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Evaluation of the Effects of Non-Invasive Auricular Acupoint Stimulation on Postprandial Blood Glucose Regulation using a CGM Device

Takahiro Fujimoto[1,2], Takeshi Hataoka[2*], Takanori Kobayashi[2], Kazuo Taniguchi[2], Miyuki Oikawa[2] and Hidetake Kobayashi[2]

[1]Medical Director, Clinic F, Tokyo, Japan

[2]Kinki Medical College, Osaka, Japan

ABSTRACT

Background: Postprandial blood glucose regulation is critical for diabetes management. Non-invasive auricular acupoint stimulation may influence metabolic functions through the autonomic nervous system. This study aimed to evaluate its effects on postprandial glucose regulation using Continuous Glucose Monitoring (CGM).

Methods: Thirteen healthy Japanese adults (10 males, 3 females) had 1.5 mm gold beads applied to six acupoints. Glucose levels were monitored over seven days using CGM. Key metrics included postprandial peak, 2-hour glucose levels, time to peak, and normalization time. Results: Auricular acupoint stimulation reduced time to glucose peak after breakfast (-14.6 min, $p = 0.01$) and glucose normalization time for breakfast and lunch combined (-20.8 min, $p = 0.04$). A significant reduction in 2-hour postprandial glucose was observed after lunch (-10.8 mg/dL, $p = 0.03$). No significant effect was found on peak glucose levels.

Conclusion: Auricular acupoint stimulation may promote postprandial glucose normalization, particularly after breakfast and lunch, and could serve as a complementary approach to glucose management.

***Corresponding author**
Takeshi Hataoka, Kinki Medical College, Osaka, Japan.

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Introduction

Diabetes and hyperglycemia are significant global health issues, and postprandial blood glucose management is a key challenge in both the prevention and treatment of diabetes [1]. Insulin and oral hypoglycemic agents are commonly used treatments, but they often come with side effects and require strict lifestyle management [2]. As a result, there is a growing need for non-invasive and convenient complementary therapies.

Auricular acupoint stimulation, a part of acupuncture therapy, has been recognized in traditional Eastern medicine for its ability to affect physiological functions through the autonomic nervous system [3]. In particular, it is thought to influence blood glucose levels and insulin sensitivity via the vagus nerve, and research on its effects on glucose metabolism is ongoing [4]. Previous studies have shown that auricular stimulation can help regulate appetite and manage body weight, and some studies have reported its impact on blood glucose levels [5,6]. Stimulation of the vagus nerve may enhance insulin secretion and improve glucose uptake, contributing to blood glucose regulation [7].

The vagus nerve is part of the parasympathetic nervous system and affects various organs, including the digestive system, pancreas, and liver [8]. When the vagus nerve is activated by auricular stimulation, it is suggested that insulin secretion and blood glucose control improve [9]. Additionally, the vagus nerve possesses an "anti-inflammatory reflex" that reduces inflammation, and auricular stimulation may lower systemic inflammation levels, improving insulin resistance [10]. Since chronic inflammation is linked to metabolic disorders, these mechanisms may contribute to blood glucose regulation through auricular stimulation.

This study aims to evaluate the regulatory effects of non-invasive auricular acupoint stimulation using metal beads on postprandial blood glucose levels, assessed through Continuous Glucose Monitoring (CGM). The goal is to clarify the effects of auricular stimulation on postprandial glucose regulation and propose a novel therapeutic approach for diabetes prevention and management. The study also investigates whether the effects of auricular stimulation differ depending on meal timing, such as breakfast or lunch.

Methods

Procedure

The acupoints for auricular stimulation were selected based on prior research. Six acupoints were used

- Ear Shen Men
- Esophagus
- Cardia

- Stomach
- Lungs
- Hypothalamohypophyseal axis.

Gold beads (1.5 mm) were taped to these acupoints on both ears. Ear Shen Men [MA-TF1] is known to alleviate anxiety and pain, and is reported to have anti-anxiety and anti-inflammatory effects [9,10]. Esophagus and cardia [MA-IC7 Benmen] are known to regulate appetite, reduce body weight and enhance sensitivity to salty tastes [11,12]. Stomach [MA-IC6 Shidao] was selected to enhance the effect on digestion, particularly cardia [stomach] [9]. Lungs [MA-1C1 Fei] stimulation is known to increase satiety, reduce hunger, decrease food intake, promote weight loss [12], and enhance sensitivity to salty tastes [11]. Endocrine (hypothalamohypophyseal axis) [MA-IC3 Neifenmi] stimulation is used to stabilize the entire endocrine system through the pituitary gland [9].

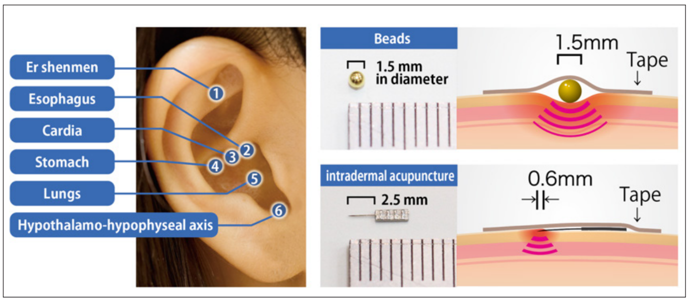

Figure 1: Locations and Effects of the Auricular Acupuncture Points

Data Used
The study utilized seven-day continuous blood glucose monitoring data collected by Kinki Medical College in 2018.

Participants
The participants were 13 healthy Japanese adults (10 males, 3 females), aged 19 to 52.

Measurement Methods
- **Explanatory Variables:** The explanatory variable was the presence or absence of auricular acupoint stimulation. Participants wore metal beads, which were alternated daily, and recorded meal timing and stimulation in self-report questionnaires.
- **Outcome Variables:** Outcome variables included postprandial glucose peak (mg/dL), 2-hour postprandial glucose (mg/dL), maximum glucose rise (mg/dL), time to glucose peak (minutes), time to glucose normalization (minutes), and time to return to baseline glucose levels after meals (minutes). Blood glucose was measured using the Free Style Libre continuous glucose monitoring (CGM) device (Abbott, UK). No dietary restrictions were imposed on participants, but missing data related to late meals and alcohol consumption were excluded from analysis.
- **Covariates:** Sex, age, and BMI were considered as covariates to adjust for potential confounding factors.
- **Statistical Analysis:** Baseline characteristics of the participants were compared by sex using t-tests. A mixed-effects model was employed to examine the relationship between auricular acupoint stimulation and each blood glucose outcome. Auricular stimulation was treated as a fixed effect, while participant ID was included as a random effect. The effects of stimulation on postprandial glucose peak, 2-hour glucose levels, maximum glucose rise, time to glucose peak, time to glucose normalization, and time to return to baseline were evaluated. Covariates such as sex, age, and BMI were adjusted for in the analysis. Statistical analysis was conducted using R version 3.6.3, with a significance level set at 5% for two-sided tests.

Results
The baseline characteristics of the participants are shown in Table 1. The male-to-female ratio was 76.9% male and 23.1% female. Non-prandial blood glucose, excluding measurements within two hours after meals, was 95.7 mg/dL for males and 94.1 mg/dL for females, showing a slight tendency for higher levels in males, though both were within the normal range. The results of the mixed-effects model analysis of the relationship between auricular acupoint stimulation and blood glucose metrics are shown in Table 2.

Table 1: Characteristics of Study Participants

Sex(n)	Female (3)	Male (10)	p.value
age (SD)	33.0 (16.5)	29.6 (7.6)	0.61
BMI (SD)	24.3 (6.3)	23.5 (3.5)	0.78
Pre-meal Blood Glucose (mg/dL, SD)	94.1 (19.7)	95.7 (18.5)	<0.01
Blood Glucose 15 min After Meal (mg/dL, SD)	89.8 (10.4)	92.1 (15.5)	0.31
Blood Glucose 30 min After Meal (mg/dL, SD)	95.7 (14.8)	102.1 (20.3)	0.03
Blood Glucose 45 min After Meal (mg/dL, SD)	112.0 (24.3)	118.8 (28.6)	0.11
Blood Glucose 60 min After Meal (mg/dL, SD)	124.5 (32.0)	124.7 (32.6)	0.97
Blood Glucose 75 min After Meal (mg/dL, SD)	122.6 (32.5)	119.1 (31.9)	0.48
Blood Glucose 90 min After Meal (mg/dL, SD)	123.5 (34.0)	112.0 (28.2)	0.01
Blood Glucose 105 min After Meal (mg/dL, SD)	121.5 (33.7)	109.2 (26.2)	<0.01
Blood Glucose 120 min After Meal (mg/dL, SD)	118.9 (34.3)	108.4 (24.6)	0.01

Table 2: Estimated Values for Each Evaluation Item by Auricular Acupoint Stimulation

	Breakfast + Lunch			Breakfast			Lunch		
Evaluation Item	**Estimate**	**Std. Error**	**p-value**	**Estimate**	**Std. Error**	**p-value**	**Estimate**	**Std. Error**	**p-value**
Blood Glucose Peak (mg/dL)	-3.2	4.0	0.42	2.3	5.5	0.68	-6.7	5.7	0.24
Blood Glucose 2 Hours Post-Meal (mg/dL)	-6.0	3.0	0.05	-0.5	2.9	0.87	-10.8	4.8	0.03*
Maximum Blood Glucose Increase (mg/dL)	-5.5	3.9	0.16	0.6	5.2	0.91	-9.4	5.6	0.10
Time to Reach Blood Glucose Peak (min)	-8.3	4.7	0.08	-14.6	5.6	0.01**	-1.3	7.3	0.86
Time to Normalize Blood Glucose (min)	-13.3	-13.3	0.10	-1.8	7.1	0.80	-21.8	12.7	0.09
Time from Meal to Blood Glucose Normalization (min)	-20.8	9.9	0.04*	-9.8	8.3	0.24	-28.0	15.7	0.08

Adjusted for confounding factors such as sex, age, and BMI. * $p < 0.05$, ** $p < 0.01$

No significant differences were found in postprandial glucose peaks between the presence and absence of stimulation, whether considering the combined breakfast and lunch peaks, breakfast peaks, or lunch peaks (all p-values > 0.05).

A significant reduction in 2-hour postprandial glucose levels was observed only for the lunch group with stimulation (-10.8 ± 4.8 mg/dL, p = 0.03).

The effect of auricular acupoint stimulation on maximum glucose rise showed a tendency for reduction but was not statistically significant (all p-values > 0.05).

The time to glucose peak after breakfast was significantly shortened by auricular acupoint stimulation (-14.6 ± 5.6 minutes, p = 0.01), while no significant changes were observed after lunch or when considering combined meal times.

The time to glucose normalization was reduced in all meal groups, but no significant differences were found for glucose peaks or post-lunch glucose peaks (all p-values > 0.05). However, the time from meal consumption to glucose normalization was significantly shortened by approximately 20.8 ± 9.9 minutes in the stimulation group (p = 0.04). An improvement of similar magnitude was observed after lunch, but the difference did not reach statistical significance (p = 0.08).

Discussion

To the best of the author's knowledge, this is the first study to examine the effects of non-invasive auricular acupoint stimulation using metal beads on postprandial blood glucose levels, measured with a Continuous Glucose Monitoring (CGM) device.

Auricular stimulation did not have a significant effect on postprandial glucose peaks, suggesting that it may not directly influence peak glucose levels after meals. Breakfast, typically lighter and lower in carbohydrates compared to other meals, may require a higher carbohydrate load for auricular stimulation to have a more pronounced effect on glucose regulation. The relatively low glucose load from breakfast could explain why the stimulation effect was not fully realized.

However, auricular acupoint stimulation appeared to reduce 2-hour postprandial glucose levels after lunch, indicating that the stimulation may have a stronger impact on glucose regulation during lunch.

The limited effect on breakfast glucose regulation may also be due to the generally lower glucose rise after breakfast. Insulin sensitivity is typically higher in the morning, allowing the body to process glucose more efficiently. Therefore, even if auricular stimulation contributes to glucose regulation, the smaller rise in glucose may not have been large enough to produce a statistically significant effect two hours after breakfast. Auricular stimulation showed potential for significantly shortening the time to glucose peak after breakfast, suggesting that it may facilitate more efficient glucose regulation during periods of higher insulin sensitivity. In contrast, its effect was less pronounced after lunch, possibly due to decreased insulin sensitivity and the larger meal size compared to breakfast.

The combined results for breakfast and lunch demonstrated that auricular acupoint stimulation significantly shortened the time from meal consumption to glucose normalization. This suggests that auricular stimulation may provide beneficial effects on overall glucose control throughout the postprandial process, including meal intake, glucose rise, peak arrival, and normalization.

Auricular acupoint stimulation may influence insulin sensitivity and glucose uptake by acting on the autonomic nervous system, particularly the vagus nerve. Postprandial glucose regulation mechanisms may differ between breakfast and lunch. For example, glucose regulation after breakfast is primarily driven by increased insulin secretion, while after lunch, insulin resistance tends to increase, slowing the glucose regulation process. The vagus nerve, which has branches in the inner ear, is part of the parasympathetic nervous system and significantly impacts organs such as the digestive system, pancreas, and liver. Several studies suggest that vagus nerve stimulation promotes insulin secretion, which could enhance postprandial glucose regulation via auricular stimulation [13].

When the parasympathetic nervous system is activated, the body enters a "rest and digest" mode, prioritizing energy conservation and recovery. In this state, insulin sensitivity improves, and cells are more efficient at absorbing glucose from the bloodstream. Auricular stimulation may improve insulin sensitivity and promote glucose metabolism by activating the parasympathetic nervous system through the vagus nerve.

Additionally, chronic inflammation is associated with increased insulin resistance and impaired glucose metabolism [14]. The vagus nerve has an anti-inflammatory reflex that reduces inflammation, and auricular stimulation may lower systemic inflammation levels through this pathway, potentially improving insulin resistance and glucose regulation.

The vagus nerve also influences the liver, which serves as a glycogen reservoir and plays a critical role in blood glucose regulation. Activating the vagus nerve through auricular stimulation may help regulate glucose uptake and release by the liver, contributing to overall glucose stability.

Moreover, the vagus nerve affects brain regions that control appetite and satiety. Auricular stimulation could enhance feelings of fullness after meals via the vagus nerve, potentially preventing overeating and indirectly mitigating postprandial blood glucose spikes.

To the best of the author's knowledge, this is the first study to examine the effects of non-invasive auricular acupoint stimulation using beads on postprandial blood glucose regulation via CGM (Continuous Glucose Monitoring) devices.

A limitation of this study is that no dietary restrictions were imposed on the participants. Variations in calorie intake, meal timing, and snacking may have influenced blood glucose levels. Future studies should standardize meal content and timing to more accurately assess the effects of auricular acupoint stimulation. Additionally, participants generally engaged in more physical activity after lunch than after breakfast. Physical activity contributes to blood glucose regulation, which may have diminished the effects of auricular stimulation after lunch. The stimulation effect may have been more pronounced after breakfast, a period with lower physical activity levels. Future research should control for activity levels or include activity in the analysis to more precisely evaluate the effects of auricular stimulation.

Conclusion

The results of this study suggest that auricular acupoint stimulation may have beneficial effects on blood glucose regulation, particularly during the postprandial recovery phase. Auricular stimulation is a non-invasive procedure that does not require highly specialized training and could serve as a complementary method for managing blood glucose levels.

Acknowledgments

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