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The pulse spectrum analysis at three stages of pregnancy

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Keywords:	TCM, women's health
Abstract:	<p>Objectives: This study is the first to detect the radial pulses of three diagnosis positions (inch, bar and cubit) in both wrists (six positions) by pulse spectrum analysis. The purpose of this study was to identify the difference among pulses of six positions at three stages of pregnancy and to verify that the result of this study agrees with the theory of TCM which states that the cubit pulse has unique change for an expectant woman and the pulse change coincides with the progression of gestation.</p> <p>Subjects and methods: One hundred and fifty healthy pregnant women were divided into three groups according to gestational age (9–14 weeks, 20–28 weeks, and 32–37 weeks of gestation) and fifty healthy non-pregnant women were used as controls. Pulse analyzer was used to detect the radial pulses of six positions and to calculate ten relative energy values of the spectrum's harmonics of six positions.</p> <p>Results: Results show that most of the ten relative spectral energy values of right and left cubits are statistically ($P < 0.01$) higher than</p>

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	<p>those of inch for pregnant women as compared with the non-pregnant women. In addition, ten relative spectral energy values of six positions are not identical at three stages of pregnancy. Conclusions: The cubit pulse is unique for pregnant women, which is consistent with the theory of TCM. Besides, the pulse conditions at three stages of pregnancy are dissimilar.</p>

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The pulse spectrum analysis at three stages of pregnancy

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Running Head: radial pressure pulse of pregnancy

Abstract

Objectives: This study is the first to detect the radial pulses of the three diagnosis positions (inch, bar and cubit) in both wrists (six positions) by pulse spectrum analysis. The purpose of this study was to identify the difference among pulses of the six positions at three stages of pregnancy and to examine whether the results of this study agree with the theory of TCM which states that the cubit pulse which shows unique changes for an expectant woman and that the pulse changes coincide with the progression of gestation.

Subjects and methods: One hundred and fifty healthy pregnant women were divided into three groups according to gestational age (9–14 weeks, 20–28 weeks, and 32–37 weeks of gestation) and fifty healthy non-pregnant women were used as controls. A pulse analyzer was used to detect the six positions of the radial pulses and to calculate the ten relative energy values of the spectrum's harmonics of the six positions.

Results: Results show that most of the ten relative spectral energy values of the right and left cubits are statistically ($P < 0.01$) higher than those of the inch for the pregnant women as compared with the non-pregnant women. In addition, the ten relative spectral energy values of the six positions are not identical at the three stages of pregnancy.

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6 **Conclusions:** The cubit pulse is unique for pregnant women, which is consistent with the theory of TCM. In addition, the pulse conditions at the
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8 three stages of pregnancy are dissimilar.

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11 **Keywords:** TCM (Traditional Chinese medicine), women's health, pulse spectrum, pregnancy, radial pulse, harmonic, three diagnosis positions
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13 (inch, bar and cubit)
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21 Introduction

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24 Pregnancy is a special stage for women and it represents a serious challenge to the pregnant female's body. To support the developing fetus
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26 and to prepare the mother for parturition, women experience a series of physiological changes that provide functional and structural adaptations
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28 at different stages of pregnancy.¹ The alteration of the cardiovascular system is the most profound physiological change,² which starts early in
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30 the first trimester and plateaus by mid-gestation, peaking again around term.¹ In Western medicine, echocardiography is performed to evaluate
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32 the changes of pregnancy in cardiac structure, cardiac function, and uterine artery,^{3,4} whereas in Traditional Chinese medicine (TCM), palpation
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6 is applied to evaluating the conditions of the expectant mother.⁵
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9 Pulse diagnosis is a very important diagnosis method in TCM,⁶ which differs in Eastern and Western cultures.⁷ A doctor can take the radial
10 pulse to evaluate whether a woman has conceived, to determine the weeks of gestation, and to predict the outcome of pregnancy.⁵ Descriptions
11 of the pregnant women's pulse are abundant, as the Huangdi Internal Classic described, but opinions differ on this article.^{5,8-10} For example,
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17 some physicians explain that the slippery pulse is taken on inch at the first stage of pregnancy, but some describe that the slippery pulse is
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19 detected on the cubit during pregnancy. Nevertheless, most doctors have a consensus that the pulse condition of the cubit is specific for an
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21 expectant woman as compared with the inch pulse, and the pulse changes with the progression of gestation. In addition, there are differences
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26 among pulse conditions of the three diagnosis positions ('cun, guan, chi' inch, bar and cubit respectively) for pregnant women in some medical
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29 books.⁵
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33 However, western practitioners are often skeptical about pulse diagnosis because it appears subjective and not repeatable. Studies of the
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37 reliability of pulse diagnosis collected in a Chinese Medicine examination also suggest considerable variability, with results ranging from low to
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6 a very good level of agreement.^{11,12} Therefore, several scientific and digital approaches to the pregnant pulse have been undertaken in recent
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9 years.¹³⁻¹⁶ For example, some studies have investigated arterial pulse wave parameters in normal pregnancy.¹⁴⁻¹⁶ The two methods that are often
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11 used to analyze the radial pulse pressure are time domain and spectral domain analyses.¹⁷ In time domain analysis, pregnant women are thought
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13 to have a higher-ratio of slippery pulse and rapid pulse than non-pregnant women.¹⁸⁻²⁰ From the comparative research on the pulse graphs and
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15 hemorheology between pregnant and pathological slippery pulses, we can discriminate the slippery pulses of pregnancy and illness.²¹ However,
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17 these studies of time domain analysis only provide a limited message that focuses on the slippery pulse. Thus, spectral domain analysis is applied
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19 to understand the hidden signal. For example, frequency parameters named phase transfer and phase variation character are used to identify the
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21 pulse between normal women and pregnant women.²² Liang first recorded the women's pulse spectra from the first trimester to postpartum and
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23 analyzed the change of harmonic components in bar pulse spectra according to the "Organs resonance" hypothesis of W.K. Wang.²³ Although
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25 there were reports on the analyses of pulse conditions during pregnancy, few studies have been done on the frequency-domain analysis of
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27 pregnant women's pulses at three stages of pregnancy, especially the pulses of the three positions. Therefore, this study attempts to detect the
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6 radial pulses of the three positions in both wrists (six positions) at three stages of pregnancy using pulse spectrum analysis.
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9 The purpose of this study is to identify differences among the pulses of the six positions at three stages of pregnancy and to determine whether
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11 the result confirms the theory of TCM which states that the cubit pulse shows unique changes for an expectant woman and that the pulse changes
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13 coincide with the progression of gestation. The value of this study is that it provides an objective view of the pulse conditions in pregnancy and
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17 to help determine the specific pulse positions from the six positions that could be used to evaluate the pulse during gestation in the clinic.
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Methods

Subjects

One hundred and fifty healthy pregnant women and fifty healthy non-pregnant women were recruited to participate in this study. All subjects were between 20 to 40 years old. Healthy pregnant women without any acute or chronic disease were recruited when they visited the clinic in the obstetrics department in China Medical University Hospital, Taichung. They were divided into three groups of fifty women each according

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6 to gestational age: group 1 consisted of women of 9 to 14 weeks of gestation, group 2 consisted of women of 20 to 28 weeks of gestation, and
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9 group 3 consisted of women of 32 to 37 weeks of gestation. The mean age in group 1 was 30.5 ± 3.29 yr (mean \pm standard deviation), group 2
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12 was 30.18 ± 3.94 yr, and group 3 was 30.52 ± 3.37 yr. Control group (group 4) consisted of fifty healthy non-pregnant women who were not
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15 under any medication that may influence menstruation. The mean age in group 4 was 27.98 ± 5.45 yr. All subjects signed an informed consent.
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18 This study was approved by the institutional review board of the China Medical University Hospital (DMR97-IRB-208).
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20 21 *Methods*

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23 A pulse analyzer (designed and patented by China Medical University, Taiwan) which consisted of a high-fidelity pressure sensor and a stable
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26 X-Y-Z axial moveable framework was used to detect the radial pressure pulse of the three positions on both wrists. All subjects were in the
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29 sitting position during the experiment. Definitions of the three positions are: the bar is just central to the radial styloid at the wrist, the inch is
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32 distal to this on the wrist, and the cubit is just proximal to it. The spectral analysis was performed to analyze the pulse: the pulse signal was
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37 digitized by fast Fourier transformation to obtain radial pulse spectra. Appearance of the first harmonic component in pulse spectrum was
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6 designated as the first harmonic. Then, these relative spectral energy values were calculated by integrating the harmonic components of the pulse
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8 spectra of the six positions. Since the signal of the 11th harmonic was too small to be valuable, only ten harmonics were analyzed and ten
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10 relative spectral energy values were obtained.
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13 14 *Statistical methods*

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17 Standard statistical methods were performed using the SPSS statistical program version 15. One-way ANOVA was used to analyze the
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19 difference of age among four groups. One-way repeated measures ANOVA was applied to each group to identifying the difference of the six
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21 positions among ten relative spectral energy values. A P value of less than 0.01 was assumed to be significant. If the F value was significant, the
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23 Bonferroni test was used for pairwise comparison.
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30 31 32 **Results**

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35 All subjects completed the full course of pulse analyses in this study. There were no statistical significance ($P > 0.01$) in the ages of four groups.
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6 Each of the four groups was analyzed and compared within group for the difference of the six positions among the ten relative spectral energy
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8 values. The data of the four groups are combined and displayed in Tables 1 and 2. Table 1 is an example to show the statistical results of the first
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10 harmonic of the six positions. The relative spectral energy values are presented as mean \pm standard error. In the control group, most of the ten
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12 relative spectral energy values of the right bar are statistically ($P < 0.01$) higher than those of the inch or cubit. For example, the ten relative
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14 spectral energy values of the 5th, 6th, and 9th harmonics of the right bar are statistically ($P < 0.01$) higher than those of the inch in the control
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16 group. For pregnant women, most of the ten relative spectral energy values of the right bar, right cubit and left cubit in the three groups of
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18 pregnancy are statistically ($P < 0.01$) higher than those of the inch. For example, the ten relative spectral energy values of the 5th to 10th
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20 harmonics of the right cubit are statistically ($P < 0.01$) higher than those of the right inch in group 1 or group 2. In addition, the ten relative
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22 spectral energy values of the 4th, 5th, 7th to 10th harmonics of the right cubit are statistically ($P < 0.01$) higher than those of the right inch in
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24 group 3. Furthermore, there is a slight difference in the three pregnant groups, seen in higher relative energy values of the 4th to 9th harmonics
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26 of the left bar compared to those of the left cubit in group 3 as compared with those in group 1 or group 2.
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Discussion

This is the first study to detect the three positions of the radial pulses on both wrists using pulse spectrum analysis and to identify the difference among pulse spectra of six positions at three stages of pregnancy. Results showed that the ten relative spectral energy values of the six positions are different in both pregnant women and non-pregnant women. It suggests that the pulse conditions of inch, bar and cubit in each person are dissimilar, which conforms with the theory of TCM. In other words, the pulse can be affected by the six positions or left/right sides, which is consistent with previous studies that state the differences of pressure pulse waveforms and inter-arm pulse strength.^{24,25} More importantly, the difference of the ten relative spectral energy values of the six positions is more prominent between non-pregnant women and pregnant women. Furthermore, there is a slight difference in the three pregnant groups which suggests that the pulse changes during the three stages of pregnancy are different.

In the non-pregnant group, most of the ten relative spectral energy values of the right bar are statistically ($P < 0.01$) higher than those of the

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6 inch or cubit. A previous study analyzed the pulses of the three positions in healthy people using time domain parameters and indicated that the
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8 amplitude of the percussion wave of the right bar was statistically higher than that of the inch and cubit.²⁶ However, few researches have
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10 conducted spectral analysis of the pulses of the six positions in normal people.²⁷ Our result is in agreement with Huang's study that found that
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12 the power spectrum between 13 to 50 Hz in the right bar was higher than that in the inch or cubit.²² Therefore, it could be stated that the pulse
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14 signal of the right bar is higher than that in the inch or cubit in non-pregnant women.
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21 For pregnant women, not only are most of the ten relative spectral energy values of the right bar but also those of the right and left cubits
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23 statistically ($P < 0.01$) higher than those of the inch. Compared with non-pregnant women, the cubit pulse is unique for pregnant women. In TCM,
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25 the cubit pulse represents the kidney system involved in promoting reproduction and the function of the uterus. In other words, the cubit pulse is
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27 highly reflective of the reproductive system. Therefore, this result is consistent in the theory of TCM that the pulse condition of the cubit shows
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29 unique changes for an expectant woman. The cubit is the specific pulse position that could be used to evaluate the pregnant pulse in the clinic.
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36 Results also showed that there are differences in the ten relative spectral energy values of the six positions at three stages of pregnancy. It
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5 suggests that the pulse conditions at the three stages of pregnancy are dissimilar. For example, the relative energy values of 4th to 9th harmonic
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8 of the left bar were higher than those of the left cubit in group 3, which is an obvious distinction between group 3 and group 1, and between
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11 group 3 and group 2. It shows that the left bar pulse has a special meaning in the late pregnancy. However, this observation needs to be further
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18 There are some aspects of this study that need to be improved. First, each person has their own constitution, and the difference of constitution
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21 between a pregnant woman and a non-pregnant woman is pronounced.²⁸⁻³⁰ The constitution could influence the pulse, so we must add the issue
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24 of constitution in the future to analyze the impact of the constitution on pulse. Second, this study was carried out through the four seasons. We
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27 don't know whether the seasonal effect on pulse is a factor involved in difference among the three stages of pregnancy although the pulse
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30 conditions in the four seasons are different by time domain analysis.³¹ Therefore, we should shorten the time of the experiment to avoid
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33 experimental error in the future studies. Third, all pregnant women were from the same hospital which may result in increase of the sampling
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36 error. It is preferable to cooperate with several hospitals in the future to reduce the sampling error.
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Conclusion

The pulse signals of the three diagnosis positions in both wrists of each subject are different. The spectral signal of the right bar is higher than that of the inch or cubit for non-pregnant women. More importantly, the cubit pulse is unique for pregnant women, which is consistent with the theory of TCM. Therefore, the cubit pulse is the specific pulse position that could be used to evaluate the pulses of pregnant women in the clinic. Furthermore, there are slight differences in the three pregnant groups, which shows that the pulse changes at different stages of pregnancy, and the left bar pulses have special meaning in late pregnancy. This study provides an objective view for the pulses of pregnancy.

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Disclosure Statement

No competing financial interests exist.

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For Peer Review

【Table 1】 The statistic results of the relative energy values of the first harmonic of the six positions in each of four groups.

groups	G1	G2	G3	G4
Pulse positions				
A	$(4.91 \pm 0.22) \times 10^{-6}$	$(4.47 \pm 0.27) \times 10^{-6}$	$(4.10 \pm 0.29) \times 10^{-6}$	$(5.22 \pm 0.33) \times 10^{-6}$
B	$(5.16 \pm 0.24) \times 10^{-6}$	$(5.08 \pm 0.36) \times 10^{-6}$	$(4.68 \pm 0.27) \times 10^{-6}$	$(5.94 \pm 0.41) \times 10^{-6}$
C	$(4.48 \pm 0.23) \times 10^{-6}$	$(4.33 \pm 0.26) \times 10^{-6}$	$(4.58 \pm 0.25) \times 10^{-6}$	$(4.51 \pm 0.34) \times 10^{-6}$
D	$(5.12 \pm 0.25) \times 10^{-6}$	$(4.96 \pm 0.29) \times 10^{-6}$	$(5.22 \pm 0.35) \times 10^{-6}$	$(5.55 \pm 0.32) \times 10^{-6}$
E	$(6.09 \pm 0.33) \times 10^{-6}$	$(5.02 \pm 0.37) \times 10^{-6}$	$(4.79 \pm 0.27) \times 10^{-6}$	$(5.64 \pm 0.37) \times 10^{-6}$
F	$(4.80 \pm 0.28) \times 10^{-6}$	$(4.26 \pm 0.20) \times 10^{-6}$	$(4.68 \pm 0.25) \times 10^{-6}$	$(4.48 \pm 0.34) \times 10^{-6}$
F value	6.16*	2.8	2.37	6.69*
pairwise comparison	E>C,F			B>C,F; E>F

The data were presented as mean \pm standard error. * Significantly different ($P < 0.01$) among six pulse positions. Pairwise comparison: significant

difference on Bonferroni test. G1=the group of pregnant women with 9 to 14 weeks of gestation (n=50). G2=the group of pregnant women with

20 to 28 weeks of gestation (n=50). G3=the group of pregnant women with 32 to 37 weeks of gestation (n=50). G4=the control group of

non-pregnant women (n=50). The capital A indicates the right inch (the radial pulse read from the inch position on right wrist). B indicates the

right bar, C the right cubit, D the left inch, E the left bar, and F the left cubit.

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For example, the relative energy values of the first harmonic of the left bar is significantly higher than those of the right cubit or the left cubit in group 1.

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6 **【Table 2】** The summary of pairwise comparisons (Bonferroni test) of the six positions among the ten relative spectral energy values in each of
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9 four groups.

	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	C ₈	C ₉	C ₁₀
G1	E>C,F	No significant difference	B>D,F	B,C,E>D	C>A,E B,C,E,F>D	C>A B,C,F>D	C,F>A C,F>D	C,F>A B,C,E,F>D C>B,E	B,C,F>A B,C,F>D	C,F>A C,F>D
G2	No significant difference	No significant difference	B>D,F C>F	B>A,D,F E>D	B,C,E>A B,C,E>D	B,C,E>A B,C,E>D	B,C,E,F>A B,C,E,F>D	B,C,E,F>A B,C,E,F>D	B,C,E,F>A B,C,E,F>D	C,E>A B,C,E,F>D
G3	No significant difference	No significant difference	B>A B,C>F	B,C,E>A B,E>D B,E>F	B,C,E>A B,E>D B,E>F	B,E>A B,E>D E>F	B,C,E>A B,E>D E>F	B,C,E,F>A B,C,E>D E>F	B,C,E,F>A B,C,E,F>D E>F	B,C,E>A B,C,E>D
G4	B>C,F E>F	B>C,F D,E>F	B>F	B>F	B>A,D,E,F	B>A,D	No significant difference	No significant difference	B>A,D E>A	C,E,F>A

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31 G1, G2, G3 and G4 are defined as in Table 1. The definition of the capital letters are the same as in Table 1, A for the right inch, B the right bar,
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34 C the right cubit, D the left inch, E the left bar, and F the left cubit.

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37 For example, in G1 group (the pregnant women of 9 to 14 weeks of gestation), the relative energy values of the seventh harmonic of the right
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cubit is significantly higher than those of the right inch or left inch, and the relative energy values of the sixth harmonic of the left cubit is significantly higher than those of the right inch or the left inch. In G4 group, there was no significant difference in the relative energy values of the seventh harmonic of the six positions. Comparing the results of group 1 with group 4, we can clearly see the differences.

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