Analysis of the Muscle Activity of Fully Immersive Virtual Reality Motions and Actual Motions in Healthy Adults

Jong-Ho Kang\textsuperscript{1} and Tae-Sung Park\textsuperscript{2}
\textsuperscript{1}Department of Physical Therapy, College of Health Sciences, Catholic University of Pusan, 57O ryundae-ro, Geumjeong-gu, Busan, 46252, Korea
swithun@cup.ac.kr
\textsuperscript{2}Department of Rehabilitation Medicine, Pusan National University Hospital, 179 Gudeok-ro, Seo-gu, Busan, 49241, Korea
ts bark@naver.com
January 17, 2018

Abstract

Background: This study compared the muscle activity of fully immersive VR motions with that of actual motions to find if there is a difference.

Methods: Study subjects were divided into a VR motion group using HTC VIVE devices and an actual motion group, and the muscle activity levels of the two groups were compared using independent t-tests.

Findings: The VR motion group showed significantly higher muscle activity in the right middle deltoid than the actual motion group ($p < 0.05$). The other evaluated muscles did not show any significant difference. The two groups showed similar muscle activity patterns.
Improvements: Fully immersive VR is deemed to be applicable for use in physical therapy. Continuous studies are deemed necessary to confirm and validate this finding.

Key Words: fully immersive virtual reality, electromyogram, wearable display, archery, HTC VIVE devices

1 Introduction

The number of patients with central nervous system injuries is increasing steadily, with more than 100,000 cases occurring each year\(^1\). Brain damage or spinal cord injury causes problems with upper extremity functions, balance, and gait, resulting in impaired activities of daily living and postural control\(^2,3\).

To date, various physical therapies have been used to treat central nervous system disorders, such as Bobath therapy, the proprioceptive neuromuscular facilitation (PNF) technique, task-oriented training, the robot treatment method, Constraint-Induced Movement Therapy (CIMT), mirror therapy, and physical agent modalities\(^4\)\(^-\)\(^9\). Task-oriented training consists of giving a goal-oriented task so that a patient exercises while moving the body to make functional movements. It has been reported that upper limb and lower limb functions have been improved in patients with central nervous system diseases treated using task-oriented training\(^10,11\). However, task-oriented training has been found to have limitations, such as the inability to induce a patients interest and motivation due to the simplicity of the tasks\(^12\). Therefore, it is necessary to develop treatment methods that prompt the interest and increase the motivation of patients in existing task-oriented training methods.

Accordingly, task-oriented types of training that combine virtual reality (VR) have been studied. Many studies have reported that VR training improves upper and lower limb functions and walking ability in patients with central nervous system disorders\(^13,14\). Unlike existing treatment methods, training based on VR promotes interest and creates environments that induce patients to concentrate on treatment while undergoing therapy\(^15\). Because of these advantages, physiotherapy based on VR is frequently performed.

Types of VR exercises that have been previously used include semi-immersive VRs, which enable patients to move using a controller or a balance board while viewing a plane screen. Recently, a
A head mounted display (HMD) that is a fully immersive VR device has emerged, enabling VR screens to be rotated 360°, unlike conventional semi-immersive VRs. This enables the configuration of environments making it possible to provide more realistic immersion. HMD devices, such as the HTC VIVE, have a headset and two interlocking controllers so the action of the upper extremity on the headset screen looks like a real action. This immersion difference has demonstrated that fully immersive VR is better than semi-immersive VR.

However, currently, very few studies have combined fully immersive VR with physical therapy. Semi-immersive VR training is known to be effective for upper and lower limb functions, balance, and gait for patients with central nervous system disorders. However, the effects of fully immersive VR, which provides a more stereoscopic reality, are almost unknown. Therefore, it is necessary to determine whether completely immersive VR has therapeutic value. Thus, this study investigates whether the motions performed using fully immersive VRs have similar muscle activity to actual motions, and it discusses the therapeutic potential of those devices.

2 Materials and Methods

2.1 Subjects

The study subjects consisted of 34 right-side dominant normal adult men without any musculoskeletal or nervous system disease, who were randomly assigned to a VR motion group and an actual motion group. The VR motion group performed archery in VR, and the actual motion group performed archery motions in reality. The general characteristics of the subjects are shown in Table 1. The study was conducted with participants who voluntarily signed an agreement after hearing an explanation of the purpose and contents of the research, in order to meet the ethical standards of the Helsinki Declaration.
2.2 Experimental method

The HTC VIVE shown in Figure 1 was used as a completely immersive VR device. The VR motion group performed VR archery motions using two controllers while wearing a headset, as shown in Figure 2. The actual motion group performed actual archery motions using a bow and an arrow, as shown in Figure 3. The basic posture was determined as the posture required to pull the bowstring with both shoulders in 90° flexion. Thereafter, the subjects were instructed to pull the bowstring aiming at the point seen by the eyes in the basic posture.

Surface electromyograms (EMG) (LXM 4204, Laxtha, Korea) were used to investigate the muscle activity patterns. Archery motions are divided into a drawing section and a release section, and the EMGs of the drawing section (set up ~ shooting) were measured and compared18. The EMGs were measured for 5 seconds in the drawing section, and 3 seconds, excluding the first 1 second and the last 1 second, were obtained. The EMGs were measured a total of three times, and the mean values were obtained. The electrodes for the EMGs were attached to the following muscles: the right upper trapezius, right anterior deltoid, right middle deltoid, left anterior deltoid, and left middle deltoid. These muscles were chosen because they are activated during archery motions18. Before attaching the EMG electrodes, the surface of the skin was wiped with alcohol cotton to remove any foreign substances. The EMG wire was fixed to the skin using medical tapes. %Reference Voluntary Contraction (%RVC) was used to determine the muscle activity patterns. The spontaneous reference posture was determined as the anatomical posture with both arms opened 90° holding a 1 Kg dumbbell in each hand. The posture was measured three times for 10 seconds, and the postures for 8 seconds, excluding the first 1 second and the last 1 second, were averaged and used.
2.3 Data processing and analysis

The data were processed using the Statistical Package for the Social Sciences (SPSS) Windows 19.0 program, and the data were described as mean and standard deviation. Independent t-tests were used to compare the % RVC of each group. The significance level $\alpha$ was set to 0.05.

Figure 1. VR archers action (set up)

Figure 2. HTC VIVE
3 Results and Discussion

The results of this study are shown in Table 2. The muscle activity of the VR motion group was found to be higher than that of the actual motion group, but only the difference in the Rt. middle deltoid was statistically significant. As shown in Figure 4, the muscle activity patterns of the VR and actual motion groups were almost the same.

Table 2: Difference in muscle activity between groups

<table>
<thead>
<tr>
<th>VR group (mV)</th>
<th>Real motion (mV)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lt. UD</td>
<td>42.06±32.29</td>
<td>.375</td>
</tr>
<tr>
<td>Lt. MD</td>
<td>81.63±20.36</td>
<td>.054</td>
</tr>
<tr>
<td>Lt. AD</td>
<td>106.6±27.73</td>
<td>.004</td>
</tr>
<tr>
<td>Lt. MD</td>
<td>106.7±11.23</td>
<td>.004</td>
</tr>
<tr>
<td>Lt. AD</td>
<td>45.7±6.69</td>
<td>.266</td>
</tr>
<tr>
<td>Lt. UD</td>
<td>27.7±6.16</td>
<td>.009*</td>
</tr>
<tr>
<td>Rt. UD</td>
<td>12.5±1.24</td>
<td>.009*</td>
</tr>
</tbody>
</table>

Figure 3. Real archers action (shooting)
Lt. UT : Lt. Upper Trapezius  
Lt. AD : Lt. Anterior Deltoid  
Lt. MD : Lt. Middle Deltoid  
Rt. UT : Rt. Upper Trapezius  
Rt. AD : Rt. Anterior Deltoid  
Rt. MD : Rt. Middle Deltoid  
= p<0.05

Figure 4. muscle activity pattern

The results of this study indicate that the muscle activity patterns were similar in the VR motion and actual motion groups. In the case of the muscle activity patterns of the fully immersive VR motions, the muscle activity value of the right upper trapezius was the largest, followed by those of the left anterior deltoid, the right anterior deltoid, the left upper trapezius, the left middle deltoid, and the right middle deltoid, in order of precedence. In the case of the muscle activity patterns of actual motions, the muscle activity value of the right upper trapezius was the largest, followed by those of the left anterior deltoid, the right anterior deltoid, the left upper trapezius, the left middle deltoid, and the right middle deltoid, in order of precedence. This finding indicates that there is no significant difference between fully immersive VR motions and actual motions.
It was found that the % RVC values of the VR motions were higher than those of the actual motions, although the differences were not statistically significant. It is thought that there should be several reasons for this. First, the % RVC values of VR motions might have been higher because of the vibration function of the HTC VIVE device. When the bowstring is pulled, vibrations are generated in both controllers. Vibrations are a commonly used treatment method in physical therapy$^{19,20}$. The mechanism of these vibrations is that the mechanical vibrations delivered to the muscles stimulate the muscular spindle, leading to increases in the activity of the afferent nerve. This results in stronger stimulation of the α motor nerve, leading to muscle contraction$^{21}$ and an increase in muscle activity.

In the present study, the muscle activity during archery was measured by selecting the drawing section (set up point to shooting start point). The significant difference in the muscle activity of the right middle deltoid is considered to be attributed to the fact that, when pulling the bowstring, VR motions can pull the arm as far back as possible regardless of the length of the bow. In the present study, the differences in muscle activity are considered to be attributed to the fact that the bows were used as toys had weak tension. This is because, in the case of fully immersive VR, the environment is reconfigured to be similar to reality$^{22}$. Therefore, when the subjects were pulling a bow in VR, they should have felt as if they were pulling a real bow.

Based on the results presented above, physical treatment effects should have been generated through fully immersive VR. Currently, fully immersive VR is being studied in many health fields. In dental treatment, fully immersive VR has been used for mental and physical stability before treatment$^{23}$. In addition, fully immersive VR can be used for vision therapies, such as amblyopia treatment and dynamic visual acuity enhancement$^{24}$. It is also applicable to psychological treatments, such as treatment of phobias$^{25}$. Thus, fully immersive VR is an effective treatment method used in various health fields. In the future, it is thought that the quality of life of patients will be increased if the effects of VR are examined not only in terms of physical activity but also in terms of mental aspects, such as depression, immersion, and stress.
4 Conclusion

This study investigated whether muscle activity patterns were different between fully immersive VR motions and actual motions in healthy adults. The results of the comparison between VR motions and actual motions indicated that the muscle activity of VR motions was a little higher, but the muscle activity patterns of the muscles mobilized were almost the same in both groups.

When seen from the perspective of normal motion training for patients with central nervous system disorders, the results of this study can be deemed to have demonstrated the therapeutic value of fully immersive VR training.

5 Acknowledgment

This paper was supported by RESEARCH FUND offered from Catholic University of Pusan.

References


