Effects of Short-term Whole Body Vibration Training on Knee Proprioception in Healthy Adults and People with Knee Osteoarthritis

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Abstract

Introduction: Many researches have studied the short and long term effects of whole body vibration on muscle strength and proprioception. The effect of this modality in athletes and healthy population have been studied by several researchers; however, to accept it as a therapeutic procedure, it needs more studies. In knee osteoarthritis, muscle weakness and joint instability can affect proprioception. Since some researchers reported the effect of whole body vibration on kinematic and neuromuscular control and some others have rejected this effect, the purpose of this study is to investigate the short term effect of whole body vibration on proprioception of the knee joint in patients with knee osteoarthritis and healthy individuals. **Materials and Methods:** In this experimental study, two groups of the same size (21 in healthy and patient groups) went through whole body vibration (60 Hz frequency, low amplitude and 25 Hz frequency , high amplitude) and the knee joint properioception accuracy was assessed (by joint angle replication test) and was compared with the no-vibration baseline results. **Results** The joint angle reconstruction error was different between two groups and also before and after whole body vibration. Whole body vibration with 25Hz frequency and high Amplitude was ineffective in improvement of knee properioception in osteoarthritis patients (P=0.09). But the vibration with 60 Hz and low amplitude was effective significantly in properiception improvement and decrease of joint angle reconstruction error in healthy (P=0.01) and patients groups. (P=0.02). **Discussion:** This study shows that the whole body vibration with proper frequency and amplitude (60 Hz and low amplitude) can have immediate effect on the knee joint properioception in patients with knee osteoarthritis and healthy people.

Key words: Whole Body Vibration; Knee; Osteoarthritis; Properioception

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Introduction

Although doing proprioception exercises is considered to be the most popular way to improve the joint proprioception, many people are not able to take this type of exercise due to the poor condition of their posture (1). It is worth mentioning that many researchers are intended to accelerate the rehabilitation programs which is an underlying trend specifically for athletes (1). In Physiotherapy, it is the basic fact that every single technique which not only can shorten the treatment but it also can increase the effectiveness of the patients attracts a lot of attention. Whole body vibration as a mechanical movement is introduced to be a suitable exercise for the neuromuscular system in which a person stands on the vibration machine and performs various types of exercises including lunging with or without an extra load, while the vibration with the frequency of 15-69 Hz, and the amplitude of 1-14 mm is transferred from the vibration plate to the body (2).

There have been several studies conducted to examine the short-term and long-term effect of the whole body vibration on the joints' strength, body balance, physiologic factors, hormones level and anabolism as well as the density of the bones (3-6). The results of these studies have demonstrated that the whole body vibration can improve the balance and proprioception, and can have influence on anabolic and hormone level, walking cycle, blood circulation and bone density by affecting the neuromuscular system. The results of these studies are derived from the stimulatory effect of the whole body vibration on the skin receivers, muscular dukes, joint Mechanoreceptors and changes in the brain (6-15). On the other hand, there is a group of researchers who do not approve the positive effects of the whole body vibration especially on the proprioception (16).

Body tissues experience the fluctuation of approximately 30 HZ due to their natural vibrating frequency. Following the tissue absorption, a decrease in the domain of this fluctuation is witnessed. In case that tissues natural frequency and the frequency of the vibration get closer, the domain of the vibration will increase because of the phenomenon called resonance. In normal conditions this domain is reduced to the minimum because of the attenuation of the body tissues. Different body structures including, bone, Cartilage, Synovial fluid, Soft tissues, Joint kinematics and muscular activities contribute to tuning and transferring vibration waves to the body (17). Body adopts the strategy of adjusting its muscular activities in order to minimize the tissues vibration, as a matter of fact the level of muscular activity depends on the interaction between the body and vibration power (18).

According to the findings of several studies, different injuries can affect the proprioception and weak proprioception itself can be the main reason for the constant injuries occurring after the joint and tendon recovery. Moreover, some studies have illustrated that the pain can have effect on the proprioception, in other words, the increase in the pain message decreases or changes the proprioception afferents due to the metabolic changes and aggregation of inflammatory substances such as; Bradykinin, Arachidonic acid, Atrophy as well as the fat filtration in muscles, this affects the local proprioception an also central mechanism of posture control so that it leads to imbalance of body. There is also evidence of the fact that due to the pain and muscle inflammation, inhibition of Osteoarthritis gamma motor neuron discharge is caused, in this condition the information transferred through dukes are not accurate and it will bring about the change in the proprioception sensitivity (18).

On the other hand, knee joint is a common place for Osteoarthritis to occur (16). Osteoarthritis usually occurs as a result of no clear reason; however, abnormal mechanism of the joint is the main reason for secondary Osteoarthritis which is a Physiological response to different forces imposed on the joint. Considering the fact that knee joint proprioception is made of the total messages of afferents from joints receivers, tendons, Joint capsule, Ligaments, meniscus connections and skin, also joint as muscles receivers are the major sources of knee joint proprioception, Paresis and Hypermobility among the patients suffering from knee Osteoarthritis result in proprioception disorders and Weakness (17).

Hurley *et al.* have shown that degenerative changes in knee joint structure (OA) might be results of sensory information changes in joint mechanical receivers (19). It may lead to weaken activation ability in quadriceps muscle at this stage. In fact there is a wide range of reasons regarding the mentioned result, the main ones to be named are; inflation, pain, lack of strength in the joint and building injuries. Although the importance of every single reason has not been clearly determined yet, it is unanimously agreed that it is caused because of the effect of discharge of the injured knee sensory receivers (20-22).

By taking the available literature into account it can be seen that some researcher have rushed to employ the whole body vibration while accompanying different types of exercises and to conclude that it can be positively effective. Although there are some sources in favor of this method and its positive effect on old patients with various knee joint problems, other resources exist which don not enjoy statistical importance (18).

Some researchers called the effect of the vibration on Kinematic and knee neuromuscular control among healthy subjects into question in 2012. They came to this conclusion that it is really important to examine the effects of the changes in the whole body vibration variables on neuromuscular system prior to the implementation of the whole body vibration therapy for different types of diereses (20). Additionally, in 2013, it was reported that the whole body vibration had no statistically significant effect on the proprioception and neuromuscular function of the knee (23). In contrast, in 2014, the effects of the times when the vibration was employed during a session, as well as its frequency a vibration domain on the Knee proprioception among healthy people were closely examined and reported to be positively effective. By following the results of this study, more fundamental and practical examination of the issue was emphasized (24).

In the study conducted by Sandudo the effect of the vibration on the improvement of knee Kinematic and neuromuscular control was tested on 40 healthy subjects and no statistically significant effect on intensity of the movement potential change in Rectus femoris and Hamstring muscles was witnessed;

however they could reach valuable information on the correction of momentum control (16). Hanah carried out a study in which the effect of the whole body vibration on Knee proprioception and knee neuromuscular function on 14 healthy subjects who underwent two different interventions was surveyed (23). It was concluded in the end that the employment of the whole body vibration had no significant effect on the Knee proprioception and knee neuromuscular function.

On the contrary, Hwai-ting studied the immediate effects of different sets of frequencies of the whole body vibration on the sample comprising 18 healthy subjects in 2014. In this study the knee sense status as the indicator of the proprioception ability was examined, every frequency was studied in several sets (sets of four, six, eight and ten). Based on the results obtained, there was a noticeable improvement in the proprioception accuracy regarding the frequency of 35 Hz in all sets and the frequency of 20 Hz only in set of ten (24). There was better result regarding the accuracy of the whole body vibration in proprioception in joint sense status with lower frequency and low amplitude. In another study by Trans *et al.*, the effect of the vibration on the Knee proprioception and the muscular strength among the women suffering from knee Arthritis. To have the proprioception evaluated, the individual's ability to recognize the passive movement of the lower limb. According to this study the body vibration could improve the proprioception and the muscular strength in comparison with the subjects in the control group who did not receive any treatment. As it was reported in 2013 that the whole body vibration had no significant effect on the knee proprioception and knee neuromuscular function (18, 25).

According to the studies conducted by Yeung et al. to study the effect of the vibration on stretch reflex (26) and by Zhang to survey the vibration effect on the body balance and the general health conditions among old people, in the former, no positive effect was reported, but in the latter the statistically significant results were obtained (26). Regarding a growing increase in the implementation of the whole body vibration in Physiotherapy clinics and at gyms and the prevalence of the knee injuries specially in the community of young people as well as the active community and the existence of the contradictory research results about the positive effect of the whole body vibration, the current study was carried out to examine the short- term effects of exposure to the whole body vibration based on the intended programs for the Knee proprioception accuracy among healthy subjects as well as the subjects with knee Osteoarthritis during one session of treatment (24). As positional error angle is considered to be one of the popular method to evaluate the proprioception, the proprioception was evaluated using this method after the whole body vibration exposure (1).

Positional Error angle of proprioception includes the status sense and movement sense which plays a functional role in controlling the purposeful movements. Performing accurate and controlled movements constitutes an important part of the physical activities which require accurate sensory information of proprioception. When there is proprioception weakness repetition of the movement angle in a joint will not be error free. This error can be considered as an absolute or a relative error, by and absolute or a relative error it is meant that the error be examined without consideration of the movement direction (25).

A: absolute error: is defined as the measurement difference between the created angle and the target angle regardless of direction.

B: relative error: is defined as the measurement difference between the created angle and the target angle regarding the direction, in other words, if a person passes the target angle the angle measurement will be positive; otherwise, it will be negative.

Materials and Methods

The current study was a crossover trial and randomized control trial one. A group of heathy, non-athletes men in the age range from 40 t0 60 and a group of patients suffering from Osteoarthritis in the same age range comprised the sample of the study who were simply selected. After having authorization issued by the ethics committee with license number of 184338-9211675009, the study was initiated by selecting the sample. The subjects were completely briefed on the procedures and the instructions, then they were required to sign the written consent to be involved in the study. The subjects were required to stand on the Fitvib Excel Version 01.2008 made by Gemena company in England and to perform lunging during a session, they had to place one foot on the machine and another one on the ground, then the vibration with the frequency of 25 Hz and high amplitude was exposed for 3o minutes and after an interval the vibration was imposed again this time with the frequency of 60 Hz and lower amplitude for 30 minutes. Every single movement was repeated for 3 times and its mean was recorded as the repeatable level.

There were several inclusion criteria upon which the subjects were selected to be a part of the control group including; being right-handed and healthy, being physically active, ranging in age from 40 to 60, being of 160 to 190 cm height, not having any resistance training program during and two months before the study and not having any record of injuries in their lower limb. Volunteer subjects diagnosed with Osteoarthritis (1 and 2 degree) by the specialist were selected as the subjects in the treatment

Figure 1. Fitvib Excel Version 01/2008

group. The subjects in this group did have no experience of diabetes, Epilepsy, systematic diseases or Rheumatologic diseases and history of any injuries in their lower limb.

On the other hand, there were some exclusion criteria including; lack of ability to tolerate the vibration, feeling pain with three VAS degree or lack of willingness to continue the study.

To start the treatment, the Calibration of the device was checked by the representative of the provider company (Figure 1).

After having the height, weight and BMI of the subjects measured, the position of the tests was randomly determined. Before and after three position stated below, reconstruction Error of target angle in the dominant knee was measured for three times.

Tests positions

1. The common program of the whole body vibration device was performed by pulling the strips of the device while it was off. In this study a subject was required to stand on the vibration device and to perform lunging movement with one foot placed on the plate and the other on the ground.
2. Then the subjects performed the same movement while the device had the frequency of 25 Hz and high vibration domain.
3. Finally, the subjects repeated the same movement while the frequency increase to 60 Hz and the vibration domain was low.

The test positions were examined at interval of 30 minutes in order to prevent the fatigue and its effect on the results. To have the sense status of the knee joint determined, Electrogoniometer was employed. It was placed on the external part of the tight and leg parallel to the line which links the great trochanter of the thigh joint and the external Epithelial condyle of the thigh center and lower external ankle. To have the knee joint ability to rehabilitate examined, the comparison of functional movement status in the evaluation of the sense status of knee joint was made by reconstruction of the 30-degree target angle of the knee joint in standing and extension and 30-degree flexion positions. Every single variable was measured three times in order to decrease the error risk and its mean was measured to consider as the variable amount. After the subjects took all the positions three turns and each three times, they were asked to reconstruct the target angle while the error was measured with goniometers.

Results

To have the data collected analyzed, several statistical procedures were used through the use of SPSS software version 18. Kolmogorov–Smirnov test was employed to examine the normal distribution of the data. Additionally, *descriptive statistics* of data were used to determine the mean and median of the data. Finally, to examine the effect the inter-group variable of the health status and the intra-group variable of vibration status on the dependent variable Anova test was used. Finally, Tukey test was applied to compare the data two by two.

The demographic information of 42 subjects of the study; 21 healthy individuals and 21 patients suffering from Osteoarthritis all male, are demonstrated in the table 1.

Mean absolute error related to the patients before and after the first and second interventions were 2.9±1.4 and 2.9 ±2.2 and 2.2±1.7 respectively. Degree and relative error were measured to be 1/6±2/8 and 1.4±2.4. Regarding the healthy subjects, mean absolute error before and after the first and second interventions were respectively 1.7±1.2 and 1.3±1.2 and 1.6±1.3; besides, degree and relative error were 0.4±2.2 and -0±1.1. Considering the total number of the subjects mean absolute error before and after the first and the second interventions were 2.3±1.4 and 2.1±1.9 and 1.9±1.5, degree and relative error were respectively measured to be 0.8±2.6 and 1.2±2 and 0.7±2.4.

The comparison of the Independent samples test results between two groups of healthy subjects and patients before (P=0.009) and after the intervention with the frequency of 25 Hz and high amplitude showed that there was statistically significant difference (P=0.008); however, regarding the second intervention with the frequency of 60 Hz and low amplitude, there was no statistically significant difference. It should also be mentioned that the statistical difference was considered to be meaningful when the subjects distributed in two groups were compared at the stage when no vibration was applied. To be more specific, on the one hand, mean analysis of the subjects in

Table 1. Demographic information of the subjects

Status	Number	Age	Height	Weight	BMI
		Mean±SD	Mean±SD	Mean±SD	Mean±SD
Patient	21	56.9±2.8	173.7±5.1	81.0±6.5	2.84±1.83
Healthy	21	51.8±3.8	177.5±7.1	78.8±7.9	2.97±1.88
Total	42	54.3±4.2	175.6±6.44	79.9±7.2	2.90±2.06

two groups of study illustrated that smaller absolute error (1.38-1.23) was measured among the healthy subjects during the vibration with the frequency of 25 Hz compared with those suffering from Osteoarthritis which was statistically important. On the other hand, considering the relative error, there was statistically significant difference between two groups during no vibration (P=0.03), during the vibration with the frequency of 25 Hz (P=0.01) and during the vibration with the frequency of 60 Hz (P=0.04). Regarding the results relating to the relative error in two groups statistical difference of the interaction between the health condition and vibration was not significant (P=0.568 and P=0.911). The vibration frequency rate between two groups witnessed statistically significant difference (P=0.003), their interaction was not significant, though.

Discussion

The current study was conducted on 21 healthy subjects and 21 subjects with Osteoarthritis in order to examine the possible effects of the whole body vibration on the knee proprioception. The effects were examined by performing a specific program in which vibration with the frequency of 25 Hz and high amplitude and vibration with the frequency of 60 Hz and low amplitude were imposed on the subjects during a session, then Knee proprioception accuracy was studied by determining the positional target angle error amount.

According to the results of several studies, the whole body vibration can improve the proprioception by affecting neuromuscular system (6-15). The researchers of these studies believe this effect is derived from stimulation effect of the whole body vibration on the skin receivers, muscular dukes, joint Mechanoreceptors and brain changes (6-15). There are also some studies on the other hand that do not support the effect of the whole body vibration on the proprioception improvement; consequently, the current study was conducted to examine these contradictions closely (20).

A published study at 2012 pointed out effects of whole body vibration on Kinematic and Neuromuscular control as a question (27). In accordance with another published study at 2013, the authors reported that whole body vibration had no statistically significant effect on knee proprioception and its neuromuscular function. Hurley *et al.* proved that degenerative changes in knee joint structure, such as Osteoarthritis, might be results of changes in sensory information of mechanical receivers of the joint (28). The results of present study are in favour of these findings. Moreover, some studies have illustrated that the pain can have effect on the proprioception, in other words, the increase in the pain message decreases or changes the proprioception afferents due to the metabolic changes and aggregation of inflammatory substances such as; Bradykinin, Arachidonic acid, Atrophy as well as the fat filtration in muscles, this affects the local proprioception an also central mechanism of posture control so that it leads to imbalance of body. There is also evidence of the fact that due to the pain and muscle inflammation, inhibition of Osteoarthritis gamma motor neuron discharge is caused, in this condition the information transferred through dukes are not accurate and it will bring about the change in the proprioception sensitivity (29).

Regarding the examination of the absolute error in two groups of this study, during no vibration stage, as well as the first intervention (vibration with frequency of 25 Hz) there was statistically significant difference between two groups. However, after having the second intervention (vibration with frequency of 60 Hz) imposed, no statistically significant difference was witnessed which could explain a very fact that among the subjects of both groups proprioception could improve due to the exposure of the vibration with the frequency of 60 Hz.

According to the data collected, regarding the relative error, in all three positions; without vibration, vibration with the frequency of 25 Hz and vibration with the frequency of 60 Hz, there was statistically significant difference between two groups. This demonstrates that relative error decreases after the exposure of vibration with the frequency of 60 Hz which can lead us to conclude that using this frequency improve proprioception in both groups of healthy subjects and patients.

During the stage when no vibration was imposed, the amount of the error was greater among the patients. The same result held true after the first and the second interventions, but the amount of the error became greater after using the vibration with the

frequency of 25 Hz, and it decreases considerably after imposing the vibration with the frequency of 60 Hz. It is basically assumed that a healthy individual has stringer proprioception in comparison with a person suffering Osteoarthritis, this necessitates the treatment to be used for the patient. Based on the findings of the present study, although vibration could make statistically significant difference between two groups, the interaction between health condition and vibration was not significant which indicates that the difference observed was due to the vibration. Target reconstruction relative error in both experimental and control groups before and after the whole body vibration was generally different, but it did not enjoy the same pattern because the effect of the vibration with the frequency of 25 Hz with high amplitude on the proprioception improvement by measuring the target angle reconstruction error among healthy subjects was negative, but the error among the subjects suffering from Osteoarthritis was not statistically significant. These findings contradict the findings of the study done by Hwai-Tin to some extent. In that study immediate effects of the whole body vibration on proprioception increased noticeably after using vibration with the frequency of 35 Hz (24). This contradiction can be explained by taking this fact into account that, body tissues fluctuate as they receive vibration wave due to their intrinsic vibrating frequency to the point that the domain of the fluctuation decreases because of tissue absorption. In case that tissues natural frequency and the frequency of the vibration get closer, the domain of the vibration will increase because of the phenomenon called resonance. In normal conditions this domain is reduced to the minimum because of the attenuation of the body tissues. Different body structures including, bone, Cartilage, Synovial fluid, Soft tissues, Joint kinematics and muscular activities contribute to tuning and transferring vibration waves to the body (23). Body adopts the strategy of adjusting its muscular activities in order to minimize the tissues vibration, as a matter of fact the level of muscular activity depends on the interaction between the body and vibration power.

The effect of vibration on error development in afferent was also studied and according to the findings it seems that vibration affects the muscular dukes and brings about an increase in the function of these receivers, central nervous system deals with this change by increasing the length of the muscle (30, 31). In case of having no access to any other data, this error can only be explained by accepting that the joint is located at an unreal angle. This can be well illustrated by the following example. Vibration causes a person to make an error in elbow flexion. If he/she is asked to keep both his/her elbows at the same angle, then Biceps on one side gets vibrated, this person will make error in that arm and will assume that the arm is exposed to further extension; consequently, he/she will keep the arm which do not experience vibration in more extension. This error can lead to imagination of impossible anatomic positions. If a person takes benefit of his/her other information resources like; sight, hearing, he/she will be able to correct the error (32). Vibration also affects the movement direction (Vibration tonic reflex) so the effect of it is not simple and direct (32, 33).

Conclusion

Taking the findings of this study into account, it can be concluded that the whole body vibration can have immediate effect on the improvement of Knee proprioception among both healthy individuals and those who suffer from knee Osteoarthritis if in this method suitable frequency with proper amplitude are adopted. It should be also mentioned that despite the studies conducted to examine the long-term and short-term effect of the whole body vibration, different variables might be affective when it comes to interpreting the results of this study among which the status and the intensity of muscular contraction at the beginning of the vibration can be referred to.

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References

1. Moezy A, Olyaei G, Hadian M, Razi M, Faghihzadeh S. A comparative study of whole body vibration training and conventional training on knee proprioception and postural stability after anterior cruciate ligament reconstruction. British journal of sports medicine. 2008;42(5):373-85.
2. Hazell TJ, Thomas GW, DeGuire JR, Lemon PW. Vertical whole-body vibration does not increase cardiovascular stress to static semi-squat exercise. European journal of applied physiology. 2008;104(5):903.

3. Luo J, McNamara B, Moran K. The use of vibration training to enhance muscle strength and power. Sports medicine. 2005;35(1):23-41.
4. Rittweger J, Schiessl H, Felsenberg D. Oxygen uptake during whole-body vibration exercise: comparison with squatting as a slow voluntary movement. European journal of applied physiology. 2001;86(2):169-73.
5. Torvinen S, Kannus P, SievaÈnen H, JaÈrvinen TA, Pasanen M, Kontulainen S, et al. Effect of a vibration exposure on muscular performance and body balance. Randomized cross-over study. Clinical physiology and functional imaging. 2002;22(2):145-52.
6. Bosco C, Iacovelli M, Tsarpela O, Cardinale M, Bonifazi M, Tihanyi J, et al. Hormonal responses to whole-body vibration in men. European journal of applied physiology. 2000;81(6):449-54.
7. Cardinale M, Soiza RL, Leiper JB, Gibson A, Primrose WR. Hormonal responses to a single session of wholebody vibration exercise in older individuals. British journal of sports medicine. 2010;44(4):284-8.
8. Cardinale M, Leiper J, Erskine J, Milroy M, Bell S. The acute effects of different whole body vibration amplitudes on the endocrine system of young healthy men: a preliminary study. Clinical physiology and functional imaging. 2006;26(6):380-4.
9. Cheung W-H, Mok H-W, Qin L, Sze P-C, Lee K-M, Leung K-S. High-frequency whole-body vibration improves balancing ability in elderly women. Archives of Physical Medicine and Rehabilitation. 2007;88(7):852-7.
10. Gusi N, Raimundo A, Leal A. Low-frequency vibratory exercise reduces the risk of bone fracture more than walking: a randomized controlled trial. BMC musculoskeletal disorders. 2006;7(1):92.
11. Cardinale M, Rittweger J. Vibration exercise makes your muscles and bones stronger: fact or fiction? British Menopause Society Journal. 2006;12(1):12-8.
12. Kawanabe K, Kawashima A, Sashimoto I, Takeda T, Sato Y, Iwamoto J. Effect of whole-body vibration exercise and muscle strengthening, balance, and walking exercises on walking ability in the elderly. The Keio journal of medicine. 2007;56(1):28-33.
13. Kerschan-Schindl K, Grampp S, Henk C, Resch H, Preisinger E, Fialka-Moser V, et al. Whole-body vibration exercise leads to alterations in muscle blood volume. Clinical physiology and functional imaging. 2001;21(3):377-82.
14. Kvorning T, Bagger M, Caserotti P, Madsen K. Effects of vibration and resistance training on neuromuscular and hormonal measures. European journal of applied physiology. 2006;96(5):615-25.
15. Rittweger J, Beller G, Felsenberg D. Acute physiological effects of exhaustive whole-body vibration exercise in man. Clinical physiology. 2000;20(2):134-42.
16. Sañudo B, Feria A, Carrasco L, de Hoyo M, Santos R, Gamboa H. Does whole body vibration training affect knee kinematics and neuromuscular control in healthy people? Journal of sports sciences. 2012;30(14):1537-44.
17. Nigg B, Wakeling J. Impact forces and muscle tuning: a new paradigm. Exercise and sport sciences reviews. 2001;29(1):37-41.
18. Jerosch J, Prymka M. Knee joint proprioception in normal volunteers and patients with anterior cruciate ligament tears, taking special account of the effect of a knee bandage. Archives of orthopaedic and trauma surgery. 1996;115(3-4):162-6.
19. Hurley MV, Scott DL, Rees J, Newham DJ. Sensorimotor changes and functional performance in patients with knee osteoarthritis. Annals of the rheumatic diseases. 1997;56(11):641-8.
20. Lamy JC, Iglesias C, Lackmy A, Nielsen JB, Katz R, Marchand-Pauvert V. Modulation of recurrent inhibition from knee extensors to ankle motoneurones during human walking. The Journal of physiology. 2008;586(24):5931-46.
21. Hopkins JT, Ingersoll CD. Arthrogenic muscle inhibition: a limiting factor in joint rehabilitation. Journal of sport rehabilitation. 2000;9(2):135-59.
22. Bergmans J, Delwaide P, Gadea-Ciria M. Short-latency effects of low-threshold muscular afferent fibers on different motoneuronal pools of the lower limb in man. Experimental neurology. 1978;60(2):380-5.
23. Hannah R, Minshull C, Folland J. Whole-body vibration does not influence knee joint neuromuscular function or proprioception. Scandinavian journal of medicine & science in sports. 2013;23(1):96-104.
24. Lin H-T, Chen Y-Y, Wang D-C, Chou P-H, Guo L-Y, Wu W-L. The Acute Effect Of Training Frequencies And Number Of Sets Of Whole Body Vibration On Knee Joint Proprioception. Journal Of Mechanics In Medicine And Biology. 2014;14(03):1450036.
25. Aaboe J, Henriksen M, Christensen R, Bliddal H, Lund H. Effect of whole body vibration exercise on muscle strength and proprioception in females with knee osteoarthritis. The Knee. 2009;16(4):256-61.
26. Yeung EW, Lau CC, Kwong AP, Sze YM, Zhang WY, Yeung SS. Acute whole-body vibration does not facilitate peak torque and stretch reflex in healthy adults. Journal of sports science & medicine. 2014;13(1):30.
27. Hurley M, Walsh N, Mitchell H, Nicholas J, Patel A. Long-term outcomes and costs of an integrated rehabilitation program for chronic knee pain: A pragmatic, cluster randomized, controlled trial. Arthritis Care & Research. 2012;64(2):238-47.
28. Hurley M, Dickson K, Walsh N, Hauari H, Grant R, Cumming J, et al. Exercise interventions and patient beliefs for people with chronic hip and knee pain: a mixed methods review. The Cochrane Library. 2013.
29. Jami L. Golgi tendon organs in mammalian skeletal muscle: functional properties and central actions. Physiological reviews. 1992;72(3):623-66.
30. Song Y-h, Lee S-y, Kwon O-y. Effect of Fatigue on Force-Matching in the Quadriceps Muscle. Physical Therapy Korea. 2006;13(4):10-5.
31. Riemann BL, Lephart SM. The sensorimotor system, part II: the role of proprioception in motor control and functional joint stability. Journal of athletic training. 2002;37(1):80.
32. Jones L, Hunter I. Effect of fatigue on force sensation. Experimental neurology. 1983;81(3):640-50.
33. Grigg P. Peripheral neural mechanisms in proprioception. Journal of sport rehabilitation. 1994;3(1):2-17.