Immediate effects of different frequencies of auditory stimulation on lower limb motor function of healthy people

LILI YU, PT1, 2), QIUCHEN HUANG, PT1, 2)*, CHUNYING HU, PT1, 2), MIAO YE, PT1, 2)

1) School of Rehabilitation Medicine, Capital Medical University, China
2) Department of Physical Therapy, China Rehabilitation Research Center: No.10 North Road, Fengtai District, Beijing 100077, China

Abstract. [Purpose] The purpose of this study was to explore the immediate effects of different frequencies of auditory stimulation on the lower limb motor function of healthy people. [Subjects and Methods] The subjects were 7 healthy people (5 males and 2 females). The subjects’ lower limb function was measured without auditory stimulation (control), and with auditory stimulation of 500, 1,000, 1,500, and 2,000 Hz. The measured parameters were maximum knee extension torque, average knee extension torque, the Timed Up and Go test (TUG) time, Functional Reach (FR), and the 10-meter walking time. [Results] The TUG times of 500, 1,500, and 2,000 Hz auditory stimulation showed significant decreases compared to the control. The 10-m walking times of 1,000 and 2,000 Hz auditory stimulation showed significant decreases compared to the control. [Conclusion] The results show that auditory stimulation improved the TUG and 10-meter walking times of healthy people and that different frequencies of auditory stimulation had different effects on lower limb motor function.

Key words: Auditory stimulation, Tones, Motor function

INTRODUCTION

Hearing is a sensory response to air vibrations in the range of 20 to 20,000 Hz, which are detected by the cochlea in the bony labyrinth. The ear is a receptor perceiving the direction of a sound source and also provides information for postural control and voluntary movements in daily life1).

The characteristics of sound are composed of three elements: loudness, tone (frequency), and timbre. Loudness is the subjective feeling of sound intensity, related to the acoustic vibration amplitude. Generally speaking, the bigger the acoustic vibration amplitude is, the greater the loudness is. Tone is the subjective feeling of the sound mainly related to frequency of acoustic waves. The higher the acoustic wave’s frequency is, the higher the tone is. Timbre is the ability to distinguish different sounds with the same loudness and tone, and is related to acoustic vibration waveform.

Sound is known to influence human brain function. Auditory stimulation not only affects the auditory system and the vestibular system2), but also activates the brain areas associated with emotional processing and higher cognitive processes3). Furthermore, sound can also activate the lateral pre-motor and supplementary motor areas4).

Recently, music therapy is increasingly being used to improve subjects’ physical and mental health. Moreover, auditory rhythm cueing is drawing much attention in the improvement of the walking ability of the elderly, stroke patients, and Parkinson patients5).

Previous studies have suggested that loud sounds substantially reduce voluntary reaction times, and loud auditory stimulation is also associated with an improvement in the force and speed of force development6). Other studies have indicated that...
major sound stimulation temporarily reduces the excitability of the motor areas of the cerebral cortex, improving flexibility\(^7\). Furthermore, one study investigated the effect of auditory simulation on balance performance, and reported that the subjects reacted differently to different frequencies of sound\(^8\).

Although there is sufficient evidence that auditory stimulation has important clinical therapeutic effects for those suffering motor function impairments, there is still a lack of clinical research concerning the effects of auditory stimulation on motor function, such as muscle strength, balance, and walking ability. Moreover, how different tones stimulate motor function needs further research.

This study explored the effects of different frequencies of auditory stimulation on the lower-limb motor function by measuring knee extension torque, the Timed Up and Go test (TUG) time, Functional Reach (FR), and the 10-meter walking time, which are commonly used indexes in clinical research.

**SUBJECTS AND METHODS**

Seven healthy people (5 males and 2 females) were recruited. They had no orthopedic or neurological abnormalities. The subjects’ characteristics are detailed in Table 1. The purpose and methods of this study were explained to all of the subjects, and all the subjects gave their informed consent before participating in the experiments. This study was conducted with the approval of the Research Ethics Committee of the China Rehabilitation Research Center, IRB approval number: 2015-zx-09.

Subjects were tested without auditory stimulation and while listening to 4 different frequencies of auditory stimulation. To avoid fatigue and carryover effects, the test was conducted over five days by the same person.

For the stimulus, a single frequency sound was emitted at \(-30\) dB, which didn’t cause pain or discomfort to the subjects, by a signal generator app (iPhone6, Signal Generator v1.7.3), at frequencies of 500, 1,000, 1,500, and 2,000 Hz. The subjects received the stimulus through earphones worn on both ears. Each test finished within 20 minutes, and the auditory stimulus continued throughout each test. For each of the 5 test conditions, maximum knee extension torque, average knee extension torque, the Timed Up and Go test (TUG) time, Functional Reach (FR), and the 10-meter walking time were measured.

For the control, subjects were tested with no auditory stimulus. For the other conditions, the subjects wore earphones and listened to the auditory stimulation until all of the tests were finished.

Knee extension torque was measured 3 times by a isokinetic dynamometer (Prima Plus, Easytech, Italy), at an angular velocity of 50 °/sec. Subjects were instructed to do their best and extend the knee as fast and as strongly as possible. The maximum knee extension torque and average knee extension torque were recorded.

The Timed Up and Go test (TUG) is a simple test used to assess a person’s mobility and requires both static and dynamic balance. Subjects wore regular footwear and sat on a chair, placing their backs against the chair; then they stood and walked to a line that was 3 meters away, turned around, walked back to the chair, and sat down, using a comfortable and safe walking speed. A stopwatch was started when the physiotherapist said “Go”, and stopped when the subject’s buttocks touched the seat. The TUG time was measured twice.

To measure functional reach, subjects stood, with both arms naturally hanging down. Then, the subjects flexed their arm at 90°and bent forward as far as possible for 5 seconds keeping their heels on the ground, before returning to the original position. The length of the trace of the fingertips in the horizontal direction during this movement was measured twice using a measure tape.

To measure the 10-meter walking time, subjects were asked to walk a total of 12 meters at their preferred speed, and the time that subjects took to walk the middle 10 meters distance was measured twice.

One-way repeated ANOVA and multiple comparisons (Bonferroni test) were used to test for statistically significant differences, and the factors were the different frequencies. Data were analyzed using SPSS Ver. 17.0 for Windows and a level of statistical significance of 0.05.

**RESULTS**

The effects of different tones of auditory stimulation (no auditory stimulation and 4 different frequencies of auditory stimulation) on knee extension torque, TUG time, FR, and 10-meter walking time are shown in Table 2.

One-way repeated ANOVA revealed that the TUG times of 500, 1,000, 1,500, and 2,000 Hz auditory stimulation showed statistically significant decreases compared to the control, and the 10-meter walking times of 1,000 and 2,000 Hz auditory stimulation also showed statistically significant decreases compared to the control. The other measured values showed no significant differences.

**DISCUSSION**

The TUG times of 500, 1,000, and 2,000 Hz auditory stimulation, and the walking speeds of 1,000 and 2,000 Hz auditory stimulation showed improvements. Obviously, the TUG time and walking speed both improved only with 2,000 Hz auditory stimulation. However, knee extension torque and FR showed no significant changes. The results show that auditory stimulation improved the TUG and 10-meter walking times of healthy people and different frequencies of auditory stimulation had
The reason for the improvement in TUG time and walking speeds is possibly that subjects’ consciousness was aroused by auditory stimulation. Furthermore, the velocity and strength of the nerve impulses may have increased, enhancing lower limb motion amplitude.

In this study, the stimuli were single frequency tones. Therefore, we could combine it with music therapy in future research, to explore the effects of different levels of loudness and tone of music on motor function. Furthermore, the auditory stimulation could also be applied to robot-assisted walking training, like ManBuZhe (Tian Jin) Rehabilitation Equipment Co., Ltd. to improve patients’ walking ability more efficiently.

Table 1. Subjects’ characteristics

|                          | Mean ± SD (N=7) |
|--------------------------|-----------------|
| Age (yrs)                | 28.6 ± 4.0      |
| Height (m)               | 1.68 ± 0.04     |
| Weight (kg)              | 63.6 ± 8.1      |
| BMI (kg/m²)              | 22.5 ± 3.0      |

SD: standard deviation, BMI: body mass index

Table 2. Effects of different frequencies of auditory stimulation on knee extension torque, TUG time, FR, and 10-meter walking time

|                          | 5 groups (Mean ± SD)                                                                 |
|--------------------------|-------------------------------------------------------------------------------------|
|                          | a. Control | b. 500 Hz | c. 1,000 Hz | d. 1,500 Hz | e. 2,000 Hz |
| Maximal knee extension  |
| torque (Nm)              | 128.4 ± 34.0 | 131.6 ± 37.9 | 127.4 ± 37.8 | 119.3 ± 50.1 | 122.1 ± 39.9 |
| Average knee extension   |
| torque (Nm)              | 117.9 ± 33.8 | 123.3 ± 38.3 | 113.4 ± 33.7 | 107.3 ± 49.2 | 116.3 ± 40.4 |
| TUG time (s)             | 8.5 ± 0.9    | 7.6 ± 0.8   | 7.8 ± 0.7   | 7.3 ± 0.6   | 7.5 ± 0.4 |
| FR (cm)                  | 35.9 ± 3.5   | 37.4 ± 2.2  | 36.8 ± 2.2  | 37.5 ± 2.9  | 38.1 ± 1.7 |
| 10MWT (s)                | 6.9 ± 0.4    | 6.5 ± 0.6   | 6.6 ± 0.4   | 6.6 ± 0.3   | 6.6 ± 0.3 |

SD: standard deviation (*p<0.05, **p<0.01)
10MWT: 10-m walking time

REFERENCES

1) Ubukata H, Maruyama H, Huo M, et al.: Body responses to sound stimulation: a crossover study. J Phys Ther Sci, 2014, 26: 1129–1131. [Medline] [CrossRef]
2) Alessandrini M, Lanciani R, Bruno E, et al.: Posturography frequency analysis of sound-evoked body sway in normal subjects. Eur Arch Otorhinolaryngol, 2006, 263: 248–252. [Medline] [CrossRef]
3) Russolo M: Sound-evoked postural responses in normal subjects. Acta Otolaryngol, 2002, 122: 21–27. [Medline] [CrossRef]
4) Pagnacco G, Klotzek AS, Carrick FR, et al.: Effect of tone-based sound stimulation on balance performance of normal subjects: preliminary investigation. Instrumentation. Syst Autom Soc, 2015, 51: 54–61.
5) Yu L, Zhang Q, Hu C, et al.: Effects of different frequencies of rhythmic auditory cueing on the stride length, cadence, and gait speed in healthy young females. J Phys Ther Sci, 2015, 27: 485–487. [Medline] [CrossRef]
6) Anzak A, Tan H, Pogosyan A, et al.: Doing better than your best: loud auditory stimulation yields improvements in maximal voluntary force. Exp Brain Res, 2011, 208: 237-243. [Medline] [CrossRef]
7) Furuwayashi T: Suppressive effect of a loud auditory stimulus on the human hand motor area. The Japanese Society of Physical Fitness and Sport Medicine, 2005, 442.