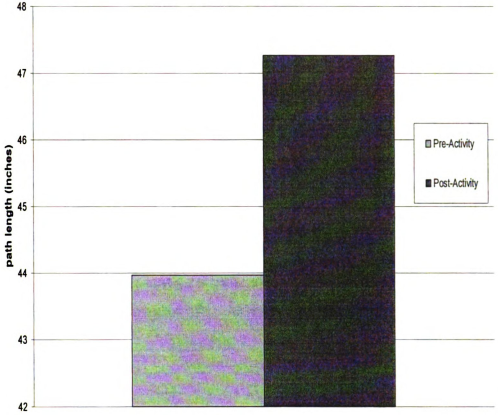

Mean Velocity Average for Postural Control: Pre-Activity vs. Post-Activity
1.58
1.56
1.54
1.52
1.5
1.48
1.46
1.44
velocity average (in/sec)
Pre-Activity
Post-Activity

Mean Area 95 Comparison for Postural Control: Pre-Activity vs. Post-Activity

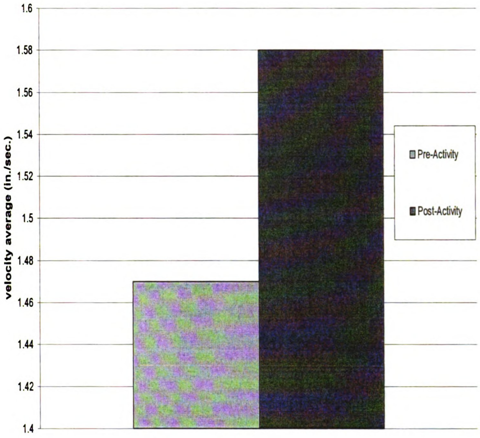



Mean Average Peak Torque Comparison for Strength: Pre-Activity vs. Post-Activity
average peak torque (ft-lbs.)
50
45
40
35
30
25
20
15
10
5
0
Pre-Activity
Post-Activity
INV60
PF60
DF60
INV120
PF120
DF120

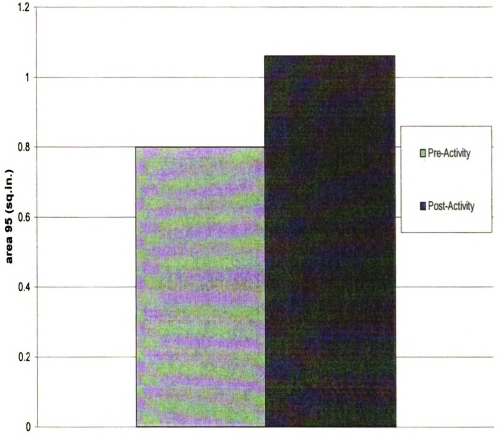
Mean Path Length Comparison for Postural Control in Females: Pre-Activity vs. Post-Activity

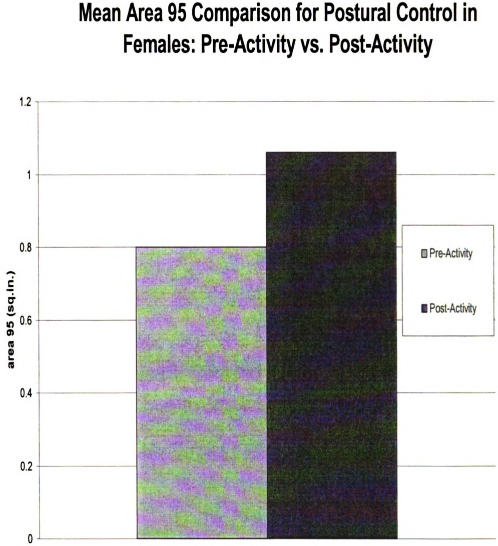


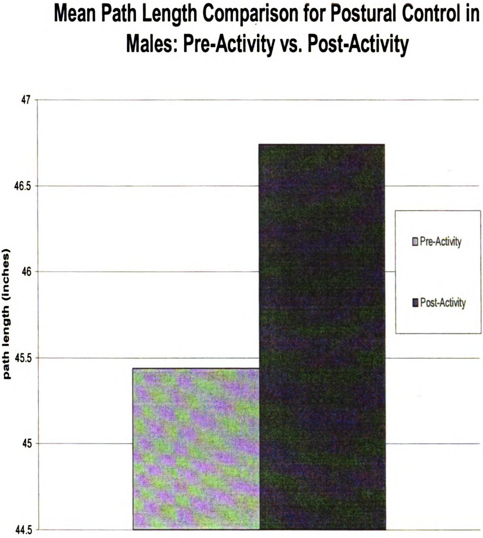
Mean Velocity Average Comparison for Postural Control in Females: Pre-Activity vs. Post-Activity



Mean Area 95 Comparison for Postural Control in Females: Pre-Activity vs. Post-Activity

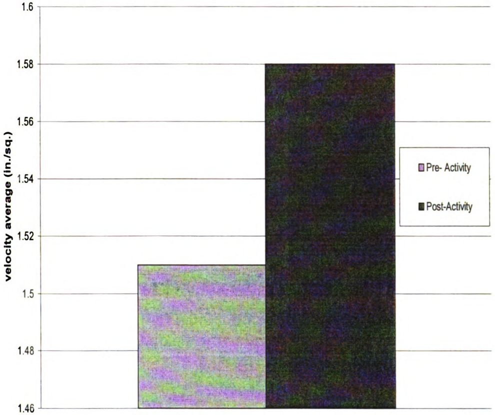



Mean Area 95 Comparison for Postural Control in Females: Pre-Activity vs. Post-Activity
1.2
1
0.8
0.6
0.4
0.2
0
area 95 (sq.in.)
Pre-Activity
Post-Activity



Mean Path Length Comparison for Postural Control in Males: Pre-Activity vs. Post-Activity
47
46.5
46
45.5
45
44.5
path length (inches)
Pre-Activity
Post-Activity

Mean Velocity Average Comparison for Postural Control in Males: Pre-Activity vs. Post-Activity



APPENDIX D

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