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Original article

Pressure differences during foot reflexology affect blood flow to brain and kidneys

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Background: Foot reflexology has been re-emerging as one of the most popular forms of alternative therapy. Although the mechanisms of reflexology have not been apparently understood yet, physiological changes can be found from reflexology, e.g., reduced blood pressure, reduced heart rate, and activated brain functions. However, there are still only a small number of studies on the physiological relationships between foot reflexology and changes in blood flow.
Objectives: This investigation aimed to study the effects of brain-associated and kidney-associated foot reflexology on blood flow to the brain and kidneys. The second objective was to examine the effects of pressure differences to reflex points on blood flow to the brain and kidneys.
Methods: Fifty participants were divided into 2 groups, including an experimental group (n = 25) and a control group (n = 25). Brain and kidney reflex points were pressed until found maximum resistance in the experimental group or lightly touched in the control group. Peak systolic velocity to the brain and kidneys was monitored by Doppler ultrasound, both during and after reflexology.
Results: For the brain, blood flow rate during brain-associated reflexology was significantly higher than that of kidney-associated reflexology in the experimental group ($P < 0.05$). Also, blood flow rate to the brain in the experimental group was significantly higher than that of the control group ($P < 0.05$). For the kidneys, only the blood flow rate during kidney-associated reflexology was significantly higher than that of brain-associated reflexology at the right foot ($P < 0.05$).
Conclusion: Brain-associated and kidney-associated foot reflexology could increase blood flow to the corresponding organs in that zone.

Keywords: Blood flow, different pressure, foot reflexology.

Massage is a manual therapeutic approach and has been re-emerging as one of the most popular forms of alternative therapy. There are 2 major types of massage, including ordinary massage and reflexology. Reflexology can be distinguished from ordinary massage by it requiring sufficient pressure to a specific position to activate sensory receptors in the deeper layers of the skin in order to generate a response in corresponding organs.[1, 2] The theory of reflexology is based on the principle that the hands and feet are a mirror of the body and that they have reflex points that correspond to the individual organs of the body.[3, 4] It is believed that the application of massage pressure to a reflex area stimulates the corresponding organs associated with the area being massaged.

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Although the precise mechanisms of reflexology remain uncertain, it refers to an automatic response which stimulates pressure receptors under the skin and transmits a signal along a sensory nerve. The signal is forwarded to the central nervous system. After that, the central nerves transmit motor commands to the organ-associated reflexology map location.[2, 4 - 5] Even though the mechanisms of reflexology have not been apparently understood yet, physiological changes can be found from reflexology, e.g., perspiration, increased blood flow, reduced blood pressure, reduced heart rate as well as respiration rate, and activated brain functions.[5 - 14] Reflexology also considers quality and safety, and is therefore currently a popular treatment for different symptoms, e.g., depression, anxiety, and high-blood pressure.[10 - 12]

The concept of reflexology confirms response areas that link to body parts. These areas are called zone therapy. There are 10 zones altogether, divided as 5 on the left and the other 5 on the right. Each zone starts from the head to the hands, and to the feet. For example, the left foot represents the heart, spleen, kidney, bladder, small intestine, etc. The right foot represents the gall bladder, liver, appendix, etc. When reflex areas at the feet are activated, the functions of their associated organs will be changed. There are 62 points in total. Those points link to 62 key organs. For example, the big toes are the reflex points of the brain while the middle of the feet are the reflex points of the kidneys.[15]

Studies on brain-associated reflex points of the feet and activation of changes in brain responses are still limited. For example, the study of Srisupornkornkool K, *et al*.[13] on the effects of brain-associated foot reflexology and simple reaction time in healthy adults revealed that brain-associated foot reflexology reduced simple reaction time. It also revealed that after brain-associated point reflexology on the right foot, simple reaction time tested by the left hand tended to be reduced more than the right hand. These findings conformed with zone therapeutic theories of reflexology, but no such tendency was found in left foot reflexology. The study of Wongcharoen C, *et al*.[14] revealed that reflexology and light touch on brain reflex points at the feet generated a high frequency of alpha brainwaves (10 - 12 Hz) in all areas of the brain (i.e., frontal lobe, parietal lobe, temporal lobe, central lobe, and occipital lobe) before and during pressure application. After reflexology and light touch, beta brainwaves were found (13 - 21 Hz).

There is no known data of any studies about changes in blood flow to brain related to brain-associated foot reflexology. Besides, according to the literature review, there are still only a few studies on the physiological relationship between foot reflexology and changes in blood flow. For example, the study of Mur E, *et al*.[8] on small intestine-associated foot reflexology revealed increased blood flow at the small intestine. Likewise, the study of Sudmeier I, *et al*.[7] on kidney-associated foot reflexology revealed increased blood flow at the kidneys. This means reflexology affects changes in blood flow to reflex organs. Hence, this research aimed to study the effects of brain-associated foot reflexology on blood flow to brain, and as previous studies revealed that kidney-associated foot reflexology could increase blood flow to kidneys, this research also included the assessment of the effects of kidney-associated foot reflexology on blood flow to the kidneys, in order to support the findings of previous relevant studies in view of physiological changes in reflex organs from reflexology.

In addition, this research also focused on studying the effects of pressure differences at brain-associated foot reflexology points on blood flow to brain. Previous studies revealed pressure differences affecting changes in brain functions. The results showed that light touches on brain reflex points at the feet generated faster simple reactions than brain-associated foot reflexology.[13] The current research, therefore, expected that pressure on reflex areas would affect physiological changes in reflex organs. The study of Diego MA, *et al*.[16] about pressure differences of massage revealed that moderate pressure increased blood flow to the brain and activated the parasympathetic nervous system; whereas light pressure generated opposite effects. However, these findings were the effects from massage, not reflexology. Surprisingly, there are no reports of any research on the effects of pressure differences from reflexology on physiological changes, despite the belief that reflexology must be performed through deep and strong pressure to activate sensory receptors under deep layers which influence changes. Also, it is still unclear which pressure levels exactly suit reflexology. Thus, the objectives of the present research were to study the effects of brain-associated and kidney-associated foot reflexology on blood flow to the brain and kidneys; and the effects of pressure differences to brain-associated and kidney-associated reflexology points on blood flow to the brain and kidneys, respectively.

Materials and methods

Study design

This research was an experimental study design and planned to monitor blood flow rate during and after the application of different pressure at brain and kidney reflex areas of the feet. Examiners who measured blood flow rates to the brain and kidneys did not know which group the participants belonged to. Also, participants were blinded to outcome measures as no results were disclosed or discussed during the study. The study was ethically approved by the Ethics Committee (HSSREC) of Naresuan University before it commenced. Potential participants were given advanced information regarding general task requirements and the opportunity to seek clarification before choosing to participate. All participants provided written informed consent before taking part in the study.

Participants

Fifty female participants, aged between 20 – 30 years were recruited to take part in this study. Based on previous research,[17] a statistical power of 80.0% was used to determine the sample size. Participants were students and personnel at Naresuan University and from outside communities around the university. All participants were screened to ensure they had a normal body mass index (BMI; normal = 18.5 – 24.5 kg/m^2) and no mental disorders. Participants with a Mini-Mental State Examination (MMSE) score below the cut-off score which adjusted for education (Institute of Geriatric Medicine, Department of Medical Services, Ministry of Public Health), drank alcohol regularly, smoked regularly, or had a medical history affecting reflexological procedures such as diabetes, high-blood pressure, heart diseases, cancer, vascular or lymphatic inflammation/occlusion, and other uncontrollable diseases were excluded. Other excluded participants were those with problems of the musculoskeletal system in the arm or leg areas (i.e., bone fractures) and neurological system (i.e., hand and foot numbness); foot wounds; pregnancy or with pregnancy symptoms during the experiment; having menstruation; and having fever.

Experimental procedures

The experiment was conducted in a quiet room within a laboratory suite at the Allied Health Science Faculty, Naresuan University. At least 12 hours before the test, the participants were not allowed to have any drinks with caffeine or with substances that activate the nervous system.[18] They must also not have any alcohol 1 day before the test[19] or eaten anything at least 1 hour before the test. Participants were randomly divided into 2 groups, including the experimental group (foot reflexology that pressed until found maximum resistance, n = 25) and the control group (light touching reflex points, n = 25). Blood flow rates to the brain and kidneys were monitored during reflexology and after reflexology.

The participants laid down on their backs in a relaxed posture and were pressed until found maximum resistance or lightly touched on the reflex points by researcher’s hand at both feet. The interval of reflexology or light touch at each foot was 30 minutes. The blood flow to the brain and kidneys was measured during and after reflexology for 5 minutes. The researcher started to press until found maximum resistance the middle of the feet first for 3 minutes in order to relax the nervous system. Next, the researcher started to press until found maximum resistance or lightly touch the brain reflex points, e.g., big toes and their knuckles. Each point was pressed or light touched and held for 15 seconds, 5 times per point; with a 15-second break. After that, the researcher pressed or lightly touched the kidney reflex points, e.g., middle of feet between the second toe and middle toe. Each point was pressed or touched and held for 15 seconds, 5 times per point; with a 15-second break.[13, 14] For pressure or light touch at the right foot, blood flow to the right brain and kidney was measured. For pressure or light touch at the left foot, blood flow to the left brain and kidney was measured.

Examination of blood flow to brain

Blood flow assessment was conducted by vascular Doppler ultrasound (Nicolet Elite200, USA; Matlab analysing sotfware v.3.2, USA) as a transmitter and receiver of 5 - 10 MHz ultrasounds at the carotid arteries. The transducer probe was tilted parallel to the arteries. The high-frequency signals were then transmitted to the arteries. The signals were received and analyzed afterwards by a signal processing program for analysis based on time domain into spectrum domain, relying on Fourier transformation. Then, the spectrums were analyzed continuously in a form of spectrum waveform at the maximum frequency of the graph during peak systolic frequency. Then, the frequencies were converted into peak systolic velocity (PSV; cm/sec).

The researcher prepared the device and checked the performance of carotid vascular Doppler ultrasound. Then, the participants laid down with their heads turned opposite to the target artery. The researcher looked for the artery position, especially the internal carotid artery on the right side. Ultrasound gel was applied to the skin over the position above the artery. The vascular probe was placed on the position that the gel was applied. Then, blood flow and vascular occlusion was measured. Reflexology or light touch was performed around the brain and kidney-associated area at the right foot. Blood flow rates of the internal carotid artery on the right side were recorded. The researcher repeated this process toward the internal carotid artery at the left neck. Reflexology or light touch was performed around the brain and kidney-associated area at the left foot. Blood flow rates of the internal carotid artery on the left side were recorded (Figure 1).

Examination of blood flow to kidneys

Blood flow assessment was conducted by Doppler ultrasound (MINDRAY; DC-6, China). Participants laid down on a bed the ultrasound gel was applied on the right side of the body, under the right ribs. B-mode gray scale was used for monochrome image display in order to find the position of the renal artery. The probe was placed obliquely on the right side of the body, under the right ribs; and was slid from the body to its right side. When the right renal artery was found, color-Doppler ultrasound was used instead in order to set the color shade frame covering the artery. Spectral analysis was displayed on screen. The measurement position was determined parallel to the right renal artery for measuring renal blood flow velocity during peak systolic velocities (PSV; cm/sec). The researcher repeated the process on the left side of the body. The probe was placed on that side and reflexology or light touch was performed on the left foot. The left renal artery flow rates were recorded (Figure 1).

Statistical analysis

Physical characteristics, e.g., age, weight, height, BMI, and MMSE score, are expressed as medians and interquartiles. They were analyzed using the Mann-Whitney U Test for comparing the differences between subject effects. The values were set with the statistical significance at $P < 0.05$.[20]

Different values of blood flow rates to the brain and the kidney (pre vs pressed at brain-associated reflexology, pre vs pressed at kidney-associated reflexology, and pre vs after pressed) were presented as medians and interquartiles, and used the Friedman test for within subject effects. Post hoc means comparisons were performed using the Wilcoxon signed ranks test. The Mann-Whitney U test was used to analyze the differences between subject effects. The level of significance was set at $P < 0.05$.[20]

Figure 1. The position of Doppler ultrasound probes at the internal carotid artery and the renal artery.

Results

Physical characteristics

Age, weight, height, BMI, and MMSE score of the volunteers in the control group did not show significant differences when compared with those of the experimental group (Table 1).

Blood flow rate to the brain

The different value of blood flow rate to the brain during conducting foot reflexology in the control group did not show significant differences when compared with brain-associated reflexology, kidney-associated reflexology, and after foot reflexology (Tables 2 and 3).

For the experimental group, it was found that the value of blood flow rate to the brain during brain-associated reflexology was significantly higher than those of kidney-associated reflexology and of after reflexology ($P < 0.05$). The blood flow rate to the brain during kidney-associated reflexology was also significantly higher than those of after reflexology ($P < 0.05$, as shown in Tables 2 and 3).

When comparing the different value of blood flow rates to the brain in right foot reflexology between the control and experimental groups, it was found that blood flow rate to the brain in the experimental group was significantly higher than that of the control group ($P < 0.05$, as shown in Table 2) during brain-associated reflexology and kidney-associated reflexology. When pressing brain and renal reflex positions at the left foot, it was found that blood flow rate to the brain in the experimental group was significantly higher than that of the control group ($P < 0.05$, as shown in Table 3) during brain-associated reflexology, kidney-associated reflexology, and after reflexology.

Table 1. Physical characteristics.

Physical characteristics	**Control group (n = 25) Median [Q1, 3]**	**Experimental group (n = 25) Median [Q1, 3]**	***P* – value**
Age (yr)	23.00 [21.00, 26.00]	22.00 [21.00, 24.50]	0.304
Body weight (kg)	53.00 [49.25, 58.00]	51.00 [48.00, 54.50]	0.465
Height (cm)	159.00 [155.50, 163.50]	159.00 [156.00, 164.50]	0.675
BMI (kg/m^2)	20.40 [19.19, 22.97]	20.17 [18.90, 22.05]	0.560
MMSE score	30.00 [29.00, 30.00]	30.00 [29.00, 30.00]	0.626

Q = interquartile; significant difference was tested by the Mann-Whitney U test at $P < 0.05$; BMI = body mass index; MMSE = mini-mental state examination

Table 2. The different value of blood flow rate to the brain and the kidneys during brain-associated reflexology, kidney-associated reflexology and after foot reflexology at the right foot in control and experimental groups.

Reflex points	**Blood flow rate to the brain (cm/sec)**		**Blood flow rate to the kidneys (cm/sec)**	
	Control group (n = 25) Median [Q1, 3]	**Experimental group (n = 25) Median [Q1, 3]**	**Control group (n = 25) Median [Q1, 3]**	**Experimental group (n = 25) Median [Q1, 3]**
Brain-associated reflex point	0.57 [0.31, 1.30]	2.28* [1.99, 3.40]	1.22 [1.92, 3.92]	0.92 [4.53, 7.35]
Kidney-associated reflex point	0.59 [0.24, 0.79]	1.72^{*,a} [1.04, 3.14]	1.54 [5.00, 5.67]	1.84^{a} [7.81, 11.70]
After foot reflexology	0.48 [0.10, 0.78]	0.69^{a,b} [0.07, 1.13]	1.53 [4.94, 13.03]	3.06 [9.29, 13.00]

Q = interquartile; significant difference was tested by Friedman test, the Wilcoxon Signed Ranks and by the Mann-Whitney U test at $P < 0.05$; * = significant difference between control and experimental group ($P < 0.05$); ^{a} = significant difference when compared with brain-associated reflex point ($P < 0.05$); ^{b} = significant difference when compared with kidney-associated reflex point ($P < 0.05$)

Table 3. The different value of blood flow rate to the brain and the kidneys during brain-associated reflexology, kidney-associated reflexology and after foot reflexology at the left foot in control and experimental groups.

Reflex points	Blood flow rate to the brain (cm/sec)		Blood flow rate to the kidneys (cm/sec)	
	Control group (n = 25) Median [Q1, 3]	Experimental group (n = 25) Median [Q1, 3]	Control group (n = 25) Median [Q1, 3]	Experimental group (n = 25) Median [Q1, 3]
Brain-associated reflex point	0.62 [0.33, 1.02]	2.33* [1.73, 3.08]	3.68 [5.75, 8.86]	0.74 [5.90, 6.61]
Kidney-associated reflex point	0.40 [0.10, 0.84]	1.67*,a [1.05, 3.00]	1.23 [5.87, 8.43]	0.62 [2.56, 6.71]
After foot reflexology	0.15 [0.06, 0.77]	0.85*,a,b [0.19, 1.04]	1.78 [6.41, 9.20]	0.00 [4.56, 5.27]

Q = interquartile; significant difference was tested by Friedman test, the Wilcoxon Signed Ranks and by the Mann-Whitney U test at $P < 0.05$; * = significant difference between control and experimental group ($P < 0.05$); [a] = significant difference when compared with brain-associated reflex point ($P < 0.05$); [b] = significant difference when compared with kidney-associated reflex point ($P < 0.05$)

Blood flow rate to the kidneys

The different values of blood flow to the kidneys during foot reflexology in the control group did not show significant differences when compared with brain-associated reflexology, kidney-associated reflexology, and after reflexology (Table 1).

For the experimental group, it was found that the different values of blood flow rate to the kidneys during kidney-associated reflexology was significantly higher than those of brain-associated reflexology at the right foot ($P < 0.05$, as shown in Table 2). In contrast, no differences were found when comparing brain-associated reflexology, kidney-associated reflexology, and after the left foot reflexology (Table 3).

When comparing the different values of blood flow rate to kidney-associated reflexology between the control and experimental groups, no significant differences of blood flow rates to the kidneys were found during brain-associated reflexology, kidney-associated reflexology, and after the right and left foot reflexology (Table 2 and 3).

Discussion

Blood flow measurement in this study used noninvasive color Doppler technology, which is widely validated as a reliable method for arterial resistive index measurement as an indication of organ blood flow velocity.(21) The current results showed that the application of pressure to the brain-associated reflexology area at the right foot could increase blood flow rate at the right internal carotid artery. This phenomenon was found after applied pressure to the brain-associated reflexology area at the left foot. Pressure at the kidney-associated point reflexology at right foot lead to increased blood flow rate to right kidney. The findings conformed with reflexology theories that the feet are mirrors of the body and have reflex areas that correspond to each of the body's organs. It is relied that when a reflex area is pressed, it activates the corresponding organ in that zone.(4) The concept of reflex areas that are linked to body parts is called zone therapy. There are 10 zones totally; divided into 5 zones on the left and the other 5 zones on the right. The right foot reacts to the right organs whereas left foot reacts to the left organs.(15)

The effects of brain-associated foot reflexology on changes in blood flow rate to the brain might be due to the affected response activation of the nervous system that controls blood flow to brain, called neurogenic regulation, which includes extrinsic and intrinsic innervation. Extrinsic innervation controls vessels outside the brain parenchyma, e.g., trigeminal ganglion, superior cervical ganglion, and sphenopalatine ganglion, especially superior cervical ganglion, which is the part of sympathetic nervous system. It innervates many organs, gland and parts of the carotid system in the head causing vasoconstriction, resulting in reduced blood flow.(22) Nonetheless, the findings from this research revealed that brain-associated foot reflexology increased internal carotid artery flow rate. Possibly, this reflexology leads to a relaxation and activation of the parasympathetic nervous system, and thus the autonomic nervous system adjusts its function, affecting the functional reduction of the sympathetic nervous system.(6, 23, 24) Because of this, vasodilation occurs along with increased blood flow. After stopping the application of pressure to the brain-associated reflexology area, the sympathetic nervous system returns to its normal function, and thus blood flow is reduced. Some studies supported that brain-associated foot reflexology helps brain relaxation. For example, the study of Wongcharoen C, *et al*.[14] revealed that reflexology and light touch on the brain reflex points at the feet generated high-alpha brainwaves (10 - 12 Hz) at all areas of brain. After finishing the application of reflexology and light touch, beta brainwaves were generated (13 - 21 Hz). It is believed that alpha brainwaves indicate reduced brain function for relaxation. Beta waves indicate brain activation and concentration on activities.[25] However, the mechanism of changes in the resistive index from reflexology is still unclear. Thus, further studies should focus on the neurophysiological and biochemical mechanisms that relate to reflexology and physiological changes.

Intrinsic innervation controls vessel function in deep layers or under the brain parenchyma. It is the function of the parasympathetic nervous system, causing vasodilation. As a result, blood flow to the brain is increased.[22] Unfortunately, this research did not measure changes in blood flow at the brain directly, so it is unable to conclude whether or not brain-associated reflexology can activate intrinsic innervation. Thus, further studies should focus on the direct measurement of changes in blood flow at the brain for a clearer explanation of the responsive mechanism of brain-associated foot reflexology.

This research also studied the effects of pressure differences to brain-associated reflexology areas on blood flow to the brain. The findings revealed that light touch on brain reflex points at the feet did not generate any changes in blood flow to the brain. This did not conform to the study of Wongcharoen C, *et al*.[14] which revealed that light touch and reflexology at the brain-associated foot reflexology area generated similar brain function measured by electroencephalography (EEG), whereby alpha waves were found indicating brain relaxation. However, this research measured blood flow rate. Only reflexology increased blood flow whereas light touch did not generate any changes. This might be due to insufficient pressure of light touch that could not activate pressure receptors under the skin of the foot. As a result, there were no reactions to target organs. In contrast, reflexology is basically performed with pressure that is strong enough to activate deep pressure receptors, which then transmit signals along the sensory nerves. The signal is forwarded to the central nervous system. After that, the central nerves transmit motor commands to the organ-associated reflexology map locations, resulting in reactions occurring.[3, 4] The findings conformed with the study of Diego MA and Field T. [26], revealing that moderate pressure massage stimulated the pressure receptors, resulting in enhanced vagal activity (parasympathetic nervous system) that generated vasodilation and increased blood flow. There were studies of anatomy supported that mechanism. It is noted that pressure receptors under the skin send signals to activate the function of the vagus nervous system.[27] This type of sensory receptor is activated by moderate pressure,[16, 26, 28] so it is possible that brain-associated foot reflexology activates pressure receptors under the skin of the foot before sending signals to activate the function of vagus nerves, resulting in vasodilation. That is why blood flow to the brain is better than light touch on reflex points. Even so, this research had some limitations, that is, neurophysiological and biochemical changes of the brain were not studied. Thus, a clear explanation about the mechanism of reflexology on changes in blood flow to brain cannot be given as there are still other mechanisms apart from neurogenic regulation, e.g., metabolism and myogenic.[22] Therefore, further studies should focus on the neurophysiological and biochemical mechanisms using functional imaging modalities, such as PET scanning and BOLD fMRI.

For the findings of kidney-associated foot reflexology, only right foot reflexology increased blood flow to the right kidney. There were no changes in blood flow rate to the left kidney when left foot reflexology point was pressed. This might be due to the limitations of proper positional arrangement for monitoring blood flow to kidneys. Generally, the position for renal assessment by color Doppler ultrasound must be arranged whereby participants lie on one side as the position of the kidney is behind the abdomen at the back of body. Lying on one side helps renal assessment become more accurate. Unfortunately, such a position could not be arranged in this research due to the simultaneous assessment of blood flow to the brain. The participants had to lie supine for internal carotid artery assessment. This position might cause inaccurate assessment of blood flow to the kidneys. However, the findings revealed increased blood flow to the right kidney when the kidney-associated point reflexology on the right foot was pressed. This conformed with the study of Sudmeier I, *et al*. in 1999 [7] which revealed that kidney-associated foot reflexology could reduce blood flow resistance and increase blood flow. Moreover, this research also found that light touch at the kidney reflex points on both feet did not affect changes in blood flow to the kidneys. This conformed with light touch at the brain reflex points on feet. Hence, it can be confirmed that pressure is crucial for physiological changes. Specifically, pressure must be strong enough to get into the deep layers for sensory receptor activation under the skin so as to generate reactions to organ-associated reflex points. Nevertheless, further studies should focus on suitable pressures at reflex points and suitable times for reflexology in order to apply the data to setting standards of appropriate reflexology methods.

Conclusions

It can be concluded that brain-associated and kidney-associated foot reflexology could increase blood flow to the brain and kidneys in compliance with zone therapy theory despite no changes in blood flow rate from kidney-associated point reflexology at the left foot. This might be due to the limitations of participant position arrangement for assessment. Moreover, this research also revealed that pressure for reflexology must be strong enough to activate pressure receptors under the skin in order to generate physiological changes in organ-associated reflex points.

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Conflicts of interest

The authors, hereby, declare no conflict of interest.

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