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Effectiveness of Whole-Body Vibration Training on Pain, Muscle Strength and Dynamic Balance among Postmenopausal Women with Osteoarthritis of Knee

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Abstract: ***Osteoarthritis (OA) is the single most common cause of disability in older adults. The WBV exercise is a useful modality and safe method for rehabilitation in the patients who are unable to participate in active modalities because of severe disability according to advancing age and progression of knee OA. Aims and Objectives: To find out the Effect of Whole Body Vibration Training on Pain, Muscle Strength and Dynamic Balance among Post-Menopausal women with Osteoarthritis of Knee. Methodology:- 30 menopausal women with Knee Osteoarthritis were assessed and selected for the study who satisfies the inclusion criteria were assigned into two groups of 15 subjects each: Group A- Experimental Group underwent a protocol with Whole-Body Vibration Training along with Conventional exercises and Group B-Control Group was treated with only Conventional exercises and performed it for 7 days (30 min/day). The outcome measures were Numeric Pain Rating Scale (NPRS), Modified Sphygmomanometer Test (MST), Timed Up to Go Test (TUGT). Using these outcome measures pre-test and post-test value were obtained. Result: In Experimental group, the Pain has reduced (p=0.000), the Hamstring muscle strength has increased (p = 0.002), the Quadriceps muscle strength has increased (p= 0.004), the Dynamic balance has increased (p = 0.012) than in Control group. On comparing the difference in the results between the groups, the Pain (p = 0.008) and Quadriceps Muscle Strength (p = 0.12) in Experimental group showed greater change from the control group. Conclusion: In this study, it is concluded that WBVT is better in pain reduction and quadriceps muscle strength when compared to the control group.***

Keywords: Osteoarthritis; Knee joint, Post-menopausal, Whole Body Vibration, Therapeutic exercise

1. Introduction

OA is one of the most prevalent condition resulting to disability particularly in elderly population [1]. It is a degenerative disorder of synovial joint, characterized by loss of articular cartilage, with reactive change in subchondral & marginal bone, resulting in the development of bony spurs and cysts at the margins of the joint [2]. OA strikes women more often than men and it increases in prevalence and incidence after menopause. Females are found to have more severe OA, a greater number of joints are involved, have more symptoms and increased hand and knee OA. Many experimental, clinical and epidemiological studies suggest that loss of oestrogen at the time of menopause increases a woman's risk of getting osteoarthritis and use of Hormone Replacement Therapy (HRT) did seem to be associated with not only relieving of symptoms but also reduced rate of progression of osteoarthritis [3] Knee Osteoarthritis (KOA) is associated with advancing age and a most common cause of locomotor disability and is characterized by the degradation an erosion of articular cartilage, inflammation of the synovial membrane, sclerosis of subchondral bone and formation of osteophytes which causes arthritic symptoms such as joint pain, swelling, stiffness, deformation and loss of function in middle aged and elderly people.[4]

Whole body vibration (WBV) is a mechanical stimulus characterized by oscillatory motion delivered to entire body from a platform where oscillator motion is of a frequency. Vibration training is a discipline where varying frequencies/ amplitudes/ forces will be transferred into separate body parts using precise joint angles for any limited time (approximately one-minute sets). This is done to create a purely eccentric muscle reaction and enable anaerobic activity. WBV training (WBVT) is done in half-squat because these static positions are usually held for a maximum of two minute and are designed to burn the maximum amount of energy in the shortest amount of time while causing no joint damage[5] Various studies regarding application of WBVT reported improvements in muscle strength, power, joint proprioception, balance and flexibility. Therefore, WBVT can be prescribed for the patients with Knee OA to strengthen the muscles in a very short time without doing a strenuous exercise.[6] Most of the studies in whole-body vibration training is focused on the weight reduction and fat loss in obese subjects and BMD in post-menopausal women and so on. There is a scarcity of literature concerning the whole-body vibration in increasing the dynamic balance and knee muscle strength in knee osteoarthritis. This study emphasis on filling up the desolate in literature.

2. Methodology

Aims

To find out the Effect of Whole Body Vibration Training on Pain, Muscle Strength and Dynamic Balance among Post-Menopausal women with Osteoarthritis of Knee.

Objectives

- To find out the effectiveness of Whole Body Vibration training in reducing Pain among post-menopausal women with OA Knee.
- To find out the effectiveness of Whole Body Vibration training in improving Knee Muscle Strength among Post-menopausal women with OA Knee.

- To find out the effectiveness of Whole Body Vibration training in improving Dynamic Balance among post-menopausal women with OA Knee.

The study was designed to determine the effectiveness of Whole Body Vibration Training on Pain, Muscle Strength and Dynamic Balance among Post-Menopausal women with Osteoarthritis of Knee. Ethical approval was obtained from the Ethical committee of Medical Trust Hospital, Cochin. Two group pre-test and post-test design was used with convenient sampling. The independent variables were Whole Body Vibration Training and conventional exercise whereas the dependent variables were pain, knee muscle strength and dynamic balance

Study Design:
Two group pre-test and post-test Experimental study.

Sampling Method:
Convenient Sampling.

Study Duration:
3 months.

Sample Size:
N = 30
15 in each group (Group A and Group B)

Outcome Measure:
- **Pain:** (NUMERIC PAIN RATING SCALE) To measure the pain intensity in adults.
- **Strength:** (MODIFIED SPHYGMOMANOMETER TEST) To assess the muscular strength.
- **Dynamic Balance:** (TIME UP TO GO TEST) To assess a person's mobility that requires both static and dynamic balance.

Selection criteria: -
Inclusion criteria
- Age- 50 to 70 years
- Postmenopausal women.
- Body mass index- 23 to 29.9 kg/m2.
- Numeric pain rating scale should be between 3 to 7.
- Subjects who are willing to participate and able to squat at 30 degrees.
- Abbreviated mental score should be more than 8.

Exclusion Criteria
- Subjects who had formal consultation of a physiotherapist for treatment of the knee in previous 12 months.
- Any kind of Knee surgery and intra-articular steroid injection in previous 6 months.
- Inflammatory Knee Osteoarthritis, Ankle, Hip and Foot pathology, other orthopaedic problems like Fracture, malformation and those who have extension lag.

Sampling Procedure:
Thirty subjects were included from KPMM Physiotherapy Centre, Tabitha Old Age Home and Medical trust hospital in Ernakulam, between the age of 50-70 years were taken for the study.

Subjects were divided into two groups: -
Group A- Experimental Group of Whole Body Vibration technique and Therapeutic exercises - 15 subjects.
Group B– Control Group of Therapeutic exercises alone - 15 subjects**.**

Pre-interventional Procedure
The participants who were diagnosed with osteoarthritis by a doctor (Rheumatologist) through an investigatory report or by ACR protocol and those who satisfy the inclusion criteria were asked to join in the study by a consent form. They were divided into 2 groups and explained the study procedure of their group and about the machine in experimental group only. They were assessed by a pre-designed Practical Performa and outcomes were measured. NPRS measuring pain in 11-point scale, MST measuring muscle strength of Quadriceps and Hamstring and TUGT measuring Dynamic Balance. These measures were noted as pre-test values before the intervention is given.

Intervention
In Experimental group, the WBVT parameters were: frequency of 45 Hz; amplitude of 4 to 6 mm displacement. Total exposure time of 30 minutes/day (vibration maximum 20 minutes, interval rest 10 minutes) on 7 days/week along with conventional exercises, whereas, in control group, conventional exercises only given for 30 min/day for 7 days in a week.

Post- interventional procedure
The outcomes were measured again, NPRS measuring pain in 11-point scale, MST measuring muscle strength of Quadriceps and Hamstring and TUGT measuring Dynamic Balance. These measures were noted as post-test values before the intervention is given.

3. Results

3.1 Paired 'T' Test (Within Group)

In comparison ofPre-Test and Post-Testvalues of NPRS in GROUP A (Experimental group), the calculated value for pain is 10.45, which is greater that the table value 2.14 and the Significance (p-value) is less than 0.05, we can conclude that there is a significant reduction of pain in WBVT Group in post-menopausal women with OA Knee, so null hypothesis is rejected.

In comparison of Pre-Test and Post-Test values of NPRS in GROUP B (Control group), the calculated value for pain is 7.79, which is greater that the table value 2.14 and the Significance (p-value) is less than 0.05, we can conclude that there is a significant reduction of pain in Conventional Group in post-menopausal women with OA Knee, so null hypothesis is rejected.

In comparison of Pre-Test and Post-Test values of Hamstrings MST in GROUP A (Experimental group), the calculated value for Hamstring Strength is 3.76 which is greater that the table value 2.14 and the Significance (p-value) is less than 0.05, we can conclude that there is a significant improvement in Hamstring Strength in WBVT

Group in post-menopausal women with OA Knee, so null hypothesis is rejected.

In comparison of Pre-Test and Post-Test values of Hamstrings MST in GROUP B (Control group), the calculated value for Hamstring Strength is 4.39 which is greater that the table value 2.14 and the Significance (p-value) is less than 0.05, we can conclude that there is a significant Improvement in Hamstring Strength in Conventional Group in post-menopausal women with OA Knee, so null hypothesis is rejected.

In comparison of Pre-Test and Post-Test values of Quadriceps MST in GROUP A (Experimental group), the calculated value for Quadriceps Strength is 3.45 which is greater that the table value 2.14 and the Significance (p-value) is less than 0.05, we can conclude that there is a significant Improvement in Quadriceps Strength in WBVT Group in post-menopausal women with OA Knee, so null hypothesis is rejected.

Quadriceps MST in GROUP B (Control group), the calculated value for Quadriceps Strength is 2.28 which is greater that the table value 2.14 and the Significance (p-value) is less than 0.05, we can conclude that there is a significant Improvement in Quadriceps Strength in Conventional Group in post-menopausal women with OA Knee, therefore, null hypothesis is rejected.

In comparison of Pre-Test andPost-Test values of TUGT in GROUP A (Experimental group), the calculated value for dynamic balance is 2.86, which is greater that the table value 2.14 and the Significance (p-value) is less than 0.05, so we can conclude that there is a significant Improvement in Dynamic Balance in WBVT Group in post-menopausal women with OA Knee, therefore, null hypothesis is rejected.

In comparison of Pre-Test andPost-Test values of TUGT in GROUP B (Control group), the calculated value for Dynamic Balance is 2.40, which is greater that the table value 2.14 and the Significance (p-value) is less than 0.05, we can conclude that there is a significant Improvement in Dynamic Balance in Conventional Group in post-menopausal women with OA Knee, so null hypothesis is rejected.

Table 1: Paired 'T' Test values

Paired 'T' Test (Within Group)		GROUP A (Experimental group)				GROUP B (Control group)			
Outcomes		NPRS	MST Quads	MST Hams	TUGT	NPRS	MST Quads	MST Hams	TUGT
MEAN	Pre-test	5.40	81.59	75.25	14.42	5.13	94.32	53.98	12.83
	Post-test	2.06	89.88	82.01	13.87	3.00	95.91	87.98	12.37
S. D.	Pre-test	1.29	20.40	18.27	2.17	1.35	3.42	2.51	0.63
	Post-test	1.27	22.13	17.23	2.25	1.06	2.03	2.09	0.68
Table 'T' value		2.14							
Calculated 'T' value		10.45	3.45	3.76	2.86	7.79	2.28	4.39	2.40
p value		$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$	$p < 0.05$

3.2 Independent 'T' Test (Between Group)

In comparison of Pre-Test andPost-Test differences of NPRS in GROUP A and GROUP B, the calculated value for pain is 2.856, which is greater that the table value 2.04 and the Significance (p-value) is less than0.05, we can conclude that there is a significant reduction of pain in between WBVT Group and Conventional Group in post-menopausal women with OA Knee, so null hypothesis is rejected.

A comparison between the groups in NPRS is showing significant difference between the two groups. The Experimental Group (Group A) shows reduction in pain through WBVT, which is statistically significant when compared with another group.

In comparison of Pre-Test andPost-Test differences of Hamstrings MST in GROUP A and GROUP B, the calculated value for Hamstring Strength is 1.37, which is lesser that the table value 2.04 and the Significance (p-value) is NOT less than 0.05, we can conclude that there is no significant Improvement in Hamstring Strength in between WBVT Group and Conventional Group in post-menopausal women with OA Knee, so null hypothesis is accepted.

A comparison between the groups in MST Hamstrings is showing significant difference between the two groups. The Experimental Group (Group A) shows greater change in Hamstrings Strength through WBVT, which is statistically significant when compared with another group.

In comparison of Pre-Test andPost-Test differences of Quadriceps MST in GROUP A and GROUP B, the calculated value for Quadriceps Strength is 2.68, which is greater that the table value 2.04 and the Significance (p-value) is less than 0.05, we can conclude that there is a significant Improvement in Quadriceps Strength in between WBVT Group and Conventional Group in post-menopausal women with OA Knee, so null hypothesis is rejected.

A comparison between the groups in MST Quadriceps is showing significant difference between the two groups. The Experimental Group (Group A) shows greater change in Quadriceps Strength through WBVT, which is statistically significant when compared with another group.

In comparison of Pre-Test andPost-Test differences of TUGT in GROUP A and GROUP B, the calculated value for dynamic balance is 0.34, which is lesser that the table value 2.04 and the Significance (p-value) is NOT less than 0.05, we can conclude that there is a no significant Improvement in Dynamic Balance between WBVT Group and Conventional Group in post-menopausal women with OA Knee, so null hypothesis is accepted.

Comparison between the groups in TUGT is showing significant difference between the two groups. The

Experimental Group (Group A) shows greater change in Dynamic Balance through WBVT, which is statistically significant when compared with another group.

Table 2: Independent 'T' Test values

Independent 'T' Test (Between Group)		NPRS	MST Quads	MST Hams	TUGT
MEAN	Pre-test	3.33	8.28	6.76	0.55
	Post-test	2.13	1.58	3.99	0.46
S. D.	Pre-test	1.23	9.29	6.95	0.74
	Post-test	1.06	2.68	3.52	0.74
Table 'T' value		2.04			
Calculated 'T' value		2.856	2.68	1.37	0.34
p value		$p < 0.05$	$p < 0.05$	$p = 0.179$	$p = 0.736$

3.3 Comparison of Outcome in Experimental Group

The Mean Percentage Change from the four outcomes in the Experimental Group, it is concluded that the NPRS outcome is the most effective in reducing pain through WBVT and followed by MST Quads, MST Hams and TUGT. Among the MST outcome Quadriceps muscle strength showed the greater mean percentage change than Hamstring muscle strength. When compared, the Dynamic Balance showed the least change in mean percentage in experimental group.

Table 3: Comparison of outcome in Experimental Group

Outcomes	Mean Change	Obtained Maximum	Mean Percentage Change $\frac{Mean\ change}{Obtained\ maximum} \times 100$
NPRS	3.33	5	66.6
MST Quads	8.28	22	37.63
MST Hams	6.76	19.3	35.02
TUGT	0.55	1.65	33.33

4. Discussion

Osteoarthritis (OA) is the result of mechanical and biologic events that destabilize the normal process of degradation and synthesis of articular cartilage chondrocytes, extracellular matrix, and subchondral bone. It involves the entire joint, including the articular cartilage, subchondral bone, pericapsular muscles, capsule, and synovium. The condition leads to loss of cartilage, sclerosis and eburnation of the subchondral bone, osteophytes, and subchondral cysts. It is clinically characterized by joint pain, stiffness, and functional limitation. Risk factors include genetics, female sex hormones, past trauma, advancing age, and obesity. The diagnosis is based on a history of joint pain worsened by movement, which can lead to disability in activities of daily living.

The result was analysed using t-test; paired t-test was used to compare the change within the group and unpaired t-test was used to compare results between the groups. It was found that in paired t-test, the Pain reduced significantly in Experimental group ($p=0.000$) and in Control group ($p = 0.000$) between pre and post intervention. Pain had reduced by Pain gait theory where Cutaneous vibration is able to reduce pain, as an effect called vibratory analgesia. The traditional explanation for this phenomenon is that it is mediated by lateral inhibition at the segmental (spinal cord) level, in pain-coding cells with centre surround receptive fields. There was also little evidence to support the view (widely held by subjects) that distraction between the noxious and vibratory stimuli is the primary mechanism of vibratory analgesia [7]. Some evidences that pain reduction may have contributed to improved performance. Pain relieving effects be influencing peripheral nociception and central pain sensitivity. Facilitation of internal opioids that makes the patient more tolerant. These opioids bind to pre-synaptic afferents and thus inhibit the release of substance P; as substance P is a neurotransmitter necessary for nociceptive transmission this leads to inhibition of the pain at spinal cord level [8].

It was found that in paired t-test, the Hamstring muscle strength has increased significantly in Experimental group ($p = 0.002$) and in Control group ($p = 0.001$) and Quadriceps muscle strength has increased significantly in Experimental group ($p= 0.004$) and in Control group ($p = 0.038$) between pre and post intervention.

Individual studies have reported knee extensormuscle weakness to be a risk factor for knee osteoarthritis, particularly in women. In a recent review of the literature investigating quadriceps muscle weakness and the risk of developing knee osteoarthritis, it was concluded that greater quadriceps muscle strength seemed to be related to lower risk of incident symptomatic, but not radiographic knee osteoarthritis [9].

The knee extensors work as shock absorbers and stabilizers, and hence protect the joint surfaces during loading and movement. Excessive mechanical stress on articular cartilage due to muscle weakness has been suggested to induce a degenerative process [9]. Such muscle weakness, characterised by a reduction in muscle force or motor unit activation, could lead to changes in gait and decreased performance in everyday functional activities [10].

The results of the meta-analysis for knee extension strength in knee OA groups demonstrated that high-intensity resistance exercise resulted in larger strength benefits Exercise of enough intensity will create the impetus for muscle activation, initially resulting in strength changes through neural adaptation and hypertrophy and this may explain greater strength benefits associated with the high-intensity resistance programs [10]. The energy consumptions of various exercises with WBV has been studies and found out that the oxygen consumption in muscles is greater than in any other exercise. This is done to create a purely eccentric muscle reaction and enable anaerobic activity (burning energy without oxygen) [5].

Improvements are thought to be due to reflex activation of the a-motor neuron via muscle spindle activation. WBVT is a time-saving and safe method for rehabilitation of patients with KOA and may counteract reduced cartilage thickness by modulating skeletal tissue, increasing oscillation of chondrocytes, and augmenting the thickness of the chondrocyte layer.

It was found that in paired t-test, the Dynamic balance has increased significantly in Experimental group ($p = 0.012$) and in Control group ($p = 0.031$) between pre and post intervention.

The addition of WBV to squat exercise training generates vertical sinusoidal vibrations that stimulate the primary endings of the muscle spindles, activating α-motor neurons that results in muscle contractions that are comparable to the tonic vibration reflex. As a result, the vibration stimulus strengthens the lower limb and improves proprioception in elderly patients with knee OA by inducing isometric, concentric and eccentric, contraction of hip and knee extensor muscle group and plantar flexors, thereby improving the control and execution of functional movements such as those required for the static and dynamic balance and gait performance. Therefore, WBV may be useful to stabilize and minimize the symptoms and consequences of knee OA in elderly patients by reducing the inflammatory joint process and self-perception of pain [11].

Muscle weakness is associated with changes in gait and decreased performance in everyday functional activities [1]. The presence of Knee pain and quadriceps muscle weakness is associated with Knee OA, which could explain the lower TUGT score in subjects with knee OA as compared to healthy older adults.

On comparing the difference in the results between the groups, the Pain ($p = 0.008$) and Quadriceps Muscle Strength ($p = 0.12$) in Experimental group showed greater change from the control group. From statistical analysis of comparing the outcomes in Experimental Group, it was found that pain reduction was the highest change than that of quadriceps muscle strength, hamstring muscle strength and dynamic balance respectively.

Hamstring muscle performance: The results of this study showed that the addition of WBV training on strengthening training when compared with control group did not have any significant impact on hamstring muscle performance, in patients with OA.

However, it should be noted that the effects of WBV training on muscle depends on three main factors; frequency of vibratory stimulations, the extent of activation of motor units and the initial length of the muscle architecture (Bosco et al., 1999b) [12]. The initial length of the muscle is one of the key factors determining the effectiveness of training. Studies have shown that muscles at stretch, are more sensitive to vibrational excitation, and are more contract more rapidly. This hypothesis states that the greater the length of the muscle, the more muscle tension there will be, thus producing a greater response to vibration (Macintyre and Kazemi, 2008) [12]. Because the vibration is more effective in stretched muscle, the squat is the optimum condition for vibrational excitation of the quadriceps muscle (Cardinale and Lim, 2003), but not for the hamstring muscles (Feland et al., 2010) [12]. Though it seems, the difference in stretch is only in the single joint muscles, because two joint muscles are stretched roughly to the same degree by a normal free standing squat, in this study, we used the squat position to apply WBV.

TUGT values are less when compare to control group, because of short duration study, the values weren't enough to show significance between group. There are studies and evidences of improvement in dynamic balance, but those studies are of longer duration. In this study there is significant improvement in both experimental and control group but when compared between the group there is no significance, since this study has a limitation of short-term duration.

5. Conclusion

This study results shows that whole body vibration technique is effective in pain reduction and improving quadriceps muscle strength when compared to the control conventional group. And there is significant reduction in pain and improvement in quadriceps and hamstring muscle strength and dynamic balance in one week WBVT protocol. Therefore, I concluded that WBVT is effective in short term duration among post-menopausal women in osteoarthritis of knee.

6. Future Scope

- The sample size of subjects should be increased; hence it may lead to a better valuable result.
- The treatment sessions of the study should be increased. It may lead to better and valuable result.
- Future investigations can be conducted in different population and age group.
- A follow-up study could ensure the long-term effect of the treatment program.
- Future studies can be done with large group and longer follow up.
- Another outcome measuring tools can be used.
- Other parameters such as BMI, BMD, Confidence scale, ADL scale could be checked.

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