Objectives: Digitized infrared segmental thermometry (DIST) is a method for measuring and recording skin surface body temperatures. The project evaluated the required length of time for patients to acclimatize their core body temperature to ambient conditions to obtain stable DIST readings.

Methods: Seventeen subjects were allowed a 20-minute acclimatizing period in a temperature-controlled room. The bilateral DIST temperature was measured with thermistors in combination with infrared cameras (IRCs) at the C4 and L4 levels. All IRC temperatures were recorded after a 20-minute stabilization period. The room temperature and relative humidity were recorded throughout all trials. The acclimatization trend was computed from the 20- to 24-minute period for the IRCs, and the acclimatization trend was computed continuously for a total of 30 minutes (at 2-minute intervals) for 5 days.

Results: We discovered a stabilization trend in the early trial stages, with the thermistor recordings between 8 and 16 minutes. The IRC trend was also conclusive for the core temperature requirements.

Conclusions: This study determined a core body temperature acclimatization trend tested among patients using thermistor recordings in a controlled environment. Based on these findings, we recommend acclimatization in a temperature- and humidity-controlled environment for a minimum 8-minute period, followed by an 8-minute maximum recording period with the patient in a prone position to obtain accurate DIST recordings. (J Manipulative Physiol Ther 2006;29:468.e1-468.e10)

Key Indexing Terms: Thermography; Chiropractic

Core body temperature is regulated precisely, with the traditional normal value for the oral temperature being 37°C (98.6°F). The rectal temperature usually best represents the core temperature of an individual, as it does not fluctuate appreciably with environmental temperature changes. The circadian rhythm oscillates the normal human core temperature by approximately 1.0°C over a 24-hour period. Exercise also influences the core body temperature, causing it to rise to as high as 40°C. The better known and clinically relevant form of heat production, however, is fever. Any deviation from the normal core temperature of 37.5°C is an indication of an underlying pathologic condition.

In the chiropractic field, thermal evaluation of the skin surface temperature (SST) over the spine has been used since 1924. Surface skin temperature measurements have been used in other instances to identify somatotropic anomalies. Technologies have emerged to measure paraspinal SST with normative values based on spinal area thermography data obtained by Uematsu et al. Several studies using the SST recordings have shown that there are temperature gradients along the length of the spine. In addition, several investigators have hypothesized that vertebral temperature differences from one side to the other may be indicative of somatospinal inconsistencies that may benefit from chiropractic intervention. There is only 1 study that establishes a certain timeline showing a stable SST. A stable SST could serve the investigating clinician in the clinical assessment of the patient status. A recent study by Hart and Owens indicates that a 16-minute acclimatization period is adequate for SST stabilization, based on temperature averages and modulation of the recorded thermal patterns. Thus, the goal of the present study was
to verify the period of acclimatization required to obtain valid and reliable patient re-assessment criteria based on absolute SST measurements.

**METHODS**

**Participants**

Seventeen healthy subjects were recruited from the student population of the Université du Québec à Trois-Rivières. The sex distribution included 11 females and 6 males, the anthropometric characteristics of whom are shown in Table 1. The subject inclusion criteria were that they had to be free of any underlying pathologic conditions (acute or chronic diseases, cold, menses, and/or any thermogenic disease) that might affect their core temperatures. Each subject participated on 5 different occasions with a few hours (maximum of 2 sessions in a single day) to a few days in between sessions. The ethics committees from both the Université du Québec à Montréal and the Université du Québec à Trois-Rivières approved the research protocols for the acclimatization period evaluations. We obtained informed written consent from all subjects.

**Materials**

The core temperatures were estimated with a tympanic thermistor (TT; model MA-100 BF 103 A, General Electric via http://www.digi-key.com; part number, 235-1064-ND) and a rectal thermistor (TR; model MA-100 GG 103 A, General Electric via http://www.digi-key.com; part number, 235-1060-ND; TT and TR, respectively, precision, ±0.1°C at 37°C). The SSTs were recorded with thermistors (model Et-016-1060-1180; precision, ±0.05°C at 37°C) placed directly on the skin at 4 different sites. The body sites of interest were defined at the level of the lumbar spine, left and right L4 (ThL4L and ThL4R, respectively) and at the level of the cervical spine, left and right C4 (ThC4L and ThC4R, respectively). Detailed placement is described below in the experimental protocol section. The TT, TR, and thermistor (Th) SST recordings were directed into an 8-channel data logger (Smart Reader Plus 8, 128 Kb, ACR Systems, Inc, Surrey, BC, Canada) at a rate of 0.125 Hz. The TTs and TRs were sterilized with antibacterial soap and then rinsed with alcohol and immersed for 60 minutes in a solution of CIDEX (Johnson & Johnson, Toronto, Ontario, Canada). Another alcohol rinse with alcohol and antibacterial soap wash followed. All data were collected at room temperature. The room temperature and relative humidity were recorded with a THR-1000 (ACR Systems Inc).

**Experimental Protocol**

Before the day of the measurement, subjects were instructed not to drink any coffee or any other beverages containing caffeine (eg, cola soft drink, tea) on the day of the recordings. Subjects were also instructed not to smoke or chew tobacco for a period of at least 2 hours before the recording session. On every recording day before the recording session, subjects were asked if they had complied with the inclusion criteria.

When the subjects arrived for a recording session, they were asked to remove their clothing, with the exception of undergarments, and to wear a cotton gown. The subject was then instructed to wear gloves and insert the TR to a depth of 15 cm beyond the anal sphincter to record the core body temperature; the TR wire had a plastic bulge at the 15-cm length. After the TR placement, we began recording isothermal body temperatures using the chronometer. As a backup to the TR, we inserted the TT into the left ear and then stabilized it with a foam anti-noise plug. The anti-noise plug isolated the tympanic probe from the environment air temperature. The subject then proceeded to lie prone on a chiropractic table. The subject’s head was placed in a neutral position by adjusting the headrest portion of the table.

We then installed the spinal Ths at each of the following sites: ThL4L, ThL4R, ThC4L, and ThC4R. All Ths were installed on the skin 4 cm lateral to the spinous process at the lumbar site, 1 each on the left and right sides, and 2 cm lateral to the spinous process at the cervical site, 1 each on the left and right sides. Once all the Ths were in place, the subject remained in the same position during the 20-minute acclimatization period.

Surface skin temperature was also measured with infrared cameras (IRCs) that compose part of a computerized commercially available system (Subluxation Station Insight 7000; EMG Consultant, Inc, Mahwah, NJ). Both the left and right IRC measuring IRL4L, IRCL4R, IRCC4L, and IRCC4R were used in conjunction with the ThL4L, ThL4R, ThC4L, and ThC4R sites, respectively. The SST measurements obtained with the IRC were compared to the Th measurements. To respect the distance between the IRC and the skin, wooden sticks (popsicle style) were attached to the side of each IRC casing, 1 each on the medial and lateral IRC aspects. The sticks were held in place by ventilation duct tape. The tips of the sticks extended 0.5 in beyond the IRC’s lens to maintain a constant distance between the IRC and the skin surface, as recommended by the IRC manufacturer. Before recording,

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**Table 1. Anthropometric measurements of the subjects**

<table>
<thead>
<tr>
<th></th>
<th>Females (n = 11)</th>
<th>Males (n = 6)</th>
<th>Group (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>25.6 (5.66)</td>
<td>25.5 (5.22)</td>
<td>25.6 (5.39)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>60.2 (6.35)</td>
<td>80.1 (11.43)</td>
<td>67.14 (12.72)</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.66 (0.08)</td>
<td>1.79 (0.07)</td>
<td>1.70 (0.10)</td>
</tr>
</tbody>
</table>

Values are shown as mean (±SD).
the IRCs were synchronized to the manufacturer’s standard. All temperatures were recorded in degrees Fahrenheit.

When we started the recording sessions, we positioned the IRCs at the immediate inferior aspect of the Th already positioned and adhered to the skin. When the curve was stable on the computer screen, after roughly 5 to 10 seconds, the recording pedal was activated and the computer recorded the temperature at that moment. The SST was simultaneously recorded with the data logger. We consistently started our recording sessions at L4. We then moved the IRCs to the C4 site and repeated the procedure. We repeated this alternative site recording until we had 15 recordings from each site. This exact procedure was repeated on each of the 5 different days of recordings. When the recording session was terminated, we disconnect the TR from the data logger immediately. This provided a clear break in the recording trace representing the end of the recording session. All Ths were removed from the subject. The subject was gloved and instructed to remove the TR and dress.

RESULTS

Core Temperature

Fig 1 illustrates the core temperature recordings obtained with the TR and TT from each experimental day. Fig 1A and B shows the temperatures recorded at the onset (~2 minute) of probe placement for the entire 30-minute duration of TR and TT measurements. Fig 1C and D represents TR and TT measurements starting at +2 minutes until the end of the entire 30-minute duration of TR and TT measurements on a different temperature scale. The 5- to 15-minute interval (black bar on the time scale) represents the TR and TT temperature time interval where the Th SST measurements were found at posteriori
to be stable. The 20- to 24-minute interval (gray bar on the time scale) represents the IRCs recording period. As shown in Fig 1C, the core temperature recorded with the TR during the 20- to 24-minute interval varied between 0.04°F and 0.06°F over the 5 recording days. On the other hand, Fig 1D shows that the TT increased during most of the recording period, stabilizing near the end of the 30-minute recording session. Nonetheless, between the same time interval (20-24 minutes), TT was highly stable and similar to TR (between 0.04°F and 0.06°F variation over the 5 recording days). Overall, the rectal temperature variability over a 30-minute period decreased by 0.28°F, and the tympanic variability increased by 0.45°F.

**Infrared Cameras**

We collected 2550 IRC SST recordings for the cervical and lumbar areas, respectively, from 17 subjects. As we ascertain in Fig 2A-D and in Fig 3A and B, on a different temperature scale (inset in Fig 3A), the lumbar spine warms up by 1.4°F and the cervical spine cools by 1.2°F during the recording period.

**Thermistors**

In the overall evaluation of the Th SST, we obtained a stable trend in the analysis of the 30-minute period of the thermistors recording (Fig 4A-D). As illustrated in Fig 5, the most stable timeline of the trend was during the 8- to
ThL4L = 0.01°F, ThL4R = 0.05°F, ThC4L = 0.02°F, ThC4R = 0.06°F. During this 8- to 12-minute period, TR and TT varied by 0.08°F and 0.1°F, respectively.

Room Temperature

We found notable temperature and relative humidity differences on different recording days. Some days can be warmer by up to 12°F and the relative humidity could be lessened by up to 32% (Table 2 and Fig 6). The subject’s thermal comfort is optimal at a core temperature range between 97.9°F and 98.8°F, and an SST range between 89.6°F and 95.9°F. In our study, 98.9°F ± 0.14 represents the average core temperature on the upper edge of the subject core temperature comfort zone. However, the SST is well within the comfort zone (Fig 7). We therefore consider that the subjects were not uncomfortable during the recording sessions.

DISCUSSION

The goal of this project was to obtain a reliable timeframe that represents the best SST stabilization period for accurate and repeatable IRC recordings. The lumbar and cervical variability within a subject shows the adaptability by body region to thermoregulation. In effect, we noticed a temperature stabilization in the early stage of our recordings (during the 8- to 16-minute interval), as illustrated by Fig 4. Moreover, we observed another overall stabilization of the core temperature near the end of the recording session (Fig 1).

Core Temperature

The recommended time for a stable core temperature reading at the rectal level is 30 to 40 minutes in a constant environment. The ideal difference between the SST and the core temperature is 7°F at rest. When we looked at the overall trend for 30 minutes (Fig 1) for the rectal and tympanic temperatures, we found that they varied respectively by 1.8°F and 0.8°F. When we looked at the spinal sites, however, we found a stable Th SST recording trend near the end of the recording session (Fig 4). A more precise evaluation (Fig 5) revealed the most stable area of the trend to be within the 8- to 12-minute range of the timeline. During the same interval, we noticed that the rectal and tympanic temperatures varied respectively by 0.06°F and 0.1°F. The afferent thermoreceptors from the skin can signal peripheral temperature changes before the central core temperature has had a chance to adapt. This, in effect, is the central nervous system (CNS) demonstration of its rapid adaptation over the overall blood circulation adaptation, which depends upon the CNS and the sympathetic nervous system at the segmental level. We are well within the limits of the ideal difference between the SST and the core temperature. The subject’s thermal comfort is optimal at a core temperature range between 97.9°F and 98.8°F, and an SST range between 89.6°F and 95.9°F. In our study, 98.9°F ± 0.14 represents the average core temperature, correlated with an SST within the norms suggested for subject comfort (Fig 7). With the IRC SST, we found our subjects well within the comfort zone limits. Even if our subjects were at either end of the comfort zone for both the core and Th SST temperatures, and within the normal limits for the IRCs SST, we believe that the room temperature and relative humidity may have had an effect on the standard deviation and may have affected the
fluctuation of our interday temperature recording variability (Fig 6).

Infrared Cameras

During our evaluation, we used a previous study as a baseline blueprint and acted conservatively by adding 4 minutes to the recommendation resulting in a 20-minute stabilization period. When we initially analyzed our results (Figs 2 and 3), we discovered that the IRC recordings at both sites stabilized near the end of the IRC recording cycle, which constitutes the 24-minute mark. This is congruent with the rectal core temperature recording and the recommended time for a stable rectal core temperature. Our data from the IRC reflect a parallel situation revolving around the core temperature stabilizing at the same time (Fig 1). We would therefore recommend an acclimatization period of 30 minutes, which correlates with the minimum time required for a stable reading of the core temperature at the rectal level. However, before we could come to this conclusion, we had to review the total period of acclimatization to establish the absence or presence of any other area of fluctuation or stabilization in the SST. So we investigated the recordings of the Th SST.

**Fig 4.** The daily average SST temperatures (for each site: [A] ThC4L, [B] ThC4R, [C] ThL4L, and [D] ThL4R) for 17 subjects during the 30-minute recording session. The black box represents the 5- to 15-minute time interval for the Th stable trend. The gray block represents the 20- to 24-minute time interval for the IRC recording.
Thermistors and SST

We recorded temperatures from each site (TR, TT, ThL4L, ThL4R, ThC4L, and ThC4R) for a period of 30 minutes (with 8-second intervals) from the beginning of each recording session. We reviewed the data for each site and we chose to present the data at preselected 2-minute intervals from a point at -2 minutes, continuously for 30 minutes. We observed the overall results from the 17 subjects during the 5 days at 15 recordings per day (Fig 5) and observed a stable trend from 6 to 16 minutes of recording. Excessive variability, characterized by ascension and plunging in the recorded SST, follows this time interval. The trend is at its most stable between 8 and 16 minutes (Fig 5). In this range, the variability for each site is as follows: ThL4L = 0.01°F, ThL4R = 0.05°F, ThC4L = 0.02°F, and ThC4R = 0.06°F. These results appear to contradict those reported by Hart and Owens. However, we used absolute data vs thermal pattern modulation and thermal slope averages. In addition, our subjects were lying face down. This simple position eliminated the activity of the postural muscles, hence reducing heat production and

Fig 5. The daily average SST temperatures (for each site: [A] ThC4L, [B] ThC4R, [C] ThL4L, and [D] ThL4R) for 17 subjects during the interval of 4 to 16 minutes. Also note the smaller temperature scale (84°F-94°F).
unstable SST because of the inconsistent effort associated with the maintenance of posture and muscle fatigue.\textsuperscript{1,14,15} This eliminated a variable for the SST measurement and represents a divergence from the procedures previously implemented.\textsuperscript{13}

The Th SST is stable between 8 and 16 minutes, whereas the core temperature is on a continuing slow descending trend, therefore should be considered the normal adaptation process for the core temperature reacting slowly to maintain the SST. After the 16-minute mark, we observed the beginning of fluctuation and dispersion in the Th SST recording. This, we assume, represents the total body adaptation to the continued lowered core temperature. Near the 30-minute mark, which is considered the minimal time required for rectal core temperature stabilization,\textsuperscript{14} we observed that the SST and the core temperature both seem to restabilize. This finding seems to indicate that the segmental controlled SST and the CNS thermoregulation are balancing, thus maintaining an appropriate correlation between SST and core temperature. In theory, the afferent thermoreceptors are still reacting rapidly, informing the brain that the SST is cooling. Eventually, the basal metabolic rate reacts and thermogenesis will be regulated to prevent freezing of the body.\textsuperscript{16} Thermogenesis is a CNS-controlled reaction, whereas SST is controlled by the sympathetic nervous system and thus is dependant on CNS modulation.

**Room Temperature**

The air temperature affects convective heat loss from the subject.\textsuperscript{14} Although we had a room with no window, we still had a central ventilation/heating/cooling system. The air movement\textsuperscript{14} from the researcher displacement could also affect the subject at any time. Thus, we took great care not to move during the acclimatization period, and, in addition, once the researcher was ready to perform the IRC SST recording, his movements were restricted to a minimum. The researcher moved only his arms and upper torso to proceed with recordings from both sites.

For some subjects, the room temperature from days 1 to 5 could be warmer by 15.6°F, and the relative humidity could be reduced by approximately 53.8% (Table 2). These 2 factors undoubtedly affect the SST.\textsuperscript{14} Thus, the graphic representation of Figs 1-4 shows this effect.

Our results indicate that room temperature and relative humidity impact the SST during the recording session. Therefore, we recommend that the manufacturer incorporate

<table>
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<th>Subject No.</th>
<th>Day 1 (F/%RH)</th>
<th>Day 2 (F/%RH)</th>
<th>Day 3 (F/%RH)</th>
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<th>Day 5 (F/%RH)</th>
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</table>

RH indicates relative humidity.

**Table 2. The daily room temperature and relative humidity (%) for each subject on each day of recording**

**Fig 6. The average temperature and relative humidity (%) for 17 subjects for the daily recordings.**
temperature and relative humidity sensors in their instrument. Coupling these 2 factors will allow for a more accurate SST reassessment index for clinicians. The software should be modified accordingly to bring to scale all recordings and represent a more stable pattern of comparison. In addition, to permit the entry of temperature and relative humidity data from previous recording days, the software should have a window for date entry to allow a more comprehensive view of patient data and reassessment. The software should also allow for the incorporation of the recording session start and end times.

In the case where the software is not yet modified or available, we recommend that the clinician use a thermometer and relative humidity measuring device in the room where the DIST is performed. The information should be recorded in the patient file for later entry when the software permits. Clinicians should be aware that the most stable time for recording starts at 8 minutes and that the recording session should be 8 minutes maximum for the best and most stable SST. Clinicians record core body temperatures from 24 different bilateral body sites; it takes approximately 10 seconds per site for a total of 240 seconds (4 minutes). Clinicians should be aware of the patient’s position during the recording of DIST. We do not recommend extracting these recordings from a seated patient, as the activity of the postural muscles while the patient is sitting influences the paraspinal temperature. Thus, although this is currently against manufacturer’s instructions on the use of the IRC, we recommend that the patient be in the prone position for recording to replicate these study results.

**Limitations**

The present data reflect the absolute values that were recorded. In our case, the room temperature and the relative humidity, which remained stable on the same day but varied from 1 day to the next (68°F-83.6°F/13.5%-65.3%), may have affected the subject’s thermoregulatory capability (Table 2). In addition, the research was conducted over a span of 5 months (July-November). During this time, the ambient temperature and humidity changes may also have an effect on the heating/cooling ventilation central system and the room temperature and relative humidity that may have affected our subject’s thermoregulation (Fig 6). Other limitations included that we did not include anthropometrics as a factor in our analysis, skin/fat thickness may have affected the rate of heat radiation, and core temperature changes over time.

The goal of this study was not to determine the differences recorded at the SST level of each segment, nor was it trying to ascertain any clinical value of thermal patterns. As well, we did not attempt to correlate any neurologic, orthopedic, or chiropractic findings to evaluate the relevancy of this evaluation method. These types of correlation should be evaluated in other studies with appropriate study designs.

**Conclusions**

We found the most stable SST trend to be between 8 and 16 minutes, with increasing volatility and dispersion in the recording pattern after the 16-minute mark. We therefore recommend a period of acclimatization in a temperature- and humidity-controlled environment for no shorter than 8 minutes and a recording period no longer than 8 minutes to remain inside the most stable interval of 8 to 16 minutes, with the patient in a prone position.
ACKNOWLEDGMENT

The authors would like to express their gratitude to the Fondation Chiropratique du Québec (Subvention à la recherche 2004-2005) for their financial support.

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