9-7-2011

Whole Body Vibration in Anterior Cruciate Ligament Rehabilitation

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WHOLE BODY VIBRATION IN ANTERIOR CRUCIATE LIGAMENT REHABILITATION

by

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A Project Submitted in Partial Fulfillment for the Requirements for the Degree

of

Masters of Science

in

Health and Human Movement

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2011

Abstract

There has been an increasing prevalence of anterior cruciate ligament (ACL) injuries. In the literature describing ACL rehabilitation program flexibility, muscle strength, proprioception, and postural stability have been identified as reoccurring struggles that have arisen during rehabilitation. Whole Body Vibration (WBV) has been investigate as a rehabilitation tool that can be used when recovering from an ACL injury. Research has suggested that WBV can be used to increase flexibility, improve muscular strength, increase proprioception, and improve postural stability. The purpose of this review is to gather the WBV protocols used in previous research and apply them to ACL rehabilitation. An EBSCO and Google Scholar search was initiated with key words of: whole, body, vibration, anterior, cruciate, ligament, injury, and rehabilitation. Articles were saved that explained how vibrations worked, use of WBV to advance athletic performance, injury rehabilitation, vibrations during ACL rehabilitation, and protocols for using vibration on athletes. The protocols that are described have shown to improve the rehabilitation programs and as a collection will act as a guide and provide a starting point for health-care professionals to use WBV as a rehabilitation tools for patients recovering from ACL injuries.

Context

For years the effects of vibration on the human body have been investigated. In fact, there was a time when a ride over a rough road was suggested to individuals who were suffering from kidney stones (Griffin, 1996). Vibration stimulation has been investigated for the physiological affects on motor and sensory properties on the human body. Further, vibration has begun to be explored as a rehabilitation tool when recovering from sport related injuries.

WBV exposes the athlete to sinusodial oscillations in a vertical motion (Dolny & Reyes, 2008). The variables that determine the intensity of vibration are frequency and amplitude (Cardinale & Wakeling, 2005). The amount of oscillatory movement correlates to the amplitude (mm) and the rate of cycles of oscillation determines the frequency of vibration (Hz) (Cardinale & Wakeling, 2005). WBV has typically been achieved by athletes standing on a plate or platform that produces the vibrations. WBV platforms produce vibrations that have frequencies between 15-60 Hz and vertical displacements from ~1-11mm (Dolny & Reyes, 2008).

The transmissions of the mechanical oscillations to the body are noted to effect several physiological systems like skin receptors, muscles spindles, joint mechanoreceptors, vestibular system, changes in cerebral activity, and changes in neurotransmitter and hormone concentrations (Moezy et al, 2008). It has also been suggested that WBV can affect muscle strength, and power, soft tissue flexibility, balance, gait, and neuromuscular conditions (Moezy et al, 2008).

Injuries to the ACL of the knee joint has grown to be a frequently discussed topic in sports medicine. ACL injuries are a common injury that is suffered by athletes worldwide. In a epidemiology of division I collegiate sport injuries done through the NCAA 4800 ACL injuries occurred between 1988-2004 (Hootman, Dick, & Agel, 2007). The discussions have been aimed on the increasing prevalence of anterior cruciate ligament tears and the areas where athletes struggle to re-establish pre-injury performance. Addressing the areas where long term deficits have occurred will improve ACL rehabilitation allowing the athletes to better return to their sport.

It is crucial for athletic trainers to address the deficits that athletes report during rehabilitation of an injury. After ACL injuries the main frustration has been that even after an

extensive rehabilitation program athletes consistently reported that their knee is not fully recovered and that they feel as though they are not able to perform at the level they did before their ACL injury. The rehabilitation process after ACL reconstruction surgery has lasted from as early as six months to one year.

Whole body vibration continues to be investigated for its potential use in rehabilitation of ACL injuries. Over all the the use of WBV as a tool can be helpful in the rehabilitation process after going through ACL reconstruction surgery. This collection of protocols will give health care professional a starting point to initiate WBV in the design of the rehabilitation program.

Objectives

The purpose of this project is to investigate the research on whole body vibration programs. This investigation gathers the guidelines from the protocols that have been used in areas of interest as well as protocols that were used on people who suffered ACL injuries in past studies. This guideline puts together a summary of current studies as to provide information for athletic trainers and other health care professional who wish to use vibration during a ACL rehabilitation.

Evidence Acquisition

Resources were gathered via electronic research and database. An EBSCO and Google Scholar search was initiated with varying combinations of the key words being : whole, body, vibration, anterior, cruciate, ligament,ACL, sprain, injury, rehabilitation, quadriceps, hamstring, strength, flexibility, proprioception, and postural stability. Articles were included that followed one or more the following criteria:

- history of whole body vibration
- how WBV functions

•use of vibration in order to advance athlete performance

•use of vibrations after injuries

•use of vibrations to prevent injuries

•rehabilitation protocols for using vibrations

•vibration and ACL rehabilitation

•WBV and muscular strength

•WBV and proprioception

•WBV and postural control

•WBV and flexibility

•At least one measured outcome showed improvement.

Protocols from research that resulted in improvements with WBV were saved for this project. These protocols separated into section for flexibility, muscular strength, proprioception, and postural stability. Together these protocols were used to develop the guidelines to use WBV in ACL rehabilitation.

Some articles where discovered that were not included in this study. This was due to:

•study did not yield statistically significant improvement with WBV

•study used local vibration and not WBV.

Whole Body Vibration for Flexibility

Having adequate range of motion of the knee is crucial for the performance of any athlete after sustaining an ACL injury. Obtaining full and healthy range of motion will also decrease the possibility of re-injury of the knee joint from a result of compensating between the uninjured and previously injured knee joints.

Goals: Increase flexibility of the lower extremities through WBV and stretching

Protocol 1:

Duration: 8 week protocol
Exposure per week: 3 times per week
Settings: 35 Hz, +/- 4mm
Stances:

1. Both legs on Vibration Plate with knees at 90 degrees and hands on hips
2. Single leg on Vibration Plate with knees at 90 degrees and hands on hips

Procedures:

Week 1-2:

Stance 1: 3 Sets of 20 seconds with 1 minute rest

Stance 2: 3 Sets of 15 seconds with 30 seconds rest

Week 3-4:

Stance 1: 3 sets of 30 seconds with 1 minute rest

Stance 2: 3 Sets of 20 seconds with 30 seconds rest

Week 5-6:

Stance 1: 3 Sets of 45 seconds with 45 seconds rest

Stance 2: 3 Sets of 25 seconds with 30 seconds rest

Week 7-8:

Stance 1: 4 Sets of 1 minute with 1 minute rest

Stance 2: 4 Sets of 30 seconds with 30 seconds rest

In a study by Fagnani showed that WBV is a effective rehabilitation tool to increase muscle flexibility on athletes (Fagnani, Giombini, Di Cesare, Pigozzi, & Di Salvo, 2006). This study was designed to investigate the short-term effects of an 8-week whole body vibration on muscle performance and flexibility in female competitive athletes. 26 female athletes competing in different sports were randomly assigned into two groups. One was a group that underwent WBV while the second group was a control group. The vibration plate for the WBV group was set at 35 Hz and 4mm amplitude. The participants were exposed to the vibration three times a week for eight weeks using two different forms of exercise. Exercise one was the subject

standing upright with knees flexed at 90 degrees and hands on hips. Exercise two was subject standing on one leg with knee bent at 90 degrees. Each week sets and reps were planned for each exercise along with rest time between vibration exposures. The study showed that the group who underwent WBV improved flexibility significantly more so than the control group.

Thus, using WBV in ALC rehabilitation would be beneficial when goals are to restore functional flexibility of the hamstrings and quadriceps.

Protocol 2:

Durations: 4 week protocol

Exposure per week: 3 times per week

Settings: 28 Hz, 10mm for 30 seconds

Procedures:

1. Begin with 5 min general warm-up
2. Stand on the vibration plate and stand in a squat position with knees bent at 90 degrees for 30 seconds.
3. Stretch the hamstring muscle group of each leg using contract release method
4. After stretching each leg once return to vibration plate
5. Repeat the exposure to WBV and stretch for a total of three times per leg

In a study by Van Den Tilaar (2006) investigated if pairing stretching and whole body vibration would increase hamstring flexibility (Van Den Tilaar, 2006). Specifically the study was to determine if WBV training on a vibration platform would have a positive effect on flexibility training and range of motion of the hamstring musculature. Nineteen undergraduate student were chosen to participate in the study; twelve females and seven males with the average age of 21.5 . The participants first underwent baseline passive hamstring flexibility measures. Then the participants were randomly assigned into two groups of ten and nine. One group went through WBV combined with contract release stretching then remeasured hamstring range of motion. The vibration plate was set at a frequency of 28 Hz and an amplitude of 10mm for 30 seconds.

The participants were asked to stand in the squat position with knees bent at 90 degrees. The second group was the control group went through contract release stretch of the hamstrings and then measured range of motion. Participant were told to stretch by placing back on heel on table and then isometrically contracting the hamstring for five seconds. Next, the contraction was released and participants stretched by bending forward at the hip holding for 30 seconds. Each leg was stretched three times alternately. The participants performed these session three times a week for four weeks. The results of the study showed that WBV training had a positive effect on ROM of the hamstrings when combined with contract-release stretching method. There was a significant increase after week 1 of training and continued to increase each week except for week 3-4. Overall there was a 26.8 degree average gain of hamstring flexibility in the WBV group and a 12.4 degree gain in the control group.

Whole Body Vibration for Muscular Strength

Regaining muscle strength and neuromuscular control a key stone goal in ACL rehabilitation. Without muscle strength and regaining muscle fiber firing it would prove difficult to be able to achieve pre injury sport performance.

Goals: Increase Muscular Activity

Protocol 1:

Duration: One time exposure

Settings: 35 Hz, 2.5mm for 20 seconds

Stances:

High Squat:

Straight Back, Hip 140 degrees of Flexion, Knee 125 degrees of flexion.

Low Squat:

Straight Back, Hip 90 degrees of Flexion, Knee 90 degrees of flexion.

Single-leg Squat:

Straight Back, Hip 140 degrees of Flexion, Knee 125 degrees of flexion.

Procedures:

1. 5 minute warm-up on stationary bicycle without resistance
2. Each stance was applied in random order
3. Apply first stance for an exposure time of 20 seconds
4. Have patient rest for one minute while sitting on a chair
5. Apply second stance for an exposure time of 20 seconds
6. Have patient rest for one minute while sitting on a chair
7. Apply third stance for an exposure time of 20 seconds
8. Have patient rest for one minute while sitting on a chair
9. Repeat until patient has completed four sets of each exercise

In a study done by Roelants (2006) investigated the magnitude of WBV-induced increase in the activity of different leg muscles in subjects performing three standard unloaded isometric exercises: high squat, low squat and 1-legged squat (Roelants, Verschueren, Delecluse, Levin, & Stijnen, 2006). To test the muscle activity of the rectus femoris, vastus lateralis, vastus medialis, and gastrocnemius EMG readings were recorded. EMG reading were taken through all three exercises with and without WBV. The vibration plate was set at 35 Hz, 2.5 mm amplitude and participants were exposed for 20 seconds. Fifteen male students with an average age of 21.1 years were selected for this study. EMGrms activity was always higher in WBV. For the Vastus Medialis muscle EMGrms reading were higher for high squat, low squat, and 1-legged squat. In the Vatus Lateralis muscle EMGrms reading were more significant in 1-legged squat with WBV but in high and low squat EMGrms reading were still higher in in WBV group. In the Gastrocnemius muscle EMG activity was higher in WBV group for all exercises. They were particularly higher again in 1-legged squats. This study show the potential of using WBV for regaining muscle strength in the quadriceps musculature.

Protocol 2:

Durations: One time exposure

Settings: 26 Hz, 10mm for 10 repetitions

Stance: One leg on the vibration plate, knee at 100 degrees of flexion. Other leg is kept off ground.

Procedures:

1. Begin with 5 minute warm up on bicycle
2. 5 minutes of static stretching of the quadriceps and triceps surae
3. Apply first 60 seconds of whole body vibration in stance
4. After stretching each leg once return to vibration plate
5. Repeat the exposure to WBV for a total of 10 minutes

In a study completed by Bosco, elite female Volleyball players went under WBV before completing a leg press (Bosco, Colli, Introini, Cardinale, Tsarpela, Madella, Tihanyi, & Viru, 1999). The aim of the study was to investigate the effects of WBV on the mechanical behavior of the human skeletal system. The vibration plate was set at 26Hz and 10mm amplitude. The participants were exposed to the vibrations for 60 seconds with 60 second rest between each treatment. WBV showed to improve average velocity, force, and power of the leg press.

Protocol 3:

Duration: One time exposure

Settings: Hz incraese per minute see procedures below, 10mm displacement for 4 min

Stances: middle of platform each foot kept 28m away from center of platform

0-10 sec: light squatting

10-20sec: standing in erect position

20-30sec: relaxed position the knees in slight flexion

30-40sec: light jumping

40-50sec: alternating body weight from one leg to the other

50-60sec: standing on heels.

Procedures:

1. Begin with 4 minute warm up on bicycle
2. Rest for 10 minutes
3. 4 minutes of exposure to WBV
    a. Minute 1: 15Hz
    b. Minute 2: 20 Hz
    c. Minute 3: 25 Hz
    d. Minute 4: 30 Hz

4. Repeat the stance cycle 4 times through during WBV
5. Conclude with 4 minute cool down on bike

Trovinen (2002) conducted a study that investigated the effects of a 4 minute vibration bout on muscle performance and body balance (Trovinen, Kannus, Sievanen, Jarvinen, Pasanen, Kontulainen, Jarvinen, Jarvinen, Oja, &Vuori, 2002). 16 Volunteers participated in the study; 8 females and 8 males that were between the ages of 24-33 years old. The vibration plate was set at 15 Hz for the first minute, 20 Hz for the second minute, 25 Hz for the third minute, 30 Hz for the last minutes. Bipolar surface EMG for soleus, gastrocnemius, and vastus lateralis muscles were recorded. Isometric lower limb strength was increased 2kg at 2 minutes after vibration, but after 60 minutes the vibration intervention benefit diminished. This study suggests that there is a time frame where the benefit of WBV can be most successfully used.

Whole Body Vibration for Proprioception and Postural Stability

Proprioception is the ability of the human body to have the conscious perception of each limb in space (Moezy, Olyaei, Hadian, Razi, & Faghihzadeh, 2008). The ACL proprioception abilities initiate protective and stabilizing muscular reflexes (Moezy et al, 2008). This is important in prevent ACL injuries especially after they have occurred. Regaining this proprioception is key in full recovery after an ACL injury.

Goals: Use WBV to improve lower extremity proprioception and postural stability

Protocol 1:

Durations: 12 session of WBV for 1 month
Exposure per week: 3 times per week
Settings: Varying depending on the session
Stance:

a. static position, standing with knees bent, feet in the middle of platform, back straight.
b. static position, one leg stance with knee in slightly bent, foot in middle of platform

c. static or dynamic mini squat

d. static or dynamic single leg mini squat

e. static or dynamic deep squat

f. static or dynamic single leg deep squat

g. static or dynamic wide stance squat

h. static or dynamic lunge one foot in middle of platform, knee 90 degrees flexion

i. static or dynamic toe standing

Session	Duration of Set (seconds)	Frequency (Hz)	Amplitude (mm)	Rest (seconds)
1	30	30	2.5	60
2	30	30	2.5	60
3	30	30	2.5	60
4	30	35	2.5	50
5	45	35	2.5	50
6	45	35	2.5	50
7	45	40	5	40
8	45	40	5	40
9	45	40	5	40
10	60	40	5	30

Session	Duration of Set (seconds)	Frequency (Hz)	Amplitude (mm)	Rest (seconds)
11	60	50	5	30
12	60	50	5	30

Procedures:

1. Begin with 10 min warm-up jogging on treadmill.
2. Stretch the lower extremity.
3. For session 1 complete two sets of exercise a and b; one set of exercises c,e,h, and i.
4. For session 2 complete three sets of exercise a and b; two sets of c and one set of e,h, and i.
5. For session 3 complete three sets of exercise a, b, and c; one set of e, h and two sets of i.
6. For session 4 complete three sets of a,b,c; one set of d,g,h and two sets of e and i.
7. For session 5 complete two sets of a,b,d,e,h and i. Complete three sets of exercise c and one set of g.
8. For session 6 complete two sets of a,b,d,e,h and i. Complete three sets of exercise c and one set of g.
9. For session 7 complete three sets of c; two sets of a,b,d,e,g,h,i, and one set of f.
10. For session 8 complete complete three sets of c,e, and i. Two sets of a,b,d,g, and h. Also complete one set of f.
11. For session 9 complete three sets of c,e,and i. Complete two sets of a,b,d, g, and h.
12. For session 10 complete one set of and b; complete two sets of c-i.
13. For session 11 complete one set of and b; complete two sets of c-i.
14. For session 12 complete one set of and b; complete two sets of c-i

Moezy (2008) conducted a study to compare the effect of whole body vibration training program with conventional training on knee proprioception and postural stability after ACL reconstruction. Twenty athletes were randomly assigned into two groups. One group went under WBV while the second was the control group. Subject were asked to stand on the vibration platform with knees bent to 15 degrees of flexion. With this vibration plate the platform was programmed to go from a level eight to level four in 25 seconds. This change in levels signifies a decrease of stability of the platform. The vibration platform began at 30 Hz and increased to 50 Hz in the protocol. Postural stability and proprioceptive improvements were significantly greater in the WBV group than what was achieved in the control group.

Discussion

By analyzing the collection of protocols is can be seen that WBV can be beneficial in ACL rehabilitation to address the reoccurring struggles of flexibility, muscular strength, postural stability and proprioception that appear through the rehabilitation process.

As a result of any surgery muscles surrounding the joint will tighten as a protective mechanism while healing occurs. After ACL reconstruction the goals of early rehabilitation is to restore normal range of motion (Vathrakokilis, Malliou, Gioftsidou, & Godolias, 2008). Deficits in knee ROM is a frequent complication after ACL reconstruction (Almekinders, Moore, Freedman, & Taft, 1995, & Quelard, Sonnery-Cottet, Zayni, Ogassawara, Prost, & Chambat,2010). Stretching the muscle groups of the hamstring and quadriceps is critical in regaining normal range of motion after ACL reconstruction. Obtaining the goal of normal active and passive range of motion is a key component to achieve knee function. Two studies that created protocols were explained in the guide that can aid during ACL rehabilitation and both showed to increase knee flexibility.

Strengthening and regaining muscle strength between the quadriceps and hamstring has been a essential goal in ACL rehabilitation. Muscle strength deficits of the hamstring and quadriceps have been reported after ACL reconstruction (Hiemstra, Webber, MacDonald, & Kriellaars, 2000). Also, in a research report that was conducted by Eitzen focused on the importance of pre-operative muscle strength on the knee (Eitzen, Moksns, Snyder-Mackler, & Riseberg, 2010). Eitzen found that post-operative deficients persisted as long as two years after surgery (Eitzen et al, 2010). Possible reasons for this deficits can be explained by the lack of reestablishing neuromuscular control; therefore there are muscle fibers that are not being recruited to restrengthen after surgery. This project outlined three studies that were done on WBV and muscular strength. Each protocol improved muscular strength.

ACL reconstruction surgery has been shown to reduce instability but not completely eliminate it. The inability to gain full function of the knee after ACL reconstruction has been blamed on sensory deficit caused by the surgery (Brunetti, Filippi, Lorenzini, Liti, Panichi, Roscini, Pettorossi, & Cerulli, 2006). The ACL is a mechanical stabilizer and provides crucial sensory information about proprioception. Proprioception is conscious perception of limb position in space (Moezy, Olyaei, Hadian, Razi, & Faghihzadeh, 2008). Several proprioceptors have been found in the ACL such as Ruffini and Paccini endings (Moezy et al, 2008). When lacking sensory information from proprioception athletes are susceptible to re-injury of the knee and struggle to perform at pre-injury level. After reconstruction surgery, joint mechanoreceptors and nervous central connections are permanently altered leading to a lack of sensory information. This can lead the athlete to unconsciously reduce the load on the operated leg. Without correction this lack in postural stability can hinder knee stability during ACL rehabilitation and

after rehabilitation is complete. To address this issue a study was presented in this project that helped improve postural stability and proprioception using WBV.

Conclusion

Whole Body Vibration (WBV) is a tool that has recently been integrated into rehabilitation programs. These protocols act as a guide that will give health care professionals a summary of the research that has been done regarding the use of WBV during ACL rehabilitation. It give the details of each protocol and the results that the protocol yields.

As common with any rehabilitation or training device there are some cautions and consideration to be acknowledged in order to best avoid negative effects. Human being are exposed to vibration through out the environment. Some instances occur in motorized vehicles, marine ships, aircraft, buildings, and industrial equipment.(Jordan, Norris, Smith, & Herzog, 2005). Vibration are also seen in the athletic environments in several sports like alpine skiing, sailing, skating, and horse-back riding to name a few (Jordan et al, 2005). The key to preventing biological effects that can be harmful from vibration is to control: frequency, magnitude, duration, and type of vibration (Jordan et al, 2005). Exposure to large vibration loads or chronic exposure to vibration has caused damage to peripheral nerves, blood vessels, joints, and perceptual function (Jordan et al, 2005). Frequencies below 1Hz have been shown to cause motion sickness due to sensory mismatch (Seidel, 1988).

Therefore, it is crucial for athletic trainers to have an understanding of how vibration works and the effects on human body. Taking an accurate history, familiarizing with the vibration plate, and taking note of any complaints from the athlete is important when using vibration. Also, starting with the protocols listed above will provide a safe starting point for athletic trainers and their patients. With a general-frame work and control over the frequency,

magnitude, duration, and type of vibration the positive effects can be utilized for ACL rehabilitation while minimizing the chance of negative effects.

Further research is needed for each of these protocols. Each ACL rehabilitation is unique and may call for a blend of these protocols to aid in the struggles that the athlete is facing with their ACL rehabilitation. More research is also needed in understanding the effects of WBV and flexibility, muscular strength, postural stability, and proprioception. Better comprehension in these areas will allow for the advancement of setting so that they athlete may receive the best benefit from the exposure to WBV.

The strength of these recommendation comes from the synthesis of the information that is collected here in this project. The protocols that were included in this project are from the most recent research and that yields results that improved the health and performance of the participants of each study.

Authors	Title	Subjects	Protocol	Measured Outcomes	Results	Significant
(Fagnani, Giombini, Di Ceasar, Pigozzi, and Di Salvo, 2006)	The Effects of a Whole Body Vibration Program on muscle performance and flexibility in female athletes.	26 F Athletes ages: 21-27 years (University of Rome Rome, Italy)	8 week WBV 3 session per week	Counter movement jump Extension Strength on Lower Extremities Sit and Reach test for flexibility	WBV group saw improvements on : counter-jump (P=0.00,002) bi-lateral extension strength (P=0.0004) Sit and Reach Test (P=0,00,004)	P<0.001 Yes Yes Yes
(Van Den Tillaar, 2006)	Will Whole-Body Vibration training help increase the range of motion of the hamstrings?	19 undergraduate students in physical education 12 F 7 M ages 21.5 +/- 2 (Sognal, Norway)	4 week WBV 3 Session per week	ROM measured via goniometer Measured degrees of hamstring extension	30 % increase in hamstring flexibility in WBV group vs 14 % in control group	Yes

Authors	Title	Subjects	Protocol	Measured Outcomes	Results	Significant
(Roelants, Verschueren, Delecluse, Levin, & Stijnen, 2006)	Whole Body Vibration Induced Increase in Leg Muscles Activity During Different Squat Exercise	15 M Physical Education Students (Katholieke University Leuven Leuven, Belgium)	1 time exposure	EMG reading on quadriceps muscles during high squat, low squat, and single leg squat on vibration platform.	EMG reading higher on vibration platform vs control group EMG showed increase in High Squat, Low Squat and single leg squat Highest EMG reading in single leg squat	P<0.001 Yes Yes

Authors	Title	Subjects	Protocol	Measured Outcomes	Results	Significant
(Torvinen, Kannus, Sievanen, Jarvinen, Pasanen, M., Kontulainen, Vuori, 2002)	Effect of a vibration exposure on muscular performance and body balance. Randomized cross-over study	16 volunteers 8 M 8 F age 24-33 (University of Tampere Tampere, Finland)	1 time exposure	Stability Platform grip strength isometric extension strength tandem walk vertical jump Shuttle Run	2.5% increase in jump height (P=0.019) 3.2% benefit in the isometric extension strength of lower extremities (P=0.020) 15.7 % increase improvement in body balance	(P>0.001) Yes Yes Yes

Authors	Title	Subjects	Protocol	Measured Outcomes	Results	Significant
(Bosco, Colli, Introini, Cardinale, Tsarpela, Madella, Tihanyi, Viru,1999)	Adaptive responses of human skeletal muscle to vibration exposure	6 F National Team Volleyball Athletes (University of Rome Rome Italy)	1 time exposure	Averages Velocity Average Force Average Power	Average Velocity was the only section to show statistically significant results in post-test	P<0.005 Yes in Average Velocity

Authors	Title	Subjects	Protocol	Measured Outcomes	Results	Significant
(Moezy, Olyaei, Hadian, Razi, Faghihzadeh,2008)	A comparative study of whole body vibration and conventional training on knee proprioception and postural stability after anterior cruciate ligament reconstruction	20 Athletes with unilateral ACL reconstructions (University of Tehran Tehran, Iran)	12 sessions of WBV 3 timer per week	postural stability test Knee Joint reposition test (proprioception)	Improvement of postural stability with WBV Improvement with reposition test	P<0.05 Yes Yes

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Whole Body Vibrations in ACL Rehabilitation

Introduction:

In the literature describing ACL rehabilitation program flexibility, muscle strength, proprioception, and postural stability have been identified as reoccurring struggles that have arisen during rehabilitation. Whole Body Vibration (WBV) has been investigate as a rehabilitation tool that can be used when recovering from an ACL injury. Research has suggested that WBV can be used to increase flexibility, improve muscular strength, increase proprioception, and improve postural stability. The purpose of this guide is to provide a starting point for Health Care Professionals who have patients who encounter these struggles and would like to use WBV as a rehabilitation tool to address them.

Cautions and Consideration:

The key to preventing biological effects that can be harmful from vibration is to control: frequency, magnitude, duration, and type of vibration. Exposure to large vibration loads or chronic exposure to vibration has caused damage to peripheral nerves, blood vessels, joints, and perceptual function. Frequencies below 1Hz have been shown to cause motion sickness due to sensory mismatch.

Starting Guidelines:

1. Always use the surgeons rehabilitation plan to frame each athletes program
2. Consults surgeon about when it is safe to begin WBV. It is typically recommended to not use WBV for the first six weeks after surgery because this is when the graft is at its highest vulnerability to loosen.
3. Educate athlete about how WBV functions and what is being used to improve on. (i.e. flexibility or strength)
4. Educate athlete about what sensation will be experience during exposure time and what if any functional movements they will need to perform.
5. Follow all cautions from the manufacturer of the WBV product that is being used.

WBV for Flexibility

Goals: Increase Flexibility through WBV

Duration: 8 week protocol

Exposure per week: 3 times per week

Settings: 35 Hz, +/- 4mm

Stances:

1. Both legs on Vibration Plate with knees at 90 degrees and hands on hips
2. Single leg on Vibration Plate with knees at 90 degrees and hands on hips

Procedures:

Week 1-2:

Stance 1: 3 Sets of 20 seconds with 1 minute rest

Stance 2: 3 Sets of 15 seconds with 30 seconds rest

Week 3-4:

Stance 1: 3 sets of 30 seconds with 1 minute rest

Stance 2: 3 Sets of 20 seconds with 30 seconds rest

Week 5-6:

Stance 1: 3 Sets of 45 seconds with 45 seconds rest

Stance 2: 3 Sets of 25 seconds with 30 seconds rest

Week 7-8:

Stance 1: 4 Sets of 1 minute with 1 minute rest

Fagnani, F., Giombini, A., Di Cesare, A., Pigozzi, F., & Di Salvo, V. (2006) The effects of a whole-body vibration program on muscle performance and flexibility in female athletes. *American Journal of Physical Medicine & Rehabilitation, 85,* 956-962.

Goals: Increase hamstring flexibility by coupling contact release stretching method and WBV.

Durations: 4 week protocol

Exposure per week: 3 times per week

Settings: 28 Hz, 10mm for 30 seconds

Procedures:

1. Begin with 5 min general warm-up
2. Stand on the vibration plate and stand in a squat position with knees bent at 90 degrees for 30 seconds.
3. Stretch the hamstring muscle group of each leg using contract release method
4. After stretching each leg once return to vibration plate
5. Repeat the exposure to WBV and stretch for a total of three times per leg

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Van Den Tilaar, R. (2006). Will whole-body vibration training help increase the range of motion of the hamstrings?. *Journal of Strength and Condition Research, 20,*192-196.

WBV for Muscular Strength

oals: Increase muscular activity in quadriceps

uration: One time exposure

ettings: 35 Hz, 2.5mm for 20 seconds

tances:

High Squat:

Straight Back, Hip 140 degrees of Flexion, Knee 125 degrees of flexion.

Low Squat:

Straight Back, Hip 90 degrees of Flexion, Knee 90 degrees of flexion.

Single-leg Squat:

Straight Back, Hip 140 degrees of Flexion, Knee 125 degrees of flexion.

* Muscle activity was higher in single-leg squat for all muscles that were studied

rocedures:

1. 5 minute warm-up on stationary bicycle without resistance
2. Each stance was applied in random order
3. Apply first stance for an exposure time of 20 seconds
4. Have patient rest for one minute while sitting on a chair
5. Apply second stance for an exposure time of 20 seconds
6. Have patient rest for one minute while sitting on a chair
7. Apply third stance for an exposure time of 20 seconds
8. Have patient rest for one minute while sitting on a chair
9. Repeat until patient has completed four sets of each exercise

Roelants, M., Verschueren, S. P., Delecluse, C., Levin, O., & Stijnen, V. (2006). WHOLE -BODY-VIBRATION-INDUCED INCREASE IN LEG MUSCLE ACTIVITY DURING DIFFERENT SQUAT EXERCISES. *Journal of Strength & Conditioning Research* (Allen Press Publishing Services Inc.), 20(1), 124-129. Retrieved from EBSCOhost.

oals: Increase muscle performance and body balance by using WBV.

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urations: One time exposure

ettings: Increases per minute see procedures below,10 mm displacement, for 4 minutes

tance: middle of platform each foot kept 28m away from center of plateform

0-10 sec: light squatting

10-20sec: standing in erect position

20-30sec: relaxed position the knees in slight flexion

30-40sec: light jumping

40-50sec: alternating body weight from one leg to the other

50-60sec: standing on heels.

rocedures:

1. Begin with 4 minute warm up on bicycle
2. Rest for 10 minutes
3. 4 minutes of exposure to WBV
   a. Minute 1: 15Hz
   b. Minute 2: 20 Hz
   c. Minute 3: 25 Hz
   d. Minute 4: 30 Hz
4. Repeat the stance cycle 4 times through during WBV
5. Conclude with 4 minute cool down on bike

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orvinen, S., Kannus, P., Sievanen, H., Jarvinen, T. H., Pasanen, M., Kontulainen, S., & ... Vuori, I. (2002). Effect of a bration exposure on muscular performance and body balance. Randomized cross-over study. *Clinical Physiology & unctional Imaging*, 22(2), 145. Retrieved from EBSCOhost.

oals: Increase lower body muscular strength by using WBV.

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urations: One time exposure

ettings: 26 Hz, 10mm for 10 minutes

tance: One leg on the vibration plate, knee at 100 degrees of flexion. Other leg is kept off ground.

rocedures:

1. Begin with 10 minute warm up on bicycle
2. 5 minutes of static stretching of the quadriceps and triceps surae
3. Apply first 60 seconds of whole body vibration in stance
4. After stretching each leg once return to vibration plate
5. Repeat the exposure to WBV for a total of 10 minutes

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osco, C., Colli,R., Introini, E., Cardinale, M., Tsarpela,O., Madella, A., Tihanyi, J., & Viru, A. (1999). Adaptive response o uman skeletal muscle to vibration exposure. *Clin. Physiol.19*: 183-187

WBV for Proprioception and Postural Stability.

Goals: Improve knee proprioception and postural stability after ACL reconstruction.

Durations: 12 session of WBV for 1 month

Exposure per week: 3 times per week

Settings: Varying depending on the session

Session	Duration of Set (seconds)	Frequency (Hz)	Amplitude (mm)	Rest (seconds)
1	30	30	2.5	60
2	30	30	2.5	60
3	30	30	2.5	60
4	30	35	2.5	50
5	45	35	2.5	50
6	45	35	2.5	50
7	45	40	5	40
8	45	40	5	40

Stance:

a. static position, standing with knees bent, feet in the middle of platform, back straight.

b. static position, one leg stance with knee in slightly bent, foot in middle of platform

c. static or dynamic mini squat

d. static or dynamic single leg mini squat

e. static or dynamic deep squat

f. static or dynamic single leg deep squat

g. static or dynamic wide stance squat

h. static or dynamic lunge one foot in middle of platform, knee 90 degrees flexion

i. static or dynamic toe standing

Procedures:

1. Begin with 10 min warm-up jogging on treadmill.
2. Stretch the lower extremity.
3. For session 1 complete two sets of exercise a and b; one set of exercises c,e,h, and
4. For session 2 complete three sets of exercise a and b; two sets of c and one set of e,h, and i.
5. For session 3 complete three sets of exercise a, b, and c; one set of e, h and two sets of i.
6. For session 4 complete three sets of a,b,c; one set of d,g,h and two sets of e and i
7. For session 5 complete two sets of a,b,d,e,h and i. Complete three sets of exercise and one set of g.
8. For session 6 complete two sets of a,b,d,e,h and i. Complete three sets of exercise and one set of g.
9. For session 7 complete three sets of c; two sets of a,b,d,e,g,h,i, and one set of f.
10. For session 8 complete complete three sets of c,e, and i. Two sets of a,b,d,g, and h Also complete one set of f.
11. For session 9 complete three sets of c,e,and i. Complete two sets of a,b,d, g, and h
12. For session 10 complete one set of and b; complete two sets of c-i.
13. For session 11 complete one set of and b; complete two sets of c-i.
14. For session 12 complete one set of and b; complete two sets of c-i

Nezy, A., Olyaei, G., Hadian, M., Razi, M., & Faghihzadeh, S. (2008). A comparative study of whole body vibration trainin

Conclusions:

It is crucial for athletic trainers to have an understanding of how vibration works and the effects on human body. Taking an accurate history, familiarizing with the vibration plate, and taking note of any complaints from the athlete is important when using vibration. Also, starting with the protocols listed above will provide a safe starting point for athletic trainers and their patients. With a general-frame work and control over the frequency, magnitude, duration, and type of vibration the positive effects can be utilized for ACL rehabilitation while minimizing the chance of negative effects.

Further research is needed for each of these protocols. Each ACL rehabilitation is unique and may call for a blend of these protocols to aid in the struggles that the athlete is facing with their ACL rehabilitation. More research is also needed in understanding the effects of WBV and flexibility, muscular strength, postural stability, and proprioception. Better comprehension in these areas will allow for the advancement of setting so that they athlete may receive the best benefit from the exposure to WBV.

The strength of these recommendation comes from the synthesis of the information that is collected here in this project. The protocols that were included in this project are from the most recent research and that yields results that improved the health and performance of the participants of each study.