Body Responses to Sound Stimulation: A Crossover Study

HITOMI UBUKATA, MS, PT[1, 2]*, HITOSHI MARUYAMA, PhD, PT[2], MING HUO, PhD, PT[3],
QIUCHEN HUANG, MS, PT[4]

[1] Department of Physical Therapy, Faculty of Human Health Sciences, Takasaki University of Health
and Welfare: 501 Nakaoorui, Takasaki, Gunma 370-0033, Japan
[2] Department of Physical Therapy, Health and Welfare Science Course, Graduate School of
International University of Health and Welfare, Japan
[3] Department of Physical Therapy, Faculty of Health Care Sciences, Himeji Dokkyo University, Japan
[4] China Rehabilitation Research Center, China

Abstract. [Purpose] Auditory stimulation is used for the functional assessment of the saccule and saccule-derived vestibule-cervical reflex in clinical environments. The present study aimed to clarify the influences of sound stimulation as a type of auditory stimulation on the body. [Subjects] The subjects were nine healthy youths (2 males and 7 females). [Methods] FFD, FRT, the muscle hardness of hamstrings, and RT were measured after the sound stimulation of 1,000 Hz and 70dB. [Results] RT was markedly shortened, and the FFD significantly increased with sound stimulation. [Conclusion] Sound stimulation improved the RT and flexibility, possibly resulting in an effective approach in physical therapy.
Key words: Sound stimulus, Reaction time, Flexibility

INTRODUCTION

Postural maintenance and movements we unconsciously execute are based on the sensory information which is entered, according to circumstances and physical conditions, all the time, and appropriate sensory input is necessary for normal postural reflexes and adjustments. Senses are classified into somatic, special, and visceral. All of these 3 senses are indispensable for daily living activities, and it becomes difficult to execute smooth movements if one of them does not appropriately function. Hearing is a sensory response to sound vibrations at 20 to 20,000 Hz, detected through the cochlea in the bony labyrinth as a receptor perceiving the direction of a sound source and providing a basis for postural control and voluntary movements in daily life[1].

Among previous studies, Russolo[2] reported that fluctuations of the center of gravity toward the source of pure tone stimulation at 500 Hz and 105 dB were observed in all healthy individuals with normal hearing. However, when Shibata et al.[3] conducted a study, involving 7 healthy subjects and using Russolo's method, responses were not characteristic, and fluctuations of the center of gravity were observed along both the X- and Y-axes. Watson et al.[4] re-

ported a lower-limb muscle reflex as a response to a clicking sound, while Furubayashi[5] performed surface electromyography to measure tibialis anterior and pectoralis major muscle contraction with sound stimulation at 110 dB in 7 healthy adults. The author also previously reported that major sound stimulation temporarily reduces the excitability of the motor areas of the cerebral cortex, depending on the intensity and duration of the sound. The startle reflex as a somatic, reflexive motor response to sudden, intense sensory stimulation has also been examined using auditory stimulation in most cases. In the auditory startle reflex, a reflexive response is generally generated in the craniocervical region, and expands to the extremities. Based on these findings, sound stimulation is likely to change muscle tone and consequently affect flexibility. Although auditory stimulation is used for the functional assessment of the saccule and saccule-derived vestibule-cervical reflex in clinical environments, there have been no reports regarding its influences on posture-related muscle tone and movements. Considering such a situation, the present study aimed to clarify the influences of sound stimulation as a type of auditory stimulation on the body.

SUBJECTS AND METHODS

Subjects

A total of 9 healthy youths (2 males and 7 females) were studied, excluding those with orthopedic or neurological abnormalities. With a view to adopting a crossover design to treat all subjects with both sound and control stimulation,

*Corresponding author. Hitomi Ubukata (E-mail: ubukata@
takasaki-u.ac.jp)

they were randomized into 2 groups: those initially undergoing sound stimulation (5, "preceding"); and those initially undergoing control stimulation (4, "following group"). They were also provided with sufficient written and oral explanations regarding the study objective and methods, as well as personal information management, to obtain their written consent. This study was conducted with the approval of the Research Ethics Committee of the International University of Health and Welfare (approval number: 12-25.2).

Methods

As a stimulus, a sound was created at 1,000 Hz and 70 dB with a standard signal generator, and was entered into the subjects through an earphone on both sides for 2 seconds. To prevent measurement-related carryover effects, an interval of 1 week was inserted between the intervention and control periods.

Before and after the intervention and control periods, the finger-floor distance (FFD), functional reach (FR), hamstring muscle hardness, and reaction time (RT) were measured.

Based on a physical fitness test developed by the Ministry of Education, Culture, Sports, Science, and Technology and using the Standing Trunk Flexion Meter (Takei Co., Ltd.), the FFD was measured while standing on a 30-cm table. The measurement was repeated twice at an interval of 1 minute to measure absolute values, and means were adopted for statistics. On measurement, the subjects were instructed to maintain their knee joints completely straight and place their feet close to the anterior edge of the table, with a distance of 5 cm between the tiptoes of both feet and the heels contacting each other. Subsequently, they bent forward to push down a measurement bar with the hands joined and fingers straight. Based on the level of the upper surface of the table as 0 cm, those at which they were able to maintain the bar with the lowest part of the fingertips of both hands for 2 seconds were measured in cm, adopting values in the first decimal place.

The FR measurement was initiated in a standing position, with both arms naturally hanging down. Subsequently, the subjects bent forward as much as possible for 5 seconds, with upper-limb flexion at 90 degrees, and returned to the original position, taking 5 seconds. The length of the trace of the fingertips in the horizontal direction during this movement was measured twice using a measuring tape, and means were adopted as representative values in cm, rounding them down to the first decimal place. The hardness of the right medial part of the hamstrings was measured twice in a prone position, using a muscle hardness meter (NEU-TONE TDM-N1). Similar measurements were performed before and after intervention.

The RT was measured using a portable auditory stimulator (Hitachi Living Systems, Ltd., DIGITAL AUDIO PLAYER i.μ's) and recorder (Olympus Corporation, Voice-Trek V-62). An sound stimulation file was created by compiling a vocal advance notice signal and stimulating sound (50 msec) using a personal computer with voice processing software Digion Sound 5 (DigiOn Inc.). The intervals between the advance notice signal and stimulating sound and

Table 1. Characteristics of subjects (n=9)

Characteristics	Preceding group (n=5)	Following group (n=4)
Gender (Male/female)	1/4	1/3
Age (years)	20.6±0.5	20.5±0.6
Height (cm)	162.8±8.6	163.8±12.8
Weight (kg)	59.1±8.5	62.7±9.1

Mean±SD

between the latter and the following advance notice signal were randomly set at 2.0 to 0.5 seconds, based on a table of random numbers. On measurement, the subjects were instructed to implement a task of responding to the stimulating sound emitted after the vocal advance notice signal as soon as possible in a standing position. The task was sufficiently rehearsed before measurement, and the RT was measured 5 times to adopt means as representative values. The sounds generated by the subjects were recorded with the recorder.

For statistics, baseline values before stimulation were compared between the groups, using one-way repeated measures analysis of variance and the Bonferroni method for multiple comparisons. Variations in measurement values before and after intervention were also compared by conducting a t-test. All statistical procedures were implemented using SPSS 17.0, with the significance level set at 5%.

RESULTS

There were not significant differences between the groups in baseline values before stimulation (Table 1). On comparison of variations in measurement values before and after intervention, the RT was markedly shortened, and the FFD significantly increased with sound stimulation. Neither group showed differences between before and after intervention in the other items (Table 2).

DISCUSSION

With sound stimulation, a significant improvement in both the RT and FFD was observed on comparison between before and after intervention and that of the variation between conditions. The RT improved most markedly with sound stimulation. It represents the entire process from stimulation input to response, which is divided into the following periods: receiving stimulation through the receptor and transmitting it to the primary sensory area; processing stimulation-related information in the high-functioning areas of the brain for cognition, classification, and motor preparation; and transmitting an order generated in the primary motor area to the effector. The position of the body and posture, arousal of the central nervous system, synaptic transmission speed, and attention level have been reported to be factors influencing the RT[6]. Kurosawa et al.[7] examined the influences of variations in the auditory stimulation intensity level on the simple RT of the upper limb, and re-

Table 2. Comparison of the measurement items in the presence and absence of sound stimuli

	Sound stimulus		Non-sound stimulus	
	Pre	Post	Pre	Post
FFD (cm)	5.8±13.1	8.1±12.5 *	5.1±12.7	5.1±13.2
RT (msec)	35.8±2.1	36.8±3.2 *	39.4±7.3	35.8±2.9
Muscle-hardness (TONE)	318.3±77.7	289.5±64.6	335.6±62.4	325.4±80.7
FRT (cm)	18.3±4.1	18.9±3.6	19.5±3.4	18.1±4.5

Mean±SD, *: $p<0.05$

ported that the RT was shortened with increased stimulation intensity. Based on these findings, RT shortening may be considered to represent central nervous system activity to process stimulation-related information, and, in the present study, it was observed, presumably as a result of the expansion of the activating region of the brain with sound stimulation, increasing the synaptic transmission speed.

The FFD is an index to measure the thoracolumbar range of flexion, which may be limited by factors, such as hamstring shortening and abnormal muscle tone in the lower back[8]. Sound stimulation has been reported to temporarily suppress the activity of the motor areas of the cerebral cortex[4]. As these areas are involved in muscle tone adjustments, in the present study, decreased muscle tone due to their suppression may have increased extensibility, consequently improving the flexibility of the thoracolumbar region and hamstrings. Furthermore, sound stimulation at 80 dB or more has been reported to induce the startle reflex as a somatic motor reflex[9], and considering the similar stimulation intensity level, such a reflex may also have been generated in the present study, inducing flexor contraction. By the mechanism of reciprocal innervation, this may also have suppressed extensor muscle tone, improving flexibility.

Sound stimulation improved the RT and flexibility, supporting the usefulness of physical therapy approaches using it to improve the physical condition, warm up, and prevent injury in clinical environments in which it is necessary to obtain favorable treatment outcomes within a limited time frame. Further studies are needed to compare various sound stimuli and examine the duration of the effects. Considering the possibility of the vocal advance notice signal used to measure the RT having served as a stimulus, it may also be necessary to measure and compare RTs using other advance notice signals, such as visual stimuli.

REFERENCES

1) Gotoh A: Functional Anatomy of the Center Nervous System—Sensory nervous system—. J Kansai Phys Ther, 2005, 5: 11–21.
2) Russolo M: Sound-evoked postural responses in normal subjects. Acta Otolaryngol, 2002, 122: 21–27. [Medline] [CrossRef]
3) Shibata D, Nishiike S, Uno M, et al.: Effects of powerful sound stimulation on postural stability in humans. Equilib Res, 2009, 68: 21–27. [CrossRef]
4) Watson SR, Colebatch JG: Vestibular-evoked electromyographic responses in soleus: a comparison between click and galvanic stimulation. Exp Brain Res, 1998, 119: 504–510. [Medline] [CrossRef]
5) Furubayashi 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.
6) Nakamura R: Factors affecting motor initiation—revealed by EMG reaction time—. Clin Electroencephalogr, 1988, 30: 566–572.
7) Kurosawa K: Movement Analysis. —Analysis based on the Reaction time—. J Exerc Physiol, 1993, 8: 135–140. [CrossRef]
8) Matsuzawa T: Examination for Orthopedic Diseases; Assessment for Physical Therapy. Tokyo: Kanehara, 2012, p 82 (in Japanese).
9) Jodo E: Startle reflex. Clin Neurosci, 2012, 30: 772–775.