Effects of Whole-body Vibration on DOMS and Comparable Study with Ultrasound Therapy

Abstract

The purpose of this study was to analyze the effects of whole body vibration (WBV) and to compare with conventional therapy (ultrasound therapy) on the delayed onset muscle soreness (DOMS) after eccentric exercise of forearm flexor muscle. Whole subjects of this study were 21 students. They were distributed into three groups: WBV group, ultrasound therapy group, and control group. After eccentric exercise by arm curl machine, the same indicator was measured before the DOMS, just after exercise, at 24hr, 48hr and 72hr. Also the DOMS level was evaluated at same intervals by making use of algometer and visual analogue scale (VAS). Data of measurement were analyzed by using SPSS 12.00 Ver. To analyze the difference between WBV-control groups and between WBV-ultrasound therapy groups used General Repeated Measure ANOVA. The results were as in the following: There were no significant differences between the groups for algometer, but VAS was difference (p<0.05). And within groups at all groups was a significant difference but there was difference in VAS. And there was a significant difference within all groups for measurement time-courses (p<0.05). The results of this study indicated that WBV group was the most effective group of decreased DOMS among three groups.

Key words: DOMS, WBV, ultrasound therapy
I. Introduction

The studies on vibration have been currently done by researchers in the world and their subsequent varied experiment results have been published. These studies focused on the physical change in the workers who used the vibrating tools in industrial spots. In 1991, Bovenzi reported that those who were exposed to a long-term vocational vibration had a weak grip. In addition, it has been reported that the laborers who worked with vibrating tools such as an electric saw experienced paleness in fingers due to the contraction of finger blood vessel (Bovenzi & Griffin, 1997). In the similar token, there have been reports that the amount of blood flow of industrial workers who worked with industrial devices with $80 \sim 100 \text{Hz}$ of the number of vibrations has been significantly reduced (Lundsrom & Burstrom, 1988). As such, most of the researches claimed that the long-term use of vibrating tools in the industrial spots would cause a negative effect on physical activities.

However, there have been many researches on the 'differences of physical reactions and effects' between vibrations in industrial spots applied in high-frequency, large amplitude and physical body for a long period of time and vibrations applied in low-frequency, small amplitude and physical body for a short period time in the 1990s; in this process, the usefulness of whole body vibration has been evaluated as a new exercise method. In particular, as the studies on sports and rehabilitation fields have been conducted actively, some data that evaluated the effects of whole body vibration have been released (Rittweger et al, 2002). These data had something to do largely with the effects on muscular power, nervous system, blood circulation, change in metabolism and bone density.

Kannus et al (2002) conducted whole body vibration at the frequency of 3-5 times a week for 4 months for 56 male and female healthy participants and the vertical jumping power increased by 10.2% in 2 months and by 8.5% in 4 months in the experimental group; meanwhile, flexion muscle strength of leg muscles increased by 3.7% in 2 months and by 2.5% in 4 months. According to Torvinen et al (2002), the application of a 4-minute short-term whole body vibration enhanced the isometric muscular strength of knee extensor by 3.2% and the bodily balance by 15.7%. Delecruise (2003) applied the existing resistance exercise and whole body vibration for 12 weeks into female participants who were not trained; as a result, two exercises showed the muscular increase in knee extensor for the same knee joints and only whole body vibration increased significantly in the counter movement jump. In addition, there have been reports that the application of a single vibration (26Hz, 10 minutes) increased the muscles of female volley ball athletes temporarily (Bosco et al, 1999). Besides, in another experiment, Bosco et al (1999) announced that the highest jumping height, agility at time of highest jump and consecutive jump for five minutes in the experimental group increased noticeably in the mean of height and they were statistically significant. When applying three exercises such as standing on the vibration board that had whole body vibration, squat and squat loaded with weight, it would increase oxygen uptake ($\text{VO}_2$) and metabolism by adding vibration on whole body more than by not adding vibration on whole body, according to the research (Rittweger et al, 2001). Furthermore, Schin (2001) announced that the speed of blood flow of peripheral blood vessel increased and the resistance to blood flow decreased when adding whole body vibration of 26Hz of frequency and 3mm of amplitude of vibration. As such research results that whole body vibration had positive effects on physical abilities were published, it has been suggested as a new exercise method to the
athletes of various sports teams.

In addition, it has been found that a 3-month whole body vibration affected the increase in lumbar strength in the treatment of chronic lumbago (Rittweger et al., 2002). Furthermore, there was also a research claiming that whole body vibration had the functions of strengthening neuromuscular activities and muscular strength (Bosco et al., 1999). In another research, it has been shown that a sense of unique acceptance of lumbosacral part was improved as a result of performing a 5-minute statically closed chain motion (18Hz) on the vibration board (Fontana et al., 2005). As such, there have been some grounds that current whole body vibration could be used in treatment as well as strengthening muscular strength or physical power. However, what was missing was that there have been researches only on the improvement of muscular strength weakening of whole body vibration by chronic lumbago, lumbar diseases or long-term hospitalization for the purpose of treatment; for this reason, there have been less studies on the short-term injuries such as a bruise or delayed onset muscle soreness (DOMS).

Therefore, this study attempted to compare whole body vibration with a ultrasound therapy (Hasson et al., 1990) (that has been published as an effective treatment for the DOMS) in order to look closely into the effects of whole body vibration on the DOMS that had short-term continuance of symptoms.

II. Research methods

1. Subject of study

The subjects of study included 21 students from K University. The subjects did not have any diseases or take any medicine that could affect this experiment, and they have not done a muscular exercise for the last 6 months. The subjects of study were allocated randomly to whole body vibration group, ultrasound therapy group and control group. During the experiment, they were forced not to do exercises and drink alcohol that could affect the results of study and they were limited to the use of cigarettes, coffee, meal, etc. that could also affect the results of study 2 hours before the experiment.

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (yrs)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Man</td>
<td>22.75 ±1.70</td>
<td>175.75 ±1.03</td>
<td>72.50 ±7.59</td>
</tr>
<tr>
<td>Woman</td>
<td>20.82 ±0.34</td>
<td>161.05 ±0.83</td>
<td>51.76 ±0.63</td>
</tr>
</tbody>
</table>

*p < 0.05

2. DOMS-causing exercises

In this experiment, it caused DOMS on non-dominant hand to prevent any inconvenience on daily lives. The maximum isometric muscular strength for the subjects was measured (dynamometer, JAMAR); then, centrifugal contraction exercise was conducted on biceps with 70% of the maximum isometric muscular strength. While the shoulder and elbow joints of participants were flexed by 45 and 90 degree, respectively, the study conducted a 1-minute isometric contraction; then, it performed a centrifugal contraction up to the range of the maximum extension for 3 seconds.

Such exercises were conducted 70 times in total (7 sets with each 10 times with a 1-minute rest time per each time) (Behm et al., 2001).

3. Experiment methods

For the subjects of whole body vibration, the method used by Rittweger (2002) was slightly modified and applied in the experiment. Sonic whole-body vibrator (Turbo sonic,
TSKorea Co., Ltd.) was used and its frequency was fixed at 26 Hz and its intensity was applied from 100 to 30. Then, the center of vibration board was located between two legs at the width of shoulder at the same interval; in the meantime, the participants experienced the vibration intensity of 70 for a minute before starting to have actual vibration so as to avoid the change in their physical activities with the sudden application of vibrations.

The participants from the ultrasound therapy group were placed on the table while a rotation transfer method was applied so as for each half of the contact surface of a converter to be overlapped. The converter was put at right angle to their skin and the coupling medium of ultrasound was rubbed lightly between the converter and skin. The frequency and intensity were 1 and 1.2 W/cm², respectively, and it was applied to the biceps area for 12 minutes. For the control group, no further treatment has been done.

### Table 2. The exercise program on WBV

<table>
<thead>
<tr>
<th>time(min)</th>
<th>2</th>
<th>2</th>
<th>2</th>
<th>1</th>
<th>1</th>
<th>1</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>volume</td>
<td>100</td>
<td>90</td>
<td>80</td>
<td>70</td>
<td>60</td>
<td>50</td>
<td>40</td>
</tr>
</tbody>
</table>

* Frequency = 26 Hz

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### 4. Measurement methods

A pressure measuring device was used to measure the pressure threshold before DOMS' being induced and after 24, 48 and 72 hours. The measurement was made in the same point after marking it in the center of muscle belly of biceps. Pressure was added perpendicularly to the measurement point by the pressure measuring device. In case that the participants screamed 'Ah!' when they felt a pain, the tester measured the pressure of that moment by pressure threshold and its measurement unit was kg/cm². Besides, the study utilized a VAS (visual analog scale) using the scale of 10 cm in total at 1 mm interval to examine the degree of a pain felt subjectively after having the DOMS.

### 5. Data treatment

The study used the repeated measures ANOVA to compare the differences between the pressure threshold before DOMS' being induced and after 24, 48 and 72 hours and VAS measurement value. Windows SPSS Ver. 120 program was used for statistics.
### Table 3. Changes of VAS in DOMS (unit: score)

<table>
<thead>
<tr>
<th>Group</th>
<th>Before</th>
<th>24hr</th>
<th>48hr</th>
<th>72hr</th>
<th>F</th>
<th>sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBV</td>
<td>0.00</td>
<td>±0.00</td>
<td>3.32</td>
<td>0.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rate of</td>
<td>-</td>
<td>-</td>
<td>27.69</td>
<td>-70.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasound</td>
<td>0.00</td>
<td>±0.00</td>
<td>4.20</td>
<td>3.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rate of</td>
<td>-</td>
<td>-</td>
<td>-31.26</td>
<td>-18.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0.00</td>
<td>±0.00</td>
<td>4.97</td>
<td>2.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rate of</td>
<td>-</td>
<td>-</td>
<td>6.42</td>
<td>-53.72</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.05 (Mean±SD)

### Table 4. Changes of Pressure Threshold Algometer in DOMS (unit: kgf/cm²)

<table>
<thead>
<tr>
<th>Group</th>
<th>Before</th>
<th>24hr</th>
<th>48hr</th>
<th>72hr</th>
<th>F</th>
<th>sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBV</td>
<td>2.56</td>
<td>±0.15</td>
<td>2.21</td>
<td>2.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rate of</td>
<td>-</td>
<td>-34.96</td>
<td>4.24</td>
<td>19.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasound</td>
<td>2.67</td>
<td>±0.13</td>
<td>1.94</td>
<td>2.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rate of</td>
<td>-</td>
<td>-19.83</td>
<td>5.67</td>
<td>25.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>2.60</td>
<td>±0.10</td>
<td>1.67</td>
<td>1.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rate of</td>
<td>-</td>
<td>-39.71</td>
<td>0.00</td>
<td>16.76</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.05 (Mean±SD)

### III. Results

**1. VAS**

In case of whole body vibration group, VAS changed from 0.00±0.00 point before DOMS' induction to 2.60±0.51 points after 24 hours, to 3.32±0.38 points after 48 hours and to 0.97±0.28 points after 72 hours.

In case of the ultrasound therapy group, VAS changed from 0.00±0.00 point before DOMS' induction to 6.11±0.85 points after 24 hours, to 4.20±0.78 points after 48 hours and to 3.42±0.79 points after 72 hours.

In case of a control group, VAS changed from 0.00±0.00 point before DOMS' induction to 4.67±0.47 points after 24 hours, to 4.97±0.88 points after 48 hours and to 2.30±0.20 points after 72 hours.

It has been demonstrated that all of VAS scores increased for 24 hours, but all groups decreased after 48 hours.

In case of whole body vibration group-control group, there were significant differences in the change of value according to time (F=41.875, p=0.000) and there were
significant differences between groups (F=12.664, p=0.004).

There were significant differences in the change of value in accordance with time in whole body vibration group-ultrasound therapy group (F=44.020, p=0.000) and there were also significant differences between groups (F=7.005, p=0.020).

As a result of a posterior analysis between three groups in repeated measures ANOVA, whole body vibration group had lower value than the other two groups, and there were no significant differences between ultrasound therapy group and control group.

In case of whole body vibration group, pressure threshold changed from 2.56±0.15 points before DOMS' induction, to 2.12±0.18 points after 24 hours, to 2.21±0.24 points after 48 hours and to 2.63±0.36 points after 72 hours. In case of the ultrasound therapy group, it changed from 2.67±0.13 points before DOMS' induction, to 1.94±0.09 points after 24 hours, to 2.05±0.10 points after 48 hours and 2.58±0.17 points after 72 hours. In case of control group, it changed from 2.60±0.10 points before DOMS' induction, to 1.67±0.45 points after 24 hours, to 1.67±0.06 points after 48 hours and to 1.95±0.11 points after 72 hours.

In case of whole body vibration group-control group, there were significant differences in the change of values corresponding to time (F=18.498, p=0.000), but there were no significant differences between groups.

In case of whole body vibration group-ultrasound therapy group, there were significant differences in the change of values corresponding to time (F=13.741, p=0.000); however, there were no significant differences between groups.

2. Pressure threshold

Figure 2. After DOMS induced by eccentric exercise, WBV group was maintained lower than Control group on the VAS(p<0.05).

Figure 3. After DOMS induced by eccentric exercise, WBV group was maintained lower than Ultrasound Therapy group on the VAS(p<0.05).

Figure 4. After DOMS induced by eccentric exercise, WBV group was more quickly returned than Control Group on the pressure threshold algometer(p<0.05).
Before 24hr 48hr 72hr (time)

Figure 5. After DOMS induced by eccentric exercise, WBV group was a little more quickly returned than Ultrasound Therapy group on the pressure threshold alometer (p<0.05).

IV. Consideration

The whole body vibrator was devised initially to increase bone density of astronauts. This equipment has been used to strengthen muscular strength and to improve a sense of balance with regards to sports as there have been many active current studies on the effects of low-frequency vibration on human body. Meanwhile, after applying whole body vibration for the female elderly for 24 weeks, it has been demonstrated that the muscular strength and movement speed of leg extensor, counter movement jump, etc. have increased significantly (Roelants et al, 2004). In addition, Rittweger (2002) applied whole body vibration for 60 patients with chronic low back pain for 6 months; as a result, their lumbar extensor (muscle) was strengthened; accordingly, there have been several research results that it could be applied to the exercise of patients with chronic low back pain. It has been shown that whole body vibration was an effective exercise treatment that could have a positive effect on the improvement of patients with chronic low back pain.

This study has started from the question of whether the effect of whole body vibration on such a chronic disease could be applied to more diseases more widely. In this regard, this study compared the ultrasound therapy (Hasson S et al, 1990; Oh Haksu et al, 2003) (that has been proven to be effective in the treatment of DOMS) with pain reducing effect in order to examine the effects of whole body vibration for one of acute pains, DOMS..

The DOMS takes place due to the excessive use of muscles, its subsequent irregular blood supply, hypoxia caused by muscle ischemia or the accumulation of by-products such as lactate and potassium in the muscle caused by fierce or unfamiliar exercises and it is a state of temporary increase in muscle tone (Cleak & Eston, 1992) and people feel it from about 8 hours to 1 day after the said activities and it reaches its peak 1 to 2 days after exercise, but it reduces gradually and disappears in 5 to 7 days (Armstrong, 1984).

This study used VAS and pressure threshold as measuring tools to examine the effects of whole body vibration for the pain recovery of DOMS. After the experiment, it could not find statistical significance in pressure threshold, but it could find similarity for the pain reducing effect of whole body vibration in VAS. Namely, it has been shown that the whole body vibration group had significantly higher pain reducing effects than other two groups in VAS values. When comparing it with the control group, it has been assumed that the whole body vibration group was effective in DOMS. On the other hand, the ultrasound therapy did not have significant differences with the control group; therefore, it did not affect the recovery of DOMS to a great extent.

It has been believed that such results of whole body vibration could find their probability on the following grounds. First, it had something to do with muscle ischemia and hypoxia among the factors that caused DOMS. Among the studies on the effects of whole body vibration that could affect DOMS with regards to muscle ischemia and hypoxia, there have been studies on the increase in
According to Schin (2001), it has been reported that the amount of flowing blood in quadriceps and gastrocnemius muscle increased by whole body vibration, the average blood speed of popliteal artery and peripheral blood circulation increased and the reduction in the resistance of blood vessel took place significantly. Rittweger (2001) announced that 26% of whole body vibration increased oxygen uptake (VO2) so that oxygen metabolism increased and oxygen uptake per unit weight (specific VO2(sVO2)) also increased by 4 ml/kg.min.

From the said results, it could be estimated that the effects of blood circulation promotion for whole body vibration increased the blood circulation in the DOMS parts caused by muscle ischemia and it could affect the reduction in the pain of DOMS. In addition, it has been believed that the increase in oxygen uptake with respect to whole body vibration would provide necessary oxygen and eventually play a positive role in reducing the pain in DOMS.

Second, among the researches on the reduction in DOMS, there have been some that focused on the effects of exercise. Boyle et al (2004) claimed that DOMS was reduced by the centrifugal exercise of yoga movements when letting DOMS-induced participants perform yoga movements once. Cheung et al (2003) mentioned that the effects of exercise were excellent even if they were temporary in the reduction of DOMS. Whole body vibration adds various low frequencies and amplitudes of vibration on the vibration board; in doing so, it changes the acceleration of gravity that is applied to the participants on the vibration board and it enhances not only the effects of exercise (Bosco et al. 2000), but it also leads TVR (tonic vibration reflex) with mechanical vibration (Seidel, 1988) and activates muscle spindle and adjusts muscle fiber through the reaction of Ia centripetal neuron and α-motor neuron and increases the mobilization of motor unit and increases the activation of muscles temporarily with the activation of multiple connection paths (Torvinen, 2002). It has appeared that such characteristics of whole body vibration would play a positive role in amplifying the effects of exercise in DOMS.

From the said results, it has been demonstrated that whole body vibration amplified the effects of exercise and increased the peripheral blood circulation, oxygen uptake and oxygen metabolism; through these effects, it would be possible to be used in DOMS that had relatively short period of symptom continuance as well as in the recovery of chronic diseases such as chronic lumbar pain through the exercise of muscle strengthening.

In contrast to such positive results of whole body vibration group, the results of ultrasound therapy group did not show statistically significant differences between its control group in the value of pain and they did not affect the reduction in pain to a great extent.

When applying the ultrasound therapy into the parts of DOMS twice a day for 7 minutes after doing exercise with the intensity of 1MHz of 1.5W/cm², there were no significant differences in pain perception, edema, motion range of elbow joint at time of muscular relaxation and muscular strength, according to Stay et al (1998)'s research results. Meanwhile, those of Craig et al. (1999) were the same as those of Stay et al. in a way that there were no specific effects of ultrasound therapy on the healing of DOMS in the blastic phase at the intensity of 1MHz 0.8W/cm². As seen in the research results of Hasson S et al (1990) and Oh Haksu et al (2003) and those of Stay et al (1998) and Craig et al (1999), the effects, experiment results and opinions of ultrasound therapy for DOMS have been varied according to scholars; therefore, more studies on it should be done in the future. In this study, it has been found
that the ultrasound therapy did not have significant effects on DOMS; in this regard, it should be further studied in the future.

As a result of this experiment, there was no significant differences in pressure threshold. It would be hard to judge the moment of pain threshold if pressure increased very slowly to check the pressure value when pressure threshold used a pressure measuring device; on the other hand, if pressure increased rapidly, it would be very clear to feel the moment of a pain, but difficult to trust the value of pressure threshold, according to List (1991)'s research. From the said experiment results, the pressure threshold measured by people was not accurate in measurement value because of their inaccuracy and inability to pin down the moment of pressure; for this reason, it has been estimated that it would affect the statistical significance.

As such, this study examined the effects of whole body vibration through 26Hz of fixed frequency and 12 minutes of application time. In the next studies, there shall be a comparison of the mechanical characteristics of whole body vibration whose effects will be varied according to the differences of frequency and amplitude of vibrations and their applicable time (Bovenzi & Graffin, 1997); in doing so, the most appropriate applicable factors shall be found.

V. Conclusion

This study induced DOMS to 21 participants of the experiment to find out what effects the application of whole body vibration and ultrasound therapy have on DOMS; then, each 7 participants were allocated to the whole body vibration group, ultrasound therapy group and the control group (there were no treatment in the control group). In the treatment of the whole body vibration group and ultrasound therapy group, each mediation was applied after 24 and 48 hours of inducing DOMS and each pressure threshold and VAS were measured before the induction of DOMS, and after 24, 48 and 72 hours of inducing DOMS; then, the study compared and analyzed the change in variables and the following results were obtained.

1. In terms of VAS value, a pain has increased for 24 hours in all groups, but it has decreased after 48 hours in all groups.

2. It has been shown that pressure threshold increased in all groups after 24 hours in the change of a pressure measuring device.

3. VAS scores of the whole body vibration group-control group and the whole body vibration group-ultrasound therapy group: it has been found that the value in a pain changed as time went (p<0.05) and there were significant differences between two groups (p<0.05).

4. Pressure threshold of the whole body vibration group-control group and the whole body vibration group-ultrasound therapy group: it has been demonstrated that the value in a pain changed as time went (p<0.05) and there were no significant differences between two groups.

5. As a result of conducting a posterior analysis between the three groups of repeated measures ANOVA in VAS value, it has been found that the whole body vibration group was significantly lower than the other two groups in the value of a pain.

From the aforementioned results, the application of whole body vibration group in VAS value showed the effects on the reduction in DOMS and it had better effects than the ultrasound therapy group. Therefore, it has been believed that whole body vibration would be a treatment method that would be helpful in recovering DOMS.

Furthermore, there should be further studies on the development, consolidation and method for enhancing the effects of whole body vibration.
vibration programs appropriate to the reduction in DOMS.

VI. Reference


Rittweger J, Mutchelekhanuss M, Felsenberg D. Acute changes in neuromuscular excitability after exhaustive whole body vibration exercise as compared to exhaustion by squattig exercise. Clin physiol Funct Imaging. 23(2); 81-86, 2003.


