Research Article

Long-Term Effect of Caffeine Intake on Speech and Sound Perception in People with Normal Hearing

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Highlights

- Caffeine is a stimulant of the central nervous system
- This substance can affect the central auditory system and improve ANL
- Caffeine consumption increases noise tolerance, which depends on the dose

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ABSTRACT

Background and Aim: Caffeine intake enhances concentration through affecting brain functions. It also improves attention to the signal which is believed to be associated with increased noise tolerance and improved speech perception. This study aimed to evaluate the long-term effects of caffeine intake on simultaneous speech and sound perception in people with normal hearing.

Methods: This double-blind study was conducted on 90 people aged 18-34 years (45 males and 45 females), randomly assigned to two intervention groups (receiving 3 and 5 mg/kg caffeine) and a control group (receiving placebo). The acceptable noise level (ANL) test was conducted before and five hours after intervention.

Results: Comparison of ANL scores before and after intervention showed a significant difference in the 3 mg/kg caffeine group (p=0.002), but not in the placebo (p=0.497) and 5 mg/kg caffeine (p=0.146) groups. Between-group analysis showed a significant difference between the placebo and 3 mg/kg caffeine groups in the ANL five hours after (p=0.005), while the difference was not significant between the placebo and the 5 mg/kg caffeine groups (p=0.139). Moreover, there was no significant difference in the ANL between the 3 and 5 mg/kg caffeine groups (p=0.148).

Conclusion: Caffeine intake affects noise tolerance, depending on the dose of caffeine. The ANL and speech tolerance improve five hours after consuming 3 mg/kg of caffeine.

Keywords: Caffeine; noise perception; normal hearing; acceptable noise level test

Introduction

In normal people, speech-in-noise (SIN) perception and noise isolation are the activities of the central auditory system. Understanding SIN is one of the most complex tasks of listeners [1]. Speech and verbal communication are an important part of human life. Problems with speech perception can have adverse effects on a person's life, especially in hearing-impaired people who have more speech perception problems [2]. Using a hearing aid cannot help the person in all environments; difficulty in SIN perception causes many patients not to use their hearing aids [3].

The central nervous system (CNS) including the central auditory area, may be affected by drugs and chemical compounds [4]. Caffeine is a CNS stimulant [5] that naturally exist in fruits, seeds, and leaves of coffee, tea, cocoa, and more 60 other plants [6], and is used in different forms; e.g. in coffee, non-alcoholic drinks, chocolate, and drugs. Caffeine (1,3,7-trimethylxanthine) is a natural alkaloid classified as a methylxanthine [7]. This stimulant reduces the blood flow to the brain and causes dopamine release. Dopamine is a neurotransmitter that improves concentration [8]. When caffeine is taken orally, regardless of its dosage, the maximum plasma concentration will reach about 30-60 minutes. The effect of caffeine decreases five hours after consumption [9-11].

The effect of chemical compounds on the auditory system has been investigated in several studies. Caffeine affects auditory system responses including action potential (AP), summating potential (SP), distortion product otoacoustic emissions (DPOAE) [12], auditory brainstem response (ABR) [13, 14], middle latency responses (MLR), and P1 [14], P300 [15], P1, P2, and P3b [16] responses, while it has no effects on vestibular responses of P13/N23 [17]. Speech processing in a noisy environment is done in multiple stages. In other words, the signal input from the cochlea to the brainstem is not the only determinant of accurate signal reception in the presence of noise, and top-down processing is also involved [1]. Therefore, it can be stated that the central auditory areas are effective in SIN perception [18]. Since caffeine is a CNS stimulant and considering the effects of caffeine intake on the auditory system, it is possible that caffeine may increase noise tolerance as reported by Taghavi et al. [19]. In their study, the effect of taking different doses of caffeine (3 and 5 mg/kg) on short-term (one hour after consumption) speech and sound perception was investigated and the results were compared with those of placebo group. They suggested that this increase in noise tolerance depends on the dose of caffeine which was higher at 5 mg/kg.

The acceptable noise level (ANL) test is one of the methods for the evaluation of noise perception. This test, developed by Nabelek et al. in 1991 at Tennessee University, provides a central assessment of noise perception [20]. The ANL score is not affected by gender, age, intensity level, speaker, and level of hearing loss [21]. Its Persian version was developed and validated by Ahmadi et al. [22]. This test includes measurements of the most comfortable level (MCL) and background noise level (BNL), which are used to calculate the ANL score. The MCL indicates the level at which the subject can hear speech quite easily, and the BNL indicates the maximum noise level at which the subject is able to put up with a running speech. The ANL score is obtained by subtracting the BNL from the MCL, where a lower score indicated that the person can tolerate louder noise.

The aim of this study was to evaluate the effect of caffeine intake on SIN perception in people with normal hearing using the Persian ANL test. The difference between our study and Taghavi et al.'s study [19] is that they examined the short-term effects of caffeine intake while we aimed to examine the long-term effects of caffeine intake. The methods are similar; hence, comparing the results can reveal the effects of caffeine over the time.

Methods

This double-blind study was approved by the Ethics Committee of Tehran University of Medical Sciences. The study population included 45 male and 45 female subjects aged 18-34 years. All participants had hearing thresholds ≤25 dB at frequencies of 500, 100, and 2000 Hz determined by using a clinical audiometer (AC40, Interacoustics, Denmark), and their otoscopy and tympanometry results were normal using a tympanometer (Madsen Zodiac, United State) with no history of neurological and psychological disorders. They were not using drugs that affect the CNS. Participants were randomly divided into three groups. The first group was placebo and the two other groups received low (3 mg/kg) and high (5 mg/kg) doses of caffeine. Caffeine was dissolved in 100 mL of water and some sugar and powdered milk were added to improve its taste. The used glass was the same for all groups so that the evaluator be unaware of group assignments. The dose of 3 mg/kg has been used in many studies as a standard dose to evaluate the effect of caffeine on the nervous system [23]. In addition, the recommended dose for a healthy adult is typically ≤5.71 mg/kg to avoid the side effects.

In this regard, we used 5 mg/kg dosage which has also been used in a previous study [15].

The ANL test was first performed using the standard method [21, 22, 24]. The MCL was determined using a running speech at 2 dB steps. Then, the noise was added to the running speech at the MCL and changed by 2 dB steps to reach the maximum intensity that the speech could be traced. Then, the participants used caffeine or placebo. Studies have shown that when caffeine is consumed orally, it is completely absorbed in the stomach [7, 8, 10]. In humans, regardless of dosage, caffeine reaches a peak level within 30-60 minutes after consumption with a half-life of 4-6 hours (ranged 2.5-10 hours) [11]. Therefore, the greatest effect of caffeine is one hour after consumption which begin to decrease five hours after consumption [9, 10]. To evaluate the long-term effect of caffeine, the second ANL test was conducted five hours after caffeine intake to see if the effects of caffeine persisted or not.

Collected data were analyzed in SPSS v.17 software. Kolmogorov-Smirnov test was used to evaluate the normality of data distribution (difference between pre- and post-test caffeine use at different doses). Since the distribution was not normal, Mann-Whitney U test was used for data comparison after applying Bonferroni correction. P-value <0.05 was considered as the significance level.

Results

Within-group analysis

All MCL, BNL and ANL results before and five hours after caffeine intake in all three groups are presented in Table 1. There was no significant changes in ANL, BNL, and MCL scores in the placebo group ($p>0.05$). After intake of 3 mg/kg caffeine, a significant change in BNL ($p=0.001$) and ANL ($p=0.002$) scores after five hours was observed where the BNL score increased and the ANL score decreased; however, the MCL score remained unchanged ($p>0.05$). In terms of 5 mg/kg dose, there was no significant difference in the MCL, BNL, and ANL scores ($p>0.05$).

Between-group analysis

The mean of MCL, BNL and ANL scores in all three groups are presented in Table 2. Based on Kruskal-Wallis test results, there was no significant difference among the three groups in MCL ($p>0.05$), while BNL changes between the placebo group and the group received 3 mg/kg caffeine was significant ($p=0.003$). The placebo group and the group received 5 mg/kg caffeine did not differ significantly in BNL ($p>0.05$), and the difference between the groups received 3 and 5 mg/kg caffeine was not significant ($p>0.05$). The ANL test results before and five hours after caffeine intake to investigate the between-group effect of caffeine intake are presented in Table 2. The results showed a significant difference in the ANL score between the placebo and 3 mg/kg caffeine groups ($p=0.005$), and but there was no significant differences between placebo and 5 mg/kg caffeine groups and between the 3 mg/kg and 5 mg/kg caffeine groups five hours after caffeine intake ($p>0.05$).

Discussion

This study was conducted to examine whether caffeine intake can affect SIN perception in people with normal hearing aged 18-34 years. For this purpose, the MCL, BNL, and ANL scores were compared before and five hours after receiving caffeine (3 and 5 mg/kg) and placebo. The results showed a significant difference in the ANL score before and 5 hours after between the placebo and 3 mg/kg caffeine groups, while there was no significant difference between the placebo and 5 mg/kg caffeine groups. Moreover, no significant difference was found between 3 mg/kg and 5 mg/kg caffeine groups five hours after caffeine use. Increase of the BNL can reduce the ANL score and the person will be able to tolerate more noise, which means they can track the target speech in the presence of more intense background noise.

Within-group comparison of MCL score showed no significant difference between the baseline scores and the scores five hours after, indicating that caffeine intake did not change the MCL scores of individuals in any group. On the other hand, the results showed no significant difference in MCL between caffeine (3 or 5 mg/kg) and placebo groups. A study on the effect of Ritalin, a CNS stimulant, on the ANL score reported similar results, indicating that CNS stimulants have no effect on MCL responses [25]. There are some possible reasons for this outcome. At the time of MCL evaluation, there is no need to judge words in the presence of distractor. Moreover, the ANL response probably requires complex cortical function, but the MCL response does not require such function. Therefore, stimulant drugs may not have an effect on a simple cortical activity [25]. Taghavi et al. [19] also concluded that caffeine consumption had no effect on MCL. They studied the effects of caffeine on the ANL score one hour after consumption when there is probably the highest level of caffeine in the blood.

Table 1. Within-group comparison of most comfortable level, background noise level and acceptable noise level scores before and five hours after caffeine use in placebo, 3 mg/kg and 5 mg/ kg groups (n=30)

Group	Test	Mean (SD)		Mean difference (SD)	p
		Before	After		
Placebo	MCL	38.30 (5.32)	38.90 (6.89)	−0.60 (0.21)	0.995
	BNL	35.40 (2.50)	36.00 (5.67)	−0.60 (0.32)	0.992
	ANL	2.90 (0.53)	2.93 (1.03)	−0.03 (0.96)	0.497
3 mg/kg	MCL	36.67 (5.69)	37.53 (9.54)	−0.86 (0.45)	0.053
	BNL	34.23 (7.28)	35.33 (2.64)	−1.10 (0.73)	0.001
	ANL	2.43 (0.23)	1.66 (0.58)	0.77 (0.64)	0.002
5 mg/kg	MCL	38.43 (8.64)	38.57 (7.13)	−0.14 (0.91)	0.993
	BNL	35.03 (6.94)	35.50 (8.25)	−0.47 (0.56)	0.279
	ANL	3.40 (0.46)	3.07 (0.98)	0.33 (0.34)	0.146

MCL; most comfortable level, BNL; background noise level, ANL; acceptable noise level

Regarding the ANL, our results is consistent with those of Ahmadi et al. who conducted a study to prepare the Persian version of the ANL [22]. The participants in both studies were at the same age range (19-39 years), and there was a same speech signal and noise in both studies. These can be the reasons for agreement. In the present study, the results showed a significant decrease in the ANL score five hours after receiving 3 mg/kg caffeine, while the results showed no significant difference after receiving 5 mg/kg caffeine. It seems that the effect of caffeine also depends on its dosage. A study on the effect of caffeine on the startle reflex showed that a dose of 2 mg/kg affected the recorded response, but 6 mg/kg dose had no effect [26]. The age of participants and doses used in this study are close to our study. The sample size in both studies was small. Perhaps the difference observed between the two groups can be attributed to the difference in the speed of caffeine metabolism in different people [11]. There was a significant difference in ANL scores between the groups received 3 and 5 mg/kg caffeine at baseline, which was because it was not possible to homogenize the participants due to the double-blind design of the study. The decrease in the ANL score may become more remarkable by increasing the number of subjects in the 5 mg/kg caffeine group. Freyaldenhoven et al. also found that the use of stimulant drug (Adderall) significantly reduced the ANL Score. They studied young women with attention-deficit/hyperactivity disorder before and after medication [25]. This finding can be attributed to changes in the auditory processing or central non-auditory changes that affect auditory processing (inhibited cortical activity, increased inhibitory processing, etc.). Since caffeine is also a stimulant of the CNS, the reason for the decrease in the ANL score in the present study can be the increase in inhibitory processing of auditory system.

Table 2. Between-group comparison of most comfortable level, background noise level and acceptable noise level scores difference between placebo, 3 mg/kg and 5mg/kg groups

Group	Placebo vs. 3mg/kg		Placebo vs. 5mg/kg		3mg/kg vs. 5mg/kg	
	Mean difference (SD)	p	Mean difference (SD)	p	Mean difference (SD)	p
MCL	0.26 (0.35)	0.617	0.46 (0.75)	0.098	0.72 (0.90)	0.250
BNL	0.50 (0.42)	0.003	0.13 (0.63)	0.300	0.44 (0.28)	0.144
ANL	0.74 (0.81)	0.005	0.30 (0.43)	0.139	0.44 (0.99)	0.148

MCL; most comfortable level, BNL; background noise level, ANL; acceptable noise level

Speech perception in noise is one of the functions of the central auditory area that depends on the interaction between sensory and cognitive processing. The auditory brainstem has several roles, including phase-locked responses to stimulation regulators, strong pitch encoding, and maintenance of temporal differentiation in the presence of noise [1]. The auditory brainstem performance is modulated and regulated in a top-down fashion. This sensory-cognitive interaction is possible through the afferent pathways that carry sensory information to the midbrain (inferior colliculus) and the auditory cortex associated with the corticofugal pathways [1]. Reduced ANL score after use of a CNS stimulant such as caffeine can increase noise tolerance, concentration, and ultimately improve SIN perception. Therefore, it can be concluded that if people can tolerate more ambient noise in a listening environment, it can improve their speech perception. However, this depends on the tolerance level of individuals in normal conditions. This is probably because of signal processing approaches in the brain and changes in the balance of neuronal excitatory and inhibitory mechanisms, which affect perceptual binding and SIN abilities [27].

Based on the results of the present study, it can be possible to use drugs or chemical compounds to modulate the central auditory system responses to improve tolerance to loud noises through affecting central auditory processing. On the other hand, it can be possible to improve a patient's attention to speech signal through reducing the undesirable effects of noise, leading to enhanced speech perception. The point to be noted is that this study was performed in a normal population. This means that samples have no problem tolerating noise. Doing this study in a group of people with high ANL scores is likely to show a clearer picture of the effects of stimulants on noise tolerance. So further studies are recommended to evaluate the effect of caffeine intake in hearing aid users.

Conclusion

Caffeine intake has long-term effects on the acceptable noise level test score in a specific dose, which can be due to the effect of caffeine as a central nervous system stimulant on auditory cortical activity and inhibitory processing. To further evaluate the long-term effects of caffeine, it is recommended that the acceptable noise level test be repeated at longer intervals after caffeine intake.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of TUMS (Ethics Code No. IR.TUMS.FNM.REC.1396.2393).

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Authors' contributions

SMRT: Study design, acquisition of data, interpretation of the results, statistical analysis, and drafting the manuscript; AG: Study design, interpretation of the results, final revise, drafting the manuscript; NR: Study design, interpretation of the results; HS: Study design; AP: Study design, interpretation of the results.

Conflict of interest

The authors declare that they have no conflict of interest.

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