

Rapid Skin Temperature Measurement is Valuable in Evaluating Inflammation and Functional Status After Total Knee Arthroplasty—A Case Control Study

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Abstract

Background The skin temperature of the knee joint changes after total knee arthroplasty (TKA), and these changes are easy to detect and can be measured simply and accurately, but its significance is not clear.

Methods: A total of 205 patients who underwent unilateral primary TKA were selected; the bilateral knee skin temperature, inflammatory indicators, pain score, knee range of motion (ROM) and quadriceps muscle strength of the patients were measured from preoperatively to 6 months postoperatively; and the relationships between the differential skin temperature and inflammatory and functional prognosis were analyzed.

Results: The differential skin temperature was significantly correlated with the inflammatory index, pain score, ROM and muscle strength. A difference in skin temperature between the two sides of $>0.52^{\circ}\text{C}$ at 2 weeks after the operation suggested that the level of c-reactive protein increased (sensitivity 81.4%, specificity 39.8%) and affected the ROM at 2 weeks and 6 weeks after the operation, as well as the muscle strength at 6 weeks and 3 months after the operation. A difference in skin temperature of $>2.15^{\circ}\text{C}$ at 2 weeks after the operation suggested that the level of c-reactive protein increased by more than three times (sensitivity 90.9%, specificity 95.2%) and affected the ROM at 3 months and 6 months after the operation and muscle strength at 6 weeks and 3 months after the operation.

Conclusion: The difference in the knee skin temperature between the operated side and contralateral side is closely related to functional recovery and the magnitude of increase in inflammatory indicators in patients after TKA. Skin temperature measurements can be used as references for predicting functional recovery and inflammatory indicators.

Trial registration Medical Ethics Committee of Affiliated Hospital of Qingdao University, QYFYKYL2327945, 2015-03-01

1. Background

Infection and functional recovery after total knee arthroplasty (TKA) are the two major concerns of joint surgeons, but the early detection of infection and the prediction of poor functional recovery are difficult. At present, the commonly used infection detection indicators mainly include blood indicators (white blood cell count, c-reactive protein, hematocrit rate, interleukin-6, etc.), joint fluid indicators (percentage of neutrophils, c-reactive protein, c-defensin, etc.) and tissue cultures [3, 9, 16]. The methods used to evaluate functional recovery include an early postoperative range of motion (ROM) measurement, a quadriceps muscle strength measurement, the sit to stand test, the 6-minute walking test [18], and a psychological assessment [7].

TKA is often accompanied by a rise in the local skin temperature postoperatively, which may be directly related to the progression of local knee inflammation postoperatively and affect functional recovery of the knee joint [6, 12, 21]. Only a few studies have been conducted on this topic, and the sample sizes of

the studies are small; in addition, we have not seen reports demonstrating that skin temperature measurements can be used to screen for inflammation or infection after TKA or to determine functional prognoses. A systematic study needs to be conducted to determine the relationship between skin temperature changes after TKA and inflammation and functional recovery.

2. Methods

2.1 Patient population

Patients undergoing TKA in the joint surgery department at the affiliated hospital of Qingdao University between September 2015 and March 2018 were selected as subjects for this study. The inclusion criteria were as follows: (1) patients who met the OA diagnostic criteria of the American College of Rheumatology (ACR) [2]; (2) postmenopausal women; (3) patients who underwent unilateral primary TKA with a mild or moderate varus deformity; and (4) patients who agreed to adhere to the clinical protocol of this study. The exclusion criteria were as follows: (1) a valgus deformity or severe varus deformity; (2) OA with other types of arthritis; (3) a serious medical disease or a disease affecting one's body temperature (such as thyroid disease, trauma, and rheumatoid arthritis); (4) high fever, infection, significant thrombosis, severe anemia, significant drug allergy, or another condition that occurred within 2 weeks after the operation and may seriously affect the results of the study; and (5) incomplete follow-up information.

All operations were performed by the same group of surgeons. A total of 238 patients met the inclusion criteria and were included; 3 patients who underwent contralateral TKA during the follow-up period and 30 with incomplete follow-up data were excluded. A total of 205 patients completed the follow-up, including 117 (57.1%) patients who underwent TKA on the right knee and 88 (42.9%) who underwent TKA on the left knee. The mean age was 66.17 ± 6.29 years, and the BMI was 27.54 ± 3.13 .

2.2 Operation And Postoperative Management

All surgeries were performed before 3:00 PM with a Wright ADVANCE MP prosthesis (Microport Orthopedics Inc. Arlington, USA). All operations were performed with a nerve block combined with intravenous anesthesia. After the operation, the patients were administered the same analgesic drugs (intravenous infusion of flurbiprofen 50 mg bid within 48 hours after the operation and oral administration to celecoxib 200 mg bid after 48 hours until 2 weeks after the operation). A CPM (continuous passive motion) machine and ultrasonic drug permeation therapy instrument were used to assist functional exercise and analgesia.

2.3 Data Collection

The knee skin temperature, white blood cell count (WBC), erythrocyte sedimentation rate (ESR), c-reactive protein level (CRP), pain score, range of motion (ROM), and quadriceps muscle strength were recorded at 1 day preoperatively and 1 day, 3 days, 5 days, 2 weeks, 6 weeks, 3 months and 6 months postoperatively.

The skin temperature was measured with an OPTRIS MS-B hand-held temperature detector (Hengaode Instrument Co., Ltd, Beijing, China) at 3:00 PM, during which both sides of the knee were fully exposed for 5–10 minutes. The skin temperature detector was held 1 cm away from the patient's skin for the measurement. The four quadrants of the knee were measured sequentially. The average value of the four values was taken as the skin temperature of the knee joint. A numerical rating scale (NRS) was used to assess the patient's perceived overall pain level on that day. Quadriceps muscle strength was measured by the numerical grade muscle strength classification method proposed by the Medical Research Council (MRC) in 1976.

2.4 Data analysis

All statistical analyses were performed with SPSS statistical software version 25.0, with $\alpha = 0.05$.

The Pearson correlation coefficient test was used to determine the correlation between the differential skin temperature, which equaled the operative side's temperature minus the contralateral side's temperature, and other indexes.

A receiver operating characteristic curve (ROC curve) of the differential skin temperature was drawn with the upper limit being the normal CRP (5 mg/L) and the CRP increased by 3 times (15 mg/L) to determine the differential skin temperature value that could be used for screening.

According to the differential skin temperature value determined by the ROC curve, the differential skin temperature values taken at 2 weeks after the operation were categorized into two groups, and the differences in the CRP, ROM, NRS and muscle strength indexes at 6 weeks, 3 months and 6 months after the operation between the two groups were assessed.

3. Results

A total of 205 patients were followed up, and no complications occurred during the follow-up. The data are shown in Table 1.

Table 1

Values of the knee skin temperature, inflammatory indicators, NRS, ROM and muscle strength of the patients from before TKA to 6 months after TKA (n = 205).

Factors	Pre-operation	Post-operation						
		1 day	3 days	5 days	2 weeks	6 weeks	3 months	6 months
Skin temperature								
Operated	35.28 ± 0.60	37.18 ± 0.52	36.75 ± 0.67	36.51 ± 0.78	36.57 ± 0.45	36.15 ± 0.28	35.89 ± 0.42	35.26 ± 0.34
Contralateral	35.27 ± 0.66	36.24 ± 0.55	35.90 ± 0.58	35.54 ± 0.75	34.98 ± 0.66	35.20 ± 0.51	35.00 ± 0.42	34.90 ± 0.42
Differential	0.01 ± 0.40	1.32 ± 0.43	0.85 ± 0.69	0.97 ± 1.01	1.59 ± 0.73	0.95 ± 0.55	0.89 ± 0.38	0.37 ± 0.31
WBC	5.27 ± 0.74	8.58 ± 2.15	7.33 ± 1.34	7.12 ± 1.30	6.34 ± 1.03	6.22 ± 0.99	6.65 ± 0.74	5.43 ± 0.64
ESR	12.27 ± 7.63	18.20 ± 10.96	38.26 ± 14.94	41.69 ± 17.49	30.27 ± 17.95	13.41 ± 7.38	15.25 ± 6.03	12.94 ± 4.22
CRP	1.41 ± 2.01	39.47 ± 38.71	101.85 ± 45.39	19.69 ± 5.60	5.41 ± 7.75	1.88 ± 2.50	1.53 ± 2.29	1.32 ± 0.93
ROM	88.13 ± 13.57	22.12 ± 11.95	76.68 ± 12.53	96.22 ± 5.87	91.14 ± 5.04	92.05 ± 5.55	92.67 ± 3.76	91.39 ± 4.48
NRS	6.28 ± 1.66	4.27 ± 2.25	3.77 ± 1.48	2.55 ± 0.62	2.52 ± 1.13	2.28 ± 0.64	0.76 ± 0.74	0.17 ± 0.38
Muscle strength	4.28 ± 0.69	2.32 ± 0.47	3.32 ± 0.65	4.00 ± 0.37	4.45 ± 0.56	4.59 ± 0.49	4.76 ± 0.43	4.99 ± 0.12
Values are shown as mean ± SD.								
Differential, differential skin temperature = operated knee skin temperature – contralateral knee skin temperature.								
WBC, white blood cells; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein; ROM, range of motion; NRS, numerical rating scale.								

1. **Correlations between the differential skin temperature and inflammatory indicators (Table 2).**
Correlations between the differential skin temperature and NRS, ROM and muscle strength (Table 3).

Table 2

Correlation analysis of the differential skin temperature and inflammatory indexes at different time points (n = 205).

Differential temperature	WBC		ERS		CRP	
	r	Significant	r	Significant	r	Significant
Pre-operational	0.227** Δ	P = 0.001	-0.032 Δ	P = 0.652	0.031 Δ	P = 0.657
Within 1 week	-0.006	P = 0.886	0.034	P = 0.395	-0.076	P = 0.060
After 1 week	0.176**	P < 0.001	0.475**	P < 0.001	0.358**	P < 0.001
2 weeks	0.231**	P = 0.001	0.211**	P = 0.002	0.274**	P < 0.001
6 weeks	-0.356** Δ	P < 0.001	0.513**	P < 0.001	0.149*	P = 0.033
3 months	-0.206** Δ	P = 0.003	-0.078	P = 0.367	-0.012	P = 0.864
6 months	0.004 Δ	P = 0.950	0.493** Δ	P < 0.001	-0.050 Δ	P = 0.480
*P < 0.05, **P < 0.01.						
Differential, differential skin temperature = operated knee skin temperature – contralateral knee skin temperature.						
r, Pearson's correlation coefficient; WBC, white blood cells; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein						
Δ All patients' values are in the normal range.						

Table 3

Correlation analysis of the differential skin temperature and NRS, ROM and muscle strength at different time periods (n = 205).

Differential temperature	NRS		ROM		Muscle Strength	
	r	Significant	r	Significant	r	Significant
Pre-operational	0.091	P = 0.091	0.188**	P = 0.007	-0.043	P = 0.539
Within 1 week	0.192**	P < 0.001	-0.111**	P < 0.001	-0.151**	P < 0.001
After 1 week	0.535**	P < 0.001	-0.169**	P < 0.001	-0.331**	P < 0.001
2 weeks	0.185**	P = 0.008	-0.374**	P < 0.001	-0.053	P = 0.452
6 weeks	-0.082	P = 0.242	-0.177*	P = 0.011	-0.095	P = 0.177
3 months	0.614**	P < 0.001	-0.076	P = 0.278	-0.268**	P < 0.001
6 months	0.180**	P = 0.009	0.124	P = 0.077	-0.045	P = 0.524
*P < 0.05, **P < 0.01.						
Differential, differential skin temperature = operated knee skin temperature – contralateral knee skin temperature.						
r, Pearson's correlation coefficient; ROM, range of motion; NRS, numerical rating scale.						

3.3 Screening Index Test Results

Differential skin temperature and CRP5mg/L ROC curve showed that the screening index was 0.52°C. (Fig. 1)

Differential skin temperature and CRP15mg/L ROC curve showed that the screening index was 2.15°C. (Fig. 2)

3.4 Relationships Between The Screening Indicators And Prognoses

The CRP, NRS and muscle strength measurements of the patients from 2 weeks to 6 months after TKA are shown in Table 4. The relationships between the differential skin temperature at 2 weeks after surgery and the ROM, CRP, NRS and muscle strength measurements at 2 weeks, 6 weeks, 3 months and 6 months after surgery are shown in Table 5.

Table 4
Distribution of CRP, NRS and muscle strength in patients 2 weeks to 6 months after TKA.

Frequency in time points				
Variable	2 weeks	6 weeks	3 months	6 months
CRP				
0–5 mg/L	155	183	190	205
5–10 mg/L	21	22	15	0
10–15 mg/L	14	0	0	0
15–20 mg/L	8	0	0	0
20–25 mg/L	7	0	0	0
NRS				
0	0	0	85	170
1	42	14	105	35
2	71	127	15	0
3	43	57	0	0
4	42	7	0	0
5	7	0	0	0
Muscle strength				
grade 3	7	0	0	0
grade 4	98	85	50	3
grade 5	100	120	155	202
CRP, C-reactive protein; NRS, numerical rating scale				

Table 5

The relationship between differential skin temperature at 2 weeks after operation and ROM, CRP, NRS and muscle strength at 2 weeks, 6 weeks, 3 months and 6 months after operation

Elevation in differential temperature in 2 weeks						
	Separated by 0.52			Separated by 2.15		
Factors	< 0.52(n = 14)	> 0.52(n = 191)	Significant	< 2.15(n = 176)	> 2.15(n = 29)	Significant
Differential temperature	0.45 ± 0.07	1.68 ± 0.68		1.42 ± 0.62	2.69 ± 0.21	
ROM ^t						
2 weeks	95.00 ± 1.18	90.86 ± 5.11	P < 0.001**	91.30 ± 5.23	90.17 ± 3.66	P = 0.266
6 weeks	95.00 ± 4.66	91.84 ± 5.53	P = 0.028*	92.22 ± 5.64	91.07 ± 4.71	P = 0.244
3 months	92.50 ± 2.60	91.59 ± 3.73	P = 0.236	92.10 ± 3.29	88.90 ± 4.62	P < 0.001**
6 months	92.50 ± 2.60	91.31 ± 4.58	P = 0.137	91.66 ± 4.22	89.72 ± 5.59	P = 0.030*
CRP ^z						
2 weeks	78.00	104.83	P = 0.030*	96.89	140.07	P < 0.001**
6 weeks	92.00	103.81	P = 0.180	96.08	145.02	P < 0.001**
3 months	95.50	103.55	P = 0.277	95.50	148.52	P < 0.001**
6 months	103.00	103.00	P = 1.000	103.00	103.00	P = 1.000
NRS ^z						
2 weeks	78.00	104.83	P = 0.091	102.82	104.10	P = 0.911
6 weeks	124.00	101.46	P = 0.111	102.08	108.57	P = 0.526
3 months	43.00	107.40	P < 0.001**	92.12	169.03	P < 0.001**
6 months	85.50	104.28	P = 0.079	101.81	110.24	P = 0.276

*P < 0.05, **P < 0.01.

Differential, differential skin temperature = operated knee skin temperature – contralateral knee skin temperature.

t, Values are shown as mean ± SD. t-test is used ; z, Ranked data are shown as mean rank, rank sum test is used; ROM, range of motion; CRP, C-reactive protein; NRS, numerical rating scale.

Elevation in differential temperature in 2 weeks						
Muscle strength ^z						
2 weeks	106.00	102.78	P = 0.824	102.22	107.71	P = 0.600
6 weeks	145.50	99.88	P = 0.001**	112.89	43.00	P < 0.001**
3 months	128.00	101.17	P = 0.028*	107.62	74.98	P < 0.001**
6 months	104.50	102.89	P = 0.637	102.75	104.50	P = 0.480
*P < 0.05, **P < 0.01.						
Differential, differential skin temperature = operated knee skin temperature – contralateral knee skin temperature.						
t, Values are shown as mean ± SD. t-test is used ; z, Ranked data are shown as mean rank, rank sum test is used; ROM, range of motion; CRP, C-reactive protein; NRS, numerical rating scale.						

4. Discussion

The skin temperature of the knee joint changes after TKA, and these changes are easy to detect and can be measured simply and accurately. At present, there are few studies on skin temperature after TKA, and its significance is not clear. The relationships between skin temperature and inflammation, pain and function also needs to be further studied. There are many influencing factors of skin temperature. In addition to factors related to a patient's body, the season, the ambient temperature and even the dressing conditions have a significant impact on skin temperature. In this study, postmenopausal women undergoing unilateral primary TKA were included, and the skin temperature difference between the operated and contralateral sides was used as an index, which greatly reduced the influence of environmental and individual differences on skin temperature.

4.1 Changes In Skin Temperature After Tka

After TKA, the skin temperature of the knee joint increased and changed regularly. In our study, we found that the skin temperature of the knee joint of the patients increased rapidly in the early stage after TKA, peaked 2 days after TKA, decreased slowly, and then, returned to the preoperative level 6 months after TKA, which was consistent with the results in study conducted by Mehra et al. [11] and Haidar et al. [5].

The skin temperature on the operated side is believed to increase due to the inflammatory response caused by surgical trauma and implant implantation [6, 12], as well as due to an increase in the local blood supply, which has little influence on incision trauma [20]. Our study showed that the change in the trend of skin temperature was the same as those of the inflammatory indicators. The skin temperature at 2 weeks or more after TKA was significantly associated with the CRP, ESR and WBC measurements,

which also suggested that an increased skin temperature was associated with inflammation. Moreover, we found a significant correlation between skin temperature and pain, which may be related to the neurogenic response [10].

4.2 Skin Temperature And Infection

It is difficult to treat an infection after TKA, which is disastrous for the operation [19]. The early detection and treatment of infections greatly affects the selection of treatment options and the success rate of prosthesis retention [4]. There are many indexes that are used to examine infections, including the CRP, which is a sensitive index and is widely used in clinical practice [9, 16]. A large increase in the postoperative skin temperature accompanied by a continuous elevation in the CRP can indicate the presence of postoperative TKA infections [5, 6, 8, 11, 12]. However, there are few studies on the correlation between skin temperature and inflammatory indicators, and although Mehra et al.[11] believe that the CRP is related to the skin temperature and postoperative infections, CRP has not been shown to be related to the skin temperature.

Through time interval analysis, we found that the CRP was significantly correlated with the differential skin temperature at 2 weeks or more after TKA, suggesting that the differential skin temperature can be a screening indicator for CRP increases. There may be a discrepancy between this result and the results reported by Mehra et al. [11] because we used the differential skin temperature between the two knee joints, which reduces the influence of environmental factors. In addition, there was no clinical significance when the CRP was in the normal range (0–5 mg/L), so the CRP data was transformed into ranked data in the analysis; it was found that an increase in the CRP may be vigilant when the skin temperature difference is > 0.52 °C at 2 weeks after the operation. The actual skin temperature difference was > 2.15 °C, which strongly indicated that the patient's CRP increased by more than three times, so the patient should return to the clinic promptly for the early detection of infection or other complications. The measurement of the skin temperature is convenient and can be used as a screening index for the diagnosis of infection-related complications after TKA.

4.3 Skin Temperature And Functional Recovery

The influencing factors of functional recovery after TKA mainly include the patient's age, sex, preoperative pain level, total duration after TKA and preoperative knee functional state [1, 14, 15]. There are few studies on the effect of skin temperature on knee joint function, and only a few studies have reported that an increase in the skin temperature can affect the prognosis of knee joint function [1]. To exclude the interference of age and sex, we included only postmenopausal women. We found that only the speed of ROM recovery was affected when the differential skin temperature was > 0.52 °C, while the long-term prognosis showed no difference. However, the ROM at six months after TKA was reduced when the differential skin temperature was > 2.15 °C. This result is roughly consistent with the observed relationship between the differential skin temperature and inflammatory indicators, suggesting that more

severe inflammatory responses can affect both the skin temperature and joint motion [17]. In addition, we found that the incidence of chronic pain was significantly increased in patients with high differential skin temperatures, which may be due to the pain sensitization effect of high temperatures [13], which aggravates the pain experienced by patients and thus affects the range of motion of joints. Therefore, for patients with a 2-week postoperative differential skin temperature of > 0.52 °C, it may be recommended that the dosage of NSAID drugs is increased, the duration of consumption is prolonged, or additional treatments such as a cold compress for an early intervention are implemented to reduce the severity of the postoperative pain experienced by the patients and speed up the ROM recovery. For the patients whose differential skin temperature is > 2.15 °C, measures should be taken to improve ROM recovery in the long term.

When the differential skin temperature was > 0.52 °C or > 2.15 °C, the recovery rate of the knee extensor muscle strength slowed, but the degree of recovery at six months after the operation was not affected. The results showed that the increase in the skin temperature only affected the speed of muscle strength recovery, not the final outcome.

Our study, however, has some limitations. During the follow-up, we did not observe any cases of infection, and we did not follow up the patients after six months. Therefore, only an increase in the CRP could be used to indirectly detect infection risk, and the relationship between the skin temperature and the prognosis of infection could not be determined.

5. Conclusion

The difference in the knee skin temperature between the operated side and contralateral side is closely related to functional recovery and increases in inflammatory indicator levels in patients after TKA. Measurements of the skin temperature can be used as references for predicting functional recovery and inflammatory indicators. When the differential skin temperature is > 0.52 °C, NSAID drugs and physical therapy should be recommended to increase the speed of ROM recovery. When the differential skin temperature is > 2.15 °C, it is strongly indicated that the patient's CRP has increased by more than three times, so the patient should return to the clinic promptly for the early detection of infection. Moreover, it is also strongly recommended that measures are taken to improve ROM recovery in the long term.

Abbreviations

TKA
total knee arthroplasty
ROM
range of motion
ACR
American College of Rheumatology
CPM

continuous passive motion
WBC
white blood cell count
ESR
erythrocyte sedimentation rate
CRP
c-reactive protein level
NRS
numerical rating scale
MRC
Medical Research Council
ROC curve
receiver operating characteristic curve

Declarations

- Ethics approval and consent to participate

We got verbal consent from the participants for getting back to the hospital to take tests and to confirm whether complications or poor function had happened. This study was approved by Medical Ethics Committee of Affiliated Hospital of Qingdao University.

- Consent for publication

Not applicable

- Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request

- Competing interests

The authors declare that they have no competing interests

- Funding

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- Authors' contributions

HX and WY were major contributors in writing the manuscript. YW and HZ were surgery doctors in this study. HH assessed pain score and adjusted the painkillers of the patients. LY, SX and GS collected,

analysed and interpreted the patient data. All authors have read and approved the manuscript

- Acknowledgements

Not applicable

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Figures

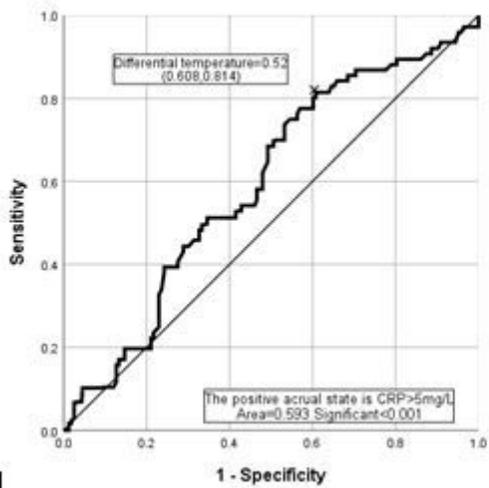


Figure 1

Differential skin temperature and CRP>5mg/L ROC curve showed that the screening index was 0.52°C.

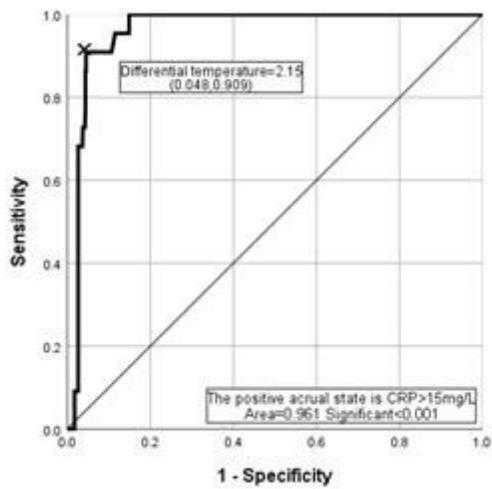


Figure 2

Differential skin temperature and CRP>15mg/L ROC curve showed that the screening index was 2.15°C.