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Effect of Wearable Vibration Therapy on Muscle Soreness, Joint Position Sense and Dynamic Balance

Giyilebilir Vibrasyon Terapisinin Kas Ağrısı, Eklem Pozisyon Hissi ve Dinamik Denge Üzerine Etkisi

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ABSTRACT

The aim of this study is to investigate the effects of wearable local vibration therapy (VT) on muscle soreness, joint position sense, and dynamic balance in recovery after squat exercise. Twenty males (age: 22.25±1.97 years) participated in the study. Muscle soreness, joint position sense, and dynamic balance were evaluated before exercise, 24 and 48 hours after exercise. All participants performed six sets of 10 repetitions of squat exercises. VT was applied to one thigh of the participants randomly for 10 minutes after exercise, and the other thigh was determined as the control. The muscle soreness increased significantly for VT ($p<.001$) and control ($p=.014$) at 24 hours after exercise. However, there were no significant differences 48 hours after exercise for both conditions ($p>.05$). No significant difference was found between VT and control (p>0.05). No significant difference was found after exercise at knee joint position sense for both conditions ($p>.05$). No significant difference was observed between VT and control ($p>.05$). There was a significant difference between before exercise and 48 hours after exercise at anterior direction of the modified Star Excursion Balance Test for VT ($p=.033$). A significant difference was found between before exercise and 24 hours after exercise at posteromedial ($p=.012$) direction for VT. There was only significant difference at posteromedial ($p=.028$) direction at 24 hours after exercise between VT and control. The wearable local VT after squat exercise did not affect muscle soreness and knee joint position sense. However, local VT contributed to the improvement of dynamic balance.

Keywords: Muscle damage, pain, proprioception, balance, vibration

ÖZ

Bu çalışmanın amacı, giyilebilir lokal vibrasyon terapisinin (VT) squat egzersizi sonrası toparlanmada kas ağrısı, eklem pozisyon hissi ve dinamik denge üzerine etkilerini araştırmaktır. Çalışmaya 20 erkek (yaş: 22,25±1,97 yıl) katıldı. Egzersiz öncesi, egzersizden 24 ve 48 saat sonra kas ağrısı, eklem pozisyon hissi ve dinamik denge değerlendirildi. Tüm katılımcılar 10 tekrar, 6 set squat egzersizi yaptı. Katılımcıların bir uyluğuna egzersiz sonrası 10 dakika rastgele VT uygulandı ve diğer uyluğu kontrol olarak belirlendi. Kas ağrısı egzersizden 24 saat sonra VT ($p<,001$) ve kontrol ($p=,014$) için anlamlı olarak arttı. Ancak egzersizden 48 saat sonra her iki durum için anlamlı fark yoktu ($p>,05$). VT ile kontrol arasında anlamlı fark bulunmadı ($p>,05$). Egzersiz sonrası diz eklem pozisyon hissinde her iki durum için anlamlı fark bulunmadı ($p>,05$). VT ile kontrol arasında anlamlı bir fark gözlenmedi ($p>,05$). VT için modifiye Yıldız Denge Testinin anterior yönde egzersiz öncesi ve egzersiz sonrası 48 saat arasında anlamlı bir fark vardı ($p=,033$). VT için posteromedial yönde egzersiz öncesi ile egzersiz sonrası 24 saat arasında anlamlı fark bulundu ($p=,012$). VT ve kontrol arasında egzersizden 24 saat sonra sadece posteromedial yönde ($p=,028$) anlamlı fark vardı. Squat egzersizi sonrası giyilebilir lokal VT, kas ağrısını ve diz eklemi pozisyon hissini etkilemedi. Ancak lokal VT, dinamik dengenin gelişmesine katkı sağladı.

Anahtar Kelimeler: Kas hasarı, ağrı, propriyosepsiyon, denge, vibrasyon

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Introduction

Delayed-onset muscle soreness (DOMS) is the complaint of discomfort that appears 24-72 hours after unaccustomed workouts, especially involving eccentric contractions, in both sedentary people and athletes. In exercise-induced muscle damage, which is classified as Type I muscle strain injury, swelling, tenderness, stiffness, decrease in joint range of motion, and muscle strength are seen as well as pain (Cheung et al., 2003; Lewiset al., 2012).

Athletes experience DOMS when they return to training after a break during or after intense training at any time during the training season. Although DOMS, a temporary disorder, may seem insignificant for sedentary individuals, it causes performance loss in athletes who participate in consecutive competitions may negatively affect the outcome of the competition. Therefore, DOMS is a health problem that must be dealt with by both athletes and trainers and physiotherapists. There is a wide choice of interventions in treating DOMS, including pharmacological treatments, physical modalities, and nutritional supplements (Cheung et al., 2003).

Vibration intervention, which is used in treating kidney stones, osteoporosis (ElDeeb et al., 2020), and spasticity (Tekin & Kavlak, 2021), has been widely preferred in recent years to improve performance in athletes. Biomechanically, vibration, consisting of amplitude, frequency, and power parameters, is a mechanical stimulus characterized by oscillating movements. Vibration is applied locally or as whole-body vibration using a device. Stimulation of a muscle with vibration elicits a response called the "tonic vibration reflex", which involves the activity of the muscle spindle and the activation of muscle fibers via alpha motor neurons (Jordan et al., 2005). Due to this effect of vibration stimulation that triggers muscle contraction, vibration intervention is frequently used in addition to exercises to increase muscle strength and power in athletes (Mester et al., 2006). It is claimed that vibration application increases flexibility and improves position sense and muscle strength (Cochrane, 2016; Lee et al., 2018). The sense of position is impaired due to a traumatic injury to the ligaments and muscles. Muscle fatigue may also negatively affect the sense of position. Position sense is an important sense for the accuracy of movement, joint stability, coordination, and balance (Roijezon et al., 2015). Especially in athletes, impaired position sense may cause performance loss and injuries during complex motor skills (Ogard, 2011). In a study, Bakhtiary et al. (2007), applied vibration intervention to the quadriceps, hamstring, and gastrocnemius muscles in healthy sedentary individuals following walking and found a significant decrease in pain intensity 24 hours later. According to a recently published systematic review study, it is reported that vibration intervention is beneficial in alleviating DOMS, but the available evidence is weak, and large-scale, high-quality, and randomized controlled studies are needed (Lu et al., 2019). Previous studies have mostly investigated the effects of whole-body vibration devices, which are not always accessible to athletes, on pain and muscle strength (Hong et al., 2010; Rhea, 2009; Wheeler & Jacobson, 2013). Therefore, the aim of this study is to investigate the effects of wearable local vibration therapy (VT) on muscle soreness, joint position sense, and dynamic balance in recovery after squat exercise.

Methods

Participants

Twenty healthy male university students (age, 22.25±1.97 years; height, 178.60±5.43 cm; weight, 84.30±15.53 kg) participated in the study. This study included healthy and untrained sedentary individuals. Participants who had chronic diseases of the musculoskeletal system, previous severe injuries to the spine and lower extremity, current pain in spine and lower extremities were excluded in the study. The sample size was calculated as 18 individuals, with level of 0.05, power of 0.8, and effect size=0.62 to obtain a significant increase in pain intensity at 24 hours after vibration intervention (Bakhtiary et al., 2007). This study was approved by the Ethics Committee of Karabük University (approval no: 2020/857, approval date: 25.04.2022) and adhered to the Declaration of Helsinki. All participants provided written informed consent before the study began. Participants were asked to refrain from physical exercise for their lower extremities at least one week before first testing session and during the study period. Participants were asked not to use pain relievers to relieve exercise-induced muscle soreness.

Procedures

All participants completed three separate testing sessions. Muscle soreness, joint position sense and dynamic balance evaluated before exercise, 24 and 48 hours after exercise. Participants were given an exercise protocol to induce DOMS following initial testing. Then, VT was applied to one thigh of each participant and other thigh did not receive vibration.

Muscle soreness was measured on both thighs using an algometer (Baseline, USA). The measurement was performed from the midpoint of the line connecting the superior central edge of the patella and the anterior superior spine iliaca over the quadriceps femoris muscle in a sitting position with 90˚ flexion of the hip and knee joints. The researcher applied a 1 cm2 metal algometer probe perpendicular to the skin with a gradually increasing pressure on the measurement point marked with a pen. Participants were asked to report when they felt "pain or discomfort" and the measurement was stopped at that time. At this point, the value in the algometer was recorded (Ozmen et al., 2016). The algometer is valid and reliable (r = 0.99) to assess the pressure-pain threshold (Kinser et al., 2009).

Joint position sense was assessed by passive-active repositioning using a digital inclinometer (Baseline, USA). Participants sat on the stretcher with their hips and knees flexed to 90˚ and their eyes closed. Target angles were determined as 30 and 60 degrees at the knee joint. The researcher passively moved the leg of the participant to be tested to a randomly chosen target angle and held it there for 5 seconds. The participants were asked to remember this position, and then their leg was returned to the starting position. The participants were asked to reposition their leg to the target angle. The researcher recorded the deviation value from the target angle that the inclinometer showed. The best of the two trials was used for data analysis (Suner-Keklik et al., 2017).

Dynamic balance was evaluated with the modified version of the Star Excursion Balance Test (SEBT). First, the distance between the anterior superior iliac spine and the ipsilateral medial malleolus was measured with a standard tape measure to determine leg length. Three tape measures were fixed in the anterior (A), posteromedial (PM), and posterolateral (PL) directions on the floor. Each participant was asked to stand on the dominant leg at the intersection of the three tape measures. Then, the participants were instructed to reach as far as possible with their other extremities without disturbing their balance in these three different directions, respectively. Participants performed three trials with 30 seconds intervals, and the longest distance they could reach was recorded. The test was performed barefoot to prevent the support of the shoe. Distance reached by participants divided by their leg lengths and multiplied by 100 (Gribble et al., 2013). The dominant leg was defined as their preferred leg for kicking a ball.

Intervention

Participants performed squat exercises of six sets of 10 squats per set (total 60 squats) with their body weight as workload to induce DOMS in the quadriceps an exercise protocol following warm-up (Ozmen et al., 2016). There was a 1-minute break between sets and a 5 second break between repetitions. All participants were familiarized with the exercises before the start of the study. Following exercise, single bout of VT was applied with a local vibration device (MyoVolt™, Christchurch, New Zealand) that produced vibration in 3 different modes at an amplitude range of 0-1.2 mm in 0.5 s and a frequency of 0-120 Hz. One randomly determined using the coin toss method thigh of each participant was stimulated with 120 Hz vibration in pulsed mode for 10 minutes, while the control thigh was applied no vibration. The vibration device was fixed to the rectus femoris muscle (i.e., 40% of the muscle length from the top edge of the patella to the anterior superior of the spine iliac) on the thigh of the participants in the sitting position with velcro tape (Souron et al., 2019).

Statistical analysis

Data analysis was performed with the SPSS (version 25; IBM, Armonk, NY) computer software program. Using the Shapiro-Wilk test, the dependent variables' normality was examined. A two-way repeated measures analysis of variance (ANOVA) was performed to evaluate over-time changes (before exercise, 24 and 48 hours after exercise) in the data from the dynamic balance and muscular soreness tests. Post hoc least-significant difference (LSD) test was performed to find pairwise differences. Data from the position sense was not normally distributed and Friedman's two-way ANOVA was used to compare over time changes (before exercise, 24 and 48 hours after exercise). The Wilcoxon's Signed Ranks test was performed for multiple comparisons. The independent samples t test and Mann-Whitney U test were used to compare the mean changes in the muscle soreness, position sense and dynamic balance scores between the conditions. All results are shown as mean ± SD. Significance was set at $p < .05$.

Results

Descriptive characteristics of participants are shown in Table 1. The muscle soreness increased significantly for VT ($p < .001$) and control ($p = .014$) at 24 hours after exercise compared with before exercise. However, there were no significant differences 48 hours after exercise for both conditions ($p > .05$) (Table 2). No significant difference was found between VT and control ($p > .05$) (Table 3). No significant difference was found 24 and 48 hours after exercise compared to before exercise for joint position sense at angles of 30 and 60 degrees of knee joint flexion for both conditions ($p > .05$) (Table 2). No significant difference was observed between VT and control ($p > .05$) (Table 3). There was a significant difference between pre-exercise and 48 hours after exercise at anterior direction of the modified SEBT for VT ($p = .033$). Also, a significant difference was found between before exercise and 24 hours after exercise at posteromedial (p = .012) direction of the modified SEBT for VT (Table 2). There was only significant difference at posteromedial (p = .028) direction of the modified SEBT at 24 hours after exercise between VT and control (Table 3).

Table 1. Descriptive Characteristics of Participants (n=20)

Variables	Mean	SD
Age (year)	22.25	1.97
Height (m)	178.60	5.43
Weight (kg)	84.30	15.53

SD: Standard Deviation

Table 2. Pre-test and post-test muscle soreness, position sense and dynamic balance scores of participants

Measurement	Condition	Before exercise Mean ± SD	24 hours after exercise Mean ± SD	48 hours after exercise Mean ± SD
Muscle soreness (kg/cm^2)	VT	16.14±1.89	13.70±2.43* p < .001	15.55±1.75
	Control	16.03±2.58	14.50±2.41* p=0.014	15.36±2.15
Position sense 30°	VT	1.00±1.33	1.45±1.23	1.70±1.38
	Control	1.35±1.22	2.10±1.51	1.35±1.04
60°	VT	2.32±3.55	3.10±3.16	1.55±1.39
	Control	2.58±3.83	2.65±2.62	2.45±1.60
Dynamic balance Anterior	VT	84.32±11.95	84.40±7.91	88.09±7.28* p=0.033
	Control	79.99±21.99	85.60±8.58	88.14±6.63
Posteromedial	VT	89.96±12.42	93.73±10.98* p=0.012	92.53±11.35
	Control	91.50±11.81	90.95±12.70	91.99±11.75
Posterolateral	VT	88.50±9.23	90.26±11.92	90.34±13.75
	Control	88.16±11.30	90.32±10.28	89.65±11.55

Table 3. Mean changes in muscle soreness, position sense and dynamic balance scores of conditions

Measurements	Time	VT Mean ± SD	Control Mean ± SD	p
Muscle soreness (kg/cm^2)	Before-After exercise 24 hours	2.44±1.75	1.53±0.21	0.180
	Before exercise- After exercise 48 hours	0.59±0.11	0.66±0.23	0.409
Position sense 30°	Before-After exercise 24 hours	0.45±0.15	0.75±0.18	0.796
	Before exercise- After exercise 48 hours	0.70±0.21	0.00±0.18	0.380
60°	Before-After exercise 24 hours	0.77±0.52	0.06±0.04	0.641
	Before exercise- After exercise 48 hours	0.77±0.40	0.13±0.03	0.380

Anterior	Before-After exercise 24 hours	0.07±7.94	5.60±2.60	0.270
	Before exercise- After exercise 48 hours	3.76±0.73	8.15±2.09	0.382
Posteromedial	Before-After exercise 24 hours	3.76±0.60	0.54±0.05	0.028*
	Before exercise- After exercise 48 hours	2.56±0.87	0.49±0.09	0.466
Posterolateral	Before-After exercise 24 hours	1.76±0.75	2.15±0.08	0.873
	Before exercise- After exercise 48 hours	1.83±0.98	1.49±0.09	0.911

Abbreviation: VT: Vibration Therapy, SD: Standard Deviation, *: Statistically significant difference among groups ($p < .05$).

Discussion

The results of the present study showed that muscle soreness significantly increased in the vibration applied extremity and the other extremity at 24 hours after exercise. However, muscle soreness in both extremities approached before exercise levels at 48 hours after exercise. Although the change in the level of muscle soreness after squat exercise was different in both extremities, the squat exercise applied to the participants caused a significant muscle soreness. When both extremities were compared, it was observed that VT did not affect muscle soreness after squat exercise.

Previous studies investigated the effects of whole-body vibration in athletes and sedentary individuals (Hong et al., 2010; Pollock et al., 2011; Rhea et al., 2009; Wheeler & Jacobson, 2013). In whole-body vibration, vibration energy is distributed over many body parts, such as the ankle, calf, and knee joints. Therefore, it is suggested that local VT applied directly on the muscle-tendon unit will be more effective in activating the target muscle and produce a more substantial proprioceptive effect (Abercromby et al., 2007; Marconi et al., 2008; Pamukoff et al., 2016). However, in our study, 120 Hz vibration stimulation for 10 minutes applied directly on the quadriceps femoris muscle did not significantly affect the pressure pain threshold. In the present study, the vibration device was placed superiorly along the quadriceps femoris muscle from the upper edge of the patella. Since the vibration device may not cover the entire muscle, which has a large surface area, it was thought that its position close to the insertion would create a more substantial effect. A pulsed vibration stimulation, which was reported to be more effective than other modes of the device, was preferred (Chandrashekhar et al., 2021). In this study, no significant change was observed in muscle soreness after 24 and 48 hours after local VT. This may be explained by the lack of adequate vibration stimulation in terms of time and area in the recovery of the quadriceps femoris muscle, which has a large area. Similar to our study, Mepocatych et al. (2014) reported that after the push-up exercise to physically active men, the 10-minute whole-body vibration (30 Hz) applied to the upper and lower body increased muscle pain. However, no significant difference was observed compared to the control group. Researchers attributed this result to less vibration frequency and duration than other studies (Mepocatych et al., 2014). Lau and Nosaka (2011) applied a 6-minute local VT (65 Hz) after ten sets of 6 repetitive eccentric exercises to the elbow flexors in sedentary healthy male individuals. When compared with the control group, the researchers found that although there was a significant decrease in the VAS score in the vibration group, there was no significant difference in the pressure pain threshold. The researchers suggested that the pressure pain threshold and VAS evaluates pain from different perspectives and may not give precisely the same result. In our study, pain intensity was evaluated with an algometer, which is an objective measurement method according to VAS (Kinser et al., 2019). However, no significant results were found with pressure pain threshold after VT. Fuller et al. (2015) compared the effects of VT, massage and stretching on recovery following eccentric knee extensor exercise in sedentary male participants. The researchers applied 20 minutes of vibration (73 Hz) to one group twice daily, 14 minutes of massage, and 6 minutes of stretching to the other group. While muscle soreness increased in both groups after exercise, no significant difference was observed between the groups in the evaluations made up to 7 days. The researchers suggested that the lack of a significant difference in vibration intervention compared to massage and stretching may be due to the insufficient magnitude and frequency of vibration stimulation. Contrary to our study, Cochrane (2017) reported that after eccentric exercise in physically active men, 15 minutes of VT (120 Hz) in continuous mode with Myovolt™ on the biceps brachii significantly reduced the pressure pain threshold after 48 and 72 hours.

In the present study, although the 30 and 60 degree knee joint position sense angular errors increased in the extremities with and without VT after squat exercise, no significant change was obtained after 24 and 48 hours. Physiological responses occurring within the muscle to vibration stimulation may vary according to the characteristics of the vibration. The response of the primary (Ia) and secondary (II) afferents of muscle spindles that transmit position sense in the muscles to vibration stimulation depends on the amplitude and frequency of the vibration. Vibration stimulation at smaller amplitudes (0.2-0.5 mm) and low frequencies (<150 Hz) is more effective in activating Ia afferents. Vibration stimulation with a frequency in the 20-60 Hz range causes activation of both Ia and II afferents. At larger amplitudes (>0.5 mm), activation of Ia, Ib and II afferents occurs (Roll et al., 1989; Souron et al., 2017). Also, as the vibration frequency increases, illusions in position sense and motion perception are observed (Albert et al., 2006). Similar to our study, Pollock et al. (2011) did not find a significant increase in the sense of position in the 30, 60, and 80 degree flexion of the knee joint immediately after 5x1 min whole body vibration (30 Hz) in healthy young individuals. In another study, Hong et al. (2010) observed that three sets of 1-minute vibration (30 Hz) intervention did not cause a significant change in shoulder joint position sense in healthy young individuals.

It was observed that VT applied following the squat exercise provided a significant improvement in dynamic balance performance in the anterior direction at 48 hours after the exercise and in the posteromedial direction at 24 hours after the exercise. Furthermore, VT showed a significant difference in the posteromedial direction after 24 hours compared to the control. Similar to our study, Torvinen et al. (2002) observed that a 4-minute VT (15-30 Hz) produced short-term improvement in knee extensor muscle strength, tandem gait, vertical jump, shuttle-running, and balance performance in healthy young individuals. On the other hand, in another study, it was reported that 5x1 min whole-body vibration (30 Hz) did not cause a significant change in static balance scores (Pollock et al., 2011). It has been reported that there was a significant relationship between quadriceps femoris muscle strength and static and dynamic balance ability (Wang et al., 2016). The increase in the contraction strength that occurs with the tonic vibration reflex in the quadriceps femoris muscle stimulated by vibration may contribute to balance performance. In addition, body balance is provided by the integration of many signals from the visual, vestibular, and somatosensory systems, as well as muscle strength (Hrysomallis, 2011).

One limitation of the present study is that intensity of muscle soreness was measured using an algometer from a single central point on the body of the quadriceps femoris muscle. It is considered that measurement from a few sites on the muscle body can produce a significant result. Another limitation of our study is that the blood levels of the inflammatory markers which are the determinants of the intensity of muscle soreness were not measured. However, it has been suggested that the presence of muscle soreness may not be associated to the grade of inflammation (Yu et al., 2013). Moreover, it is thought that the most obvious sign of exercise-induced muscle damage is pain that occurs over time (Iodice et al., 2019).

Conclusion and Recommendations

The results of vibration interventions applied to different regions at different times, frequencies, amplitudes, and positions may be variable. In this study, it was observed that wearable local VT applied for alleviating DOMS and recovery after squat exercise was not effective on muscle soreness and knee joint position sense. However, it contributed to the improvement of dynamic balance. Future studies should be investigated effectiveness of portable and wearable vibration device interventions at different frequencies and modes in athletes

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