Effects of Vibration Stimuli on the Knee Joint Reposition Error of Elderly Women

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Abstract. [Purpose] This study investigated which frequency levels of vibration affect the knee joint reposition error of elderly women. [Subjects] The subjects of this study were 13 healthy elderly women who had no orthopedic or neurological problems. [Methods] Oscillators were attached to the e bellies of the tibialis anterior, gastrocnemius, biceps femoris, and rectus femoris muscles on the dominant-side lower limbs of the subjects. In order to identify the effects of vibration stimuli on elderly women’s knee joint position sense, knee joint reposition error tests were conducted under randomly selected different conditions (open kinetic chain or closed kinetic chain) and frequencies of vibration (control condition, placebo condition, 10 Hz, 60 Hz, and 120 Hz). [Results] In the open kinetic chain, the knee joint reposition errors were significantly different among conditions (control, placebo, 10 Hz, 60 Hz, and 120 Hz). The knee joint reposition error of 60 Hz vibration was the smallest, but that of 120 Hz was higher than those of the other conditions. In the closed kinetic chain, there were no significant differences among the conditions. [Conclusion] Vibration of 60 Hz is an appropriate frequency for decreasing knee joint reposition error, and for stimulating the proprioceptive sense of the human body. Further studies will be required of the effects of vibration stimulation in future.

Key words: Vibration, Reposition error, Elderly

INTRODUCTION

Proprioception perceives joint position and helps to reposition joint angles after movement of limbs1. However, abnormalities of the structures around joints due to injury or disease prevent proprioceptive functions from respond properly to movements, and may subsequently result in declines of posture control, protective reflex, joint motion, and balance reactions in response to postural disturbance2, 3. Petrella et al.4 reported that joint reposition errors of elderly people, who were aged 65 or over, increased along with the aging, and that the increase was associated with the decline in the proprioceptive sense. Hurley et al.5 also reported that aging decreased joint position sense, accompanying muscle weakness of the lower limbs and decreases in standing stability. Various types of exercises are being prescribed to improve proprioception. Specifically, exercises that maintain balance on unstable surfaces such as sand or soft floors are known to have substantial effect on proprioception6. Resistance exercises are also known to improve proprioception when muscle spindles or joint receptors are strongly stimulated simultaneously by external weights7.

On the other hand, vibration stimulation of the muscles or tendons is known to affect afferent nerve pathways8. Wall and Kentala9 and Kwon et al.10 reported that vibration stimuli have a positive effect on the proprioceptive sense, whereas Verschueren et al.11 and Rogers et al.12 reported that vibration stimuli can have a negative effect on proprioception disturbing the joint position sense.

Previous studies have measured the error ratios of joint reposition of different joints or postures. Moreover, previous studies many used various frequencies for vibration stimuli. This indicates that a lot of previous studies have not suggested an appropriate frequency for vibration stimuli. Therefore, this study investigated which frequencies of vibration affect the knee joint reposition error of elderly women.

SUBJECTS AND METHODS

Thirteen healthy elderly women who had no orthopedic problems, such as fracture, malformation, or severe osteoarthritis, or neurological problems, such as damaged central nerves, scalavestibuli, visual disabilities, vision field defects, or hearing problems, participated in this study. Eleven subjects were right-side and two subjects were left-side dominant and the subjects had an average age of
Table 1. Comparison of the knee joint reposition error under the various frequency conditions of vibration in the open kinetic chain (unit: °)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
</tr>
<tr>
<td>Knee joint reposition error*</td>
<td>7.39 ± 3.79</td>
</tr>
</tbody>
</table>

*significant difference between the control and 10 Hz condition (p<0.05), †significant difference between control and 60 Hz condition (p<0.05), ‡significant difference between placebo and 60 Hz condition (p<0.05), ††significant difference between 60 Hz and 120 Hz condition (p<0.05), NOTE. Each value is the mean ± SD.

Table 2. Comparison of the knee joint reposition error under various frequency conditions of vibration in the closed kinetic chain

<table>
<thead>
<tr>
<th>Variable</th>
<th>Conditions</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Control</td>
</tr>
<tr>
<td>Knee joint reposition error</td>
<td>3.53 ± 3.42</td>
</tr>
</tbody>
</table>

((unit: °)

68.13 ± 2.23 years, an average height of 152.72 ± 4.18 cm, and an average weight of 56.23 ± 5.22 kg. Approval for the study was obtained from the institutional review board of the National Evidence-based Healthcare Collaborating Agency (PIRB11-015–1) and written informed consent was obtained from each subject before starting the study.

In this study, a custom-made vibrator was used to apply vibration stimuli to the subjects. This vibrator was composed of 4 oscillators (10 g, a diameter of 1 cm) and circuits that were used bread-boards. The vibrator was designed so that the frequency of vibration could be adjusted by the changes of voltage. The oscillators were attached to the bellies of the tibialis anterior, gastrocnemius, biceps femoris, and rectus femoris muscles on the dominant-side lower limbs of the subjects. The subjects wore short pants to minimize external cutaneous inputs through the skin, except for the vibration stimuli, and were prevented from wearing shoes and socks. Additionally, they were an eye patch during the experiment to block visual information. In order to identify the effects of vibration stimulation on elderly women’s knee joint position sense, knee joint reposition error tests were conducted under randomly selected conditions at various frequencies of vibration. Further, to avoid learning effects, measurements were taken once a week at each frequency of vibration. The knee joint reposition error test conditions were without attaching the vibrator (control condition), with the vibrator attached but no vibration stimuli (placebo condition), and with 10 Hz, 60 Hz, and 120 Hz vibration in open kinetic chain or closed kinetic chain condition. In the open kinetic chain, the knee joint reposition error tests were conducted while the subjects sat comfortably on a table with their feet not reaching the floor. They were asked to maintain their feet not reaching the floor. In the closed kinetic chain, the subjects stood adopt a static position with their feet apart at shoulder width on a flat floor. They were then asked to a squatting position corresponding to the target angle. After practicing at target angle of target knee joint angles, subjects were verbally asked to position the knee joint 40°, 50°, and 60° which were given randomly. They were asked to maintain for 10 seconds the knee joint angle that they thought was the target angle, and then return to their start position. These experimental procedures were performed with and without vibration stimuli applied to the lower extremity on the dominant side. We used the Hawk Digital System (60 Hz, Motion Analysis, America). When the subjects attempted positioning at the target knee joint angles, they were induced to reach the target angles by real-time monitoring of the interior angles between the vector from the anterior superior iliac spine to the lateral femoral epicondyte and the vector from the lateral femoral epicondyte to the lateral malleolus. The test data were processed to provide the error ratios in the sagittal plane, and the error angle was defined as the difference between the passively-induced target knee joint angle and the actively-induced knee joint angle utilizing a musculoskeletal model provided by the SIMM Program 6.2 version. For each condition, the reposition test was conducted three times and the average value of the error angle was used in the data analysis. The measurement results were calculated as averages and standard deviation of the error angles between the passively-induced knee joint target angle and the actively-induced knee joint target angle, using SPSS 12.0 for Windows. One-way repeated measures ANOVA was performed to identify the differences of knee joint reposition error between with and without vibration stimuli. Significance level was accepted for values of p<0.05.

RESULTS

In the open kinetic chain, the results were 7.39 ± 3.79° in the Control condition, 6.32 ± 4.12° in the Placebo condition, 4.15 ± 5.4° in the 10 Hz condition, 3.42 ± 1.84° in the 60 Hz condition, and 6.50 ± 3.49° in the 120 Hz condition, in the knee joint reposition error statistically significant differences between the Control and 10 Hz conditions, the Control and 60 Hz conditions, the Placebo and 60 Hz conditions, and the 60 Hz and 120 Hz conditions (p<0.05). The knee joint reposition error of 60 Hz vibration was the smallest and that of 120 Hz was greatest(Table 1). In the closed kinetic chain condition, the results were Control 3.53 ± 3.42°, Placebo 2.85 ± 3.05°, 10 Hz 3.18 ± 2.55°, 60 Hz 3.23 ± 2.44°, and 120 Hz 3.76 ± 2.84°. There were no significantly differences
conditions (Table 2).

DISCUSSION

There are many different views on the receptors that perceive vibration stimuli. Gardner et al.\(^{13}\) reported that Merkel disk receptors sense vibration in the low-frequency domain of 5–15 Hz, Meissner corpuscles sense the mid-frequency domain of 20–50 Hz, and Pacinian corpuscles sense the high-frequency domain of 60–400 Hz. Mark\(^{14}\) suggested that high-frequency and small-sized muscle vibrations, such as vibration stimuli with frequencies of 100 Hz or higher and a size of 1 mm, can activate all the main sensory endings of muscle spindles. Based on the studies of Gardner et al.\(^{13}\) and Mark\(^{14}\), the frequencies of vibration stimuli in this study were chosen as 10 Hz for the Merkel disk, 60 Hz for the Pacinian corpuscle, and 120 Hz for the muscle spindle.

In the open kinetic chain, there were statistically significant differences between the Control and 10 Hz, the Control and 60 Hz, the Placebo and 60 Hz, and the 60 Hz and 120 Hz conditions. In the closed kinetic chain, however, there were no significant differences among the conditions. These results are contrary to the reports of Hall and Brody\(^{15}\), and Kisner and Colby\(^{16}\), who reported that closed chain exercises more strongly stimulated the proprioceptive sense. We believe our results arise from pressure changes of the articular capsule, and that the simultaneous contraction of agonistic and antagonistic muscles in the closed kinetic chain likely to inhibit the repositioning of joint positions under external vibration stimuli. Mark\(^{14}\) reported that strong muscle vibrations can stimulate muscle spindle receptors, and vibrations can induce high activities at sensory nerve endings. As a result, they create a false perception of new joint position that it doesn’t correspond to the changed muscle length. In this study, unlike vibrations of 10 Hz and 60 Hz, vibration stimulation of 120 Hz increased the knee joint reposition errors, which were similar to induces the joint position that it doesn’t correspond to the changed muscle length. It seems that vibration of 120 Hz induces a high muscle spindle activation.

Based on the above results, we propose that 60 Hz vibration is a suitable frequency for decreasing knee joint reposition error and stimulating the proprioceptive sense of the human body. Moreover, further research will be necessary on the effects of vibration stimuli applied to patients with nervous system or musculoskeletal system disorders. Such research findings are expected to suggest more systematic and effective methods of applying external stimuli.

ACKNOWLEDGEMENTS

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2011–0008849).

REFERENCES