International Journal of Medicine Research
www.medicinesjournal.com
ISSN: 2455-7404
Received: 27-10-2025, Accepted: 26-11-2025, Published: 11-12-2025
Volume 10, Issue 2, 2025, Page No. 7-12

Cardiovascular effects elicited by Auriculopuncture in the Anxiety Point

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Abstract
The Anxiety point has some therapeutic indications, likely related in part to modification of sympathetic nervous activity, but no systematic studies have examined its cardiovascular effects. The objective of this study was to examine the effects of the Anxiety auricular point using a kinetic analysis of digital volume pressure-volume curve variables. Digital volume pulse (DVP) was measured using a photoplethysmograph, and participants received manual acupuncture at the right Anxiety auricular point. The maximum slope of the systolic pressure rise curve of the DVP, and the area under the curve of each cardiac cycle of the DVP were analyzed, and linear polynomial interpolation was performed to obtain a kinetic model. The Pearson correlation analysis of baseline heart rate values with the trans-acupuncture and post-acupuncture periods showed positive, highly significant correlations. The experimental results regarding changes in slope, area under the curve, and linear interpolation resulting from auricular acupuncture stimulation of the Anxiety point allow us to differentiate the sequence of primary and secondary changes produced by this stimulation. The Pearson correlation analysis clearly showed that the effect of the Anxiety point correlates significantly with the initial values of the variables. The results also support the importance of kinetic analysis in evaluating clinical cardiovascular responses induced by auricular acupuncture and systemic acupuncture.

Keywords: Auriculopuncture, anxiety auricular point, digital volume pulse, electrocardiogram, spline

Introduction

The therapeutic use of ear areas has ancient origins in China, Egypt, Greece, and Rome. Its use in the West has been more recent, with clinical and experimental studies being published [1, 2]. From a neurological perspective, the ear is a complex region with varied innervation. Different areas of the auricle receive sensory input from the auriculotemporal nerve (a branch of the V3 nerve), the vagus nerve (cranial nerve X), the facial nerve (cranial nerve VII), and the lesser occipital and transverse cervical nerves.

Auriculotherapy is a therapeutic discipline derived from complementary medicine, and related neuroanatomical and neurophysiological studies are scarce. Stimulation of auricular points can elicit neurophysiological responses, including the release of neurotransmitters such as glutamate, GABA, acetylcholine, and serotonin, in the nucleus of the solitary tract (NTS), thereby affecting various mental spheres, including mood, appetite, sleep, and pain perception. Furthermore, this type of stimulation has been shown to trigger the release of endogenous peptides, such as β-endorphins and enkephalins, with analgesic and anxiolytic effects, as well as altering sympathetic-parasympathetic activity [3, 4]. Auriculotherapy can also modify cardiovascular variables; this occurs through the vagus nerve and the cervical plexus, which, when stimulated, can induce peripheral vasodilation and generate sensations of reflected heat in body areas related to the treated points [5]. The Anxiety point (Figure 1) on the earlobe is used in various anxiolytic therapies and for the treatment of insomnia [6-8]. However, no studies have been found regarding its potential cardiovascular effects. The purpose of this study was to analyze the cardiovascular effects of auricular point anxiety.

Materials and Methods

A cross-sectional experimental kinetic study was conducted. The subjects in this study were healthy volunteers recruited by invitation. Ten healthy male or female subjects, aged 18 to 35 years, were included; all were non-smokers with no clinical history of cardiovascular disease or obesity, and no competitive athletic training. None of them received any medication or acupuncture treatment during the week prior to the study.

Fig 1: The Anxiety point on the earlobe

Ethical Considerations. The Ethics Committee of the Division of Biological and Health Sciences at the Iztapalapa Unit of the Metropolitan Autonomous University approved the study, which adheres to the principles of the revised Declaration of Helsinki [9]. Subjects were provided with an explanation of the study objectives, and written informed consent was obtained.

Digital volume pulse (DVP) measurement. A photoplethysmography transducer (BIOPAC Systems, TSD200) was placed on the middle finger of the right hand. This transducer transmits infrared light at 860 ± 90 nm to obtain a digital volume pulse (DVP) recording. The photoplethysmograph's frequency response was flat at 10 Hz. The digital output of the photoplethysmograph was recorded using an analog-to-digital converter with a sampling rate of 200 points per second (BIOPAC Systems, MP150) and the AcqKnowledge v. 4.0 analysis platform. For each participant, a 90-second recording was obtained, see Figure 2.

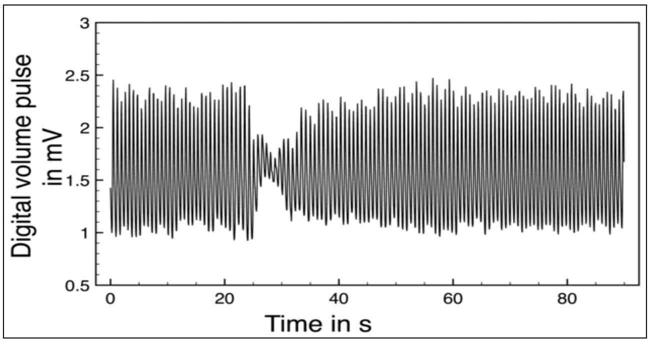

Fig 2: Characteristic recording of the digital volume pulse (DVP) during the 90-second recording period

Calculation of the change in systolic arterial filling velocity of the DVP. To estimate the changes in velocity during the systolic filling period of the DVP, the initial slope of the corresponding DVP cycle was calculated, see Figure 3.

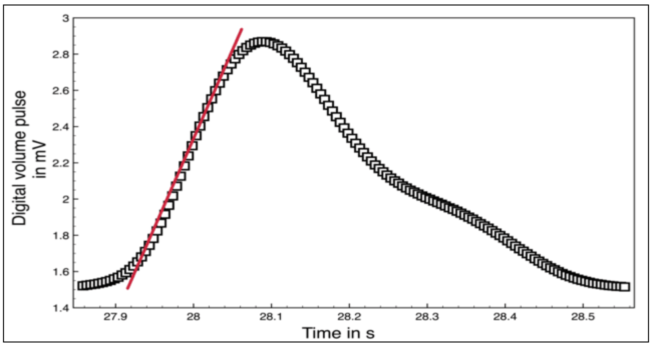

Fig 3: Digital volume pulse (DVP in dashed line) and slope (red line) of the initial rise in systolic pressure or early ejection phase

Calculating the area under the digital volume pulse (DVP) curve. Different methods can be used to find the area under the curve of one cycle of the DVP curve. The most common method is integration, which is used to find the area under any continuous curve, see Figure 4.

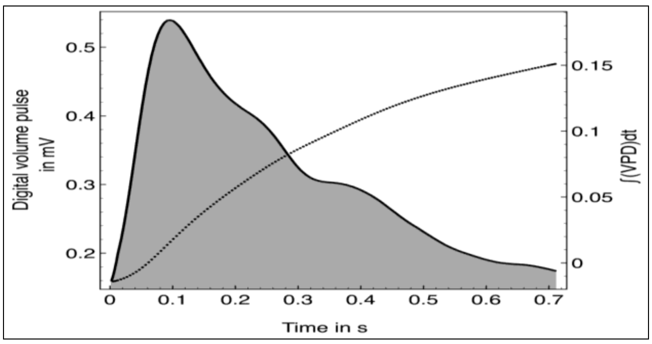

Fig 4: Area under one cycle of the digital volumen pulse (DVP) and its integral ∫(VPD)dt

To integrate the area under the curve for each cycle of the VPD, the Riemann sum method was used. This method involves taking a small section of the curve and approximating the area under that section with a rectangle. The width of the rectangle is equal to the length of that small section of the curve, and the height is equal to the value of the function at that point. This process is then repeated for each small section of the curve until the entire curve has been covered. The web application Plot2 (v.2.6.15, 2019 micw.org) was used to perform the Riemann sum. The function and the limits of integration on the x-axis were entered; this yielded ∫VPDdt.

Linear polynomial or spline interpolation: To construct the kinetic curves using linear polynomial or spline interpolation of the effect of auricular acupuncture on the Heart or Anxiety points, the maximum values of the beginning of each cycle of the slopes were taken—systolic rise; and with respect to the integrals, the value of the area of the systolic component and the total area of each cycle for the period 15-40 s of each recording.

Auricular acupuncture treatment: Manual acupuncture was applied without additional electrical or laser stimulation to the auricular points Heart or Anxiety. The points were located on the ear using anatomical landmarks, as described in standard auriculotherapy texts. The needle was inserted perpendicular to the skin plane to a depth of 3 mm for 10 seconds. Sterile 13 mm x 0.22 mm acupuncture needles with stainless steel handles (HBW, MABB, Silverstar, China) were used.

Practitioner background: A physician with more than one year of experience in acupuncture performed all auricular acupuncture stimuli.

Study protocol: Measurements were taken after a 3-hour fasting period. During the study, subjects remained seated. After recording their clinical information, signing the informed consent form, and receiving an explanation of the protocol, all subjects rested for 10 minutes before recording began. Measurements were taken between 11:00 AM and 2:00 PM to standardize conditions for cardiovascular circadian variations. After the rest period, a digital photoplethysmograph was placed on the index finger of each subject's right hand. Electrodes were placed on both wrists and the right ankle for electrocardiographic recording. The quality of the recording was then verified, and electrode adjustments were made as needed. Next, the recording proceeded. After a baseline recording period of 20 seconds, acupuncture was applied to the Heart or Anxiety points of the right ear during the 21-30 second recording period; after removing the needle, the VPD recording continued until 90 seconds were completed.

Comparisons: The recordings for each subject during the study periods were plotted using the Plot2 v.2.6.15

application, (Michael Wesemann, Berlin, Germany, 2019). The following parameters were compared: a) the slope values for the recording period 16–40 s, Figure 9; b) the integral values for the areas under the curve for each cycle during the recording period 15–40 s; c) the areas under the curve during the total beat and the period corresponding to systole for the recording period 15–40 s; and d) the linear polynomial interpolation curve of the maximum slope values and areas under the curve for the period corresponding to the cycles during the auricular acupuncture stimulation period, period 21–30 s.

Results

Figure 5 shows a characteristic recording of the digital volume pulse (DVP) and electrocardiogram (ECG).

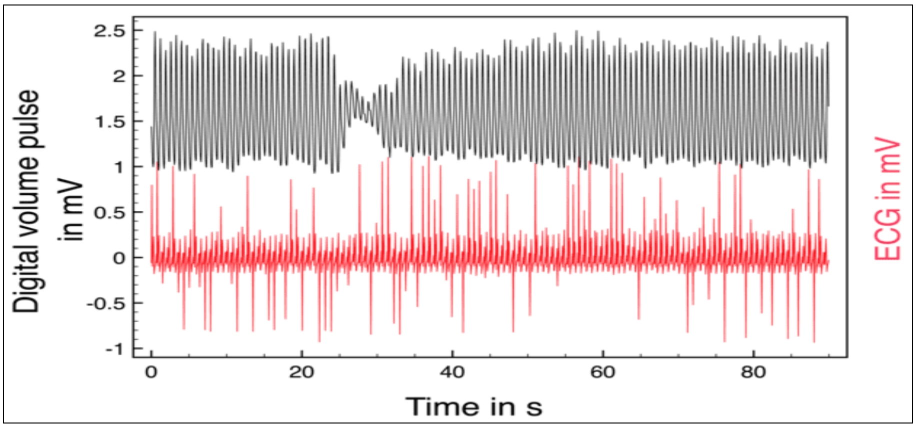

Fig 5: Characteristic recording of the digital volume pulse (DVP, in black) and the electrocardiogram (ECG, in red).

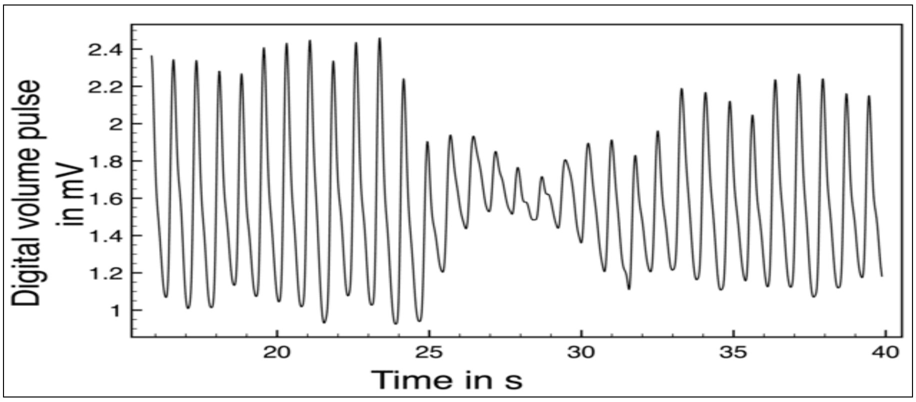

Fig 6: Characteristic recording of the digital volume pulse (DVP) of the pre-acupuncture period (16-20 s), the trans-acupuncture period (21-30 s) and the post-acupuncture period (31-40 s).

Figure 6 shows a 25-second segment of the DVP recording as follows: five seconds of pre-acupuncture recording, 10 seconds of trans-acupuncture recording, and 10 seconds of post-acupuncture recording is shown in Figure 6.

Heart rate

Auriculopuncture at the Anxiety point of the right ear did not cause significant changes in baseline heart rate values 81.2 ± 15.7 (mean ± SD), in the transacupuncture period 74.9 ± 15.9 (mean ± SD), p= .88; neither in the postacupuncture period 69.8 ± 14.5 (mean ± SD), p= .24. Pearson correlations between changes in baseline heart rates versus trans- and postacupuncture heart rates at the anxiety point are shown in Table 1.

However, although no significant changes in HR were observed secondary to stimulation of the Heart point of the right ear, a significant Pearson correlation was observed between the initial HR values and the trans- and post-acupuncture values.

Table 1: Pearson correlations between changes in baseline heart rates versus trans- and post-acupuncture rates following auricular acupuncture at the right ear Anxiety point of the participants.

Variable	R (8)	P value
HRb vs HRt	0.93	< .001*
HRb vs HRp	0.46	.042*

HRb= Initial heart rate; HRt= Heart rate during transacupuncture period; HRp= Heart rate during posacupuncture period. r= Pearson r coefficient. *p < 0.05

Although no significant changes in heart rate (HR) were observed secondary to stimulation of the Anxiety point on the right ear, a significant Pearson correlation was found between baseline HR values and transacupuncture values. However, no significant correlation was found in the post-acupuncture period.

The changes in heart rate (HR) produced by stimulation of the Anxiety point during the transacupuncture period are shown in Figure 7.

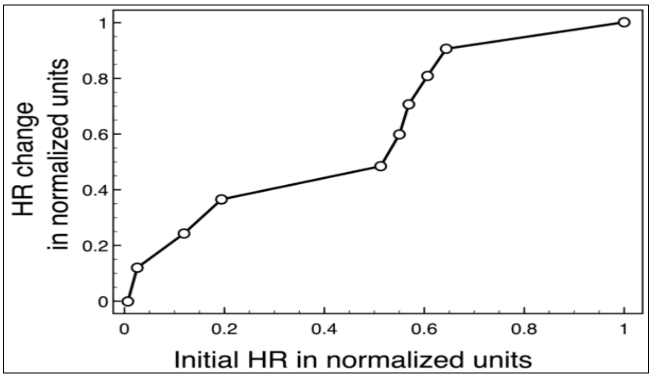

Fig 7: Relationship of initial heart rate with changes secondary to stimulation of the anxiety point during the transacupuncture period in normalized units

Pulse Pressure

Auricular acupuncture at the Anxiety point on the right ear did not cause significant changes in baseline heart rate values 0.33 ± 0.17 (mean ± SD), during the acupuncture period 0.29 ± 0.21 (mean ± SD), p = 0.47; nor in the post-acupuncture period 0.62 ± 0.47 (mean ± SD), p = 0.07.

Pearson correlations between changes in baseline pulse pressure values versus those during and after acupuncture following auricular acupuncture at the Anxiety point are shown in Table 2.

Table 2: Pearson correlations between changes in baseline pulse pressures versus trans- and post-acupuncture following auricular acupuncture at the right ear Anxiety point of the participants

Variable	R (8)	P value
PPb vs PPt	.63	.052
PPb vsPPp	.47	.17

PPb= basal pulse pressure; PPt= change of pulse pressure in transacupuncture period; PPp= change of pulse pressure in posacupuncture period. r= Pearson r coefficient. *p < 0.05

No significant Pearson correlations were found between baseline pulse pressure (PP) values and changes produced by stimulation of the Anxiety point on the right ear.

Changes in pulse pressure (PP) produced by stimulation of the Anxiety point, related to baseline PP during the transacupuncture period, are shown in Figure 8.

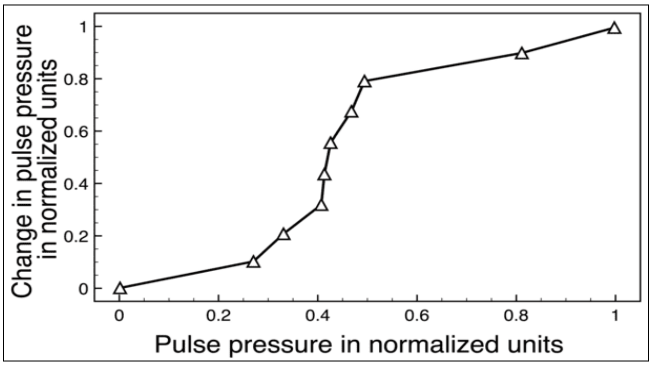

Fig 8: Relationship of initial pulse pressure (PP) with changes produced by acupuncture at the Anxiety point during the transacupuncture period in normalized units

Linear interpolation. The linear or spline interpolation of pulse pressure changes by stimulation of the Anxiety auricular point is shown in Figure 9.

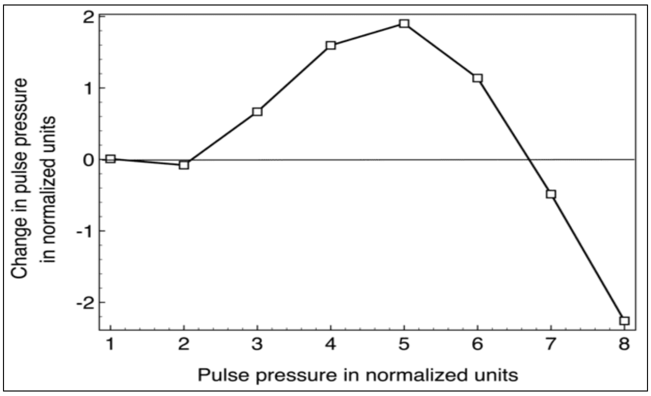

Fig 9: Linear interpolation or spline of the changes in pulse pressure (PP) in relation to the initial pulse pressure produced by stimulation of the right atrial point Anxiety

Systolic slope

Changes in systolic slopes caused by stimulation of the Anxiety point related to the initial slope values in normalized units are shown in Figure 10.

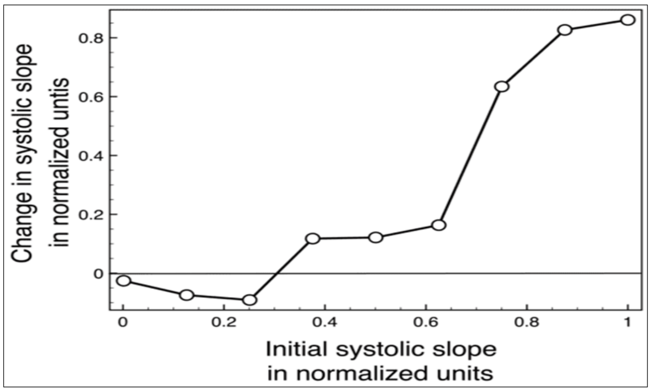

Fig 10: Changes in systolic slopes caused by stimulation of the Anxiety point in normalized values

The value of the systolic slope is related to the rate of increase in vascular pressure at the onset of the systolic period of vascular filling, or the early ejection pase.

Isovolumetric contraction. The changes in the period between the R wave of the ECG and the onset of systolic pressure increase in the DVP cycles were compared to evaluate the effects of auricular acupuncture at the Anxiety point on the isovolumetric contraction period, as shown in the Figure 11).

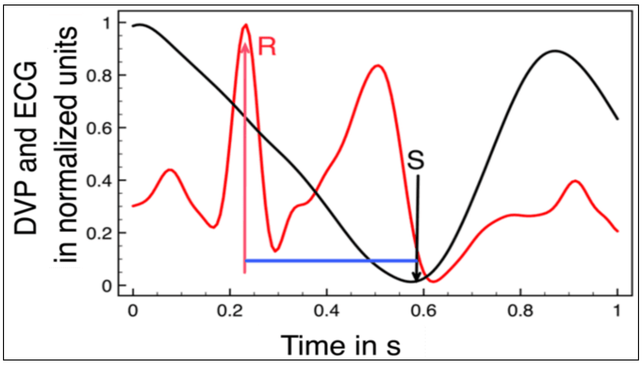

Fig 11: Evaluation of the period (blue line) between the R wave of the ECG (red line) and the beginning of the elevation of systolic pressure (S) in a cardiac cycle of the VPD (VPD in black)

The effect of the atrial anxiety point on the period between the electrical activity of the heart and the beginning of systole in the digital volume pulse or early ejection phase, expressed as: Δ ECG - R to the start of systole, is shown in Figure 12. This period corresponds to the isovolumetric contraction of the heart.
Anxiety point produced a discrete increase in the period Δ ECG - R onset systole, indicating a delay in the start of the systolic period of the VPD cycle, as shown in Figure 12.

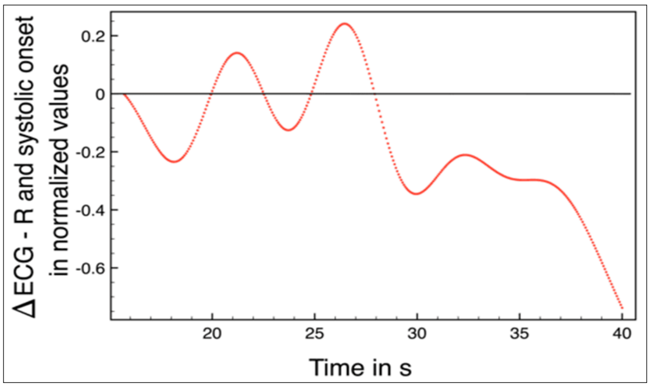

Fig 12: The effect of the right atrial point of anxiety on the period between the electrical activity of the heart and the onset of systole in each cycle of the digital volume pulse or isovolumetric contraction period of the heart

Discussion
The main findings of this kinetic study were as follows
Regarding the heart rate, the Anxiety point did not produce significant changes related to baseline. Furthermore, Pearson's correlation coefficient for baseline heart rate values versus transacupuncture and postacupuncture periods showed positive and highly significant correlations, except in the baseline versus postacupuncture comparison at the Anxiety point. The Anxiety point stimulation generated a sigmoid S-shaped kinetic curve [11].
Regarding pulse pressure, the Anxiety point did not cause significant changes compared to baseline values. The kinetic analysis of the effect of the Anxiety point on pulse pressure yielded a sigmoid S-shaped curve. An S-shaped growth curve describes an initial slow increase, a positive acceleration phase, a rapid increase approaching an exponential rate, and a decline [12].
Regarding the methods used, we can affirm that photoplethysmography is a simple method for obtaining a digital volume pressure (DVP) curve. The pressure-volume dynamic (PVD) results from the interaction of two main variables: the efficiency of cardiac contraction and the distensibility of the arterial system, primarily the large and medium-sized arteries [13]. The physiological components of the PVD pressure-volume curve can be analyzed using slope calculations, integration, and linear interpolation or spline [14].
Slope, integration, and area under the DVP curve. The slope measures the rate of change of a function, while the integral measures the area under the curve, in this case, the DVP curve. The slope describes the function at a specific point, while the integral accumulates the discrete values of a function over a range of values [15]. Integrals are used in various fields, including the calculation of distance, area, volume, and work. For example, the work done by a variable force or fluid dynamics can be calculated using integrals. The area under the DVP curve represents the cardiovascular work during each cycle of the vascular pressure-volume variation following each heartbeat. Integration allows us to analyze the different areas of each cardiac DVP cycle. Obtaining the area under the DVP cycle curve using Riemann sums approximates the actual area, which is the integral [16].
Thus, analyzing the maximum slopes by deriving the pressure-volume change curve provides information about the rate of pressure changes during the arterial pressure-volume cycle. Pressure-volume changes during each cardiovascular cycle are related to the efficiency of cardiac contraction and the degree of arterial distensibility, especially in the large vessels [17].
Furthermore, the integral of the area under the curve for each DVP cycle provides information about the physical work performed during the different phases of the circulatory cycle. The cardiovascular work performed during the variations in the pressure-volume curve is directly related, from a physiological and clinical standpoint, to the balance between oxygen availability and consumption, and to cardiac work. The area components of the pressure-volume curve in each circulatory cycle are as follows: The initial slope of vascular filling corresponds to the efficiency of ventricular systole and the initial arterial resistance. The total integral for a cycle corresponds to the cardiac and vascular work involved in each DVP cycle.
Linear polynomial or spline interpolation. Linear interpolation is a suitable method for fitting curves using linear polynomials. It helps generate new data points within the range of a discrete set of experimentally obtained data points. In mathematics, a linear polynomial or spline-interpolated curve is a piecewise-defined function defined by polynomials. Linear polynomial or spline interpolation is achieved through the application of polynomial theory. Interpolated curves are standard in the fields of design and biomedicine due to their simplicity of construction, ease and accuracy of evaluation, and ability to approximate complex shapes through curve-fitting related to drug behavior.
We propose that the levels and phases of functional response to acupuncture can be analyzed using interpolated curves, thus creating kinetic models of the effects of acupuncture and auricular acupuncture. These kinetic models, in turn, allow us to propose mechanisms of action for auricular acupuncture and acupuncture.

Conclusions
The experimental results regarding changes in slope, area under the curve, and linear interpolation resulting from auricular acupuncture stimulation of the Anxiety point allow us to differentiate the sequence of primary and secondary changes produced by this stimulation. Pearson's correlation analysis clearly showed that the effect of the Anxiety point is significantly correlated with the initial values of the variables. Kinetic analyses aid in understanding the probable mechanisms of action of acupuncture points and, in turn, in optimizing their clinical application. The results also support the importance of kinetic analysis in evaluating clinical cardiovascular responses induced by auricular acupuncture and systemic acupuncture.

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