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The Effects of Whole Body Vibration on Dorsiflexion in Chronic Ankle Instability

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Abstract

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BACKGROUND: Whole body vibration (WBV) platforms are currently used as adjunctive training devices for exercise programs, and have been shown to facilitate flexibility. One of the biggest contributing factors to chronic ankle instability (CAI) is the lack of dorsiflexion after lateral ankle sprains and WBV may be an effective way to increase range of motion in this population. **PURPOSE**: Determine if WBV done concurrently with static stretching (SS) is more effective then SS alone in improving dorsiflexion ROM in subjects with CAI. **METHODS**: Subjects were divided into 3 groups (control, static stretch, and static stretch and vibrate). Subjects stretched 4 days/wk for 3 wks for 4 sets of 30 seconds alternating 2 different positions to stretch both the soleus and the gastrocnemius. Imposed vibration at 34 Hz 2mm during the stretches for the stretch group. **ANALYSIS**: Repeated measures ANOVA was performed using SPSS (version 19), with post-hoc Tukey tests as needed ($p<.05$). **RESULTS:** In both the straight and bent leg position, a significant group x time interaction was found for dorsiflexion range of motion. Post hoc tests revealed significance in the SV group between pre-tx and post-tx 1 and pre-tx and post-tx 2. No statistical significance was found between post-tx 1 and post-tx 2 in the SV group or at any time in the N or SS group. **DISCUSSION:** Static Stretching with vibration increases dorsiflexion ROM in subjects with CAI better than static stretching alone.

Key words: chronic ankle instability, whole body vibration, flexibility, dorsiflexion

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Introduction

Ankle sprains are the most common injury sustained during sports participation.[1-4] Lateral ankle sprains, in which the foot inverts are more prevalent than medial or eversion ankle sprains.[5] Unfortunately, up to 80% of athletes who have experienced a lateral ankle sprain will also have reoccurring sprains.[5, 6] This re-injury rate is the same even if the rehabilitation program was completed before return to activity.[7] This along with other symptomology is known as chronic ankle instability (CAI).

Chronic ankle instability can be classified as either functional and/or mechanical. Functional instability is described subjectively by the patient as the feeling of the foot "giving way" during everyday activities and insecure feelings of instability, also a negative talar tilt and anterior drawer test is present, as determined by a clinician.[8] Mechanical instability is defined as a 5 degree difference in the talar tilt test and a 4 mm side to side difference in the anterior drawer test.[9] Variable theories as to why ankle sprains reoccur include; joint,[10-12] neural deficit (such as proprioception, reflexes, reaction time),[10-13] decreased muscular,[10-12] and loss of range of motion (ROM), specifically dorsiflexion.[7,10-13] All of these occur after an ankle sprain. However, the loss of dorsiflexion ROM appears to be a main contributing factor to CAI.

A loss of dorsiflexion is one of the main contributing factors to why re-injury occurs [7,10,14,15] Leanderson et al.,[10] suggest that restricted dorsiflexion increases risk of re-injury because it does not allow the ankle to reach its maximal closed-pack position, which is considered the most stabile position of any joint. More specifically, the talocrural joint is not able to achieve normal talar arthrokinematics, giving the patient full dorsiflexion ROM.[15] Restricted movement at the accessory tibiofibular, subtalar, or midtarsal joints may also have an effect on maximum dorsiflexion.[16] Dorsiflexion ROM can be limited by many factors; adhesions in the joint after immobilization,[17,18] a positional fault of the fibula during dorsiflexion,[19] impingement caused by a decreased space in the talocrural joint,[20] restricted posterior glide of the talus on the tibia,[16] decreased proprioception/balance,[10,12,21] and inflexible muscles and dense connective tissues.[10,12,13,22]

There are many techniques and options for helping change dorsiflexion ROM. Joint mobilizations are a great tool to use to increase range of motion in any joint.[23] Surgery is drastic, but another viable option to help patients with CAI. One of those surgeries is the Brostrom repair when existing tissue is reattached or sewn together tighter. Many have linked the lack of dorsiflexion in CAI patients to gastrocnemius or soleus inflexibility.[10,12,13,22]

Stretching has been shown in many studies to be an effective way to increase flexibility of the gastrocnemius and soleus.[24-27] Guissard and Duchateu[28] reported a 30.8% increase in ankle dorsiflexion ROM after 6-weeks of performing four variable calf stretches each day for 10 minutes. Johnson et al.[25] also reported increased calf flexibility with older women who performed a standing calf stretch on both limbs for 60 seconds once per day, 5 days per week, for 6 weeks. The average increase in dorsiflexion ROM was 12.3 degrees. Likewise, Mahieu et al.[24] reported significant increases in gastroc and soleus flexibility in both static and ballistic stretch groups. However, the results of these previous studies were in varying age populations without CAI.

Recently, a few Whole Body Vibration platform training (WBV) studies have reported increases in flexibility as a result of vibration.[29-34] WBV and segmental vibration devices are relatively new and have been used successfully in increasing strength,[35-37] power[38] hormone production,[39] joint stability,[40] and flexibility.[41-46] To date there are no studies that have used a WBV platform to increase dorsiflexion ROM. Research by Pelligrini et al.[47] did have their subjects perform a stretch of the plantarflexors while using a WBV, in order to test the voluntary activitation of the plantarflexors, however, no dorsiflexion ROM was measured.

There are several mechanisms that describe why flexibility may be altered by WBV. Changes may be attributed to the opposing responses of the passive and active components of the muscle.[43] Vibration has been shown to cause vasodilation of muscle capillaries, increase blood flow and intra muscular temperature.[48] This increase in intramuscular temperature would create an atmosphere for the muscle being stretched to relax.[41] ROM may also be increased through a decrease in tissue viscosity.[43] All of these in conjunction with stretching force can increase relaxation, extensibility, and elasticity of the area being exposed to WBV and decrease pain associated with stretching.[49] Therefore, WBV may have a positive effect on dorsiflexion ROM in patients with CAI, who appear to have more factors contributing to their lack of ROM than gastrocnemius and soleus flexibility alone. Thus, the purpose of this research study was to determine if WBV done concurrently with static stretching is more effective than static stretching alone in improving dorsiflexion range of motion in subjects with chronic ankle instability.

Methods

Research Design

This study was a controlled laboratory study using a 3 x 3 repeated measures design. Subjects were randomly assigned to three groups: (N) normative group, (SS) static stretching group (stretched on the WBV platform with it turned off), and (SV) stretching and vibrating group (static stretches with simultaneous vibration). Ankle dorsiflexion ROM was measured 2 different positions (straight leg and bent knee) at 3different time periods: The first measurement was a pre-treatment measurement, the second was immediately after the first treatment to measure acute effects (post-tx 1), and the third was at the end of the 3 weeks of treatment (Post-tx 2). The independent variables are group and time. The dependent variable was passive non-weightbearing dorsiflexion range of motion.

Subjects

39 subjects (15 male and 24 female) participated in this study. Subjects were college-aged students 18-25 years of age (mean age of 22.36 +/- 2.09). Subjects had chronic ankle instability as defined by the Foot and Ankle Ability Measure (Appendix 1) and the subjective feeling of their ankle "giving way". Subjects who scored below 90% on the ADL subscale and below 80% on the sport subscale qualified as having CAI. Qualified subjects also exhibited a deficiency in dorsiflexion, which for this study was defined as less than 15 degrees passive dorsiflexion from non-weight bearing neutral in both a straight and bent knee position. Baggett and Young[50] consider a passive dorsiflexion of less than 10 degrees in a non-weight bearing position as the ROM needed for normal running. However, based on our pilot study, we chose subjects with dorsiflexion ROM of 15 degrees or less to acquire a sufficient subject population. The human subjects institutional review board of Brigham Young University approved this study. All qualified subjects signed a written consent form pertaining to testing procedures. Subjects were disqualified from the study if they missed more than 1 day of treatment. No subjects were disqualified or dropped from the study.

Instruments

1. V-Force (Dynatronics, France). This is a whole body vibration platform device with synchronized dual motors to cause a uniform vertical sinusoidal vibration. The V-Force, as listed on their website, is able to perform amplitudes 2-6 mm and pre-set frequencies ranging from 30-50 Hz.

2. The fluid filled bubble inclinometer (FFBI) This device was used for measuring passive ankle dorsiflexion ROM which, for purposes of this study was a representative of plantarflexor muscle group flexibility.[7,51]

Procedures

All subjects who met qualifying criteria reported to the lab in comfortable clothes that exposed the lower leg and no shoes. Subjects were randomly put into 1 of the 3 treatment groups. Their original measurement for qualifying criteria was used as the baseline measurement. Subjects then received their assigned treatment and were measured (post-tx 1).

Subjects followed Taylor et al.[52] treatment protocol by reporting to the lab 4 days a week for 3 weeks for their assigned protocol, with the initial treatment counting as one of those days. The vibrating groups performed 4 sets of 30-second bouts of vibration at the setting 35 Hz, low amplitude with 30-seconds between bouts. Vibration frequency and amplitude was checked in our biomechanics lab using a vicon system and found to be equal to 34 Hz 2mm, Non-vibrating groups stood on the platform 4 sets of 30 seconds with a 30-second rest in between sets. All subjects in all groups stood with their assigned foot in the middle of the WBV platform either on a 20 degree slant board (SS and SV groups) or not (N) and were asked to stand straight up with their eyes forward and hands on the rails.

Group 1: (C) Normative group. Stood on the WBV platform on one leg with the heel in the middle of the platform. This was performed in 4 sets for 30 seconds with a 30-second rest in between sets. The sets were alternated between knee fully extended and bent knee. The subjects were instructed to only slightly bend their knee and to have NO stretch occur in either position (Figure 1 & 2). The WBV platform was turned off.

Group 2: (SS) Static stretching group. Stood on the WBV platform with the ankle to be stretched in the middle of the 20 degree slant board, the heel in the middle of the platform. The subjects were instructed to lean forward until they felt a mild stretching discomfort. This was repeated for 4 sets for 30 seconds with a 30-second rest in between sets. The sets were alternated between full extension of the knee and bent knee to ensure stretch of both the soleus and gastrocnemius. There was no set angle of bent knee. It was described as the angle where mild stretching discomfort was felt. This was performed with the WBV platform turned off (Figure 3 & 4).

Group 3: (SV) Stretching and Vibrating group. The procedure was the same as the SS group except the stretches were performed with WBV turned on.

Measurements

All subjects were measured for passive ankle dorsiflexion ROM on three separate occasions in two separate positions. First; before any treatment was administered (pre-tx), second; 1 minute following the first treatment (post-tx 1), and third; 1 minute after the end of the three-week treatment period (post-tx 2). During each measurement, passive non-weightbearing dorsiflexion ROM was measured three times in both positions and then averaged. Ankle dorsiflexion was measured according to Denegar's[7] straight knee and a modified bent knee procedure to ensure both the soleus and the gastrocnemius flexibility is being measured. Each subject was fitted with a fluid filled bubble inclinometer, attached with a Velcro strap around the foot with the inclinometer over the 5th metatarsal head, facing lateral. For the straight knee, the subject laid supine on an examining table with the distal half of the lower leg extended beyond the edge of the table. Following the placement of the inclinometer, the patient was asked to relax and the examiner put the ankle joint in talar neutral position. After neutral was found the inclinometer was zeroed by rotating the degree dial until the fluid meniscus read zero. The examiner, then passively dorsiflexed the talocrural joint until a restriction was met which was indicated by a firm end point (Figure 5). The degree angle was then recorded. For the modified bent knee measure the subjects laid supine instead of prone as described by Denegar.[7] The procedures followed the straight knee procedure, except in that the subjects had a firm pillow under the distal leg to bend the knee to approximately 90 degrees (Figure 6).

Statistical Analysis

The independent variables were group and time with the dependent variables being passive non weightbearing dorsiflexion range of motion. A repeated measures ANOVA was used in SPSS (v. 19) to determine statistical significance ($p < .05$). A post-hoc tukey test was performed to detect specific significance.

Results

In the straight leg position, a significant group x time interaction ($F_{(4, 72)} = 19.856$, $p < .0001$) was found for dorsiflexion range of motion. The post hoc revealed the significance to be in the SV group between pre-tx and post-tx 1 ($p < .05$) (see Table 1) and pre-tx and post-tx 2 ($p < .05$). No statistical significance was found between post-tx 1 and post-tx 2 in the SV group or at any time in the N or SS group.

In the bent leg position, a significant group x time interaction ($F_{(4, 72)} = 7.751$, $p < .0001$) was found for dorsiflexion range of motion. The post hoc revealed the significance to be in the SV group between pre-tx and post-tx 1 ($p < .05$) (see Table 2) and pre-tx 1 and post-tx 2 ($p < .05$). No statistical significance was found between post-tx 1 and post-tx 2 in the SV group or at any time in the N or SS group.

Discussion

This research is the first of its kind to study the effects of WBV done concurrently with static stretching compared to static stretching alone on improving dorsiflexion range of motion in subjects with chronic ankle instability. The results of this study showed that only the SV group had a significant increase in dorsiflexion range of motion between the baseline measurement (pre-tx) and the first treatment (post tx-1) and after 3 weeks (post tx-2) for both straight and bent leg positions. No significant increase was found between post tx-1 and post tx-2 or in the N and SS groups. This increase in dorsiflexion ROM with SV was an expected result since many studies have reported an increase in flexibility with vibration.[30,31,35] Feland et al.[29] reported greater increases in flexibility when vibration was superimposed on static stretching, however, their study as well as other vibration and flexibility studies have primarily focused on the hamstrings in healthy populations. Studies using static stretching as a way to increase ROM of the gastrocnemius and soleus have also reported a positive correlation between stretching and increased dorsiflexion ROM.[24-27] In our study, no significant increase in dorsiflexion ROM was observed in the SS group. This non-significant increase in ROM in the SS group is interesting. According to the research, all subjects in the SS and SV groups should have increased in ROM because of the stretching element of their protocol.[26,27,29,30]

Limited DFROM has been attributed to capsular tightness due to adaptive shortening of fibrous tissue and scar tissue adhesions.[53] While most of the attention of WBV focuses on neuromuscular alterations,[35,41,46] we propose that the mechanical properties of this modality could have decreased capsular tightness. Indeed, this idea is consistent with our data. The SV group displayed significant increases in DFROM while the SS group did not. If ankle arthrokinematics were limited due to capsular tightness, then a mechanical stimulus that helped posterior glide of the talas during loaded DF could provide the needed stress to enhance normal athrokinematics and subsequent osteokinematics (DFROM). This is supported by several studies[18,23,54] that have reported enhanced DFROM following joint mobilization treatments (posterior glides) in patients following ankle injury and instability. Further, joint mobilizations with movement (ie. posterior glides with the foot in a loaded DF position) seem to be most effective for enhancing DFROM.[18,55,56] In the current study, we postulate that WBV acted as a series of high frequency oscillations at the arthrokinematic point of limitation, providing the necessary stimulus to restore normal posterior glide and subsequently, DFROM. More data are needed to confirm the idea that WBV acts as a stimulus to enhance or achieve normal ankle arthrokinematics. Other possible explanations for ROM gains secondary to WBV treatment include: an increase in blood flow and intra muscular temperature[35,41,44] and an increase in pain tolerance.[48,49] All three may have contributed to the ROM increases we observed.

Prior research has shown that WBV increases heart rate, fluid volume, blood flow velocity,and blood pressure.[48] This collectively would cause an increase in overall blood flow and local muscular temperature. Other research, not involving WBV, has found a link between increased muscle temperature and increased muscle extensibility[57] while others have found a significant increase in hip ROM when heat is applied during stretching.[26] Kerschan-Schindl et al.[48] reported a significant decrease in blood flow resistance in the popliteal artery after 9 minutes of WBV with the number of distinctly visual vessels significantly increased in both the quadricep and gastroncnemius muscles, with the gastroncnemius having a greater difference. They cited the effect to be due to vasodilation and thixotropism for reducing the viscosity of the blood and improving the mean speed of blood flow. This increase in blood flow and temperature to the surrounding muscles and joint capsule may have contributed to the increase in ROM observed here, although we did not measure temperature to verify if an increase actually did occur.

Pain tolerance has been shown to increase through WBV and/or flexibility training[48,49] and result in an increase in range of motion. Issurin et al.[41] noted that their subjects had a reduction in pain sensation 10-15 s after the beginning of a static stretching during vibration protocol. Robot-Cisar et al.[49] believes this increase in pain tolerance may be due to a decrease in the spontaneous firing rate of muscle spindles' primary endings originating from the tibialis anterior, extensor digitorum longus, and lateral peroneal muscles. Other research using a variety of frequencies found that frequencies ranging from 20-230 hz were found to interfere with A and C nociceptors.[58] Both are responsible for sharp ("first") pain and dull ("second") burning pain. The possibility that WBV also increased blood flow and tissue temperature could also have affected the perception of pain.[59] Anecdotally, many of the subjects in our study did verbally state that they had a decrease in pain in or around their ankle. Oscillating joint mobilizations (grade I and II) have been shown[39] to decrease pain with low amplitude mobilizations. This possible modification in pain tolerance associated with WBV warrants further investigation.

Subjects used in our study were suffering from CAI and started at a less than normal DFROM.[50] This reduced DFROM could be related to a complex interplay of; tight gastrocnemius and soleus,[10,12,13,22] altered athrokinematics of the talocrual joint,[16,60] and joint adhesions.[17,53] Our only form of measurement in this study was dorsiflexion ROM, which may reflect changes to any of these, but is not sensitive enough to detect which structures would have changed to contribute to the results seen.

Hypomobility of the ankle is commonly seen after an ankle sprain and in patients with chronic ankle instability. While limited DFROM may be attributed to factors previously discussed, gastrocnemius and soleus tightness may also play a significant role.[7,10,14,15] Many studies have found a significant increase in dorsiflexion ROM following a stretching protocol in healthy ankles and in ankles with a decreased dorsiflexion ROM (but without having CAI).[24,25,28,61] Prior research performed on elderly women with a less than normal dorsiflexion ROM (average -11.1 degrees) displayed a statistical 12.3 degree increase in ROM following a 6 week stretching protocol.[25] Guissard and Duchateau[28] also found a significant increase in dorsiflexion ROM following a 6 week stretching protocol. Subjects increased by 30.8% in ROM with 56% of that coming in just the first 10 sessions (3 weeks).

The important implication of this study is that stretching and vibrating concurrently increase dorsiflexion ROM more than static stretching alone in participants with CAI. This research is limited to a population 18-25 years old and a protocol of 4 sets of 30 second stretches at a frequency of 34 hz at 2 mm amplitude on a vertical vibration platform. Further research should be performed at different amplitudes, frequencies, time durations, and ages to see if results vary. Also, varying degrees of slant boards should be given so each subject can use the appropriate board to get the feeling of "slight discomfort" that should be felt while stretching. Many studies have been done on WBV and its effects on flexibility but the variation of parameters and kinds of vibration devices (localized vibration, specially built vibrating modules, vibrating cables, oscillating or vertical vibration) varies widely. Also, more data need to be collected to confirm the idea that WBV acted as a mechanical stimulus to restore normal ankle arthrokinematics.

Conclusions

Our hypothesis that WBV with static stretching is more effective at increasing dorsiflexion ROM in subjects with CAI than stretching alone was supported. However, SS did not show a significant increase in dorsiflexion ROM in subjects with CAI. Mechanical effects of vibration at the arthrokinematic point of limitation could explain the increased dorsiflexion ROM in patients with CAI, although further studies are needed to verify this hypothesis. Increased DFROM may help reduce ankle sprain occurrences in patients with CAI.

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Figure 1

Figure 2

Figure 3

Figure 4

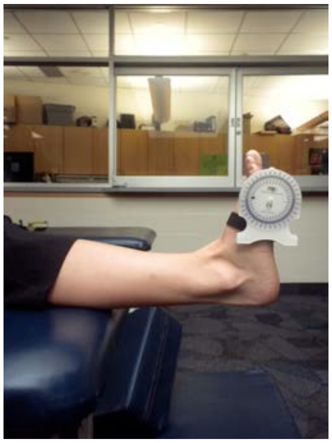


Figure 5

Figure 6

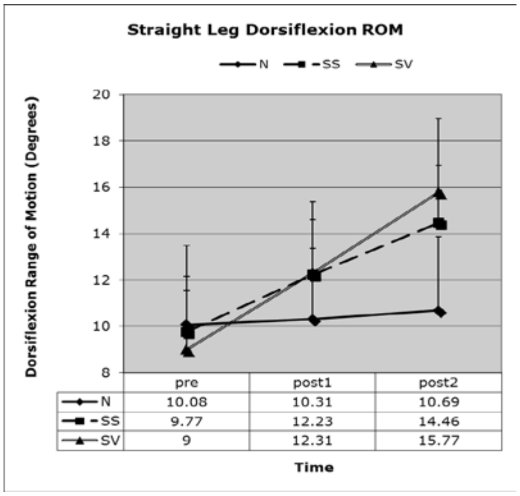


Table 1

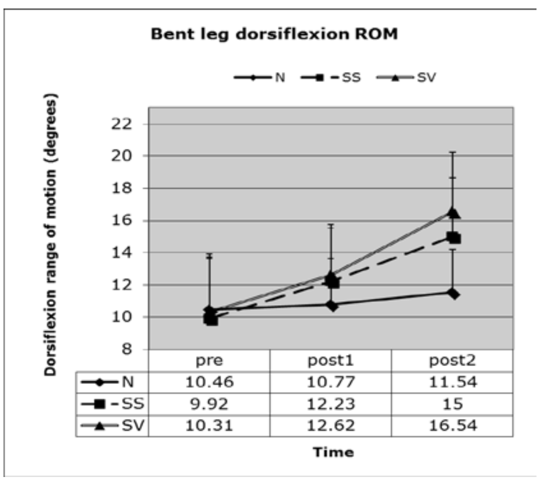


Table 2

Appendix A Prospectus

Chapter 1

Introduction

Ankle sprains are the most common injury sustained during sports participation.[1-4] Lateral ankle sprains, in which the foot inverts are more prevalent than medial or eversion ankle sprain.[5] The rehabilitation of ankle sprains is usually strenuous and return to activity is often accomplished before the ankle is fully recovered. Unfortunately, up to 80% of athletes who have experienced a lateral ankle sprain will also have reoccurring sprains.[5,6] This along with other symptomology is known as chronic ankle instability (CAI). This re-injury rate is the same even if the rehabilitation program was completed before return to activity.[7]

Chronic ankle instability can be classified as either functional and/or mechanical. Functional instability is described subjectively by the patient as the feeling of the foot "giving way" during everyday activities and insecure feelings of instability, also a negative talar tilt and anterior drawer test is present, as determined by a clinician.[8] Mechanical instability is defined as a 5 degree difference in the talar tilt test and a 4 mm side to side difference in the anterior drawer test.[9] Variable theories as to why ankle sprains repeat after acquiring the first include; joint laxity, neural deficit (such as proprioception, reflexes, reaction time), decreased muscular strength, loss of range of motion, specifically dorsiflexion.[7,10-13] All of these occur after an ankle sprain. However, the loss of dorsiflexion appears to be a main contributing factor to CAI.

A loss of dorsiflexion is one of the main contributing factors to why re-injury occurs.[7,12,14,15] Leanderson et al.[12] suggest that restricted dorsiflexion increases risk of re-injury because it does not allow the ankle to reach its maximal closed-pack position, which is considered the most stabile position of any joint. More specifically, the talocrural joint is not able to go through its normal arthrokinematics of the talus posteriorly gliding on the tibia, giving the patient full dorsiflexion ROM.[15] Restricted movement at the accessory tibiofibular, subtalar, or midtarsal joints may also have an effect on maximum dorsiflexion.[7] Dorsiflexion ROM can be limited by many factors, adhesions in the joint after immobilization,[16,17] a positional fault of the fibula during dorsiflexion,[18] impingement caused by a decreased space in the talocrural joint,[19] restricted posterior glide of the talus on the tibia,[20] decreased proprioception/balance,[11,12,21] and inflexible muscles and dense connective tissues.[11-13,22]

There are many techniques and options for helping change dorsiflexion ROM. Joint mobilizations are a great tool to use to increase range of motion in any joint.[23] Surgery is drastic but yet another option to help patients with CAI. One of those surgeries is the Brostrom repair when exiting tissue is reattached or sewn together tighter. Many have linked the lack of dorsiflexion in CAI patients to gastrocnemius or soleus inflexibility.[11-13,22] Stretching is a way to maintain and/or increase ROM in muscles.[24-27] Guissard and Duchateu[28] reported a 30.8% increase in ankle dorsiflexion ROM after 6-weeks of performing four variable calf stretches each day for 10 minutes. Johnson et al.[25] also reported increased calf flexibility with older women who performed a standing calf stretch on both limbs for 60 seconds once per day, 5 days per week, for 6 weeks. The average increase in dorsiflexion ROM was 12.3 degrees. Mahieu et al.[24] results also agree with the previous. Ninety-six volunteers were put into one of three groups: static-stretch, ballistic stretch, control. Both stretching groups were asked to stretch their calf muscles every day (5 sets of 20 seconds) for 6 weeks. Static stretching group performed a classic standing wall push on both legs while the ballistic group performed the same stretching but moved up and down. Both groups showed a significant increase in dorsiflexion ROM with the knee flexed and extended.

Recently, a few Whole Body Vibration training (WBV) studies have reported increases in flexibility as a result of the vibration.[29-33] WBV is a relatively new device that has been used successfully in increasing strength,[34-36] power,[37,38] hormone production,[39] joint stability,[40] and flexibility.[41-46] To date there are no studies that have used a WBV platform in order to increase dorsiflexion ROM. Research by Pelligrini et al.[47] did have their subjects perform a stretch of the plantarflexors while using a WBV, in order to test the voluntary activitation of the plantarflexors. No dorsiflexion ROM was measured.

There are several mechanisms that describe why flexibility may be altered by WBV. Changes may be attributed to the opposing responses of the passive and active components of the muscle[43] Vibration has been shown to cause vasodiliation of muscle capillaries, increase blood flow and intra muscular temperature.[48] This increase in intramuscular temperature would create an atmosphere for the muscle being stretched to relax.[41] ROM may also be increased through a decrease in tissue viscosity,[49] an increase the tonic vibration reflex(TVR)[50] leading to a decreased braking force around the joints.[46] The TVR will also increase recruitment of the motor units through activation of muscle spindles and polysynaptic pathways.[51] All of these in conjunction with stretching force can increase relaxation, extensibility, and elasticity of the area being exposed to WBV and decrease pain associated with stretching,[52] therefore increase flexibility. Therefore, WBV may have a positive effect on dorsiflexion ROM in patients with CAI.

Purpose statement

The purpose of this research is to determine if WBV done concurrently with static stretching is more effective than static stretching alone in improving dorsiflexion range of motion in subjects with chronic ankle instability.

Null hypothesis

The following null hypothesis will be tested:

There will be no difference in dorsiflexion range of motion improvement between the static stretching and vibration/static stretching groups.

Delimitations

This study will be delimited to:

1. Patients with chronic ankle instability as defined by the Foot and Ankle Disability Index (Sport)
2. Patients found on the BYU campus and in varsity athletics and exercise classes
3. Most likely all Caucasian
4. Stretching for 4 days a week for 3 weeks

Limitations

1. Results are limited to the **V force m**achine only and not other WBV platforms
2. Results will be limited to similar populations only

Disqualifications

1. Current ankle pain
2. Do not pass the FAAM
3. Do not have a dorsiflexion of less than 15 degrees in straight knee and bent knee position
4. Surgery in either ankle
5. Sprained ankle in the last 6 months
6. Has not been experiencing CAI for at least 1 year
7. If subjects miss more than 1 treatment day during the study

Operational definitions

Chronic ankle instability- An encompassing term used to classify a subject with both mechanical and functional instability of the ankle joint. To be classified as having chronic ankle instability, residual symptoms ("giving way and feelings of ankle join instability) should be present for a minimum of 1 yr post-initial sprain.

Functional instability – refers to the situation whereby a subject reports experiencing frequent episodes of "giving way" of the ankle joint and feelings of ankle joint instability with a negative talar tilt and anterior drawer as determined by a clinician.

Giving way - the regular occurrence of uncontrolled and unpredictable episodes of excessive inversion of the rear foot, which do not result in an acute later ankle sprain.

Foot and Ankle Ability Measure (FAAM) – self-reported evaluative instrument that comprehensively assesses physical function of individuals with musculoskeletal disorders of the leg, foot, and ankle. FAAM ADL- assesses function of activities of daily living. FAAM sport – assesses function of patient with higher levels of ability.

Whole- body vibration - Whole-body vibration, achieved by standing on a vibrating platform at various frequencies and amplitudes.

V- force (Dynatronics, France)- A vibrating platform which uses vertical sinusoidal vibration through dual synchronized motors to decrease horizontal amplitudes.

Static Stretching- Stretching to mild discomfort and holding the position for a set period of time.

Significance of Study

In the athletic population sprained ankles are frequent and often take the athlete out of practice. Once a sprained ankle occurs, 80% of people re-sprain it even when they have completed a rehabilitation program. This chronic ankle instability that occurs has not been able to be overcome yet. The effect of whole body vibration on dorsiflexion in chronic ankle instability will be studied to see if it increases dorsiflexion flexibility. With this increase in flexibility, it is hoped that reoccurring ankle sprains will decrease in the CAI population.

Chapter 2

Review of the literature

Ankle sprains are the most common injury sustained during sports participation. When athletes return to activity before the ankle is completely healed, re injury occurs in 80 percent. Chronic ankle instability (CAI) is the name given to this phenomenon. One of the biggest contributing factors to CAI is the lack of dorsiflexion that returns after the injury. Whole body vibration (WBV) platforms are relatively new devices used in clinical settings everywhere. Recently, much research has been done on the device to see benefits in the areas of strength, power, bone density, and proprioception. Flexibility and the use of WBV as a rehabilitation tool or preventative method has been shown to increase flexibility in muscles but has received less attention compared to the previously stated areas. This increase in flexibility may help with CAI. Therefore, the purpose of this research is to study the effects of whole-body vibration on dorsiflexion in chronic ankle instability.

Chronic Ankle Instability

Ankle sprains are the most common injury sustained during sports participation.[1-4] Lateral ankle sprains, in which the foot inverts is more prevalent than medial ankle sprains, which results from an eversion movement.[5] Ankle sprains can take from 1 to 3 weeks to completely overcome the ill effects felt from it i.e. decreased proprioception, range of motion and neuromuscular control, and increased joint laxity.[53] The rehabilitation of ankle sprains is usually strenuous and return to activity is often accomplished before the ankle is fully recovered. Unfortunately, up to 80% of athletes who have experienced a lateral ankle sprain will have it reoccur again,[5,6] often times more than once. This, along with other symptomology is known as chronic ankle instability (CAI). This re-injury rate is the same even if the rehabilitation program was completed before return to activity.[20]

Classification of CAI

Mechanical instability

Ankle instability can be classified as either mechanical and/or functional. Mechanical instability (MI) is defined specifically as a 5 degree difference in the talar tilt test and a 4 mm side to side difference in the anterior drawer test compared to the normal ankle.[9] Tropp et al.,[54] defines MI as ankle joint motion that exceeds normal physiological range and is described more generally as any abnormal mechanics in the ankle that causes hypomobility or hypermobility.[55]

Hypomobility may be a predisposing factor in the development of CAI and can be in the form of physiological or arthrokinematic impairments. Hypomobility can be assessed through manual testing such as range of motion tests and most commonly a lack of dorsiflexion is found. Although stretching of the gastrocnemius and soleus in rehabilitation has been found to increase range of motion, some attributes the loss to the inability of the accessory movements to occur properly.[56]

The hypermobility that occurs in the joint refers to the increased laxity of the ankle due to structural, mainly ligament, damage that occurs after a lateral ankle sprain occurs. Hypermobility can be demonstrated with manual stress tests such as the talar tilt and anterior drawer. These tests test the integrity of anterior talofibular ligament and the calcaneofibular ligament, which both give stability to the talocrural joint.[57] When both of these ligaments are damage, the talocrural joint mechanics are changed and allows for more movement in the accessory. An increase in the accessory movement in the joint may increase the neutral zone of the joint.[58] The neutral zone as described by Panjabi,[58] is "the area of a joint that accessory movement is possible without ligamentous tensioning." This is when greater strain may be put on the already injured ligaments. The subtalar joint is also affected by hypermobility following lateral ankle sprain. Because the subtalar joint is so complex and has a triplanar motion, it is difficult for many to assess dysfunctions in it. Hertel[59] was able to examine talocrural laxity as well as subtalar laxity in a study of subjects with a history of lateral ankle instability. It was reported that 7 of the 12 subjects had subtalar joint instability. Most individuals that experience recurrent lateral ankle sprains do not have laxity in their joint,[11] These individuals are thought to be suffering from functional instability.

Functional instability

Functional instability is described subjectively by the patient as the feeling of the foot "giving way" during everyday activities, insecurities, and feelings of instability in the ankle in combination with a negative talar tilt and anterior drawer test determined by a clinician.[8] Delahunt et al.[60] defined "giving way" as, the regular occurrence of uncontrolled and unpredictable episodes of excessive inversion of the rear foot, which do not result in an acute lateral ankle sprain. When lateral ankle sprains occur, the sensory receptors in the lateral ligaments are disrupted and their ability to sense changes in joint position, or proprioception, is decreased.[11] These sensory receptors, or mechanoreceptors, are most active at the end of range of motion. Hertel[11] explains, as an ankle is inverting and close to being sprained, afferent signals are sent to the spinal cord, which then responds and sends efferent signals to the peroneal muscles to contract in an effort to slow down the inversion and prevent a lateral ankle sprain. When ankle sprain occurs, if proper rehabilitation has taken place, the lateral ligaments and muscles will heal strong and well. However, very little research has been done to see how the mechanoreceptors heal. This is why an ankle may feel mechanically stable but it is still unable to assess joint position. Hertel[11] also lists five other ways functional instability may be shown in individuals; balance deficits, joint position sense deficits, delayed peroneal muscle reaction time, strength deficits, and decreased dorsiflexion range of motion. The inability to maintain single leg balance following a lateral ankle sprain has been found and researched by many. An increase in postural sway has been found as the most common balance parameter to be effected.[11] Postural sway is defined as the deviation from the mean centre pressure of the foot for a given trial. It is hypothesized that this change is weight distribution in the foot may lead to recurrent lateral ankle sprain.[61] Leanderson et al.[12] used thirty-eight male basketball players to study the relation between postural sway and previous ankle injury. Postural sway was measured with stabilometry and subjects were asked to stand on one leg while mean sway amplitude was measured in the sagittal and lateral direction as well as total sway area. Twenty-nine of the basketball players had reported earlier ankle sprains of both ankles while five had only inured one and four stated they had never injured an ankle. All of the players with a previously injured ankle showed stabilometry results that differed significantly from the control group. Those players had a larger mean sway and used a larger area.

Joint position sense deficits have also been shown to increase the risk of lateral ankle sprain. Joint position sense is also known as proprioception and is defined as the ability to match reference joint angles without visual feedback. Payne et al.[13] researched to see if ankle muscular strength and proprioception can predict ankle sprains in college basketball players. An electric goniometer was used in measuring proprioception. Subject's eyes were closed during testing and completed 12 trials and 3 different angles of inversion, eversion, dorsiflexion, and plantarflexion. The experimenter put the subject's ankles in a selected degree position, asked the subject to hold it and remember the position, and the experimenter returned it to neutral. The subject was then asked to repeat the position. The scored was obtained by the deviation from the referenced joint position and was recorded as an absolute error. Left inversion proprioception was the lone predictor of left ankle injury in all subjects, explaining 14.59% of variance. Left inversion and right dorsiflexion proprioception were predictors of left ankle injury in the female accounting for 37.71% of the variance. Payne et al.[13] noted that the contralateral limb explained variance in the involved limb. They were not surprised at this finding because it may explain that one unstable limb might affect how the athlete reacts to situations and cause stress on the opposite limb in an effort to avoid use of the unstable limb.

Delayed peroneal reaction time may come from the disruption of the mechanoreceptors in the ankle following a lateral ankle sprain.[11] The peroneal muscles are the first muscles to react to a sudden ankle inversion and thus are vital to controlling dynamic stability of the ankle complex. Many suggest that this delay is the cause of functional instability following lateral ankle sprain.[62,63] Konradsen and Ravn[62] used a trapdoor that was able to suddenly tilt at 30 degrees to simulate an ankle sprain event. Thirty active soccer and cross-country runners were equipped with surface electromyographic electrodes on their peroneal longus and brevis. These were used to measure the reaction time (from trap door open to the first muscular response). Fifteen of these athletes had complaints of ankle instability and used tape or braces when they participated in sports. The unstable ankles were found to have a prolonged reaction time (median 84 ms) compared to stable ankles (69 ms).

A strength deficit in the muscles that evert or pronate the ankle has been shown to be a contributing factor to functional instability also.[64] The primary everters of the ankle are the peroneus longus and brevis muscles. The importance of these muscles were demonstrated by Ashton-Miller et al.[65] when they showed that the peroneal muscles are more important and can produce greater force at the ankle than an ankle brace, taping, or orthodics. Tropp[64] used fifteen soccer and cross-country athletes who had all experienced unilateral FI of the ankle and measured the muscle torque of their pronators with an isokinetic dynamometer. All subjects were asked to supinate the foot maximally and then to pronate it with maximum force. The peak torque was analyzed and found to be less in the ankles with FI. Which according to Tropp[64] confirms an earlier theory that peroneal muscle weakness is a component of FI of the ankle joint.

Decreased dorsiflexion range of motion is the last factor that Hertel[11] states contributes most to functional instability following lateral ankle sprain and will be discussed further later on.

Dorsiflexion measurement techniques

Ankle joint dorsiflexion range of motion is done often in clinics and in sports medicine departments as part of lower extremity examinations for the assessment of dysfunctions in the lower leg.[66] However, measurement error is a real problem when attempting to measure the range of motion of the ankle joint.[67] There are many sources of variation that may attribute to measurement error: improper positioning of the goniometer, identifying anatomical landmarks incorrectly, the visual bisection of the bones, and the marking of the bisection lines.[68] Dorsiflexion in the ankle is typically measured using anatomical surface locations that are proximal and distal to the joint. Proximally, the shaft of the fibula is used to align one arm of the goniometer and distally many marks may be used. Root et al.[69] has proposed going beneath the fifth metatarsal head as a landmark. Others have suggested being parallel to the fifth metatarsal or while the patient is weightbearing, using the floor while the patient leans anteriorly with their foot flat as a landmark.[70] There is also some debate at the appropriate stance the subject should take when measuring dorsiflexion. Some measure it while the knee is flexed at 90 degrees and some do with the knee fully extended.[71] Tiberio[72] suggests that measuring dorsiflexion is best done in a fully extended knee position. This is because when a person is walking, the stance they are in just before toe off, which is when full dorsiflexion takes place, the knee is fully extended. It is seen as a better way to relate to life. There is also the question of position the subject should take; standing, seated, prone, supine.[66,70,72] Making sure all the subjects start at the same zero is also very important when comparing dorsiflexion range of motion. The Neutral Zero Method, recommended by the American Academy of Orthopaedic Surgeons,[73] is used to define a zero for each joint. In the ankle it corresponds with the leg at right angles to the thigh and the foot at right angles to the leg. Root et al.,[69] suggests that the ankle joint should neither be inverted nor everted, or subtalar neutral position. Woodburn[66] agrees and states that when a measure of dorsiflexion is needed, the measurement should be taken in subtalar neutral position. Once the details of positions are determined a form of measuring dorsiflexion needs to be decided.

The fluid filled bubble inclinometer (FFBI) was previously found reliable by Rome and Cowieson[68]. Denegar[7] described and used this technique while performing a standing bent knee and standing straight knee position. Both measurements were taken with the FFBI secured on a custom made Velcro strap and was placed just above the talocrural joint and around the subject's lower leg, with the FFBI facing the lateral direction. The subjects were asked to stand on the examining table with the feet shoulder width apart and relaxed in order to zero the FFBI. Standing bent knee was measured after the subject was instructed to slowly perform a single leg squat by flexing the hip and knee joints. A pole was used to help maintain balance. The measurement was taken once the subject's heel came off the examining table or once the subject couldn't lower her or himself more. For the standing straight knee, for the ankle to be measured the knee joint was in full extension posterior to the body and the other foot in front. The foot of the limb to be tested was parallel with the long axis of the lower leg in the transverse plane making sure to not be internally or externally rotated and the ankle in neutral position being neither inverted nor everted. The subject was instructed to keep the knee of the posterior leg in extension while slowly leaning forward. The measurement was taken once the subjects heel started to rise off the table.

Rome et al.[68] used a flexible electrogoniometer to measure dorsiflexion in ankles in order to see if it was reliable. A flexible electrogoniometer consists of a flexible measuring strain gauge steel strip mounted between two plastic end blocks, one fixed and the other telescoping on a light spring. The device is designed to measure the angular displacement between the end locks in one or two planes. All subjects were in a reclined, fully supine position on a padded examination couch. The position of the ankle when placed in the block was defined as the ankle-joint zero position. The electrogoniometer was found to be within an accepted criterion for reliability, which suggests intradevice reliability.

CAI instability instruments

With the lack of a fully enveloped test to categorize ankle instability, Docherty et al.[74] developed the Ankle Instability Instrument. The Instrument/survey allows the clinician to be consistent in their evaluation of CAI and it may give a head start on where the rehabilitation should go. The instrument asks questions to determine what may be causing the ankle to “give way”. The three factors they have used are severity of initial ankle sprain, history of ankle instability, and instability during activities of daily life. The Ankle Instability Instrument created by Docherty et al. was found to be highly reliable.

The Foot and Ankle Disability Index (FADI) developed by Martin et al.[75] was designed to assess functional limitations related to foot and ankle conditions. The Foot and Ankle Disability Index Sport was then developed to be able to detect deficits in patients that are on the high end of normal function, these patients being athletes. Hale and Hertel,[76] found that the use of these tests for athletes to be reliable in detecting functional limitations in subjects with CAI, sensitive to differences between healthy subjects and subjects with CAI, and sensitive to improvements in function after rehabilitation in subjects with CAI.

The Foot and Ankle Ability Measure (FAAM) was developed by Martin et al.[77] It was developed in order to "meet the need for a self-reported evaluative instrument that comprehensively assesses physical function of individuals with musculoskeletal disorders of the leg, foot, and ankle." Like the FADI, there is also a sport scale to test the individuals that are at higher levels of ability. The FAAM was developed using four steps, 1) generation of potential items, which were put together by physical therapist 2) Initial item reduction by clinicians form the American Physical Therapy Association and the Foot and Ankle Special Interest Group 3) Final Item reduction done by using psycometric procedures involving the Item Response Theory (IRT). The FAAM is different from other CAI instability instruments because of the IRT. The concept behind IRT is the probability of choosing a response for each item is a function of the subject's or patient's ability and the difficult level of each item.[78] Martin et al.[77] states that an appropriate evaluative instrument should contain items that are both easy and more challenging for the individual to perform. The fourth step was to measure the validity of the scores. Through a series of statistical analysis, the FAAM was found to be reliable, valid, and responsive measure of self-reported physical function for individuals participating in physical therapy, with or without operative intervention, for a broad range of musculoskeletal disorders of the leg, foot, and ankle. It was also found to have high correlations with concurrent measures of physical function and relatively low correlations with concurrent measure of mental health. The FAAM (Survey 1) is scored by using the Likert scale with 4 being no difficulty and 0 unable to do.

Score totals may range for 0-84 in the ADI and 0-32 in the sport. These scores are transformed into percentages, with a higher percentage meaning higher level of function. The subjects also complete a global rating of function scale with an overall percentage of function 0 (no ability to perform) – 100% (level of function before injury). Participants may also rate their ankles as normal, nearly normal, abnormal, or severely abnormal.

Loss of Dorsiflexion

Many have theories as to why ankle sprains repeat after acquiring the first; joint laxity, neural deficit (such as proprioception, reflexes, reaction time), decreased muscular strength, and loss of range of motion, specifically dorsiflexion. However, many think the loss of dorsiflexion is a main contributing factor to CAI.

A loss of dorsiflexion is one of the main contributing factors to why re-injury occurs[7,12,14,15]It is suggest that restricted dorsiflexion increases risk of re-injury because it does not allow the ankle to reach its maximal closed-pack position, which is considered the most stable position of any joint, when the bones have the most contact. More specifically, the talocrural joint is not able to go through its normal arthrokinematics of the talus posteriorly gliding on the tibia, giving the patient full dorsiflexion ROM.[15] Restricted movement at the accessory tibiofibular, subtalar, or midtarsal joints may also have an effect on maximum dorsiflexion.[7] There are many techniques and options for helping change dorsiflexion ROM.

Increasing dorsiflexion: Techniques

Joint mobilizations are a great tool to use to increase range of motion in any joint. The ankle is no different. "Joint mobilization is the use of gentle oscillating movements of the articular surfaces of a joint that create the movement of the joints by a means other than the musculotendinous units that normally act on those particular segments".[23] Joint mobilizations are thought to relieve pain and increase range of motion by using different amplitudes as described by Maitland's[79] classification. One of the reasons dorsiflexion may be affected after LAS or immobilization is the inability of the talus to glide posteriorly on the tibia. Joint mobilizations are thought to correct the positional fault in which the talus is subluxated anteriorly on the tibia.[18] After an ankle is immobilized, an extreme loss of dorsiflexion is noted.[23] When Maitland grade III anterior-to-posterior talocrural joint mobilizations are applied to such ankles, dorsiflexion was found to increase significantly. Joint mobilizations to the distal tibiofibular joint with the use of the cyclic load-simulating oscillatory gliding technique was found to also increase significantly.[80-82] Surgery is drastic but yet another option to help patients with CAI. One of those surgeries is the Brostrom repair. The Brostrom repair is when the existing anatomical tissue is reattached when disrupted, or sewn tighter to increase ankle instability. 26 years after a Brostrom repair for CAI, subjects reported a 1 out of 4 grade for them being full activity, including strenuous sports activities and their ankle having no pain, swelling, or giving way.[83]

Many have linked the lack of dorsiflexion in CAI patients to gastrocnemius or soleus inflexibility.[12,13,84,85] Stretching is a great way of maintaining length or elongating connective tissue of any muscle. The tension that develops in a non contractile muscle during passive stretching, is thought to be a result of a series of elastic and parallel elastic connective tissue elements of skeletal muscle.[86] Many have found a benefit of stretching and increasing ROM in muscles.[24,25,27,87] Stretching the calf muscle tendon unit is done by maximally dorsiflexing the foot and the knee in full extension. When this position was held for 5 minutes an increase in active dorsiflexion ROM was found.[88] Similarly, when stretched for 60 seconds and repeated 4 times once per day, 5 times a week for 6 weeks, a statistically significant increase was found 3 days after last treatment.[25] Youdas et al.[89] believes the lack of dorsiflexion is a result of an antalgic gait pattern resulting from the injury. Subjects were included that had sustained a lateral ankle sprain within the last 96 hours. Maximum active ankle dorsiflexion range of motion (AADFROM) was measured using a goniometry. This method was used to inhibit the calf muscle tendon unit through reciprocal inhibition. Subjects were placed in 3 groups. All stretching 3 times a day 5 times a week for 6 weeks with measures at 2, 4 and 6 weeks. Group 1 stretched for 30 seconds, two at 1 minute 30 seconds, and 3 at 2 minutes. All participated in a home exercise program. At baseline measurement all groups could not reach neutral position of 0 degrees. After 6 weeks all groups showed a significant increase ($p < .05$) in AADFROM.

Some have successfully used a vibratory device known as Whole Body Vibration (WBV) to increase range of motion while stretching.[41-46]

History of whole-body vibration

WBV is a relatively new vibratory device that has been used successfully in increasing strength,[34-36] power,[37,38] hormone production,[39] joint stability,[40] and flexibility.[41-46] However, Whole-body vibration was not always thought of as a beneficial health tool.

Bovenzi and Betta[90] performed an epidemiological study on the prevalence and relationship of low back pain and whole body vibration in tractor drivers. Out of the 1402 tractor drivers registered at the trade association only 1155 were interviewed. All were given the Standardized Nordic Questionnaire on musculoskeletal symptoms and were categorized into 9 groups (Back pain, low back pain, transient low back pain, chronic low back pain, sciatic pain, acute low back pain, treated low back pain, sick leave, and disc protrusion). Vibrations were measured on the seat pan of the tractors while they were in operation. Vibrating magnitude (years of driving) and total vibration dose (daily exposure to WBV) was also measured.

Vibration exposure was found to be one of the most important factors in predicting the occurrence of lifetime, transient, and chronic low back pain. The tractor drivers, compared to the control group, had a significant trend for an increased occurrence of lifetime low back pain, sciatic pain, and acute low back pain when total driving hours increased. Low back pain symptoms and vibration dose also had a positive relationship.

Segmental vibration and flexibility

There are several mechanisms that describe why flexibility may be altered by WBV. Vibration has been shown to, decrease pain and increase blood flow,[48] which in turn would increase the temperature of the area, and create an atmosphere for the muscle being stretched to relax.[41] Issurin and Liebermann et al.[41] took 28 healthy physically active males and found an increase in flexibility during vibratory stimulation. The flexibility group performed one leg stretching exercises where the leg was placed in a ring that was attached to a pulley system that went through a vibratory stimulation device. Flexibility was measured pre and post-test using a two leg split measurement and the flex and reach test. A significant difference was found between pre and post as well as treatment and control in both tests. These increases in flexibility are mainly attributed to the reduction in pain during the stretch. The subjects reported a decrease in pain 10-15 seconds after the vibratory stimulation was applied. Issurin and Liebermann et al.[41] hypothesized that the stimulation of the golgi tendon organ assisted in the increased flexibility. With the golgi tendon organ being excited, an inhibition contraction occurred followed by a relaxation of the muscle.

Atha and Wheatley[42] found that low frequency vibration and stretching exercises have the same effect on flexibility in the hip joint. Forty-two health young adult males were randomly sampled and were randomly given three mobilizing treatments to perform, one to be performed on each of 3 days. The first treatment was a low frequency (44Hz) cushion, second was the exercise program that consisted of four active stretching exercises repeated 10 times, and third control when they rested for 15 minutes in a chair. Before and after each treatment hip flexion was measured with a sit and reach test. It was found statistically significant that both experimental groups had an increase in hip mobility as compared to the control group. However, there was not a statistical significance between the two groups. They concluded that their active stretching exercises had the same effect in young healthy males as sitting in a chair while the hip is being vibrated. Even though, exercise would be the preferred method of increasing flexibility in a joint, having the ability to complete the same task with those that are unable to be mobile or active is very important.

Although there are many studies that support the use of WBV in increasing extensibility and elasticity, there are many that contradict these findings. This is mainly due to the differences of methods used. Because WBV is relatively new, there is not a set program or parameters when using the platform to really know what frequency (Hz), amplitude, acceleration, or time is best for accomplishing different tasks. Table 1 lists some studies on whole body vibration along with the frequency, amplitude, acceleration, treatment time, and results. Cronin et al.[43] looked into four different settings on a segmental vibratory machine. A segmental vibratory machine allows vibration in certain areas rather than the whole body. Each setting had its own set acceleration, amplitude, and frequency. Each subject was measured for hamstring range of motion (ROM), vibrated their hamstring without a stretch at each setting, and was then re-measured. A significant increase in hamstring ROM was found in settings 2-4 (24-44 Hz). However, the subjects did not stretch and vibrate at the same time, which has been found to increase flexibility even more.[44,45]

Sands et al.[44] used a different method, stretching and vibrating at the same time, to increase flexibility in young highly trained gymnasts both short and long term by using a segmental vibrating device. The athletes either stretched while vibrating or stretched alone. A significant difference ($p>0.05$) was found in both acute and long-term (4 wks) groups. This was very surprising, especially since the gymnasts were thought to already be at their biggest ROM prior to the study. Three subjects however, in the long-term study, only one leg had a significant increase in ROM pre to post test. Kinser et al.[45] performed a similar study but in female gymnasts. It was also found that vibration while stretching increased ROM in the forward split more than stretching alone. Even though these studies do show an increase in range of motion, the devices they used were not whole-body vibration.

Whole-Body Vibration platforms and flexibility

WBV platforms are a platform that can either vibrate simultaneously in a vertical direction or have a side-to-side alternating vertical sinusoidal vibration.[31] When comparing studies it is important to compare the results with what kind of vibration was administered and not just by amplitude and frequency. Gerodimos et al.[31] was the first to use a side-to side alternating vertical sinusoidal vibration platform to compare the effects of amplitude and frequency of a single bout of WBV on flexibility and jumping performance.

Twenty-five females participated in the effect of amplitude and eighteen participated in the second to examine the effects of frequency. The amplitude study performed three vibration protocols at a frequency of 25 Hz and amplitudes of 4 mm, 6 mm, 8mm with one control for 6 minutes. The frequency study included three vibration protocols at 15 Hz, 20 Hz, and 30 Hz with 6 mm amplitude for 6 minutes. Flexibility of the hamstring and vertical jump were measured before, immediately after and at the 15th min after each intervention. Flexibility was found improve immediately post-vibration and at the 15^{th} min of recovery vs. pre-vibration in all amplitudes. The frequency group showed the same improvements at all frequencies. No improvement was found in the vertical jump.

Jacobs and Burns[32] found the same results however, they studied the effect of WBV as a form of warm-up compared to a traditional warm-up, cycle ergometry in flexibility and lower-extremity strength. 20 subjects participated in this study and vibrated for a total of 6 minutes. The frequency was gradually increased during the first minute from 0 to 26 Hz and stayed that way for 5 min. The same subjects did the cycle ergometry at a later date and the sit and reach test was used to test hamstring flexibility. After cycling for 6 min the subjects had a 2.6% increase in flexibility but after WBV they experienced a 16.2% increase in flexibility. Strength was found to be increased more after WBV compared to cycling. Neither of these studies had the subjects stretch and vibrate at the same time.

Feland et al.[29] noted that only three studies have performed stretching while simultaneously using vibration, but not with a WBV platform. They hypothesized that a 4 week protocol of stretching and vibrating at the same time would increase flexibility in the hamstring more than static stretching alone and to see if the subjects retained their flexibility 3 weeks post. Subjects reported to the lab 5 days a week for 4 weeks for their given protocol. The groups performed 5, 30 second static stretches on the vibration platform with 30s rest between stretches. For the static stretching group the platform was turned off. Both groups showed a significant increase in flexibility compared to controls. The vibration group did not change during the retention period while the static stretching group returned to its baseline ROM measurement.

Other physiological effects

WBV has also been shown to decrease blood flow resistance and increase blood flow velocity.[48] Kerschan-Shindl et al.[48] studied the blood flow of the gastrocnemius and quadriceps muscles and popliteal artery after 9 minutes of vibration. A diagnostic ultrasound with color and power Doppler were used to measure the blood flow. Only vessels with a 2 mm diameter were used in this study. The subjects vibrated on a Galileo 2000 device (Novotec GmbH Pforzheim, Germany) for 9 minutes and were immediately tested. A statistical significance was found in the number of vessels with a 2 mm diameter. The blood flow was found to significantly increase using Newman's method of quantifying relative blood flow pre to post vibration. The popliteal artery was found to have no statistical significance in its mean speed of blood flow. However, the resistive index was found to be significantly less then pre vibration.

Tonic vibration reflex

It has also been found that WBV may increase the tonic vibration reflex.[50] It is proposed, that vibration inhibits activation of the antagonist muscles through Ia-inhibitory neurons. This would alter the intramuscular coordination patterns leading to a decreased braking force around the joints.[46] However, not everyone agrees with this theory.

Hopkins et al.[91] found no change in the stretch reflex in the patellar tendon following WBV. Subjects had their patellar tendon tap reflex measured before and after a WBV session. To measure the reflex, EMG was used at the vastus medialis and lateralis and a strain gauge was attached to the subject's ankle. A reflex jig was made to hold the reflex hammer at the same position for all subjects. The patellar tendon tap reflex was measured (7 times with the high and low being removed and the remaining averaged) and the treatment group received a total of 5 minutes of WBV. After which, subjects sat back down and rested for 30 minutes, the patellar tendon tap reflex was then measured again in the same fashion. There was no significant difference found in the patellar tendon tap reflex using reflex latency, reflex amplitude, EMD, and reflex force output.

Conclusion

Ankle sprains are the most common injury sustained during sports participation. When athletes return to activity before the ankle is completely healed, re injury occurs in 80 percent. Chronic ankle instability (CAI) is the name given to this phenomenon. One of the biggest contributing factors to CAI is the lack of dorsiflexion that returns after the injury. Whole body vibration (WBV) platforms are relatively new devices used in clinical settings everywhere. Recently, much research has been done on the device to see benefits in the areas of strength, power, increase hormone production, joint stability, and flexibility. Flexibility and the use of WBV as a rehabilitation tool or preventative method has been shown to increase flexibility in muscles but has received less attention compared to the previously stated areas. This increase in flexibility may benefit those with CAI.

Table 1

Author	***Frequency (Hz)***	***Amplitude (mm)***	***Vibration Time (seconds)***	***Treatment Duration (days)***	***Vibration technique***	***Results***
Atha & Wheatley, 1976	44Hz	.1 mm	900 (15min)	1	Seated cushion	Low frequency vibration increased hip flexion
Cronin et al., 2007	24	3	30	1	Segmental vibration	Sign. increase in hamstring dynamic range of motion (1.6%)
	34	3	30	1		Sign. increase in hamstring dynamic range of motion (2.0%)
	44	5	30	1		Sign. increase in hamstring dynamic range of motion (2.1%)
Cochrane & Stannard, 2005	26	6	6 positions for 30 seconds each	1	Vibration platform	Sign. increase in sit and reach test (8.2 + - 5.4%)
Kinser et al., 2007	30	2	10 sec of vibration and stretching with 5 sec of rest in-between, 4 sites, 4 repetitions		Segmental vibration	Sign. increase in right and left forward split, favored and un-favored leg split
Van den Tellaar, 2006	28	10	30	1	Vibration platform	Sign. increase in hamstring ROM
Sands et al., 2006	30	2	1 minute of stretching while vibrating in 4 positions	1	Segmental vibration	Sign. increase in right and left split

	30	2	1 min. of stretching while vibrating in 4 positions	5 days a week for 4 weeks	Segmental vibration	Sign. increase in right split. No sign. increase in left split.
Gerodiomos et al. 2010	25 Hz	4mm, 6mm, 8mm	6 minutes	1 session	WBV platform	Sign. Increase in hamstring flexibility at all amplitudes
	15 Hz, 20 Hz, 30 Hz	6 mm	6 minutes	1 session	WBV platform	Sign. Increase in hamstring flexibility in all frequencies
Jacobs and Burns, 2009	26 Hz		5 minutes	1 session	WBV platform	Sign. Increase in hamstring flexibility
Feland et al., 2010	26 Hz	4 mm	5, 30-s stretching while vibrating with 30 sec rest in between sets	5 days a week for 4 weeks	WBV platform	Sign. Increase in hamstring flexibility in static stretching and vibrating compared to control. Vibrating group had a retention of flexibility.

Chapter 3

Methods

Research Design

This study will be a controlled laboratory study using a 3 x 3 repeated measures design. Subjects will be randomly assigned to three groups: (N) normative group, (SS) static stretching group that stretches on the WBV platform with it turned off, and (SV) stretching and vibrating group that stretches simultaneously while standing on the vibration platform with it turned on. Data will be collected over 3 time intervals: pretreatment, post-treatment 1, and post-treatment 2.

The independent variables are group and time. The dependent variable is passive non-weightbearing dorsiflexion range of motion, which will be measured three times in two positions (straight leg and bent knee). The first measurement will be a pre-treatment measurement, the second after the first treatment to measure acute effects (post-tx 1), and the third will be at the end of the 3 weeks of treatment (Post-tx 2).

Subjects

At least 39 subjects male and/or female will be needed to complete this study. Subjects will college-aged students 18-25 years of age. Subjects must have chronic ankle instability as defined by the Foot and Ankle Ability Measure (Appendix B) and have the subjective feeling of their ankle “giving way”. Subjects who score below 90% on the ADL subscale and below 80% on the sport subscale will qualify as having CAI. Qualified subjects must also exhibit a deficiency in dorsiflexion, which for this study is defined as less than 15 degrees passive dorsiflexion from a non-weight bearing neutral position. Baggett and Young[70] consider a passive dorsiflexion of less than 10 degrees in a non-weight bearing position as the ROM needed for normal running. However, based on our pilot study, it was decided to increase the ROM by 5 degrees to receive a sufficient subject population. The human subjects institutional review board of Brigham Young University will approve this study. All qualified subjects will sign a written consent form pertaining to testing procedures. Subjects will be disqualified from the study if they have missed more than 1 day of treatment.

Instruments

1. V-Force (Dynatronics, France). This is a whole body vibration device with synchronized dual motors to cause a uniform vertical sinusoidal vibration. The V-Force is able to perform amplitudes 2-6 mm and frequencies ranging from 30-50 Hz.

2. The fluid filled bubble inclinometer (FFBI) This device will be used for measuring passive ankle dorsiflexion ROM which, for purposes of this study will be representative of plantarflexor muscle group flexibility.[7,68]

Procedures

All volunteers will report to Sports Medicine 1130 SFH in comfortable clothes that exposes the lower leg and no shoes. Subjects will complete the Foot and Ankle Ability Measure (Appendix B) to establish chronic ankle instability and a study-related questionnaire (Appendix C). Subjects who score below a 90% on the ADL subscale and below 80% on the sport subscale will qualify as having CAI. Qualifying subjects must also be deficient in passive ankle dorsiflexion, which will be a measure of less than 15 degrees passive dorsiflexion from a non-weightbearing neutral position in two positions, straight leg and bent knee. They will be measured with the FFBI as described below in the measurement section. If all criteria are met, subjects will be randomly put into 1 of the 3 groups described above. Their original measurement will then be used as the baseline measurement and will then receive their assigned treatment and will be measured again to receive post-tx 1

Subjects will report to the lab 4 days[92] a week for 3 weeks for their assigned protocol, with the initial treatment counting as one of those days. The vibrating groups will perform 4 sets of 30-s[92] bouts of vibration at the setting 35 Hz high which was found to be equal to 34 Hz 2mm with a 30 -s rest in between sets. Non- vibrating groups will stand on the platform 4 sets of 30 seconds with a 30 -s rest in between sets. All subjects in all groups will stand with their assigned foot in the middle of the WBV platform either on a 20 degree slant board (SS and SV groups) or not (N) and will be asked to stand straight up with their eyes forward with hands on the hand rails.

Group 1: (C) Normative group. Will stand on the WBV platform on one leg with the heel in the middle of the platform. The subjects will do this, 4 sets for 30 seconds with a 30 -s rest in between sets. The sets will alternate between knee fully extended and bent knee. The subjects will be instructed to have NO stretch occur in either position (Picture 1a & 1b). The WBV platform will be turned off.

Picture 1a

Picture 1b

Group 2: (SS) Static stretching group will stand on the WBV platform on top of the centered 20 degree slant board with the ankle to be stretched in the middle of the 20 degree slant board, the heel in the middle of the platform and knee and ankle fully extended with hands on hand rails. The subjects will be instructed to lean forward until they feel a mild stretching discomfort. The subjects will do this, 4 sets for 30 seconds with a 30 -s rest in between sets. The sets will be alternated with full extension in the knee and bent knee to ensure stretch of both the soleus and gastrocnemius. There will be no set angle of bent knee. It will be described as the angle where mild stretching discomfort is felt. This will be performed with the WBV platform turned off (Picture 2a & 2b).

Picture 2a

Picture 2b

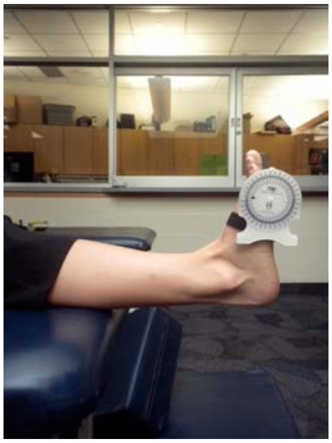
Group 3: (SV) Stretching and Vibrating. Subjects will stand on the WBV platform on top of the 20 degree slant board centered on the WBV platform with the ankle to be stretched in the middle of the slant board, the heel in the middle of the platform, and knee and ankle fully extended with hands on hand rails. The subjects will be instructed to lean forward until they feel a mild stretching discomfort. The sets will be alternated with full extension in the knee and bent knee to ensure stretch of both the soleus and gastrocnemius (Picture 2a & 2b). There will be no set angle of bent knee. It will be described as the angle where mild stretching discomfort is felt. They will

perform 4 sets of 30 -s bouts with a 30 -s rest in between sets. The WBV will be set to 35 Hz High which is equal to 34 Hz 2mm. This will be performed with the WBV platform turned on.

Measurements

All subjects will be measured for ankle passive dorsiflexion range of motion on three separate occasions in two separate positions. First, before any treatment is administered, second following the first treatment, and third, 1 minute after the end of the three-week treatment period. During each measurement, passive non-weightbearing dorsiflexion ROM will be measured in two positions three times and then averaged. Ankle dorsiflexion will be measured according to Denegar's[7] straight knee and a modified bent knee procedure to ensure both the soleus and the gastrocnemius flexibility is being measured. Each subject will be fitted with a fluid filled bubble inclinometer, attached with a Velcro strap around the foot with the inclinometer over the 5th metatarsal head, facing lateral. For the straight knee, the subject will be lye supine on an examining table and the distal half of the lower leg will extend past the edge of the table. Following the placement of the inclinometer, the patient will be asked to relax and the examiner will put the ankle joint in talar neutral position. After neutral is found the inclinometer will be zeroed by rotating the disk until the fluid is parallel and on zero. The examiner, will then passively dorsiflexion the talocrural joint until a restriction is met which will be indicated by a firm end point (picture 3). The degree at which the fluid is at will be recorded. For the modified bent knee measure we will have the subjects lay supine instead of prone as described by Denegar (2002). The procedures will follow the straight knee procedure, except in that the subjects will have a firm pillow under the distal leg to bend the knee to approximately 90 degrees (picture 4).

Picture 3



Picture 4

Statistical Analysis

Each time the passive dorsiflexion ROM for the gastrocnemius and soleus are measured it will be repeated three times and an average will be taken of those three measurements giving us 2 measurements per measurement interval, 6 measurements totals. The data collected will be put in an excel spreadsheet and exported to SPSS. Repeated measures ANOVA will be used for statistical analysis. The groups will be compared across time for plantarflexor group flexibility. A post-hoc tukey test will then be performed to detect specific differences. Significance is defined as a $p<.05$ for all analysis.

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Appendix B

Foot and Ankle Ability Measure (FAAM)
Activities of Daily Living Subscale

Please Answer **every question** with **one response** that most closely describes your condition within the past week.
If the activity in question is limited by something other than your foot or ankle mark "Not Applicable" (N/A).

	No Difficulty	Slight Difficulty	Moderate Difficulty	Extreme Difficulty	Unable to do	N/A
Standing	☐	☐	☐	☐	☐	☐
Walking on even Ground	☐	☐	☐	☐	☐	☐
Walking on even ground without shoes	☐	☐	☐	☐	☐	☐
Walking up hills	☐	☐	☐	☐	☐	☐
Walking down hills	☐	☐	☐	☐	☐	☐
Going up stairs	☐	☐	☐	☐	☐	☐
Going down stairs	☐	☐	☐	☐	☐	☐
Walking on uneven ground	☐	☐	☐	☐	☐	☐
Stepping up and down curbs	☐	☐	☐	☐	☐	☐
Squatting	☐	☐	☐	☐	☐	☐
Coming up on your toes	☐	☐	☐	☐	☐	☐
Walking initially	☐	☐	☐	☐	☐	☐
Walking 5 minutes or less	☐	☐	☐	☐	☐	☐
Walking approximately 10 minutes	☐	☐	☐	☐	☐	☐
Walking 15 minutes or greater	☐	☐	☐	☐	☐	☐

Foot and Ankle Ability Measure (FAAM)
Activities of Daily Living Subscale
Page 2

Because of your foot and ankle how much difficulty do you have with:

	No Difficulty at all	Slight Difficulty	Moderate Difficulty	Extreme Difficulty	Unable to do	N/A
Home responsibilities	☐	☐	☐	☐	☐	☐
Activities of daily living	☐	☐	☐	☐	☐	☐
Personal care	☐	☐	☐	☐	☐	☐
Light to moderate work (standing, walking)	☐	☐	☐	☐	☐	☐
Heavy work (push/pulling, climbing, carrying)	☐	☐	☐	☐	☐	☐
Recreational activities	☐	☐	☐	☐	☐	☐

How would you rate your current level of function during you usual activities of daily living from 0 to 100 with 100 being your level of function prior to your foot or ankle problem and 0 being the inability to perform any of your usual daily activities.

__ __ __ . 0 %

Martin, R; Irrgang, J; Burdett, R; Conti, S; VanSwearingen, J: Evidence of Validity for the Foot and Ankle Ability Measure. Foot and Ankle International. Vol.26, No.11: 968-983, 2005.

Foot and Ankle Ability Measure (FAAM)
Sports Subscale

Because of your foot and ankle how much difficulty do you have with:

	No Difficulty at all	Slight Difficulty	Moderate Difficulty	Extreme Difficulty	Unable to do	N/A
Running	☐	☐	☐	☐	☐	☐
Jumping	☐	☐	☐	☐	☐	☐
Landing	☐	☐	☐	☐	☐	☐
Starting and stopping quickly	☐	☐	☐	☐	☐	☐
Cutting/lateral Movements	☐	☐	☐	☐	☐	☐
Ability to perform Activity with your Normal technique	☐	☐	☐	☐	☐	☐
Ability to participate In your desired sport As long as you like	☐	☐	☐	☐	☐	☐

How would you rate your current level of function during your sports related activities from 0 to 100 with 100 being your level of function prior to your foot or ankle problem and 0 being the inability to perform any of your usual daily activities?

__ __ __ . 0%

Overall, how would you rate your current level of function?

☐ Normal ☐ Nearly Normal ☐ Abnormal ☐ Severely Abnormal

Martin, R; Irrgang, J; Burdett, R; Conti, S; VanSwearingen, J: Evidence of Validity for the Foot and Ankle Ability Measure. Foot and Ankle International. Vol.26, No.11: 968-983, 2005.

Appendix C

Subject
Information & Injury History Questionnaire

Please answer the following questions to the best of your knowledge. All information from this questionnaire
will be kept confidential.

Name: ____

Home/Work/Cell Phone Number: __________________

Email: ____

1. Are you currently suffering from any lower extremity injury (muscle strains, ligament sprains etc.)?

   Yes No

2. Are you currently experiencing any lower extremity pain? Have you experienced lower extremity pain in the last week?

   Yes No If yes, where are you experiencing pain? And how long?

3. Have you had an ankle sprain in the last 6 months?

   Yes No

4. Have you ever had surgery on either of your ankles?

   Yes No

5. Have you been experiencing chronic ankle instability longer than a year?

   Yes No