EFFECTS OF MOVEMENT SONIFICATION AUDITORY FEEDBACK ON REPETITIONS AND BRAIN ACTIVITY DURING THE BENCH PRESS

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The purpose of this study was to investigate the effects of movement sonification auditory feedback on repetitions and brain activity during bench press. Twenty participants performed bench press until failure in three different sound conditions: no-sound, self-selected music, and movement sonification. Repetition maximum was measured to assess bench press performance. Beta wave representing arousal level and frontal alpha asymmetry indicating motivation level and type were also measured. Results showed that frontal alpha asymmetry in movement sonification was significantly higher than that in music and no-sound, but no statistically significant differences were observed in repetition maximum and beta wave among the three conditions. In conclusion, this study concluded movement sonification auditory feedback can be used to motivate individuals rather than listening to music during bench press.

KEYWORDS: motivation, resistance exercise, electroencephalography, sound.

INTRODUCTION: The role of sound on perceptual-motor process has obtained increased attention to sports and rehabilitation research in recent years. The research highlighted a close interaction between auditory and motor areas of the brain and the importance of auditory feedback for improving movement execution and control. Music-assisted auditory feedback has been shown to be effective especially because it can generate internal expectations of when the next note will be heard that helps improve the movement timing. Movement sonification (MoSo) is the transformation of movement data, such as velocity and acceleration, into non-speech acoustic sounds artificially created using music elements including loudness, pitch, timbre, harmony, and rhythm. MoSo aims to assist movement execution and control by optimizing the regulation of the movement and improving self-awareness during movement execution through auditory feedback (Effenberg, 2005). Despite the significant potential effects of MoSo on exercise performance, there is a lack of in-depth information about MoSo auditory feedback in resistance exercises, such as bench press, which require high motivation and high neuromuscular activity. In addition, the underlying neurological mechanisms for the interaction of auditory feedback and movement during resistance exercises are not well understood. Electroencephalography (EEG) measures cortical brain activity, separated by frequency ranges (e.g., alpha: 8-12 Hz and beta: 13-30 Hz), with each frequency range associated with different actions regulated by the brain. The brain activity measured using EEG has been used to explain neurological mechanisms during exercises. For example, frontal alpha asymmetry (FAA), which is calculated by subtracting left frontal alpha power from that of right front alpha power, was determined to be a reliable index of motivation. In addition, beta frequency band is related to voluntary contractions and alertness and arousal during exercise. Therefore, the purpose of this study was to investigate the effects of MoSo auditory feedback on repetition maximum (RM) and brain activity during the bench press.

METHODS: Twenty recreationally trained male participants were recruited for this study (22.66 ± 3.13 years in age; 80.71 ± 15.08 kg in mass; 173.38 ± 9.33 cm in height). Participants had to have at least two years of bench press experience. Participants also had no musculoskeletal injuries within the past six months. Before participating in the study, participants were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent. Preliminary data on the vertical acceleration of the bar from twenty individuals were used to create the audio file of MoSo auditory feedback. The bench press took a total of 2.5 seconds on average, and was divided into linear acceleration (speeding up downward/upward), linear deceleration (slowing down downward/upward), and constant phases based on the value and sign of the vertical linear acceleration. Digital audio workstation software was used to digitally compose the cuing stimulus and the elements of music were used to transform time, force, and spatial components of the movement into auditory equivalents. The audio file generated conveyed the vertical linear acceleration of the bar during the bench press. The acceleration of the bend in pitch cued the acceleration and deceleration of the bench press bar. The magnitude of the vertical linear acceleration at each point in the movement sequence was used to show dynamics. Finally, tempo, meter, rhythm, and form cued the timing of the sequence (i.e., start, middle, and end of the bench press). For the choice of self-selected music, participants were given a list of music with a similar tempo to MoSo and asked to choose one music they liked.

RM performed with 80% of one repetition maximum was assessed during each of the three sound conditions including MoSo auditory feedback, self-selected music, and no-sound. The RM test began at the overhead position of the bench press where each participant was verbally instructed to un-rack the barbell and move it into alignment over the chest. An auditory cue was used to begin each test based on each sound condition. Participants then performed as many repetitions as possible until failure. Each repetition was standardized to the tempo of 60 bpm. The order in which each sound condition was completed was randomly assigned.

The B-Alert X10 Wireless EEG system was used for EEG data acquisition. The vertical distance between the nasion and inion, and horizontal distance from left to right pre-auricular, were measured to determine the precise placement of the center electrode (Cz). Using Cz as a reference point, the remainder of the electrode strip was placed on the subject at points of estimation. The B-Alert X10 EEG is a nine-channel system that collects regional activity via nine electrodes: Cz, C3, C4, Fz, F3, F4, Pz, P3, and P4 (C: central; F: frontal; P: parietal; z: middleline sagittal plane; 3: left side; 4: right side). Beta power spectral density (PSD) from the five electrode sites (Cz, C3, C4, F3, and F4) averaged was analyzed in this study because beta is a high-frequency band associated with voluntary contractions, alertness and arousal and the increased beta PSD corresponds to greater perception of the stimuli. FAA was analyzed to assess motivation during the bench press by subtracting the natural log of alpha power at F3 from the natural log of alpha power F4 because FAA has been considered the most objective means of assessing motivation at a particular moment (Maszczyk et al., 2019). Therefore, alpha (8–12 Hz) and beta (13–30 Hz) frequency bands from the electrodes of F3 and F4 (dorsolateral prefrontal cortex) and Cz, C3 and C4 (motor cortex) were extracted and used for data analysis.

To analyze differences in RM, beta PSD, and FAA across the sound conditions, a one-way repeated measures analysis of variance (ANOVA) was conducted. Additionally, in order to investigate changes in beta PSD and FAA over time, a two-way repeated measures ANOVA with sound (MoSo auditory feedback, self-selected music, and no-sound) and timepoint (0%, 20%, 40%, 60%, 80%, and 100% of time elapsed) being the independent variables was performed. The Greenhouse-Geisser adjustment was utilized when the assumption of sphericity within was found to be violated by the data. For significant main effects, a post-hoc test was performed with Bonferroni adjustment. Partial eta squared (η_p^2) was used for estimating effect size. The effect sizes of 0.01, 0.06, and above 0.14 were considered small, medium, and large, respectively.

RESULTS: A one-way repeated measures ANOVA determined that FAA differed statistically significantly among the three conditions. Post hoc analysis revealed that FAA of the MoSo auditory feedback condition was statistically significantly higher than that of music and no-sound conditions (Table 1). No statistically significant differences were observed in RM and beta PSD.

A two-way repeated measures ANOVA showed that beta PSD differed statistically significantly over time. Post hoc analysis showed that beta PSD at 60%, 80%, and 100% of time elapsed was statistically significantly higher than that at 0 % and 20% of time elapsed, and beta PSD at 80% of time elapsed was significantly higher than that at 40% of time elapsed (Figure 1A). In addition, a two-way repeated measures ANOVA exhibited that FAA differed statistically significantly over time. Post hoc analysis indicated that FAA at 100% of time elapsed was statistically significantly higher (i.e. greater absolute value) than that at 0% and 20% of time elapsed (Figure 1B).

Table 1: The results of descriptive statistics and one-way repeated measures ANOVA.

Variables	Descriptive Statistics			repeated measures ANOVA		
	No-sound	Music	MoSo	$F_{1.026, 17.44}$	p	η_p^2
	Mean (SD)	Mean (SD)	Mean (SD)			
RM (reps)	8.38 (2.59)	8.44 (2.19)	8.38 (2.26)	0.014	0.987	0.001
Beta PSD (μv^2/Hz)	3.39 (0.40)	3.52 (0.36)	3.51 (0.43)	0.721	0.493	0.041
FAA (μv^2/Hz)	-0.0079 (0.03)	-0.0083 (0.02)	-0.15 (0.23)	7.226	0.015	0.298

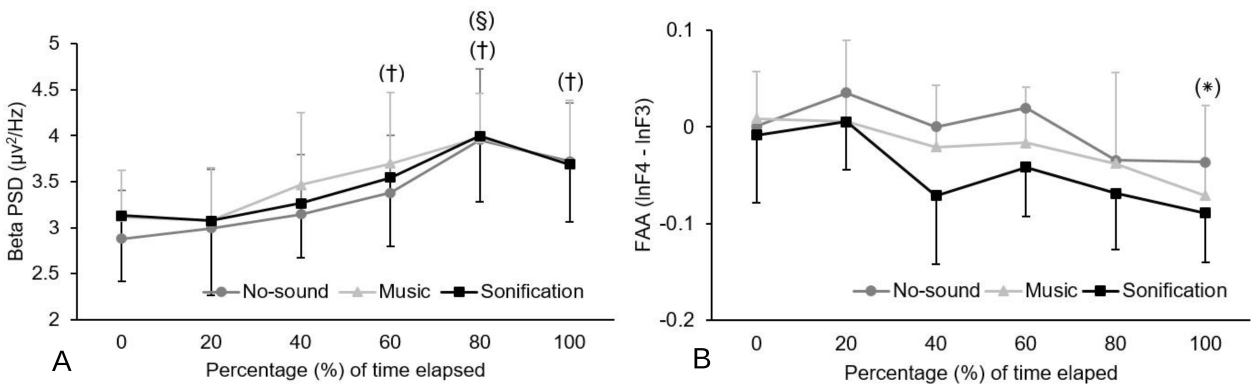

Figure 1: A: Changes in beta PSD over time. (†) indicates p<0.05 for the comparison between 0% and 20% of time elapsed and 60%, 80 %, and 100% of time elapsed. (§) indicates p<0.05 for the comparison between 40% and 80 % of time elapsed. B: Changes in FAA over time. (∗) indicates p<0.05 for the comparison between 0% and 20% of time elapsed and 100% of time elapsed.

DISCUSSION: Beta frequency band is related to voluntary contractions and alertness and arousal. In terms of beta frequency response to endocrine responses during resistance exercise, beta frequency is positively associated with the production of cortisol, and the secretion of cortisol increases with higher intensity using forced repetitions during resistance training (Kraemer & Ratamess, 2005). In our study, there was no statistically significant difference in RM and beta PSD across the sound conditions. Hence, it may be determined that repetitions and beta PSD were not significantly affected by different sounds while performing the bench press. This result may be because the high-level participants were less affected by external stimuli and can focus more on their bench press repetitions. In addition, using the same weight for all three conditions might lead to insignificant changes in RM and beta PSD during the bench press despite the different sound conditions.

In terms of a change in beta PSD overtime, beta PSD increased as the bench press repetitions approached failure in all sound conditions. The increased beta PSD may be due to higher levels of arousal and attention demand with increasing number of repetitions during the bench press.

For FAA interpretation, greater left frontal asymmetry is associated with approach motivation, while greater right frontal asymmetry is associated with withdrawal motivation. There is an inverse relationship between alpha power and cortical activity, which means that reduced alpha power reflects increased brain activation. Thus, the negative value of FAA indicates greater right frontal alpha activity than left frontal alpha activity. The result of FAA showed that significantly greater relative right frontal activation associated with withdrawal motivation was observed in the MoSo auditory feedback condition compared to the no-sound and music conditions. In addition, significantly greater relative right frontal activation was observed at the end (i.e. 100% of the time elapsed) than at the beginning (i.e. 0% and 20% of the time elapsed) of the RM tests in all sound conditions. Thus, it may be determined that individuals were more motivated by MoSo auditory feedback than the other sound conditions, and motivation became greater at the end of the bench press regardless of the sound conditions. This result may be because MoSo auditory feedback was created based on actual bar vertical movement so that participants could feel that it more closely resembles the movement of the bench press during the testing. Thus, participants were provided with direct, real-time feedback informing them of detriments to repetition performance as they could closely monitor desynchronization from MoSo that occurred with fatigue, enabling enhanced motivational responses to real-time changes in the performance of bench press repetitions.

During high-intensity resistance training, levels of hormones such as cortisol, epinephrine, and norepinephrine rise immediately in response to the stress of exercise (Kraemer & Ratamess, 2005). Especially, epinephrine and norepinephrine comprise the “fight-or-flight” response, which is associated with withdrawal motivation. Therefore, it may be determined that MoSo auditory feedback might allow participants to exert greater muscular efforts than no-sound and self-selected music, which may lead to greater hormone secretion and right frontal alpha activity during the bench press. In addition, regardless of the sound conditions, stress levels can increase as repetitions approach failure, which may result in greater hormone secretion and right frontal alpha activity over time.

Despite the novel findings of this study, the results of this study need to be carefully generalized due to potential differences among the participants. More specifically, the relatively large standard deviation compared to the mean of the PSD and FAA was observed. It may be due to different self-selected music choices and different levels of MoSo familiarization among the participants.

CONCLUSION: We obtained four findings. No statistically significant differences were observed in RM and beta PSD among the three sound conditions. Significantly greater relative right frontal activation was observed in the MoSo auditory feedback condition compared to in the no-sound and music conditions. Beta PSD increased as the bench press repetitions approached failure in all sound conditions. Significantly greater relative right frontal activation was observed at the end than at the beginning of the bench press exercise in all sound conditions. This study concluded that although MoSo auditory feedback did not improve bench press repetitions, it could be used to motivate individuals rather than listening to music while performing the bench press.

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