

## Effect of Local Temperature on the Detecting for Pulse Wave of Local Blood Volume

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**Abstract:** [Objective] Temperature of a subject's external body parts is an interference condition in pulse wave of local blood volume measurement. It is necessary to rule it out. By changing the influence factors, an experiment to research the effect of temperature of subjected part in pulse wave of local blood volume measurement was carried out. [Methods] When the 32 experimenters' left middle finger temperature fall below to 20°C, pulse wave of local blood volume would be recorded detected in real-time until the temperature returned to the measured values before the experiment [Results] While the temperature of subjected part ranged from 26°C to 31°C, the parameters of  $K'$ ,  $K_1'$ ,  $K_2'$  and the amplitude of pulse wave remain basically unchanged. [Conclusion] As a result of the research data, it is stipulated that the pulse wave of local blood volume can be measured only if the finger temperature is in the range of 26-31°C.

**Keywords:** Photoplethysmography, Blood volume index, Temperature.

### Introduction

In recent years, the fingertip photoplethysmography pulse wave tracings (PPG) provide a new method for noninvasive hemodynamic test that presents the characteristics of noninvasive detection, simple operation, stable performance, good reproducibility, safety no cross-infection and many other advantages. It is widely used in clinical examination in the hospital.

Finger pulse wave reflect the overall situation of the blood flow in the fingertip microcirculation. The fingertip pulse wave could evaluate the cardiovascular function and microcirculation [1].

Currently, fingertip pulse wave is widely used to monitor the oxygen saturation in the clinical practices [2], which also plays an important role in the detection of peripheral blood circulation function, non-invasive detection of blood flow parameters, as well as heart rate variability [3-5]. Foo [6] conducted a research on different temperature conditions on the measurement of pulse wave. The research showed that if we don't add the factor of "adaption for heat environment" in the testing procedures or even the healthy subjects who just had Extremities edge adverse perfusion then artery occlusion may be misdiagnosed. When the blood flowed into vital organs in a cold environment, pulsatile blood flow would become weaker. The lower temperature of the surface skin could generate vasoconstriction within a region, followed by vasodilation. This phenomenon will significantly reduced skin microcirculation. This includes a cold environment vasoconstriction and increasing of peripheral vascular resistance, while the properties of the vessel wall and the reflection of the pulse wave might also be changed.

In addition, through the theoretical analysis of the volume pulse flow model and the actual clinical detection, Luo Zhi-Chang, Zhang Song et al. found that: “Characteristics of blood volume pulse wave reflect the situation of the body microcirculation, and made of the pulse of blood volume pulse as a measure of the evaluating body microcirculation” [3]. However, in clinical application, the fingertip pulse wave would be influenced by the temperature of the test site, leading to the original characteristic parameters of volume of the pulse wave to produce significant differences. This study focuses on the temperature factors impact on the fingertip volume pulse spread and photoelectric sensor, and judge the detected temperature at which there will be no significant differences, so as to ensure the measurement accuracy of the volume pulse wave. This study has given the basis of acquiring for the fingertip volume pulse under static conditions for application of volume pulse wave measuring method widely used in clinical studies.

### Volume pulse wave parameters

Luo Zhi-Chang who is from the Biomedical Engineering Center of Beijing University of Technology used the double-elastic chamber model to extract characteristics  $K$  (waveform coefficients) which represents the amount of change in pulse wave map [7]. Model theory analysis, animal experiments, as well as thousands of cases of clinical testing which refer to different age healthy people and cardiovascular disease patients, confirmed the characteristics of the pulse wave graph. The corresponding change of the area will be caused by changes in cardiovascular physiology and pathology, and thus lead to the change of characteristics  $K$ . The characteristic  $K'$  of the volume of the pulse wave could be derived from the algorithm of the characteristic  $K$  of the pressure of the pulse wave. Characteristic  $K'$  represents a volumetric parameter of the volume of the pulse wave, but also reflects the change in the area of the pulse waveform, defined as follows:

$$K' = \frac{Q_m - Q_{\min}}{Q_{\max} - Q_{\min}} \quad (1)$$

$Q_{\max}$  is the maximum value of the blood flow curve,  $Q_{\min}$  is the minimum value of the blood flow curve,  $Q_m$  is the average value of the blood flow curve:

$$Q_m = \frac{1}{T} \int_0^T Q(t) dt \quad (2)$$

The characteristic parameters  $K_1'$  and  $K_2'$  of the fingertip pulse wave is based on separating the dicrotic wave trough, defined as follows [8].

$$K_1' = \frac{Q_{m_1d} - Q_{\min}}{Q_{\max} - Q_{\min}} \quad (3)$$

$$K_2' = \frac{Q_{m_2d} - Q_{\min}}{Q_{\max} - Q_{\min}} \quad (4)$$

$Q_{m_1d}$  is the average value of the preceding blood flow curve of dicrotic wave trough,  $Q_{m_2d}$  is the average value of the latter part of blood flow curve of dicrotic wave trough.

## Materials and methods

### Experimental equipment

Sphygmomanometer (Omron upper arm HEM-7112), a digital thermometer (Beijing Normal University Sinan Instrument SN2202 type), the PowerLab four-channel physiological signal

acquisition system, non-invasive transmissive photoelectric sensor, the Chart for the Windows signal acquisition software, SPSS data analysis software.

### Methods

In this study, we recruit 32 healthy male and female volunteers and kept them in an ambient temperature of 23°C to 24°C windless room. Volunteers needed to remain in the supine position with both hands kept relaxed on the sides of the body, and we measured the initial temperature of the left middle finger with a thermometer and then recorded it. After that the left hand of the subjects was put into the cold water until the temperature of the middle finger dropped to about 20°C. We then removed and wiped clean the subjects' left hand, quickly fixed the thermometer and the photoelectric sensor on the middle finger and finally recorded the waveform until the temperature of the finger returned to the measured values before the experiment. The value of the characteristics  $K'$ ,  $K_1'$ ,  $K_2'$  and the amplitude of the volume pulse wave needed to be recorded in the process of finger temperature rising.

### Results and analysis

The effective parameters of the 32 subjects were collected during the experiment. Due to the fast ascension of the temperature of the left middle finger, some data in the low temperature can't be collected. Because the temperature of some subjects' middle finger is lower than 32°C, some subjects' data can't be collected. The number of subjects according to their different temperatures at the time where data was collected is showed in Table 1. The comparison of the mean values shows that the mean values of parameters  $K'$ ,  $K_1'$ ,  $K_2'$  were decreasing as the temperature increased. This can be found in Figs. 1, 2 and 3. While the temperature was increasing, the average value of the volume pulse wave was also increasing. The relationship between the amplitude and the temperature was shown in Fig. 4.

Table 1. Quantities of data in different temperature

T°C	Sample N	T°C	Sample N
23	4	29	32
24	15	30	31
25	24	31	29
26	31	32	22
27	32	33	8
28	32		

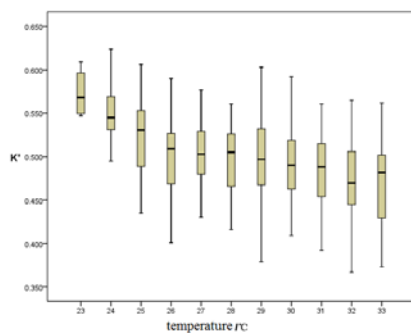


Fig. 1 Values of  $K'$  in different finger's temperatures

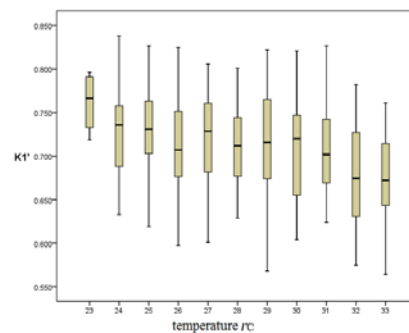


Fig. 2 Values of  $K_1'$  in different finger's temperatures

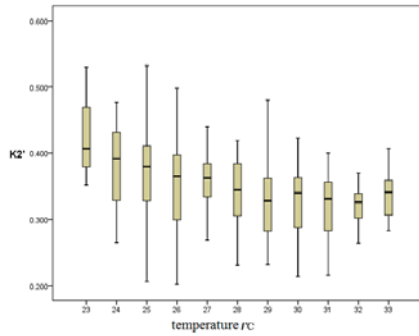


Fig. 3 Values of  $K_2'$  in different finger's temperatures

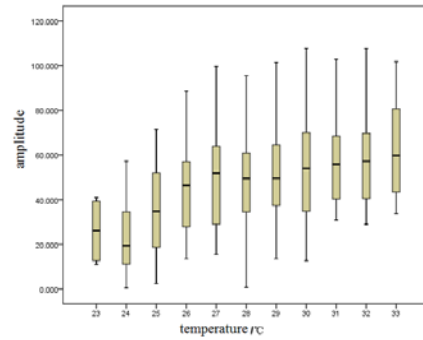


Fig. 4 Volume of pulse amplitudes in different finger's temperatures

According to the single factor analysis of variance, we studied the difference of the finger volume pulse wave parameter  $K'$ ,  $K_1'$ ,  $K_2'$  and the volume pulse amplitude under different temperature conditions,  $p$ -values were shown in Table 2.

Table 2.  $p$ -values in different finger's temperatures between 23°C and 33°C

	$P_{K'}$	$P_{K_1'}$	$P_{K_2'}$	$P_{\text{amplitude}}$
23°C - 33°C	0.000	0.025	0.001	0.000

Table 2 showed that  $p$ -values of the  $K'$ ,  $K_1'$ ,  $K_2'$  and volume pulse wave amplitude in the different fingers temperature conditions was less than 0.05, i.e. the changes in the middle finger temperature led to significant differences in the volume pulse wave parameters. In order to obtain a precise temperature range we run the single-factor analysis of variance method ( $p > 0.05$ ) to gradually narrow the range of temperature by excluding all the temperatures when we are facing samples with  $N < 10$ .

When the temperature of the finger was within the range of 26°C to 31°C, the  $P$ -values of parameters  $K'$ ,  $K_1'$ ,  $K_2'$  and the volume pulse wave amplitude were larger than 0.05 as shown in Table 3. In this temperature range, there were no significant differences in the volume pulse wave parameters.

Table 3.  $p$ -values in different finger's temperatures between 26°C and 31°C

	$P_{K'}$	$P_{K_1'}$	$P_{K_2'}$	$P_{\text{amplitude}}$
26°C - 31°C	0.142	0.218	0.184	0.238

### Conclusions

The pulse photoplethysmography technology of fingertip provides a new method for noninvasive hemodynamic monitoring. However, the studies home and abroad about ambient temperature impact measurement accuracy of volume pulse have not been reported yet. The measurement site of pulse photoplethysmography is finger pulp parts of the capillary network. Temperature has a great influence on microcirculation. The blood circulation of measurement site accelerated with the increasing temperature. Conversely it slowed. The study provides a way to detect the fingertip volume pulse when finger temperature is higher than 26°C. The basic parameters of volume pulse have no significant difference in the temperature range of 26-31°C.

## Acknowledgements

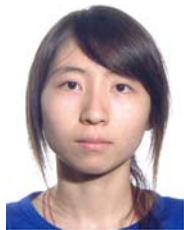
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