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Effect of Acupuncture at Tsu San Li (St-36) on the Pulse Spectrum

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Abstract: Effect of acupuncture at Tsu San Li (St-36) was examined by investigating the pulse variation of the radial artery. Our results indicated that acupuncture at Tsu San Li has a specific effect on the Fourier components of the pulse. The harmonic proportions were redistributed (C2, C4 decreased, C5, C6, C8 and C9 increased), and the phase angle of the 5th and 8th harmonic waves were decreased (propagating faster). This specific frequency effect was not found when acupuncture needle was applied on a non-acupuncture point. These results can be explained by the resonance theory, which provides a scientific explanation of the acupuncture effect from the hemodynamic view point.

The therapeutic effect of acupuncture has been demonstrated and has gained acceptance (Mann, 1990; Kao, 1992). According to the Chinese medical literature, *Huang-Ti-Nei-Ching*, acupuncture point can be roughly divided into 12 main groups that are related to different internal organs in the body. The acupuncture points in each group are connected by a hypothetical channel called a meridian, and energy, Chi, flows through the body along the meridians. Acupuncture will disturb the flow of "Chi," thus affecting the health status of the related internal organ.

In trying to understand the physiology of acupuncture points and the mechanism of acupuncture effect, studies have been done in fields such as anatomy (Liu *et al.*, 1975; Gunn *et al.*, 1976; Plummer, 1980), neurochemistry (Sjolund and Eriksson, 1976; Jansen *et al.*, 1989; Kashiba and Ueda, 1991), neuroelectricity (Rechmanis *et al.*, 1975, 1976), and biophysics (Wang, 1988; Lazorthes *et al.*, 1990). Nonetheless, the mechanism of acupuncture is still a mystery.

Pulse diagnosis is one of the important methods for Chinese doctors to monitor

acupuncture effect. We have indicated that blood pressure pulse analysis may be useful in elucidating the mechanism of acupuncture (Wang *et al.*, 1987, 1989b).

Pressure distribution to internal organs (arterial trees) could be interpreted by the resonance theory. Wang *et al.* (1989a, 1992a,b) and Wang Lin *et al.* (1991) proposed that each internal organ or arterial tree is coupled to the main artery, and resonant with a specific frequency or frequencies. The physiological origin of acupuncture points, their physical connections to the meridians and the scientific meaning of "Chi" has been interpreted as a special case in resonance theory (Wang *et al.*, 1989b,c, 1994a). It assumes that the meridian is a group of resonant arterial trees with the same frequency nature connected in series to the artery. In this weak coupled system, there are two resonant frequencies in the acupuncture point and only one in the artery. Blood distributes differently at different meridians according to its frequencies. This meridian selected frequency may be the same as the resonant frequency of its related internal organ. We have successfully used the resonance theory in solving some hemodynamic problems on internal organs (Wang *et al.*, 1992a,b; Wang Lin *et al.*, 1991), determining some resonance frequencies of the internal organs (Wang *et al.*, 1987, 1989a; Young *et al.*, 1989, 1992), as well as correlating the micro circulation in different acupuncture points to the harmonic proportions of the blood pressure spectrum (Wang *et al.*, 1994a).

The resonant conditions of the acupuncture point can be modulated by needling it. As a result, the blood pressure wave is disturbed. We have reported that some Chinese herbs can change the pulse spectrum (Wang Lin *et al.*, 1992c; Wang *et al.*, 1994b). Acupuncture can also modulate the blood pressure wave spectrum and may then change blood distribution in the body.

Acupuncture at Tsu San Li has been reported to improve physiological status in several aspects: it may adjust the movement of the stomach and intestine (Matsumoto, 1973); strengthen the immune system (O'Connor and Bensky, 1975); normalize heart rhythm (Lee *et al.*, 1975; Lee *et al.*, 1976) and blood pressure (Omura, 1974; Lee, 1974). Tsu San Li is described in the traditional Chinese acupuncture literature as one of the most important acupuncture points.

In this report, we investigated the acupuncture effect at Tsu San Li by measuring the Fourier components of the pulse wave. Meridian selected frequencies were also studied in order to evaluate the acupuncture effect based on the resonance theory.

Material and Method

1. Subjects

43 healthy subjects aged between 20 to 55 were randomly divided into 2 groups: Tsu San Li group (12 males, 14 females, average age = 30.58 ± 6.13 years) and non-acupuncture point group (7 males, 10 females, average age = 31.41 ± 8.70 years). All subjects were asked not to take any medication 3 days before the experiment. During the test day, they were not allowed to have any alcoholic or caffeinated beverages. Every subject was food restricted at least one hour before experiment. A half hour rest was routinely required before the test. Room temperature was kept between 23° C to 25° C.

2. Experimental procedure

Experimental setup was similar as that described in our previously report (Wang *et al.*, 1994b). Briefly, each subject was asked to sit down. The right hand radial artery pressure pulse was recorded with a pressure transducer (PSL-200GL, Kyowa Electronic Instrument Co. Ltd. Japan) that was fixed on the skin by scotch tape and an adjustable belt with a small button to give suitable pressure on the transducer. Our criterion of a good measurement was to seek the largest amplitude of the pulse. Six consecutive pressure pulses were taken in a two minutes interval as a control. An acupuncture needle was then inserted into Tsu San Li or a non-acupuncture point chosen freely near Tsu San Li for 15 minutes. No special acupuncture treatment (manipulating the needles to increase or decrease "Chi") was done in this period. Pressure pulses were then taken at 10 sec, 5 mins, 10 mins, and 15 mins before and after needling. Pressure transducer was not removed during the entire measuring process.

Control P(T0) ➡ Insert needle➡ 10 seconds P(T_{Ns})➡ 5 mins P(T_{N5})
➡ 10 mins P(T_{N10})➡ 15 mins P(T_{N15})
⬇
Take out needle➡ 10 seconds P(T_{Os})➡ 5 mins P(T_{O5})
➡ 10 mins P(T_{O10}) ➡ 15 mins P(T_{O15})

3. Data analyzing

Output of the pressure transducer was connected to an IBM PC via an A/D converter with sampling rate of 430 data points/sec. Pulse spectrum was analyzed with Fourier transform using T (period) = 1 pulse as described before (Wang *et al.*, 1994b).

Standard deviation of heart rate from 6 pulses in a measurement was not allowed to exceed 5%. Every pulse spectrum measurements at needle in and needle out periods were compared with the pulse spectrum measured at the control period. To keep the Fourier transform meaningful, we excluded measurements if heart rate difference exceeded 10% of control. Variations of pulse spectra between these comparisons were expressed as the phase difference and the percent difference of the harmonic proportions from harmonics 1 to 9; percent difference between DC values of the spectrums were also presented.

Percent difference of the harmonic proportions of harmonic n between period Ti and control = % Diff. - Cn(Ti) = [Cn(Ti) - Cn(T0)]/ Cn(T0)

where Cn(T0) = An/A0 at the control period = Harmonic proportion of the nth harmonic at the control period.
Cn(Ti) = An/A0 at period i = Harmonic proportion of the nth harmonic at period i
An: amplitude of the nth harmonic; A0: DC value of the pulse spectrum
Ti : period i; T0 = control period

Phase difference of the nth harmonics Diff. - Pn(Ti) = Pn(Ti) - Pn(T0)

where Pn: phase angle of the nth harmonic

4. Statistics

The Diff.-Pn(Ti) and % Diff.-Cn(Ti) of all subjects were averaged on each periods Ti for harmonics 1 to 9 and also for DC amplitude. Acupuncture effect on the Tsu San Li group was compared with the non-acupuncture point group. Students t-test for group comparison was performed.

Results

Figure 1 (a,b) shows the averaged acupuncture effects of percent difference of the harmonic proportions (% Diff.-Cn(Ti)) on the Tsu San Li group. Standard error of means and group comparison t-test results of Ns (needle-in started) and Os (needle-out started) periods were also presented. Standard error of means were all similar in the other periods. The t-test results of harmonic proportions are shown on Table 1.

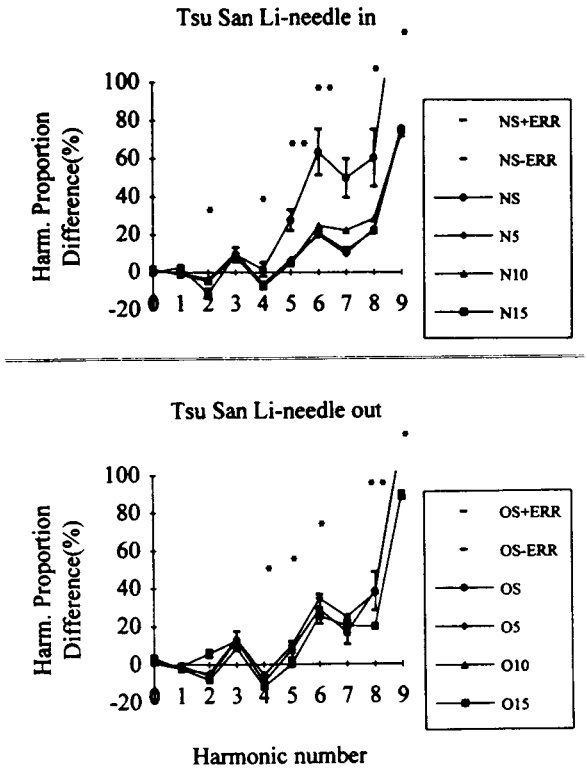

Figure 1. Effect of % difference of harmonic proportions of acupuncture at Tsu San Li. The means ± SEM (the standard error of mean) of the first curve (period Ns of a-set, period Os of b-set) were also plotted as NS + ERR, NS - ERR, OS + ERR and OS - ERR respectively. The T-test results between acupuncture at the Tsu San Li group and the non acupuncture point group of Ns and Os periods were shown as *. *: $P < (0.05)$, **: $P < (0.01)$.

Table 1. T-test results of the % difference of harmonic proportions between acupuncture Tsu San Li group and the nonacupuncture point group

	Ns	N5	N10	N15	Os	O5	O10	O15
C0								
C1								
C2	*						*	
C3								
C4	*	*	*	*	*	*	**	*
C5	**				*			
C6	**				**	**	**	*
C7								
C8	*		*		**	*	*	
C9	*	**	*	**	**	**	**	**

* : p<0.05, ** : P<0.01

As noted in Figure 1 and Table 1, energy of pressure wave was redistributed after acupuncture at Tsu San Li. The harmonic proportion of C8 and C9 increased significantly (C9: p<0.01, C8: p<0.05) as soon as a needle was inserted at Tsu San Li. The effects increased even more after the needle was taken out. Although the harmonic proportion of C5 and C6 were also increased, the effects were not significant until the needle was taken out (p<0.05). The increase in C3 was not significant for all the testing periods. C4 decreased significantly during the entire experimental periods (p<0.05). C2 also decreased, but not significant until 10 minutes after the needle was taken out (p<0.05). The effects on C0, C1 and C7 were not significant.

Average effects of phase difference (Diff.-Pn(Ti)) of the acupuncture group are shown in Figure 2 (a,b). Effects of needle-in and needle-out periods were showed in a-sets and b-sets, respectively. The phase angle of some harmonics of the pressure wave has changed after acupuncture at Tsu San Li as noted in Figure 2 (a,b) and Table 2.

Table 2. T-test results of the phase difference between acupuncture Tsu San Li group and the non acupuncture point group

	Ns	N5	N10	N15	Os	O5	O10	O15
C1		*						
C2	*							
C3	***							
C4	***		*		**			
C5	***	*	*		***	*	*	***
C6	***				**			**
C7	**	*						
C8	***	**		**	***	**	**	
C9	***				**	**	**	

*: P <0.1, **: P <0.05, ***: P <0.01

Figure 2 (a,b) and Table 2 show that the phase angle of P5 and P8 decreased significantly in almost all the experiment periods. The decrease of phase angle representing the wave was leading ahead; it propagated faster. At the Ns and Os periods, phase angles of several other harmonics also decreased significantly. The decay was not significant at other periods.

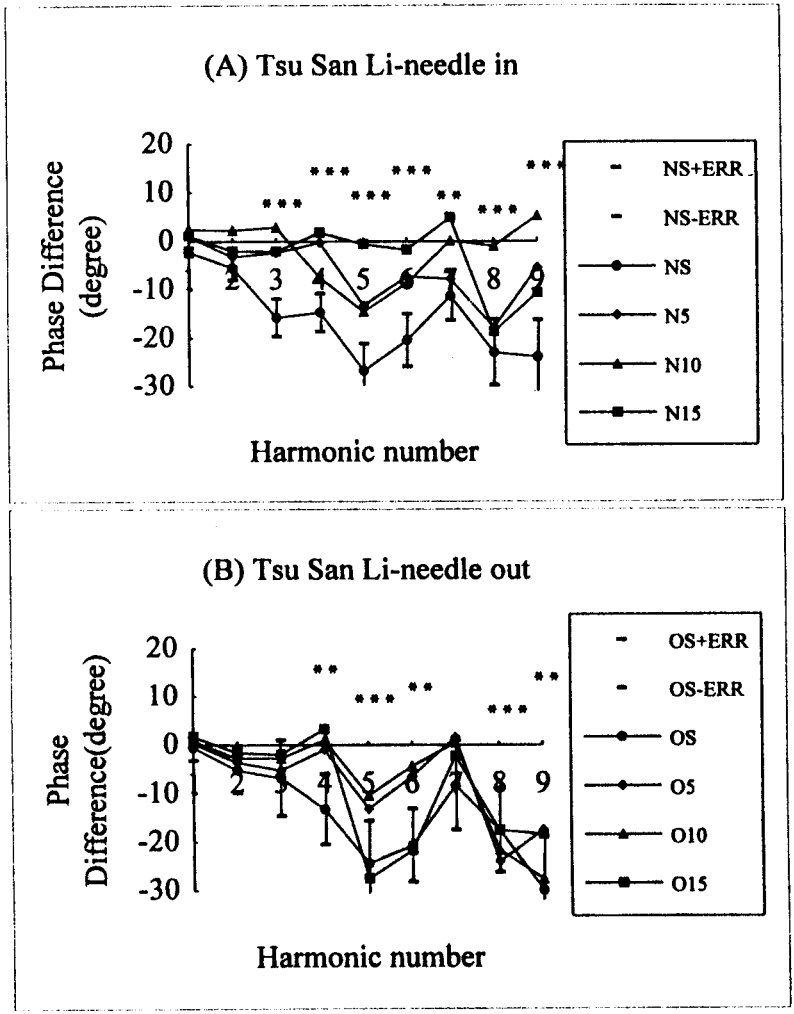

Figure 2. Effect of phase difference of acupuncture at Tsu San Li. The means ± SEM (the standard error of mean) of the first curve (period Ns of a-set, period Os of b-set) were plotted as NS + ERR, NS - ERR, OS + ERR and OS - ERR respectively. The T-test results between acupuncture Tsu San Li group and the non acupuncture point group of Ns and Os periods were shown as *. *: P<(0.1), **: P<(0.05), ***: P<(0.01).

The average acupuncture effects of harmonic proportions difference and phase difference of the non-acupuncture group are shown in Figure 3 (a,b) and Figure 4 (a,b), respectively. Acupuncture effects at a non-acupuncture point on Cn and Pn of every harmonic n from 1 to 9 were insignificant.

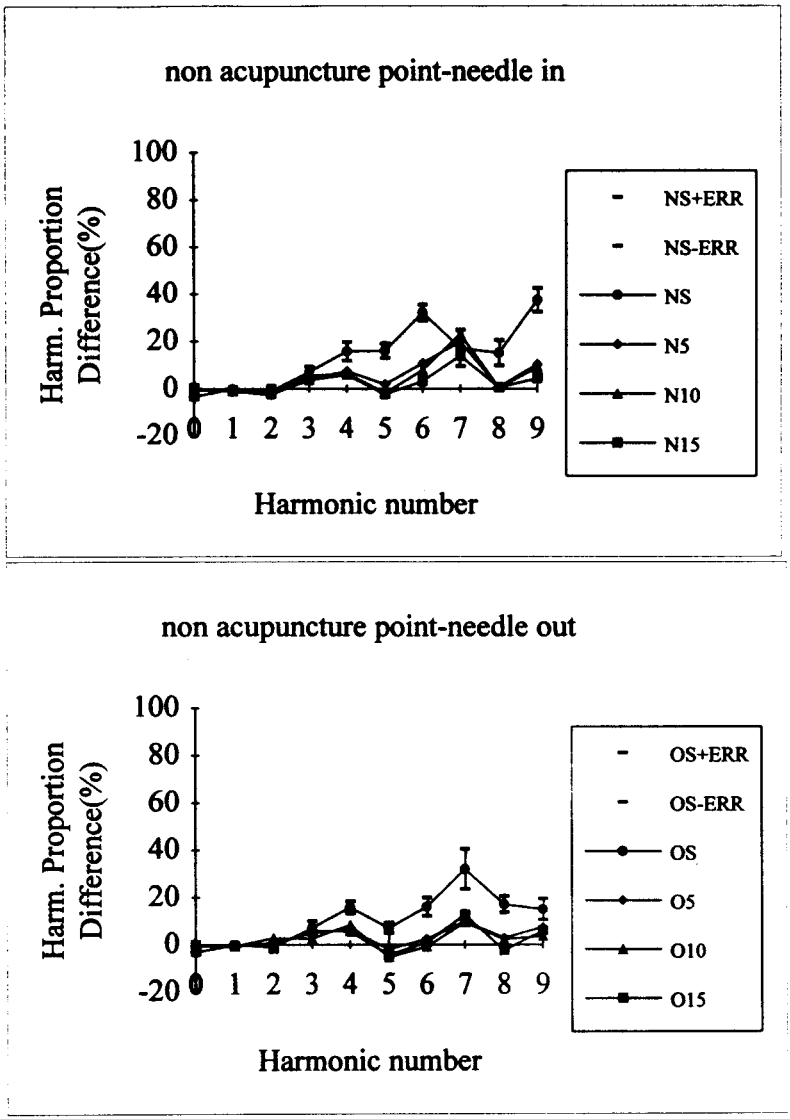

Figure 3. Effect of % difference of harmonic proportions of acupunctureat a non-acupuncture point. The means ± SEM (the standard error of mean) of the first curve (period Ns of a-set, period Os of b-set) were also plotted as NS + ERR, NS - ERR, OS + ERR and OS - ERR respectively.

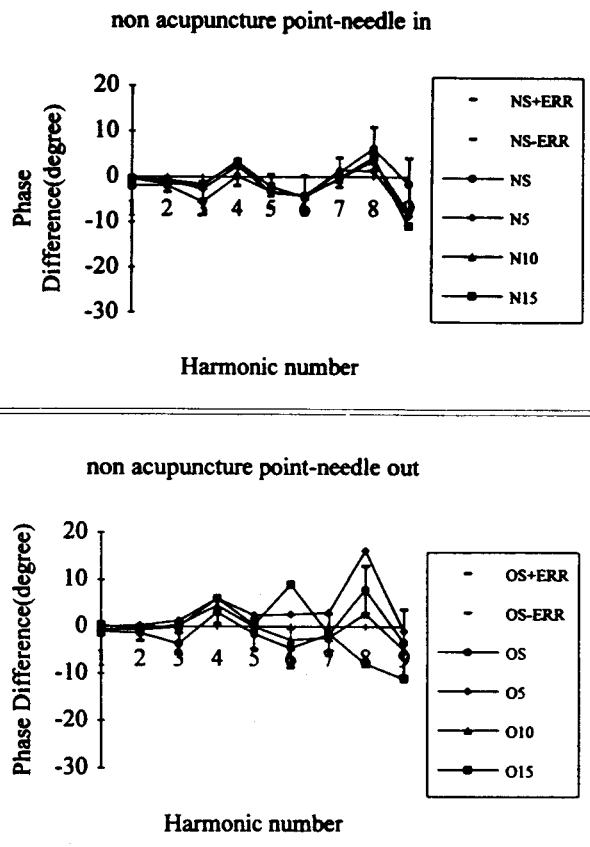

Figure 4. Effect of phase difference of acupuncture at a nonacupuncture point. The means ± SEM (the standard error of mean) of the first curve (period Ns of a-set, period Os of b-set) were plotted as NS + ERR, NS - ERR, OS + ERR and OS - ERR, respectively.

Discussion

In traditional Chinese medicine, Tsu San Li belongs to the stomach meridian, which is closely related to the stomach. Acupuncture at Tsu San Li may adjust Chi as well as the blood flow, and as a result, strengthen the spleen and the stomach.

In our previous studies, we linked internal organs with different harmonics of the pressure pulse: kidney is related to the 2nd harmonic, spleen is related to the 3rd, lung is the 4th, stomach is the 5th, and gall bladder is the 6th (Wang *et al.*, 1987, 1989a; Young *et al.*, 1989, 1992). In this study, phase angle of the 5th and 8th harmonic of the pulse was found to decrease significantly after acupuncture at Tsu San Li (i.e. these two harmonic waves would propagate faster). Phase properties described by the wave propagation equations (derived from the resonance theory) showed that phase change is very sensitive to resonance frequency (Wang *et al.*, 1991, 1992a,b, 1994a). When tissue becomes stiffer, wave will travel faster. Therefore, the decreased phase angle of the 5th harmonic wave strongly suggested that

Tsu San Li has the 5th harmonic as its resonance frequency. This is the same resonant frequency of the stomach, which links blood distribution of the meridian to its related internal organ. The slightly decreased phase angle of the 8th harmonic wave suggested that the 8th harmonic may be related to the 5th harmonic by the Mother and Son Law.

Wang *et al.* (1994a) have shown that velocity of micro circulation in different acupuncture points is related to a specific harmonic proportions in the pressure pulse. Acupuncture effects thus can be stated as a blood redistribution process. By disturbing the resonant status of a proper acupuncture point, more blood could be adjusted to flow to the location that needed to be strengthened, hence this location becomes healthier.

This proposed acupuncture mechanism is in agreement with the traditional Chinese acupuncture concept as "Acupuncture takes away the Chi in one place, and irrigates it in another place." (Huang, 1985).

Wang Lin *et al.* (1992c) and Wang *et al.* (1994b) have shown that Chinese herbal medicine could redistribute blood flow by altering the pulse spectrum. It was found that pulse spectrum changes by acupuncture at Tsu San Li are similar to taking the Chinese herbal medicine *Ganoderma lucidum* (Wang *et al.,* 1994b). As mentioned in the Chinese medical literature, *Ganoderma lucidum* strengthens Chi which has the same effect as acupuncture at Tsu San Li.

In conclusion, we suggest that effects of Chinese medicinal herbs on meridians as described in the Chinese medical literature can be expressed by the variations of the harmonic components in the pulse. Results presented in this study further suggest that acupuncture effect could be interpreted by a similar mechanism; while phase angle changes at a specific harmonic provide clues for the resonant frequency of an acupuncture point. All this evidence suggest a scientific picture in which acupuncture effect may be explained by the resonance theory in hemodynamics.

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