Comparison between sit-up and bridging exercises on trunk muscles response during sudden impact loading

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Abstract The aim of the this study is to explore the comparison between sit-up and bridging exercise on trunk muscle response during sudden impact loading. We recruited twenty four healthy adults agreed to participate in this study. The subjects were twelve healthy men and twelve healthy women who currently attending S University in Asan, Chungnam. The experiment was conducted after random placement through a draw. To remove measurement errors before measurement, the area on the subject were shaved, rubbed with alcohol cotton to cleanly prepare the skin. Electromyography(EMG) attachment location was on four areas transverse abdominis(Tra), rectus abdominis(RA), erector spine(ES), multifidus(MF) based on the anatomic knowledge by a trained evaluator. The load was given when the subjects had their eyes open(EO) and after eyes close(EC) with auditory input was cutted out. The evaluator loaded a sandbag of 5% of the subject’s body weight at the eye level of the subject. The onset latency, peak latency and peak EMG amplitude were evaluated. As a result, there were statistically significant differences in Tra, RA, MF muscles in EC condition during the sit-up and bridging exercise(p<.05). But there was no difference in other variables. In conclusion, this study suggests that when there are sudden external stimulus during sit-up exercise, due to the compensatory mechanism, the MF suddenly activates to cause microtrauma. In addition, EC condition weren't affected to healthy adult compaired to Low back pain(LBP) patients.

Key Words : Bridging, Sit-up, Low back pain, Microtrauma, Loading, Lantency, Trunk muscle
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Key Words: Bridging, Sit-up, Low back pain, Microtrauma, Loading, Latency, Trunk muscle

1. INTRODUCTION

Spinal stabilization is created through the interaction of gross and fine motor systems [5][12]. In local muscles, core muscles that provide active support for individual segments of the spine is included. Core muscles such as multifidus (MF), transversus abdominis (TrA), internal oblique (IO) organize spinal segments in stable positions and prevent stress in inactive tissue at the peak range of movement. In contrast, the gross motor system that include many surface trunk muscles such as rectus abdominis (RA) and erector spine (ES) respond to internal and external load of the trunk to regulate changes in body movement and body center [12][14][16].

Exercises for trunk muscles include bridging, sit-up, leg raise, crunch, and plank exercise. Among them, sit-up exercise is a representative trunk flexion exercise and there are a number of studies that show it has effect on overall abdominal muscle activity. Sit-up exercise is improve abdominal stabilization effect and it has the effect of increased abdominal pressure due to the increase of abdominal tension and muscle strength [19]. On the other hand, bridging exercise, which is a trunk extension exercise and because it increases trunk muscle activity, it is generally used clinically to strengthen lumbopelvic stability [22][27]. Bridging exercise strengthen neuro- muscular control of trunk flexor and extensor muscles. Also, it improves the functional stability of the trunk by strengthening the pelvis and lower body muscles and because it can help strengthen the lumbopelvic area, it is recognized clinically [10][16][28].

However, it was found that an unexpected variable that predicted in trunk loading or position was the risk factor of low back pain (LBP) [7][15][17]. Examples of risk factors include excessive and sudden external load that consist specific gravity load, falling, slipping, and internal damage to nervous reactions [20,21]. Without adequate stability and certain variables, the trunk can have excessive strain that cause tissue damage [27][35]. Also, in case of sudden neuro- muscular system response, there will be increased trunk muscle activation and mechanical loading on the spine. Here, differences occur between intended movement and actual movement and this increases spine loading. The central nervous system (CNS) attempts to compensate for these differences [8][19][33]. It is determined that excessive force applied on the spine is the main cause of spinal damage [4][23][34].
In previous studies about LBP patient and motor control, compared to a person without chronic low back pain (CLBP), a person with CLBP had delayed activation of TrA, MF, and it was reported that there was a slow response and a more severe contraction. Mahmood et al. (2015) researched about microtrauma of the back according to sudden neuromuscular system response in standing position and a different result from previous studies was derived. When sudden load was given to the upper body of a subject with LBP, it was reported that there was small rigidity or preliminary muscle activity in TrA/IO, ES muscles [19].

**[Table 1] General characteristics (n=24)**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>21.20±1.86</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.08±9.16</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>65.25±12.25</td>
</tr>
</tbody>
</table>

Values indicate mean±standard deviation

On the other hand, Michael (2014) studied about microtrauma according to degree of fatigue of the trunk muscles and it was found that in women rather than men and also in RA muscles rather than other muscles there was a faster onset latency [24]. In the study by Mahmood et al. (2015), it was shown that high increase of eye open (EO) condition ES muscle short latency and eye close (EC) condition ES muscle latency could cause microtrauma and CLBP [19]. This decrease of electrical activity is a compensatory mechanism which can be considered to be attempts by the CNS to minimize stress on the spinal tissues through muscular inhibition [6] [32]. These changes in trunk muscle activity can lead to pain by back injury and microtrauma [19]. But, previous studies set conditions to measure microtrauma according to sudden load and currently there are almost no studies on external impact that occur suddenly during trunk exercise. Although there were studies on damages during exercise, it was measured in standing positions.

However, trunk exercises are done lying down. Therefore, to our knowledge, we were trying to explore microtrauma by comparing muscle activation latency and peak according to external impact during the most representative trunk exercises, sit-up and bridging.

The first purpose of this study is to compare between sit-up and bridging exercise on trunk muscles response. The second purpose is to confirm if visual information influence on trunk muscles response. The third purpose is to compare which muscles between deep abdominal muscle and back muscle first response during sudden loading.

### 2. METHOD

#### 2.1 Subjects

The 24 subjects of the study were 12 healthy men and 12 healthy women who currently attending S University in Asan, Chungnam. And the experiment was conducted after random placement through a draw. Table 1 represents the physical characteristics of the subject. The subjects received adequate explanation about the purpose and methods of the study before conducting the experiments and participated in the experiments after voluntary agreement. The selection criteria for the subjects included those who did not have back pain and did not have nervous damage of the spine, those who did not have history of surgery in the last three months, those who did not have experience of treatment due to spinal kyphosis or lumbar pain, those who did not have orthopedic problems including recent spinal fracture, and those who did not have a history of cardiovascular diseases. Those who had sensory hypersensitivity, open wounds or inflammatory disease on the abdomen, and back pain during exercise were excluded. This study was conducted with the approval of SunMoon University Institutional Review Board [Figure 1].
2.2 Procedure

Before the study, the height and weight of the subjects were measured with Inbody (Inbody 570, Biospace, Korea, 2013) and the body composition was analyzed. The subjects went through a pilot test of catching a sandbag weighing 5% of their body weight to confirm the safety. It was randomly selected if the subjects would first conduct sit-up exercises or bridging. After the pilot test, the subjects were to carry a basket with a load of 5% of their body weight, and their arms in a bent 90 degree state, they were to grab a box, where the evaluator loaded a sandbag of 5% of the subject’s body weight at the eye level of the subject (Figure 2-B). Caution was taken so that the elbows did not touch the ground during measurement. To measure changes according to the presence of visual information, load was given when the subjects had their eyes open and load was given when eyes were closed in a state where auditory input was cut out. To avoid muscle fatigue influencing measured data during EMG measurement after exercise, 10 minutes of rest time was given between each measurement (Figure 3-A).

The initial position of bridging exercise consisted of using a goniometer to stand the knee at a 90 degree angle, placing the feet at shoulder width parallel to the ground, and hands facing the ground. The subjects were instructed to maintain a position of raising the hip joint to 0 degree flexion so that the hit and the spine would be in a straight line according to spoken instruction “raise your hips” by the evaluator (Figure 2-D). Here, the subjects were instructed to grab a box in a state where their arms were bent at a 90 degrees angle. Evaluator

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse Abdominis</td>
<td>Approximately 2cm medial and inferior to the anterior superior iliac spine</td>
</tr>
<tr>
<td>Rectus Abdominis</td>
<td>3cm lateral to the umbilicus</td>
</tr>
<tr>
<td>Multifidus</td>
<td>Approximately 2cm lateral to the L5 spinous process</td>
</tr>
<tr>
<td>Erector Spine</td>
<td>L3–L4 level approximately 4cm lateral from the midline</td>
</tr>
</tbody>
</table>
loaded weight at the same height to the sit-up exercise. The evaluator was an undergraduate student of physiotherapy and it was conducted after a number of practices. For the group that conducted the bridging first, the eye level at the position of sit-up exercise was measured before hand to load a sandbag weighing 5% of their body weight. Caution was taken so that the elbows did not touch the ground during measurement. As above, load was given when the subjects had their EO and EC condition with auditory input was cutted out.

2.3 Electromyography and electrodes location

To measure muscle activity of TrA, RA, ES, MF during sit-up and bridging, Electromyography (EMG, QUS100, Wireless EMG, Italy, 2009) device was used. EMG analysis is an analysis of muscular electrical signal activity, thus analysis by detecting muscle fiber action potential which is an electric diagnostic technique that can diagnose muscular diseases and nerve damage. Also, it indirectly shows innervation patterns of muscles and it is a non-intrusive research method used as an index to evaluate the degree of muscle weakness.

To remove measurement errors before measurement, the area on the subject were shaved, rubbed with alcohol cotton to cleanly prepare the skin. EMG attachment location was on four areas TrA, RA, ES, MF based on anatomical knowledge by a trained evaluator. To maintain coherence, electrodes were each attached to the right TrA: approximately 2cm medial and inferior to the anterior superior iliac spine), RA (3cm lateral to the umbilicus), ES (L3–L4 level approximately 4cm lateral from the midline), MF (approximately 2cm lateral to the L5 spinous process). Electrodes were longitudinally oriented along the fibers of the muscle. EMG band-pass filter was set to 20Hz~500Hz. EMG software myoReserch 1.06.44 software was used for analyzing the collected data. There were three variables: onset latency, peak latency, and the maximum EMG amplituderate.

2.4 Data analysis

The collected data was statistically processed using statistical program SPSS 18.0 for Windows (SPSS NC. Chicago, IL). For analysis methods, sit up-bridging exercise comparison between groups used paired t-test and comparison of measurement variables within group also used paired t-test. Also, to explore differences between each variable, posttest used Bonferroni method. The significance level of all statistical analysis was set at \( p < 0.05 \).

3. RESULT

TrA, RA, ES and MF activation during sandbag of 5% of the subject’s body weight load during EO and EC condition in normal adults during sit-up and bridging was compared.
3.1 Comparison of onset latency, peak latency, and peak during sit-up exercise and bridging

Comparing at EO condition, there were no significant differences in TrA onset latency ($t=1.644$), RA onset latency ($t=0.603$), ES onset latency ($t=1.231$) and MF onset latency ($t=0.242$), TrA peak latency ($t=-1.192$), RA peak latency ($t=-1.019$), ES peak latency ($t=-1.378$) and MF peak latency ($t=-0.844$), TrA peak ($t=-2.296$), RA peak ($t=-2.778$), ES peak ($t=1.539$) and MF peak ($t=3.750$) during sit-up exercise and bridging.

Comparing at EC condition, there were no significant differences in TrA onset latency ($t=-0.879$), RA onset latency ($t=-1.336$), ES onset latency ($t=-0.620$) and MF onset latency ($t=0.242$), TrA peak latency ($t=-1.192$), RA peak latency ($t=-1.019$), ES peak latency ($t=-1.378$) and MF peak latency ($t=-0.844$) during sit-up exercise and bridging. However, there were significant differences in TrA ($t=-2.296$, $p<0.04$), RA ($t=-2.778$, $p<0.02$), ES ($t=1.539$) and MF ($t=3.750$, $p<0.05$) peak of sit-up exercise and bridging at EC condition. However, there were no significant differences at ES.

**Table 3** The mean of muscle activation according to sit-up and bridging exercise. (n=24)

<table>
<thead>
<tr>
<th>Item</th>
<th>Muscle</th>
<th>EO</th>
<th>EC</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>onset</td>
<td>TrA</td>
<td>0.52±0.16</td>
<td>0.46±0.18</td>
<td>1.644</td>
</tr>
<tr>
<td></td>
<td>RA</td>
<td>0.48±0.16</td>
<td>0.45±0.18</td>
<td>0.603</td>
</tr>
<tr>
<td></td>
<td>MF</td>
<td>0.49±0.17</td>
<td>0.44±0.16</td>
<td>1.274</td>
</tr>
<tr>
<td></td>
<td>ES</td>
<td>0.51±0.18</td>
<td>0.49±0.23</td>
<td>-0.879</td>
</tr>
<tr>
<td>peak</td>
<td>TrA</td>
<td>0.65±0.18</td>
<td>0.62±0.19</td>
<td>0.656</td>
</tr>
<tr>
<td></td>
<td>RA</td>
<td>0.47±0.16</td>
<td>0.47±0.18</td>
<td>0.617</td>
</tr>
<tr>
<td></td>
<td>MF</td>
<td>0.59±0.20</td>
<td>0.59±0.20</td>
<td>-0.378</td>
</tr>
<tr>
<td></td>
<td>ES</td>
<td>0.62±0.17</td>
<td>0.66±0.22</td>
<td>-0.911</td>
</tr>
<tr>
<td></td>
<td>TrA</td>
<td>66.73±45.22</td>
<td>92.39±54.57</td>
<td>-1.838</td>
</tr>
<tr>
<td></td>
<td>RA</td>
<td>71.63±47.27</td>
<td>101.33±62.3</td>
<td>-2.011</td>
</tr>
<tr>
<td></td>
<td>MF</td>
<td>56.99±21.96</td>
<td>49.95±18.44</td>
<td>1.654</td>
</tr>
<tr>
<td></td>
<td>ES</td>
<td>60.90±23.80</td>
<td>58.49±18.82</td>
<td>0.378</td>
</tr>
</tbody>
</table>

*Mean ± standard deviation, EO: Eye open, EC: Eye close, TrA: Transverse abdominis, RA: Rectus abdominis, ES: Erector spine, MF: Multifidus

3.2 Comparison of onset latency, peak latency, and peak during EO and EC condition

Comparing at EO condition, there were no significant differences in TrA onset latency ($t=1.398$), RA onset latency ($t=0.879$), MF onset latency ($t=-0.969$) and ES onset latency ($t=-0.286$), TrA peak latency ($t=0.644$), RA peak latency ($t=0.742$), MF peak latency ($t=-1.438$) and ES peak latency ($t=-0.877$).

**Table 4** The mean of muscle activation according to EO and EC condition. (n=24)

<table>
<thead>
<tr>
<th>Item</th>
<th>Muscle</th>
<th>EO</th>
<th>EC</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>onset</td>
<td>TrA</td>
<td>0.52±0.16</td>
<td>0.46±0.16</td>
<td>1.398</td>
</tr>
<tr>
<td></td>
<td>RA</td>
<td>0.47±0.16</td>
<td>0.47±0.18</td>
<td>0.879</td>
</tr>
<tr>
<td>peak</td>
<td>TrA</td>
<td>66.73±45.22</td>
<td>92.39±54.57</td>
<td>-1.296</td>
</tr>
<tr>
<td></td>
<td>RA</td>
<td>71.63±47.27</td>
<td>101.33±62.3</td>
<td>-2.011</td>
</tr>
<tr>
<td></td>
<td>MF</td>
<td>56.99±21.96</td>
<td>49.95±18.44</td>
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<tr>
<td></td>
<td>ES</td>
<td>60.90±23.80</td>
<td>58.49±18.82</td>
<td>0.378</td>
</tr>
</tbody>
</table>

Comparing at sit-up exercise, there were no significant differences in TrA onset latency ($t=-0.969$), RA onset latency($t=-1.325$), MF onset latency($t=-0.753$) and ES onset latency($t=-1.720$), TrA peak latency($t=-0.908$), RA peak latency ($t=-0.149$), MF peak latency($t=-1.324$) and ES peak latency($t=-1.861$), TrA peak($t=1.767$), RA peak($t=0.423$), MF peak($t=1.030$) and ES peak ($t=0.851$) during EO and EC condition.[Figure 6][Table 4].

4. DISCUSSION

The purpose of the study is to investigate the latency and peak values that appear with sudden load during sit-up and bridging exercises to analyze the effects on low back. Michael(2014) mentioned that greater levels of muscular effort reduce the ability of the muscle to sustain force and maintain the task. As shown in the results, in the study, when there was sudden weight loading during bridging at EC condition, low muscle activation was shown in MF. This result was identical to the previous study. Because the amount of strength required during bridging at EC condition was larger than sit-up exercise, it could be said that muscle activation occurred[24].

On the other hand, Mahmood et al.(2015) gave a different interpretation compared to Michael (2014)[19]. About decreased muscle activation he referred, “The decrease may also be seen as an attempt by the CNS to minimize stresses on lumbar tissues through muscle inhibition in a compensatory mechanism.” According to this interpretation, the low muscle activation of TrA, RA and MF shown during sit-up exercise at EC condition when sudden weight loading was given could be said to be muscle inhibition to decrease the stress on the spine.

It has been found in the studies by Aruin and Latash(1995), Hodges and Richardson(1997), Zattara and Bouisset(1988) that trunk muscle activity occurs before more of the upper and lower limbs[2][14][36]. It was concluded that CNS predicts the reactionary force caused by the movement of the lower limbs, processing to maintain stability of the spine through the contraction of multifidus muscles[14]. Feed-forward mechanism was a motor control activity of CNS which was an important posture control mechanism to posture through trunk muscle contraction before movement of the limbs[3][13][36]. The study appeared this as the attempt by the body to minimize stress exerted to the trunk by higher muscle activity.

Comparing the peaks of TrA, RA, ES, MF were shown during sit-up and bridging exercise at EC condition, ES peak mean value during sit-up exercise was the highest with 67.99 during bridging, peak mean value of RA and TrA were the highest with 97.09 and 77.70 respectively. This could be interpreted that among sit-up and bridging exercises, during sit-up exercise that was used much of the abdominal muscle, paraspinal muscle which relatively unused was contracted to decrease the stress exerted on the trunk[26][28]. Bridging exercise also heavily was used paraspinal muscle and to decrease the stress, relatively unused abdominal muscle was contracted[9]. If compensatory mechanisms contract the muscle when there is
sudden external stimulus during trunk flexion exercise, paraspinal muscle that provide stability to the spine is suddenly activated which can cause damage or microtrauma. The fact that suddenly activated muscles can cause damage or microtrauma has been mentioned above in the introduction. Also, it showed different results in each condition. Unlike EO condition, there were significant differences in EC condition and this can be interpreted that visual information has some kind of influence on compensatory mechanism. Muscle response about sudden load in EC condition, thus when there is no visual information, is a reflexive reaction activated to prevent trunk posture and balance by responding to afferent stimulus through the upper body, it cannot be voluntary response.

In the study by Roh et al.(2007), when sudden load was given in a standing posture, in EC condition, there were no significant differences of onset latency of ES and MF between asymptomatic group and patient group[29]. This coincides with our research. On the other hand, in the study by Mahmood et al.(2015), it was mentioned that ES muscle electrical activity at EC condition was significantly lower in the asymptomatic group compared to the LBP patient group[19]. These differences could have been caused by differences in evaluating onset latency. In deciding latency, when comparing a method of calculating muscle onset latency as the time required for EMG value to be achieved which is a value adding 2.5 times standard deviation on visual determination and baseline muscle activation mean, it was shown that latency of visual determination was shorter[11].

This study utilized visual determination method. Therefore, due to the differences in data processing process, there could have been differences in latency. The study measured differentiating onset latency and peak latency considering the shortcoming of visual determination that could be subjective in the data processing process, but there was no significant differences in either.

In addition, the experiment was conducted that was divided into EO and EC condition to explore the changes according to visual input. This study found that there were significant differences in TrA, RA, and MF peak when comparing presence of visual input through experiment. There were no significant differences when comparing EO and EC condition. The fact that this kind of result was shown even though visual information and auditory information was completely cut off so that the subjects could not make visual predictions, could be due to the fact that the subjects were healthy adults in their 20s. It could be said that unlike previous studies, muscle reaction abilities of the subjects were superior and had minor influence from visual prediction. Considering that the participants were healthy adults, the researchers of the experiment increased the weight of the load, without risk to the participants, compared to previous studies, there were no significant differences. Therefore, in case of healthy adults, it cannot be said that visual information decrease the amount of microtrauma.

A limitation in this study was that although there was effort to remove elements such as noise that influence EMG signal collection due to movement, it could not be completely removed. Also, there were no accurate measurements about core muscles such as TrA and MF that contributed to trunk stabilization. Furthermore, subjects of the experiment were all people which is difficult to generalize about patients with back pain. It was considered that there needs to be research that supplements these limitations in measurement of EMG in the future. Also, it is considered that there needs to be research to utilize patients who has back pain to compare with an asymptomatic group.

5. CONCLUSION

The study had the purpose of exploring the comparison between sit-up exercises and bridging on trunk muscles response during sudden impact loading. Peak, onset latency, and peak latency of TrA, RA, ES, and MF were measured using in EMG when giving sudden load during sit-up and bridging exercise at EO and EC conditions. ES peak mean value was shown to be the highest during sit-up exercise at EC condition and RA, and TrA peak mean values were shown to be the highest during bridging. Therefore, it is determined that if there is sudden external stimulus during sit-up exercise, paraspinal muscle is
suddenly activated as a compensatory mechanism, which causes microtrauma and has large cumulative risk.

REFERENCE

[24] Michael WO. Comparison of trunk muscle reflex activation patterns between active and passive trunk flexion-extension loading


