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Clinical research of whole-body vibration training in knee osteoarthritis

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Abstract: Knee osteoarthritis (KOA) is a global public health issue with increasing age. In recent years whole body vibration (WBV) training is a safe and simple rehabilitation method for OA, most of the results showed good effect and enhancement influence, this paper provided a kind of research comprehensive analysis for researchers and clinical workers according to the main symptoms of knee osteoarthritis pain, dynamic structure of the quadriceps muscle strength, neuromuscular interaction structure of proprioception, gait walking ability. WBV can alleviate patient pain through different mechanisms. To muscle strength and proprioception improvement, WBV shows inconsistent results, which may require further exploration based on different parameter settings. And WBV training shows consistent performance in improving walking ability. The main reasons for the inconsistent results may involve factors such as vibration devices, various parameters mode, training programs, and whether they are long-term. In the future, for subjects of different ages, it is still necessary to carefully design WBV intervention plans for rehabilitation purposes in order to explore better training effects.

1. Introduction

Knee osteoarthritis is a chronic osteoarthrosis characterized by synovial inflammation, articular cartilage damage, joint edge hyperplasia, and degeneration or loss of subchondral bone reconstruction. Its typical symptoms are pain, joint stiffness, and reduced quadriceps strength, and severe physical disability [1]. According to the epidemiological investigation, the incidence of KOA is increasing with the accelerated aging of the society. Clinically, there are many treatment methods for KOA. It is always the direction of clinical efforts to find a simple, safe and effective rehabilitation method to delay its development and improve the quality of life of patients to reduce lower limb pain, improve muscle strength, and improve proprioception and walking ability. In

recent years, some studies have found that whole-body vibration (WBV) training is mostly considered to have a positive effect in knee function rehabilitation. Not only are there advantages in sports training, but also popular in community and urban health promotion centers and gyms, but also as a complementary even to traditional rehabilitation training and treatment in KOA medical rehabilitation.

This paper mainly reviews the effects of vibration training on the main symptoms of KOA pain, quadriceps muscle strength, proprioception of neural interaction, and walking ability in clinical application research.It may furtherly deepen people to understand the whole body vibration training in the clinical expected rehabilitation training methods.

2. Effect of vibration training on the pain of the subjective symptoms of KOA patients

Pain is the knee osteoarthritis that firstly shows the most prominent symptoms, most patients are trying to relieve symptoms with oral anti-inflammatory analgesic drugs or topical plaster, and this method is more for the purpose of symptomatic treatment, but can not really cure the root cause. The root cause of traditional Chinese medicine is the qi and blood, joint meridian obstruction. The understanding of pain in Chinese medicine is "those who are in pain will not feel pain, while those who are in pain will not feel pain". If the qi and blood are smooth enough, there is no pain, and the development of KOA will be greatly delayed or stalled.

Many studies have considered the therapeutic effect of using WBV for KOA on pain intensity. However, the evidence on the effectiveness of WBV in pain relief remains ambiguous in some systematic evaluations, with no additional exact improvement in pain relief. Liu et al. [2] study showed that WBV can effectively reduce knee pain in patients with KOA. They suggested that the possible mechanism of action is that vibratory stimulation causing proprioceptive feedback inhibition, reduces the pain potential difference and thus raises the nociceptive threshold. In addition, the researchers believe that one of the reasons for KOA pain is the joint instability caused by insufficient muscle strength of the knee joint. The symptoms appear when walking with weight, and the quadriceps muscle strength is increased through vibration. Then the stability of the knee joint is strengthened.

By summarizing the effect of WBV on knee osteoarthritis pain, found that many studies have analgesic effect and can relieve clinical symptoms[3] . In his paper, Rittweger and other researchers believe that WBVT can reduce pain sensitivity by affecting the peripheral and central receptors, thus relieving pain.

It is also believed that vibration causes the activation of the lower limb stretch reflex, including the I and type muscle fibers in the biceps and quadriceps muscles that are closely related to knee pain and joint function. Some studies have found that after the lower limbs are under low-frequency vibration, the blood flow speed increases and the skin temperature increases. At the same time, it has a relaxing effect on soft tissues such as joint capsule, muscles and ligaments. In the non-spasm state between soft tissues, the theory of qi and blood is easier to pass through, and the tissues around the knee joint are nourished, and the pain symptoms can be relieved.

3. Effect of vibration training on muscle strength of quadriceps of KOA dynamics

Lower limb strength in the knee joint movement buffer play an important influence, the muscle imbalance around the knee joint will affect the limb line, not only can cause pain, long cause knee varus, knee valgus deformity, and joint uncontrolled or increased load can lead to the risk of disease progression, the strength of the quadriceps is an important intrinsic factor to control the function of the knee joint. Therefore, the strength of the quadriceps muscle is a structure that must be considered in KOA studies. Quadriceps muscle strength deficiency in KOA patients is the main

factor affecting the biomechanical action and stability of joints [4]. Quadriceps imbalance can cause biological force line Q Angle abnormalities, lead to the movement of the patella trajectory change, patella and femoral cartilage on abnormal trajectory wear, the joint contact area and pressure change in pain and dysfunction, not timely looking for reasons to correct the muscles around the knee joint force line imbalance eventually lead to the occurrence of KOA, at the same time into muscle and biological force line imbalance.

3.1 Effect of vibration training on KOA muscle strength

According to previous research and practical experience, lower limb muscle strength in KOA patients has decreased to different degrees. Øiestad et al [5] studied a close relationship between knee extensor weakness and the risk of KOA, and individuals with knee extensor weakness, especially women, have a significantly increased risk of KOA.

In clinical KOA rehabilitation, most of the various muscle strength training instruments are used to play the role of muscle exercise. For older people, such as having knee joint disease, the desire to rely on simple muscle strength resistance training is less operable. Choosing the vibration training with high safety is a better scheme. Due to the advantages of vibration training, some researchers suggest to study WBV to improve the muscle strength of KOA patients as an effective alternative to anti-group training. Domestic and foreign studies showed that Trans et al [6] reported increased quadriceps muscle strength after WBV exercise on a stable vibration platform. Women with knee pain had significant improvement in quadriceps muscle strength after WBV exercise. Furthermore, Roelants et al [8] reported improvement in quadriceps muscle strength after WBV in older women. However, Park et al [9] reported a similar increase in quadriceps muscle strength after WBV training compared to its controls in their experiment. WBV shortens rehabilitation time compared to other traditional resistance training programs, it is a method of training the body on a vibration platform [10]. In another systematic review, Osawa et al [11] studied the effect of WBV on muscle strength in young and older adults was also positive. Lai et al. [12] compared simple strength training, health education and increased vibration training, and found that the addition of WBV in the rehabilitation training program could significantly enhance the muscle strength and rebound ability of the quadriceps muscle compared with the same exercise without WBV. It is predictable from the literature that adopting an optimized WBV to enhance knee muscle strength can be achieved.

3.2 Mechanism of action of the effect of vibration training on KOA muscle strength

Although vibratory stimulation can exert positive effects on lower limb muscle strength, the mechanism is not currently well defined. It is generally believed that when skeletal muscle is subjected to mechanical vibration, the muscle-tendon complex length undergo transient and rapid changes, activating the excitability of muscle spindle in muscle fibers, especially the primary Ia afferent fibers, to activate skeletal muscle fibers through large α motor neurons. Not only improves the recruitment of motor units, but also more efficiently utilizes the proprioceptive feedback loop [2].

Osawa et al [11] suggested that vibration stimulation of muscle spindle induced motor neuronal reflex of muscle contraction, similar to the tonic vibration reflex. Mechanical stimulation of muscle length is reflexively transmitted from the muscle shuttle to the CNS via monosynaptic and polysynaptic pathways for recognition and appropriate response selection. This so-called "tension vibration reflex" is associated with several peripheral responses, among them muscle contraction, that may explain the improvement in muscle strength. Excitation of the Golgi body tendon organs causes changes in muscle tone that activate reflex activity, thereby forcing the active muscle to relax and antagonize muscle contraction. In addition to these above spinal reflexes, after WBV, neuromuscular changes, increased intramuscular temperature, and increased peripheral blood flow

cause improved muscle performance. When the muscles undergo vibration training,their tension will be increased and this also improves the blood flow velocity of the muscle. Maintenance and promotion of muscle tone helps muscles to obtain sufficient blood circulation to prevent excessive reduction of blood supply in inactive muscles. The muscle elasticity and hardness increase the muscle fatigue resistance, and the knee function will be improved [2]. The above mechanism shows that the WBV training provides the training basis for increasing the knee muscle strength.

3.3 Controversy over the influence of vibration training on KOA muscle strength

The influence of vibration training on muscle strength is still controversial, involving many influencing factors. Anwer et al [13] conducted a systematic review of the literature and meta-analysis of the effect of WBV on quadriceps muscle strength in knee OA patients in four randomized controlled trials including 162 participants to assess the evidence of the effect of WBV on quadriceps muscle strength in KOA patients. The WHO report concluded that WBV training has similar effects on individual strength increases, summarizing the differences between the four studies in the article: the intervention duration, the type of control group, and vibration parameters, including frequency, amplitude, and acceleration. The study has some limitations: the sample size is very small, including only four studies, and only female participants. There are also no studies in the text assessing the prognosis effect of WBV alone. For example, it is uncertain if a single WBV produces similar or better effects when used in combination with other interventions, which is also an important area of research to determining the clinical efficacy of WBV. Moreover, different functional vibration platforms with different technical parameters may produce different therapeutic effects, such as different degrees of differences in pain reduction, improved bone mineral density, postural control and functional changes. Furthermore, none of the selected studies assessed the long-term impact of WBV on prognosis. In addition, due to the lack of consistency among many of the research methods, the optimal vibration parameters were not proposed. Based on the current retrospective analysis, WBV did not have an additional benefit on quadriceps muscle strength compared to the same training controls as in the WBV group in the KOA patients. Due to the lack of consistency of parameters such as vibration protocol, training intensity and reported results, more studies are needed to confirm the effect of WBV training on the quadriceps muscle strength in patients with KOA. In WBV, future studies should strictly consider vibration training with various parameters to standardize guidelines for further long-term studies. For example, mechanical stimuli characterized by vertical sinusoidal oscillations are transmitted from the foot to the rest of the body via a vibrational platform. The influence of WBV on the human body seems to depend on the interaction of vibration characteristics, involving vibration type (lateral alternating vertical oscillation, simultaneous vertical oscillation, multidirectional oscillation), vibration frequency (Hz) and amplitude (Mm), exercise protocol (frequency and duration, body position) and the characteristics of the subject (age, gender, training status), etc. are all factors to be considered.

4. Effect of vibration training on the proprioception of KOA neural interactions

In recent years, researchers have found that decreased proprioception is a common problem in KOA patients. It has been reported that proprioception of knee joints in KOA patients is significantly impaired [14]. And studies have shown a potential association between impaired knee proprioception and early pathological changes in KOA [15]. To date, studies have investigated the effects of WBV training on KOA proprioception. Insufficient proprioception affects the judgment of joint position and movement, so the neural interaction of proprioception is a problem that must be solved in knee rehabilitation.

Movement of the knee joint as a working mode of neuromuscular activity, WBV training is

thought to contribute to improved proprioception and neuromuscular response [16]. Xie Yujie et al [17] tested the effect of proprioceptors from the multidimensional stimulation of proprioception, and found that different vibration movements and angles have different positive advantages for KOA. The experimental group and control group of the study used different knee movements and different angles for vibration training: specifically set as "squat to the knee flexion greater than 90 and flexion 120, and move the trunk from left to right under the two angles; one leg standing training; vibration and the relaxation training. "The vibration frequency of the test group was 30Hz, and the vibration frequency of the control group was trained with three frequency changes of 20Hz, 30Hz and 40Hz. There was no significant difference between the location perception score and WOMAC scores of active 30 and 60. After 4 weeks of intervention and 3 months of follow-up, the WOMAC score was significantly reduced from the baseline level between the active 30 and 60 locations. Compared with the test group and the control group, there was significant difference between active 30 and 60 after intervention and 3 months of follow-up. The final conclusion was that the whole body vibration therapy and vibration therapy with constant parameters could improve the proprioceptive function of KOA patients with lock study subjects, and the proprioception and motor function better than the vibration training with constant parameters. In the study of Trans et al· [5], by comparing the effects of two different types of vibration training devices, the proprioceptive index (threshold to detection of passive motion, TDPM) improved in the vibration training group but not in the traditional stable vibration group. However, there are also different research views: Segal et al [18] results showed that 8 weeks of WBV training has no significant advantage on the improvement of knee proprioception. The inconsistency in the conclusions of previous studies may be due to differences in the type of vibration devices or the use of proprioceptive testing methods. Our current versatile whole-body vibration training equipment is divided into two categories. Usually WBV training is applied on a vertically vibrate stabilized platform, which can vibrate up and down. Another type, called vertical alternating vibration, is also commonly used with stable WBV devices (vertical platform), which may cause no positive results at the collected vibration perception threshold of the lower limbs. Therefore, more standard research needs to be done on the proprioception training of KOA patients.

5. Effect of vibration training on the walking ability of patients with KOA

Gait is a behavioral feature of walking ability. If KOA patients cannot get effective treatment, walking ability decreases, abnormal gait parameters, such as step frequency, step length and step speed will decline, which will affect normal walking. Rogan et al [19] suggests that neural interaction, stance and gait are a biomechanical continuum, and a recent review reported beneficial effects of long-term WBV training on balance control in postural conditions. The beneficial effects produced by vibration training can be extended to gait.

Fischer et al.[20] studied several studies on the effects of WBV in patients with knee osteoarthritis in terms of walking ability. All training studies ranged from 8 to 24 weeks, three to five times a week, and the frequency and amplitude of platform vibration were 25 to 40Hz and 2 to 6mm, respectively. The intensity was gradually increased in all of the studies. Duration periods ranged from 20 to 70s, and rest periods ranged from 20 to 70s. The walking capacity index was evaluated using the standing walking timing test (Timed Up and Go, TUG) or the 6-meter walking test (6-Meter Walk Test, 6 MWT) and the 10-meter walking test (10-Meter Walk Test, 10 MWT). Although the analysis found that the level of evidence was contradictory, it was concluded that strong evidence supports the positive effect of increasing WBV could improve 6 MWT in patients with KOA. There were also significant improvements in 10 MWT in KOA patients after WBV training.

Jia Yue et al. [21] evaluated their gait from the change of gait parameters through 8-week whole-body vibration training in elderly. The experimental group in the study performed standing, half squat posture control and half squat movements for 30 minutes of vibration strength training three times a week. The control group only completed the same movement training in the experimental group according to the time and frequency requirements of the experimental group. The results suggest that 8 weeks of WBV is very effective for gait improvement in older people with KOA. After the whole body vibration training, the gait cycle is significantly shortened, but the proportion of swing period increases, the support period ratio decreases, and the double support time ratio decreases, indicating that the step size increases, step width decrease, step frequency and step speed increase. Conclusion Supporting the elderly KOA patients to improve the gait through vibration training. In its published literature, it is believed that WBV is effective to increase gait by stimulating muscle spindle, and can increase the number of nerve impulses, and enhance the sensitivity and response ability of the nervous system, but the muscle strength change is not measured in the text. It can be seen that the researchers believe that WBV can improve the gait walking function.

6. Summary and Outlook

The articular cartilage almost has no regeneration ability. Although there are many rehabilitation training techniques for the treatment of KOA, no ideal treatment has been found up to now in clinical practice. WBV can be regarded as a safe and simple means of rehabilitation for the elderly, although we from the main clinical symptoms of pain, dynamic structure of the quadriceps muscle strength, neuromuscular interaction structure of proprioception, gait walking ability research the comprehensive findings about the vibration scheme of clinical research is not completely consistent, but most showed a good gain effect. The reasons for the inconsistency may involve the vibration device, various parameters, training program, long-term nature and other factors. The most prominent advantage of WBV for KOA patients is the small difficulty of rehabilitation training, the high safety of the machine, easy to accept, which allows the soft tissue around the knee joint to relax and feel comfortable.

In the future, for subjects of different ages who would use different vibration modes such as frequency, intensity, amplitude, time, we still need to carefully design WBV intervention programs for rehabilitation purposes, and should be implemented to evaluate its effectiveness for more popularization.

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