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THE NEUROPHYSIOLOGICAL EFFECTS OF WHOLE BODY VIBRATION TRAINING

ABSTRACT

Whole body vibration training, the person's entire body on a platform, creates a vibration that may affect the muscles and bones. Despite the vibration used of massage and treatment since ancient times, it was used as a training method in recent years and became very popular and has attracted the attention of researchers. Whole body vibration training used both sport science with the aim to improve performance and in the fields of medicine for sports therapy. Whole body vibration training brings about reflexive muscle contractions and therefore used to determine the neurophysiologic effectiveness of whole body vibration is used as a diagnostic method Hoffmann reflex. The purpose of this review, all the workouts of whole body vibrations which has been dealing with the effects of neurophysiologic studies in the literature review and discuss the effects on H reflex in a systematic.

Key Words: Whole Body Vibration, H reflex, Electromyography, Spinal Reflex

ÖZET

Tüm beden vibrasyon antrenmanı; bir platform üzerine çıkan kişinin bütün vücudunu, kaslarını ve kemiklerini etkileyebilecek bir titreşim oluşturur. Vibrasyon, eski çağlardan beri masaj ve tedavi gibi alanlarda kullanılmasına rağmen son yıllarda bir antrenman yöntemi olarak kullanılmaya başlanmış, oldukça popüler olmuş ve araştırmacıların ilgisini çekmiştir. Tüm beden vibrasyon antrenmanı, spor bilimlerinde sportif performansı artırmak amacıyla kullanıldığı gibi tedavi ve rehabilitasyon amacı ile de tıp ve fizik tedavi alanlarında da kullanılmaktadır. Tüm beden vibrasyon antrenmanı kasta refleksif bir kasılma meydana getirmekte ve bu nedenle tüm beden vibrasyon antrenmanının nörofizyolojik etkililiğini belirlemede Hoffmann refleks metodu kullanılmaktadır. Bu derlemenin amacı; tüm beden vibrasyon antrenmanının nörofizyolojik etkileri ile ilgili yapılmış olan çalışmaların H refleks üzerine olan etkilerini bir sistematik içerisinde incelemek ve tartışmaktır.

Anahtar Kelimeler: Tüm beden vibrasyonu, H refleks, Elektromiyografi, Spinal Refleks

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INTRODUCTION

Although vibration was used since ancient times in areas such as massage and treatment, in recent years it has begun to be popular as a training method. Russian scientist Vladamir Nazarov, has developed whole body vibration (WBV) to reduce the loses of both astronauts' muscle atrophy and bone density occurring in space because of the gravity environment and inactivity. He has developed this idea by giving local stimulation to astronauts' bones and muscles via vibration (Boland et al., 2009). The device that has been used for WBV creates a vibration that may affect the muscles and bones of the person's whole body a platform. Vibration platforms are different in terms of the forms of vibration. One of the most commonly used platforms is vertical platform moving up and down on the vertical axis, another is oscillating platform making rotation emitting on the horizontal axis (Cochrane, 2011).

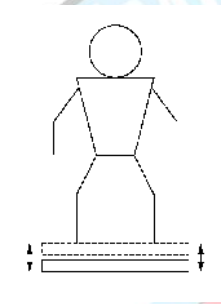

Figure1. Vertical Platform

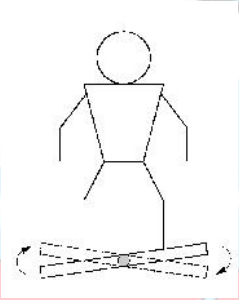

Figure 2. Oscillating Platform

Biomechanical variables that determine the intensity of vibration are frequency, amplitude and time. *Frequency* is defined as recurrence rate of oscillations in per unit time and is specified in Hertz. *Amplitude* is defined as the displacement of the positive and negative direction of an object and expressed in Millimeters (Cardinale and Wakeling, 2005).

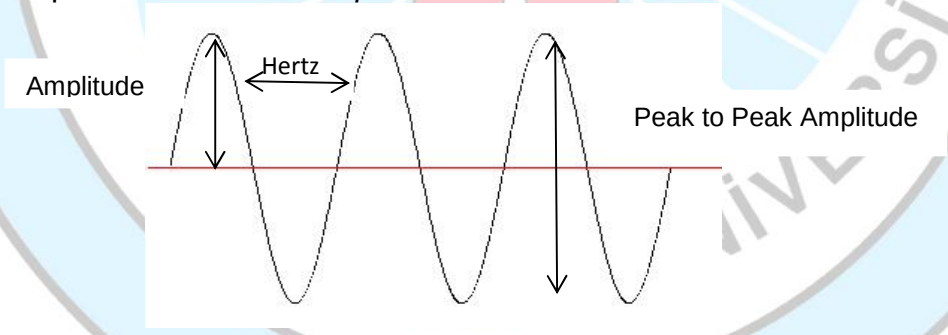

Figure 3. Variables that determine the intensity of vibration

WBV training is used for improving sportive performance in sport sciences and also rehabilitation and medical applications in the fields of medicine and physical therapy (Schmidtbleicher et. al. 2005; Zepetneket.al., 2009).The aim of this study was to review and discuss the neurophysiological effects of WBV especially on Hoffmann reflex in a systematic way.

MATERIALS and METHODS

The review of the previous literature was performed using EBSCO search engine and free access resources. This review was established by evaluating of 38 articles (between 1972 to 1992-1 article, between 1993 to 2002 9-articles, 28 articles between 2003 to 2012), which was reached on about 300 articles. "Whole Body Vibration", "Hoffmann Reflex", "EMG" and "Spinal

Reflex" are used as key words. Application of vibration from the neuromuscular responses of the human body examined on the basis of studies from sources that was obtained from four subsections. These are; Neuromuscular Basis of Whole Body Vibration Training, Hoffmann Reflex, Hoffmann Reflex and EMG Recording Methods, The effects of WBV training on Hoffmann Reflex.

Neuromuscular Basis of Whole Body Vibration Training

Activations are generated by neurons in skeletal muscle unless there is nervous activating skeletal muscles cannot contract. Neurons initiates contractions, which also create action potential in muscles, are called motor neurons (Tuncel et.al., 2000). All of the muscle fibers innervated by a single motor neuron that is called motor unit (Ertekin, 2006). An alpha motor neuron in anterior horn of the spinal cord is branching many times after taking place in the muscle and innervating big skeletal muscles (Guyton and Hall, 2007). In a study done by Matthews' on decebrate cats has shown that activity of the group fibers with muscles vibration leads to tonic reflex contraction in muscle. Hagbart and Eklund named this response as tonic vibration reflex. Belly or tendon vibration applied to a skeletal muscle constitutes an involuntary contraction of the muscle and a reciprocal relaxation in the antagonist muscle (Pöğün, 1977). When WBV is applied, an involuntary muscle contraction with tonic vibration reflex occurs and muscle contraction continuous until the application stopped (Latash, 1998). This motor response that occurred during vibration application is caused by the increase in activations of primary endings in muscle spindle with vibrations (Kin-İşler, 2007). Changes in length of muscle are detected by muscle spindle and the number of alpha motor neurons, which is returning to muscle increases by activating medulla spinalis. Muscle, in this way, can produce a small amount of force without controlling from the upper level centers (Issurin et. al., 1994).Tonic vibration reflex activation brings about an increase in motor unit synchronization and also increases voluntary muscle contraction(Martin and Park, 1997). Increase in motor unit synchronization occurs because of either activating motor units which were not used before by increasing muscles' neural mechanism or increasing in muscle strength (Jordan et.al. 2005). As shown in studies conducted in many years, though there are sciences on the contrary, the most important benefits of exercise training is to provide increase muscle strength (Issurin, 2005). Impulse occurring in muscle spindle by vibration reaches to the motor neurons in medulla spinalis as monosynaptic and provides muscle contraction. At the same time this impulse are thought to go to antagonist motor neurons with polysynaptic ways and makes reciprocal inhibition in them. Monosynaptic reflex caused by vibration in reflex contraction involving. Different statements were made about the suppression mechanism which occurs in reflexes with vibration but in recent years usually this suppression is provided by a central mechanism and this central mechanism presynaptic inhibition (Pöğün, 1977). In addition, all touch receptors are involved in perception of vibration and also different receptors detect different frequencies of vibration. For example, pacini corpuscles report the vibrations from 30 to 800 rpm/s and also per second from 2 to 80 rpm low frequency vibrations stimulated meissner's corpuscles (Guyton and Hall, 2007).

Hoffmann Reflex

The H reflex is described for the first time in 1918 by Paul Hoffmann and becomes one of the routine medical studies (Ertekin, 2006). Generally monosynaptic stretch reflex studies, sensory motor integration and spinal cord adaptation are widely used for recovery acquisition of motor skills (Knikou, 2008). H reflex is defined as a monosynaptic reflex which occurs with

electric stimulus of group 1a afferents of muscle nerve, in other words muscle potential which is lost with supramaximal electrical stimulus and occurs with low threshold electric stimulation that is called H Reflex (Ertekin, 2006). H reflex show that the size of efferent motor outputs which come from motor neuron pool, so is used in the evaluation of excitability of alpha motor neuron (Palmieri et. al., 2004; Kipp et.al., 2011(b)). The H reflex, is a diagnostic method to determine the effectiveness of a vibration training. Although H reflex has a similar volley with stretch reflex, it occurs by giving stimulus from outside and this stimulates motor units axons and also low threshold 1a afferents. Electrical stimulus applied to peripheral nerve causes direct activation in efferent fibers. Action potential is send to the point of neuromuscular junction which is applied directly. This efferent arc appears as M response in EMG and this response is simply known as a reaction of the muscle. 1a afferent activation results in action potential and spreads to spinal cord. If this activity is sufficiently excited in presynaptic terminal it causes depolarization and excitatory postsynaptic potential occurs in motor neuron. If excitatory post synaptıc potential depolarized (ıt depends on the size of excitatory post synaptic potential and membrane potential), action potential occurs. It causes the release of acetylcholine at the neuromuscular junction, muscle contracts and H reflex trace is seen in EMG (Ertekin, 2006; Palmieri et. al., 2004). As a result, two peak points are seen in EMG. First peak point is caused by direct stimulation of motor units. The second peak point is the result of monosynaptic excitation. H reflex measures effectiveness of 1a afferent synapse and consequently measures presynaptic inhibition of 1a afferent. Although H reflex is connected to stimuli transfer which comes from 1a afferents, excitability is used for the purpose of evaluation of inhibition and facilitation. The size of H reflex amplitude which is seen EMG determines the effectiveness of motor neuron pool. H reflex has the same way with the foundation of explosive strength after maximum isometric contraction. Ross and colleagues claimed that stretch reflex has more important contribution to explosive strength. But H reflex gives more clearly results in determining facilitation and inhibition of motor neurons; they claim that H reflex measurements can give more closely results to determine explosive strength. It is emphasized that an increase may occur in H reflex as a result of disinhibition of motor neuron pool (due to the exhaustion of the inhibition system). The H reflex amplitude that varies depending on training is the result of either the increase of excitation of alpha motor neurons or due to the presynaptic inhibition of 1a afferents (Gondin et. al., 2006). In summary, the most important effect of WBV training is neurological adaptation effect. But in many studies it has seen that just opposite result have emerged from the expected findings. For example; after WBV training H reflex amplitude is expected to increase but Kipp and colleagues found that a decrease in H reflex in 2011.

Hoffman Reflex and EMG Recording Methods

Printing of electrical changes which occurs in the surface of the membrane potential deals with the formation of action potentials by placing the electrode in to the surface of the muscle is called Electromyography (EMG). In general, EMG sıgnal gives information about electrical activation of muscles cells in motor unit and signals transfer to the nerve muscle junction along nerve cells (Cerrah et.al. 2010(a)). H reflex is usually obtained from m. triceps surae (particularly soleus muscle). The H reflex studies are done with EMG device and generally tree types of surface electrodes are used. These are; the active electrode, reference electrode and ground electrode. In addition to these

electrodes, stimulation electrode is used. Active electrode is placed on the motor point which nerve makes entrance to muscle on belly. Reference electrode is placed closed to the tendon or bone but away from muscle. The ground electrode is placed between recording electrode and stimulation electrode. Stimulation electrode is placed over the popliteal fossa on tibial nerve (Weiss et.al. 2010). Before replacing electrodes the skin surface should be cleaned with alcohol and appropriate impedance environment should be created (Cerrah et.al. 2010(b)). Recording method of H reflex is begin with giving low intensity electrical stimulation (0-10 mV) and impulse intensity stimulates the tibial nerve by gradually increasing with 1 ms ways. During stimulation position of electrodes and pressure on the skin should be constant at the same level. When the intensity of stimulation increase H reflex amplitude occurs that is a late response. However, at this time short latency may response starts to appear. When the intensity of stimulation increases the H reflex amplitude decreases, whereas the M response amplitude gradually increases. When it is reach to maximal or supramaximal intensity of stimulation H reflex amplitude completely disappears but M response amplitude makes plateau steadily. As a result of a stimulation depolarization of primer afferents (all the afferent nerve fibers from the environment and which have not yet synapses are called primer afferent fibers) occurs (Ertekin, 2006). As a result activation of 1a afferent results in action potential (Palmieri et.al. 2004). In H reflex, muscle spindles are not involved and receptor function reflex arc stay outside therefore H reflex can also be admitted as index for excitability of alpha motor neurons (Bulut et.al. 2000). H reflex amplitude is also an indication of the size and number of excitatory motor unit and shows that synaptic effect between 1a afferent terminals and post synaptic membranes of motor neurons. Vibration, perhaps the most effective mechanical stimulus to mobilize afferent nerves of muscle spindle. Electrical stimulus applied to tibial nerve stimulates the anterior horn motor neurons first inserting the medulla spinalis from the back of the roots and motor impulse activate striated muscle fiber which is again turning to triceps surae trough the same peripheral nerve with passing impulse to motor axons. Synchronous response shows that impulses are being taking away by fast transmitting 1a afferent fibers (Ertekin, 2006). Researches use H reflex stimulation (recruitment) curve to measure the motor neuron pool excitability. In the most commonly used H reflex recruitment curve; H reflex is compared with maximum motor response (M response). The ratio between H reflex and M response estimate that the percentage of the motor neurons which depolarize as a response of 1a afferent activation (Hmax/Mmax). Another method of evaluation of the H reflex is recording the peak of H reflex excitation curve (Hmax). This measurement is used to predict the changes in motor neuron pools excitability. The third evaluation method is used to predict excitability of low threshold motor neurons. In this method, stimulus gradually is increased starting with sub threshold levels and threshold value which is reached by H reflex is recorded (Kipp et. al, 2011). Despite the use of these three methods continuous curve data should be obtained and a method must be selected for the purpose of the study to obtain sufficient results. The H reflex measurements should be made very sensitively. Because H reflex is influenced by strong neck movements, real time increasing the frequency of stimulation, strong electrical stimulation, and vestibular effects and if measurement standards cannot be accomplished wrong conclusions and wrong comments can be done (Ertekin, 2006). Studies on the H reflex, levels of muscle activation of the subjects participated in the group need to be similar, the target muscle EMG monitoring and also antagonist EMG muscle levels should be measured to

control and limit the component like reciprocal inhibition which effect H reflex measurement. Measurements made in different circumstances and at different times, M response does not change and M wave is an available value to make comparison. In order to obtain reliable M responses muscle should be stimulated at an appropriate level. In H reflex measurements between periods of stimulation should be more than 3 s. to avoid post activation depression. The H reflex measurement made a different time and circumstances Hmax/Mmax ratio is useful method of assessment(Zehr, 2002).

The Effects of Whole Body Vibration Training on H Reflex

WBV training provides contraction of muscles as a reflex which is based on the tonic vibration reflex and monosynaptic reflex place a role in the contraction which occurs with vibration (Pöğün, 1977). Hoffmann reflex is one of the appropriate methods to determine the quality of WBV training to evaluate monosynaptic reflex activity which occurs in the spinal cord (Palmieri et. al., 2004). When examined researches are evaluated on the scope of this review, WBV training has contradictory results about the effect on H reflex which are not consistent with each other. In two research measurements made after H reflex training showed an increase (Nishihira et. al., 2002; Sayenko et. al., 2010), in three researches; there was H reflex decreased (Apple et. al., 2010; Hong et. al., 2010; Kipp et. al., 2011), in two studies; there was no change in H reflex (Armstrong et. al., 2008; McBride et. al., 2009). The reason of these contradictions was that H reflex could be affected many factors or studies were generally done by an acute time. So, in H reflex studies standardization of measurements and method should be determined carefully.

Motor units with in a muscle show different characteristics in terms of areas and fiber density. For example, before weak voluntary contraction small motor units are activated which innervate a small number of muscle fibers because small cell somas of these units are smaller and firing threshold are lower. However, in fast twitch motor units the threshold of alpha motor neuron somas are higher and fiber density of these motor units are greater and contraction times of motor units are shorter. These wide ranges of units are activated in more powerful muscle contraction. This is important in the formation of maximal contraction. In a maximal contraction, on the one hand, activated firing frequency of muscle fibers is increasing, on the other hand gradually higher arousal threshold of motor units contraction are added to contraction and so maximal contraction is provided with an intense activation of motor unit (Ertekin, 2006). For these reasons variables taken in to research should examine not only Hmax/Mmax value but also the threshold of h reflex value and a frequency of firing. In studies have been considered the duration of WBV training is applied for short periods and applications of WBV longer term training protocol are needed.

Table: The Effects of Whole Body Vibration Training on H Reflex

Author	Subjects/ Features	Training Protocol	Mm	Hz	Time	Results
Nishihira et. al. (2002)	n=17 (age:19-28 year) Neurologically healthy individual	On WBV platform the right and left study, knee angle is to be bending between 100-120 degrees.	2-4 mm	25 hz	3min.x 3 repetition	After WBV training a significant increase in H/M max and H max value (p<0,05), after training there is statistically significant decrease in H and M threshold (p<0,05). As a result, after WBV training alpha motor neuron excitability was increased.
Armstrong et. al. (2008)	n_{female}=11 n_{male}=8 Age: 19±1 year	On WBV platform, knee is to be bend nearly 10-15 degrees stand application in a fixed position	2-4 mm	40 hz	1min.	Measurement of H max and M max values before and after training, significant difference was not found statistically.
McBride et. al. (2009)	n_{male}=19 Age:22,6±2,2 year	On WBV platform, static squat work. Knee angle is 100 degree	3,5mm	30hz	30s.x3 repetition	In max. repetition of 1 RM there is statistically significant increase of %10,4 (p<0,05).After training H max and M max value; There was reduction but it was not significantly.
Sayenko et. al. (2010)	n=8 Individual who have not spinal cord diseases.	On WBV platform knee angle is to be bend 160 degrees as a natural position in a passive	1 mm	35 hz	1 minute	H reflex statistically showed significantly decreased during WBV (p<0, 05). After WBV, H reflex showed significantly increased (p=0, 01). As a result, İnhibition emerged during WBV and after WBV motor neuron excitability increased.
Apple et. al. (2010)	n=27 Age:21-41 year	On WBV platform knees are to be bend 160 degrees in a fixed position	2-4 mm	40 hz	3minute	H reflex amplitude statistically showed significant decreased (p<0, 05).
Hong et. al.(2010)	n_{female}=20 n_{male}= 20 Age= 24,27±5,97 year	On WBV platform knee angle is to be bend 100 degrees as a posture application	5 mm	20 hz	2 minute	After four weeks of WBV training H reflex showed statistically significant %32 decreased (p=0,001). As a result, WBV training increased induced synaptic input by decreasing presynaptic inhibition and so motor neuron excitability increased. In this case motor units which have got higher threshold activated and maximal voluntary contraction increased.
Kipp et. al. (2011)	n_{female}=9 n_{male}=11 Age:7,4±4,4 year	Knees are on natural position, hands are holding WBV device in a static position of stand application	2-4 mm	25 hz	5 minute	After 1 minute of WBV, there was statistically a significant a decreased in H reflex (p<0, 05). As a result, WBV training decreased spinal reflex excitability.

RESULTS

As a result of review, the appropriate time and intensity of WBV training is thought to have beneficial effects on neuromuscular adaptation. Although in many studies it was claimed that WBV trainings significantly increase the strength and also it have positive effects on explosive strength, flexibility and balance, it can't be reached

consistent result with each other about the studies of neural adaptation effects. So, for this reason, studies which are done for determine the neurological effects of WBV trainings, its limitations and groups of subjects should be determined carefully. Hoffmann Reflex is a reliable method of measurement used for many years in routine clinical studies and also is a measurement method which is used to determine the performance of motor task, the effects of training and musculoskeletal disorders associated with training. Assessment of H reflex is thought to be one of the appropriate methods to determine the effects of WBV training on neuromuscular adaptation.

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