Oral Temperature Differences in Relation to Thermometer and Technique

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The validity of oral temperature measurements depends on use of an appropriate site, a dependable thermometer, and a proper technique. Fifty febrile patients and 50 afebrile volunteers were studied to determine differences in oral temperature measured in three sublingual sites with three brands of electronic thermometers and with mercury thermometers and to learn whether two methods of probe insertion (slow-slide and direct-placement) with electronic thermometers would result in differences in either the temperature reading obtained or the instrument response time. When measured with the rapidly responding electronic thermometers, temperatures in the right and left posterior sublingual pockets were significantly higher ($p<.01$) than in the area under the front of the tongue. The difference was approximately .3° F in the afebrile subjects and approximately .4° F in those with fever. With mercury thermometers, however, the temperature differences were small and not statistically significant. There was no significant difference between temperatures measured in the two posterior pockets using either electronic or mercury thermometers. There was some individual variation in the values registered by electronic thermometers at each site, although the differences between the three sites were consistent with all three instruments. Actual temperature values differed between electronic and mercury thermometers. When electronic thermometer probes were inserted into a posterior pocket using a slow-slide technique, temperature readings were higher by approximately .1° F and were obtained a few seconds faster than when the probe was put directly in place without a prewarming procedure. These differences were statistically significant ($p<.01$) but of limited clinical importance. Findings emphasized the importance of using the posterior sublingual pocket as the site for oral temperature measurement and the value of using the same instrument to obtain repeated comparable measurements.

Body temperature measurement is an important observation in assessing a person's state of health, and oral temperatures are commonly used in screening for fever and following its course. The validity of the readings depends on the use of an appropriate site, a dependable thermometer, and a proper technique. This study was done to clarify and extend the guidelines for oral thermometry.

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Background Information

Temperature varies throughout the body, and no single value is *the* body temperature. Thermal balance is most critical in the central organs of the head, chest, and abdomen (Brengelmann, 1973), but obtaining direct temperature measurements by invading vital organs or their blood supply can be hazardous and impractical. Pulmonary artery catheters with temperature sensors are not uncommon in certain acute situations, although their temperature-measuring capability is used primarily in determining cardiac output. For general clinical and home use, however, the mouth tissue under the tongue provides a safe and easily accessible site. It has a rich blood supply and is near major vessels carrying blood which reflects temperature in the core areas. Sublingual temperature has been shown to correlate well with more central measurements such as those made in the esophagus (Cranston, Gerbrandy, and Snell, 1954; Gerbrandy, Snell, and Cranston, 1954), at the tympanic membrane (Benzinger, 1969), and in central blood vessels (Cranston, 1966).

Both sublingual and rectal temperatures behave similarly in the slow changes that generally occur with fever (Wendt, Snell, Goodale, and Cranston, 1956). However, during rapid changes in central temperature, such as occur in immersion of an extremity, warm infusions, induced hypothermia, or exercise, rectal readings tend to lag behind and, therefore, are inferior to oral measurements in indicating the onset of these changes (Gerbrandy *et al.*, 1954; Molnar and Read, 1974).

Just as there is no uniform body temperature, there are variations within the mouth of 3° F or more (Hersh, Woodbury, and Bierman, 1943). The warmest areas are underneath the tongue, most specifically in the right and left posterior sublingual pockets at the base of the tongue. These heat pockets are reported to register at least .4° F (.2° C) to as much as 1.6° F (.9° C) higher than the area under the front of the tongue, as measured with electronic thermometers, with little or no difference shown between the two posterior pockets themselves (Beck and Campbell, 1975; Beck and St. Cyr, 1974; Björn, 1973; Erickson, 1976; Jones, 1973;

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Wironen, 1975). The larger back-to-front differences were reported in studies that had relatively few or unreported controls on extraneous variables which can affect oral temperature, while the smaller differences were found when study designs provided tighter controls. Whether similar differences among sublingual sites could be shown using mercury-in-glass thermometers had not been reported. Also, there are variations in manufacturers' instructions regarding the specific location under the tongue to place a thermometer. This study provided a comparison of temperature differences among sublingual sites using both electronic and mercury-in-glass thermometers.

Predictive electronic thermometers are now used in many health care settings to measure oral temperature. The claimed advantages of these instruments include greater accuracy, overall time saving, decreased cross-infection, increased safety, cost reduction, and improved patient care. Electronic thermometers do offer the convenience of a short response time, about 30-50 seconds as compared with the 6-9 minute period recommended for acceptable registration of a mercury thermometer (Nichols and Kucha, 1972). This study addressed two areas which have been controversial, the optimal site and technique for oral temperature measurement.

Manufacturers of electronic thermometers vary in their recommendations regarding the method for inserting the sensing probe, and limited research has been reported. When the bulb of a mercury thermometer of the thermistor of an electronic thermometer is placed under the tongue, the tissue it contacts cools slightly as heat is transferred into the comparatively cool (room temperature) sensing element. This effect is termed *drawdown* (Beck and Campbell, 1975). The time required for the tissue to recover its original temperature and for the thermometer to come into equilibrium depends both on the characteristics of the tissue—amount of drawdown, rate and temperature of blood flow, amount of local heat production—and on the characteristics and volume of materials used in the sensing element of the thermometer. The smaller the difference in temperature between the sensor and its placement site, the less drawdown occurs. Some manufacturers recommend a prewarming technique; for example, moving a mercury basal body thermometer to the other posterior sublingual pocket after it has warmed or taking several seconds to slowly slide the probe of an electronic thermometer into position. Other manufacturers state that putting the sensor directly into place is satisfactory. Beck and St. Cyr (1974) reported finding as much as .8° F (.4° C) difference between slowly and rapidly inserting a probe, although Beck and Campbell later stated (1975) that the problem was lessened with a newer model of electronic thermometer. Differences in instrumentation or varied requirements for accuracy may allow for differences in insertion technique. However, there are unanswered questions about the effect of different techniques on temperature readings and instrument response times. The issue seems most relevant to electronic thermometers because of their short registration time.

Purpose

The first purpose of this study was to determine if there are differences in oral temperatures of adults between three sublingual sites—right and left posterior sublingual pockets, front sublingual area—as measured with predictive electronic thermometers and with mercury-in-glass thermometers. A second purpose was to determine if there is a difference in the temperature readings and response times with the electronic thermometers using slow-slide versus direct-placement techniques of probe insertion.

Method

Definitions. For this study, definitions were:

The *right posterior sublingual pocket* is the area where the base of the tongue joins the floor of the mouth on the right side of the frenulum, and similarly on the other side is the *left posterior sublingual pocket*. The *front sublingual area* is located beneath the tongue at the front of the mouth where the frenulum attaches to the mouth floor.

An *afebrile* (normal) thermal state was defined as an oral temperature reading no higher than 99° F (37.2° C) in all three sublingual sites. *Fever* was an oral temperature reading of 100° F (37.8° C) or more in at least one site. *Adults* were persons of either sex who were at least 18 years of age. The two techniques of probe insertion, slow-slide and direct-placement, are described with data collection procedures.

Subjects. The study sample consisted of 100 adult subjects, 50 who had oral temperatures in the normal range and 50 who were febrile. The normal subjects were volunteer nursing students and nurse faculty, 4 men and 46 women, whose temperature readings did not exceed 99° F. They ranged in age from 18 to 42 years, with a mean age of 23.6 years. The febrile subjects were hospitalized patients, 14 men and 36 women, who had at least one oral temperature reading of 100° F or more. The age range was 18 to 80 years, with a mean age of 47.9 years. They were hospitalized on eight clinical nursing units for a variety of medical, surgical, gynecologic, and orthopedic diagnoses.

All subjects met the criteria of having no known oral pathology, paralysis, or surgery; no hot or cold applications to the head or neck; no observable mouth breathing or hyperventilation; and were not edentulous. They were not in acute pain or discomfort and were able to cooperate with verbal instructions. Additionally, none of the hospital patients was receiving continuous inhalation therapy, had a nasogastric or intestinal tube, or was under any category of isolation precautions.

Variables. *Major Variables.* To meet the first purpose of the study, the independent variables of *sublingual site* and *type of thermometer* were examined for their effects on the dependent variable of the measured *oral temperature.* Using electronic thermometers, nine oral temperature measurements were made for each subject, one reading in each of the three sites with three different instruments. In the afebrile subjects, temperature also was measured in each site with a mercury thermometer.

To meet the second purpose, the independent variable of electronic thermometer *insertion technique* was examined for its effect on both *oral temperature* readings and thermometer *response time.* With the afebrile subjects, six measurements were made in the left posterior pocket using two different techniques for each of the three electronic thermometers.

Controlled Variables. Several local factors known to affect temperature in or near the mouth were controlled: recent ingestion of hot or cold substances (Breinig, 1975;

Mercury vs. electronic thermometers, 1972), smoking (Björn, 1973; Mercury vs. electronic thermometers, 1972), local applications of heat or cold (Hersh *et al.*, 1943; McCaffrey, Cook, and Wurster, 1975), and local inflammatory processes (Renbourn, 1963). Subjects also were not to have recently bathed (Renbourn, 1963) or had an extremity immersed (Gerbrandy *et al.*, 1954).

To reduce the exposure of mouth tissue to the ambient temperature and convection currents, subjects were asked to close their lips during oral temperature measurements, a technique which has been shown to provide slightly higher readings (Erickson, 1976). Persons who were mouth-breathing or hyperventilating were excluded, as these factors have more prominent cooling effects and also are physiological mechanisms for body heat loss (Cranston, *et al.*, 1954; Hanson, 1974). Conversation was not encouraged, but neither was it limited entirely, thus allowing some exposure of the mouth to ambient conditions. At least 30 minutes in the room were provided for subjects' adjustment to its temperature, and extremes of temperature were avoided (Beck and Campbell, 1975).

Edentulous persons were not included, as they possibly may have larger back-to-front differences in mouth temperature, perhaps associated with more exposure to ambient air (Erickson, 1976). Whether having lower dentures may affect oral temperature readings (Beck and Campbell, 1975) has not been clearly established and was not controlled. While the assumption often is made that inhalation therapy and nasogastric tubes may affect oral temperature, these variables have thus far received limited study. However, persons having these therapies were excluded to help tighten the study design.

Activity has long been known to raise body temperature, and it is an important mechanism for body heat production (Brengelmann, 1973). A change in body position from standing to lying down causes a fall in temperature and vice versa (Cranston *et al.*, 1954). These variables were not controlled formally in the febrile subjects, based on the assumptions that the activity of a hospitalized febrile patient is likely to be limited and that each subject would be in one position in a bed or a chair when the temperature measurements were made. (Both assumptions were valid.) However, activity and body position were controlled in the afebrile group, since students and faculty could have widely varying activities prior to data collection and because of the greater length of the data-collection sessions required with this group. The possibility was recognized that they might have a slight fall in body temperature over the course of the data-collection sessions (Cranston, *et al.*, 1954). The effect on oral temperature of movement of the mouth itself, as in chewing, is debatable and was disregarded, except that subjects were not eating or chewing gum prior to and during the data collection.

Possible short-term effects of emotional excitement on body temperature (Aschoff, Fatranska, Gerecke, and Giedke, 1974; Renbourn, 1960) were controlled only insofar as providing a comfortable physical position and room temperature, a calm approach by the investigator, and, for the afebrile subjects, soft music if they considered it pleasant. Several systemic temperature changes of a longer-term nature were not controlled, such as the well-known changes associated with advancing age (Exton-Smith, 1977) and the menstrual cycle (Zuspan and Zuspan, 1974), and possible changes resulting from seasonal differences (Renbourn, 1963).

Instruments. *Electronic Thermometers.* Three predictive electronic thermometers, designated A, B, and C, were used in the study: the Diatek 400, FILAC F-520, and IVAC 811 models.[1] These instruments use a thermistor at the tip of a plastic and stainless steel probe to detect temperature changes. Thermistors are very small, rugged, and extremely sensitive temperature transducers which convert a rise in temperature to a decreased resistance to electrical current. They respond rapidly and can be used for spot precision measurements (Thomas, 1974). Some electronic thermometers operate in a steady-state mode in which they read temperature continuously and directly after coming into equilibrium. Others employ a predictive (computed) mode which is used for intermittent measurement. A predictive thermometer decreases the waiting time for a reading by using circuitry which computes the curve of heat rise reflected in the current flow through the thermistor, anticipates where the final reading will be, and displays this prediction (Beck and Campbell, 1975; Clinical electronic thermometers, 1972). The three thermometers used in the study had ranges of 94-108° F (34.4-42.2° C), had response times of 30-50 seconds, registered to tenths of a degree Fahrenheit, and displayed the temperature reading on a lighted digital panel. Accuracy was guaranteed to ±.2° F by the manufacturers. Differences among the instruments were in such features as an audible signal, 15-second timer, progressive numerical display of the temperature en route to the final reading, and access to a steady-state mode of operation.

The electronic thermometers were calibrated before and after data collection in a well-stirred water bath against a total immersion mercury laboratory thermometer certified by the National Bureau of Standards (NBS). Calibration of research instruments both before and after use validates the original testing and provides presumptive evidence of reliability when used to obtain the study measurements.

The probes of thermometers A and C, with covers, were suspended 1½ inches in the water bath, and the instruments were put in the testing (steady-state) mode according to the manufacturers' instructions. They were checked at intervals of 1° F over their entire 94-108° F range. Thermometer A had a mean error of .18° F when tested prior to data collection and .16° F afterward. The maximal variation among individual readings during the two tests was .3° F and .1° F. For thermometer C, the mean errors were .01° F before and .00° F after data collection, with a maximal variation of .2° F among the individual readings in both tests. Thermometer B did not have a dual mode of operation and could not be tested comparably. (If testing was done in the predictive rather than the steady-state mode, the infinite heat source of the water bath would cause the thermometers to overshoot and register too high.) Readings made with 10 different probe covers for each thermometer at a bath temperature of 100° F showed a variation of .1° F, the smallest difference the thermometers could indicate, except for one cover which was associated with a variation of .2° F.

Each electronic thermometer was also checked prior to use each day with its own calibration plug. This device has a built-in resistance duplicating a given temperature value and can be used to check the circuitry of the instruments, though not their probes. On every occasion, the thermometers registered within the temperature range specified on the plugs,

[1] The electronic thermometers were donated for the study by Diatek, Inc., San Diego, California; FILAC Corporation, Sunnyvale, California; and IVAC Corporation, San Diego, California.

Table 1. Schematic Presentation of Research Design

Subjects	Preparation	Data Collection Sequence		
	Explain study Verify criteria 30-minute control period	3 sites x 3 electronic thermometers = 9 temperatures (~15 minutes)	3 sites x 1 mercury thermometer = 3 temperatures (~25 minutes)	1 site x 2 techniques x 3 electronic thermometers = 6 temperatures with response times (~10 minutes)
Afebrile subjects	X	X	X	X
Febrile subjects	X	X	O	O

providing reasonable assurance of day-to-day measurement consistency.

Mercury Thermometers. Fifteen mercury clinical thermometers[2] were also used in the study. All were the same stubby-bulb model, suitable for oral or rectal use. They were graduated in .2° F intervals on a scale ranging from 92 to 106° F (33.3 to 41.1° C). The thermometers were newly purchased from a surgical supply firm and had not had previous use.

Twenty thermometers were originally calibrated in the water bath against the NBS-certified thermometer over their full range. Ten at a time, they were placed at least ½ inch apart in a cardboard holder and suspended 1 inch into the bath. Using a hand-held magnifying glass, they were read to the nearest .2° F; when the mercury column was judged to be exactly centered between two of the markings, the value was read to .1° F.

Only 1 of the 20 thermometers did not meet the current voluntary product standard, PS 39-70, for clinical thermometers which limits error to no more than ±.2° F at 98° and 102° F and no more than ±.3° F at 106° F (U.S. National Bureau of Standards, 1971). Four more thermometers were eliminated by imposing additional criteria of: 1) a more stringent proposed revision of PS 39-70 involving accuracy over ranges of temperatures rather than at a few selected points, 2) an error of ±.3° F at no more than one test point, and 3) no error of over ±.3° F at any point.

The remaining 15 thermometers were used in the study. They had mean errors varying from −.10 to +.03° F in the testing done prior to data collection. This degree of accuracy was somewhat surprising because of reports of frequent inaccuracy in mercury thermometers (Clinical thermometers, 1966).

Eleven of the 15 thermometers could not be retested after completing data collection as they were heat damaged during storage on a hot summer afternoon. (Presumably, cracks in the glass allowed air to enter the mercury column and prevent it from registering properly or being shaken down.) However, the remaining four thermometers were retested, and showed results similar to the first testing, with mean errors that either duplicated the earlier values or were different by no more than .04° F. The five thermometers that had been eliminated previously from use in the study also retested comparably to their earlier values, with mean errors no different than .06° F. Based on this information, the assumption seemed reasonable that the damaged thermometers also would have remained reliable in their level of accuracy during the six weeks between the two calibrations.

[2] Manufactured by Becton, Dickinson and Company, Rutherford, New Jersey.

Data Collection. *Febrile Subjects.* Data-collection procedures, modified from those used in a previous study (Erickson, 1976), are shown schematically in Table 1. All temperature readings with the febrile subjects were made between 3:00-4:30 P.M. and 7:00-8:30 P.M. to correspond with the hospital's routine temperature measuring times that were closest to the expected daily peak temperature that occurs in the late afternoon or early evening (Aschoff *et al.*, 1974). Febrile patients were identified from temperature records on the nursing units; also noted were persons who potentially might be febrile because of a recent temperature trend or diagnosis. Other study criteria, such as absence of oral pathology and no hot or cold applications to the head or neck, were verified from patient records or, when necessary, by direct assessment. The study was explained to potential subjects and their verbal consent to participate was obtained. They then were requested not to eat, drink, rinse their mouths, use mouth swabs, or smoke until the investigator returned and made the temperature readings some 30-45 minutes later.

Nine oral temperature measurements were taken on each subject, one in each sublingual site with each of the three electronic thermometers. A new, clean probe cover was used for each measurement. For consistency, the same slow-slide insertion technique was used with each instrument: inserting the probe at the gum line behind the lower central incisors and slowly sliding it along the gum to the back of the mouth, taking 4-5 seconds to reach the posterior sublingual pocket. For the front area, the probe was moved inward slowly from the gum line toward the frenulum, taking 4-5 seconds to reach the point where it attached to the floor of the mouth. Special care was taken to ensure slow probe insertion, careful placement of each site, snug closure of the subject's lips around the probe, maintenance of constant probe contact with mouth tissue, and not shifting the position of the probe. With half the group, the investigator stood at the right side of the bed, and with the other half at the left. The nine measurements were taken one immediately after the other in a predetermined randomized order derived from a table of random numbers. Pulse and respiratory rates were counted also for the convenience of the nursing staff. Only one set of readings was made on each subject, and approximately 15 minutes were needed to complete the sequence.

Afebrile Subjects. Students and faculty who volunteered to participate in the study came to the nursing laboratory for individual data-collection sessions. They had been requested to refrain from vigorous exercise, ingestion of hot or cold substances, and smoking immediately before the session. Most sessions were scheduled between 7:00 A.M. and 2:00 P.M. to utilize the daytime hours before the expected diurnal temperature peak. After assuming a semi-Fowler's position, each subject first rested for 30 minutes without engaging in activity other than reading. The ambient temperature varied from 71 to 80° F, averaging about 75° F.

The nine sublingual temperature measurements with electronic thermometers were then made in the same manner as with the febrile group. These readings were followed by one measurement in each site in a randomized order with a mercury thermometer; the specific thermometer was determined by having the subject draw a number. The thermometer was shaken below 92° F, carefully positioned, and left in place for eight minutes in accordance with the general recommendation of Nichols and Kucha (1972). The subject was instructed to be attentive to keeping the thermometer in the location in which the investigator had placed it, maintaining constant contact of the bulb with the mouth tissue, and keeping the lips closed snugly without biting down on the thermometer stem. If necessary, the subject was allowed to stabilize the thermometer by holding the distal end with the fingertips; this usually was required when the thermometer was in the front sublingual area as this was a more awkward position.

Using a magnifying glass, readings were made to the nearest .2° F or, if the mercury column was midway between two markings, to .1° F. The subject also read the thermometer each time as a check, although in all cases the investigator's judgment was the value recorded. The thermometers were disinfected between subjects in a solution of 70 percent isopropyl acohol with .5 percent iodine for at least 30 minutes (Frobisher, Sommermeyer, and Fuerst, 1969).

To accomplish the second study objective regarding insertion technique, six more measurements were made for each afebrile subject. Two measurements of temperature and instrument response time were made in the left posterior pocket with each of the three electronic thermometers, using slow-slide and direct-placement insertion techniques. The left pocket was an arbitrary selection. Previous studies found no significant difference between the two pockets, with the left side slightly higher in some reports (Erickson, 1976; Jones, 1973; Wironen, 1975) and the right side in another (Björn, 1973). For the slow-slide technique, the thermometer probe was inserted in the same way as in the first nine readings. For a direct placement, the probe was put directly into the posterior pocket without moving it over other tissue en route. Timing was done with a stopwatch, beginning when the probe contacted tissue and ending when the thermometer indicated a final reading. Response time was recorded to the nearest second with any half-way values recorded as the even number. The entire session, including the initial 30-minute rest period, took about 1½ hours for each subject. All data collection, for both afebrile and febrile subjects, was done by the investigator.

Protection of Human Rights. The investigator explained the purpose of the study and the procedures to be used to potential subjects and requested their consent to participate. For the hospitalized patients, the consent was verbal; for students and faculty, it was indicated via the return of a tear-off slip with a written acknowledgement of willingness to be a study subject. Any indication of reluctance to particpate was respected and subjects were free to withdraw at any time without penalty. Only a few potential subjects declined to participate. The data-collection procedures involved minimal physical risk to subjects, and little or no discomfort was associated with the repeated oral temperature measurements.

Results

Sublingual Temperatures with Electronic Thermometers. Table 2 presents the mean temperatures measured at the three sublingual sites for both the afebrile and the febrile subjects. It also includes the mean temperature differences between the sites for each group along with the ranges of individual differences.[3] As summarized in Table 3, an analysis of variance indicated that although both the site of measurement and the electronic thermometer used made a significant difference in the actual temperature values obtained ($p<.01$), the differences in temperature between the sites did not vary significantly according to which electronic thermometer was used ($p>.05$). Therefore, the results were combined for further analysis with the three electronic thermometers considered as group.

In the afebrile subjects, the mean temperature difference between the right posterior sublingual pocket and the front area was .30° F (.17° C), with individual differences ranging from −.4 to 1.5° F (−.2 to .8° C). The difference between the left pocket and the front area was .24° F (.13° C), with a range of −.5 to 1.3° F (−.3 to .7° C). The difference between the two posterior pockets was only .06° F (.03° C) and ranged from −.7 to .8° F (−.4 to .4° C). Analysis with

[3] Data for Table 2 were compiled by computer to three decimal places and later rounded to two decimal places for the report. As a result of rounding, if the mean temperatures at each site were used to calculate the temperature differences between sites, results would be slightly different than the more accurate values for the differences actually shown in the table.

Table 2. Mean Temperatures at Three Sublingual Sites and Differences between Sites with Electronic and Mercury Thermometers

Subjects	Thermometer	Sublingual Temperatures (°F)			Sublingual Temperature Differences and Ranges (°F)		
		Right Pocket	Left Pocket	Front Area	Right-Front	Left-Front	Right-Left
Afebrile	Electronics A	98.31	98.24	98.01	.31 (−.4 to .9)	.23 (−.4 to 1.2)	.08 (−.7 to .7)
	B	98.00	97.92	97.75	.25 (−.4 to 1.2)	.17 (−.5 to .8)	.07 (−.6 to .6)
	C	97.85	97.80	97.49	.36 (−.3 to 1.5)	.31 (−.4 to 1.3)	.04 (−.6 to .8)
	All electronics	98.05	97.99	97.75	.30 (−.4 to 1.5)	.24 (−.5 to 1.3)	.06 (−.7 to .8)
Afebrile	Mercury	98.16	98.16	98.10	.06 (−.2 to .4)	.06 (−.2 to .3)	−.01 (−.2 to .3)
Febrile	Electronics A	100.73	100.68	100.31	.42 (−.7 to 1.4)	.38 (−.8 to 2.2)	.05 (−.9 to 1.4)
	B	99.83	99.81	99.49	.34 (−.4 to 1.4)	.33 (−.7 to 2.0)	.01 (−.6 to 1.7)
	C	100.38	100.31	99.96	.42 (−.4 to 1.2)	.35 (−.5 to 1.1)	.08 (−.8 to 1.0)
	All electronics	100.31	100.27	99.92	.40 (−.7 to 1.4)	.35 (−.8 to 2.2)	.05 (−.9 to 1.7)

Table 3. Analysis of Variance for Thermal State, Sublingual Site, and Electronic Thermometer

Source	SS	df	Variance Estimate	F	p
Independent groups					
Thermal state (afebrile, febrile)	1125.6025	1	1125.603	551.3	<.01**
Error	200.0710	98	2.042		
Repeated measures					
Electronic thermometer	53.6514	2	26.826	386.5	<.01**
Sublingual site	21.2820	2	10.641	153.3	<.01**
Thermal state x thermometer	20.0642	2	10.032	144.6	<.01**
Thermal state x site	.5333	2	.267	3.8	<.05*
Thermometer x site	.2867	4	.072	1.0	N.S.
Thermal site x thermometer x site	.1209	4	.030	.4	N.S.
Pooled error	54.3749	784	.069		

*However, $p>.05$ with df=1,98 (conservative) and not significant. Therefore, the effect of thermal state on the temperature differences between sublingual sites is at a borderline level

**Also, $p<.01$ with df=1,98 (conservative)

Table 4. Analysis of Variance for Type of Thermometer and Sublingual Site

Source	SS	df	Variance Estimate	F	p
Repeated measures					
Type of thermometer (electronic, mercury)	3.3567	1	3.357	176.7	<.01*
Sublingual site	1.8654	2	.933	49.1	<.01*
Type x site	.8162	2	.408	21.5	<.01*
Pooled error	4.7069	245	.019		

*Also, $p<.01$ with df=1,49 (conservative)

the Bonferroni t test[4] indicated that the temperatures in the two posterior pockets were significantly higher than in the front area ($p<.01$) and that there was no significant difference between the two pockets themselves ($p>.05$).

The temperature differences found in the febrile subjects between the back and front of the mouth were about .1° F greater than those in the afebrile group. The mean difference between the right pocket and the front area was .40° F (.22° C), with individual differences ranging from −.7 to 1.4° F (−.4 to .8° C). The left-pocket-to-front-area difference was .35° F (.19° C), with a range of −.8 to 2.2° F (−.4 to 1.2° C). The difference between the two pockets was only .05° F (.03° C), with a range of −.9 to 1.7° F (−.5 to .9° C). Oral temperature was significantly higher in the posterior pockets than in the front of the mouth ($p<.01$) and there was no significant difference between the two pockets.

As shown in Table 2, each electronic thermometer registered a somewhat different mean temperature value at each site. Thermometers A and C maintained a fairly consistent relationship to each other, with about .4-.5° F (.2-3° C) difference between their readings in both groups of subjects. Thermometer B registered at an intermediate level for the afebrile subjects; but for the febrile group, its readings were another .6-.7° F (.3-.4° C) lower in relationship to the other two instruments. Assuming the latter two thermometers were reflecting reality, the values registered by thermometer B appeared to dampen at higher temperature ranges. Recall, however, that all three instruments registered similar *differences* between the sublingual sites in both normal and febrile thermal states.

Comparison of Electronic and Mercury Thermometers. Temperatures measured with the grouped electronic thermometers were compared with mercury readings for the afebrile subjects. The mean mercury reading at each sublingual site and the differences between the sites are included in Table 2.[3] The analysis of variance summarized in Table 4 indicated that temperature differences between the sites depended on the type of thermometer used. Further analysis with the Bonferroni t test demonstrated that significantly higher temperatures were not apparent in the posterior pockets when measurements were made with mercury thermometers. Although there was still a small back-to-front difference of .06° F (.03° C), this value did not have statistical significance. The mean difference between the pockets, .01° F (.006° C), was essentially nonexistent.

Each type of thermometer provided a somewhat different mean temperature at each site. The mean readings of the grouped electronic thermometers were less than those of the mercury instruments by .10° F (.06° C) in the right pocket, .18° F (.10° C) in the left pocket, and .35° F (.19° C) in the front area. Individually, however, thermometer A had readings that were higher in the posterior pockets by .1-.2° F than the values with the mercury thermometers, while thermometers B and C registered lower by .2-.4° F (.1-.2° C).

Insertion Technique. The effects of using a slow-slide versus direct-placement technique for inserting an electronic thermometer probe were studied in the afebrile subjects. Table 5 shows the mean temperature values and instrument response times obtained with each technique. The analysis of variance for these data is summarized in Table 6. The three thermometers showed the same .5° F (.3° C) variation among themselves as they did with the same afebrile subjects in the first part of the study, and they had a 10- to 15-second variation in their individual response times ($p<.01$ for both values). However, the manner in which they responded to the two insertion techniques did not vary significantly. The mean temperature for the grouped electronic thermometers using a slow-slide probe insertion was .09° F (.05° C) higher than the reading obtained with direct probe placement and was accompanied by a mean instrument response time that was 2.3 seconds faster. Both of these values had statistical significance ($p<.01$).

Other Effects. Contrary to expectation, there was no evidence that the subjects' body temperatures decreased as they

[4] In a repeated measures design, the Bonferroni t test avoids the increased chance for error that exists when repeated Student's t tests are used (Wike, 1971, pp. 72-73).

Table 5. Mean Temperatures and Response Times in Afebrile Subjects with Electronic Thermometers Using Slow-Slide and Direct-Placement Insertion Techniques

Electronic Thermometer	Temperature (°F)			Response Time (Seconds)		
	Slide	Direct	Difference	Slide	Direct	Difference
A	98.14	98.04	.10	40.4	42.6	−2.2
B	97.86	97.75	.11	46.0	47.3	−1.3
C	97.63	97.58	.05	34.2	37.5	−3.3
All electronics	97.88	97.79	.09	40.2	42.5	−2.3

Table 6. Analysis of Variance for Electronic Thermometer and Insertion Technique

Source	SS	df	Variance Estimate	F	p
Variance in Temperature					
Repeated measures					
Electronic thermometer	11.8761	2	5.938	156.3	<.01*
Insertion technique	.5633	1	.563	14.8	<.01*
Thermometer x technique	.0469	2	.023	.6	N.S.
Pooled error	9.2571	245	.038		
Variance in Response Time					
Repeated measures					
Electronic thermometer	5792.4067	2	2896.203	187.4	<.01*
Insertion technique	394.4533	1	394.453	25.5	<.01*
Thermometer x technique	46.4067	2	23.203	1.5	N.S.
Pooled error	3786.7333	245	15.456		

*Also, $p<.01$ with df = 1,49 (conservative)

lay quietly in bed over the course of the data-collection sessions. Comparable readings made during the first and second parts of the study (same afebrile subjects, electronic thermometers, left pocket site, slow-slide insertion technique) showed no lowering of temperature in spite of the 30-60 minutes that elapsed; in fact, the later readings were actually a little higher.

As expected, there was some evidence of local tissue cooling as a result of temperature drawdown from contact with the comparatively cool electronic thermometer probe. For example, when the six measurements were made in the left pocket over an approximately 10-minute period to gather data about insertion technique, the mean readings at the end of the sequence were about .1-.2° F lower than those at the beginning. Drawdown is also suggested by the finding that temperature readings were slightly higher and obtained a little faster with a slow probe insertion (tissue cooled less by a prewarmed probe).

Discussion

Sublingual Site and Thermometers. The first purpose of the study was met by determining that oral temperatures of adults were significantly higher in the posterior sublingual pockets than in the front area when measured with predictive electronic thermometers, but not when measured with mercury thermometers. Electronic readings were higher in the back of the mouth by approximately .3° F in afebrile persons and .4° F in those with fever. Differences of this magnitude begin to have practical clinical importance, since in some situations they may affect the frequency of assessing temperature status and judgments about the need for treatment.

Body heat is generated primarily in core areas, and tissue generally becomes cooler toward the periphery. The posterior sublingual pockets are closer to large vessels carrying blood that reflect central core temperature than is the area under the front of the tongue. It seems reasonable that differences between these sites would be larger as a person moved into the febrile range of body temperature. In this study, being febrile added another .1° F difference between the back and front of the mouth.

The existence and directions of temperature differences between the sublingual sites reinforce the findings of previous oral temperature studies with electronic thermometers (Beck and Campbell, 1975; Björn, 1973; Erickson, 1976; Jones, 1973; Wironen, 1975). Thus, the posterior pockets seem well established as the sites of highest oral temperature. The differences between the sites shown in this study were almost identical in size to those of a related study of febrile subjects (Erickson, 1976), but were less than reported elsewhere by a few tenths to more than 1° F. The relatively tight controls of the two similar studies may have resulted in greater reliability by limiting the number of extraneous variables known to affect oral temperature.

Although important differences were shown between temperature readings in the pockets and front area when measuring with electronic thermometers, this was not the case with mercury thermometers—at least in afebrile persons and when using the recommended eight-minute registration time. The very small back-to-front difference of .06° F (.03° C) was neither statistically nor clinically significant. Therefore, readings were comparable at the three sublingual sites. A probable explanation for this finding is that subjects had their lips tightly closed around the thermometer the entire eight minutes, thus blocking a direct cooling effect on the mouth by the ambient temperature and convection currents. Such factors would be more likely to affect the relatively exposed front area than the posterior pockets, which are protected deep in the mouth under the base of the tongue. The long registration period would allow temperature in the mouth to even out by conduction and vascular convection of heat. Presumably, there would be a greater back-to-front difference if a shorter time was used—perhaps from impatience, lack of knowledge, incorrect timekeeping, or the person's difficulty in keeping the thermometer in place a long time. The same kind of finding was reported, but to a much lesser extent, for a closed- versus open-mouth position for temperature-taking with an electronic thermometer (Erickson, 1976). The rapid response time of this type of instrument would allow little of the heat transfer effects to occur in warming the front area to a level comparable with the pockets.

This study demonstrated that there are variations among measuring instruments, and some of the differences are large enough to affect decisions based on the clinical assessment of temperature status. Interchangeable use of various types, brands, and models of thermometers could lead to error in assessment by exaggerating or underrepresenting real temperature changes or giving the appearance of change when none had occurred. This concept applies to many kinds of measuring devices. Just as successive measurements are more comparable when a person is weighed on the same scale and abdominal girth is encircled with the same tape measure, the preferable practice in clinical thermometry is to make repeated temperature measurements with the same reliable thermometer.

Insertion Technique. The second purpose of the study was met by determining that prewarming the probe of an electronic thermometer by sliding it slowly into a posterior pocket resulted in temperature readings that were approximately .1° F higher and obtained about two seconds faster than when the probe was put directly into place. While these values had statistical significance, they are of limited clinical importance. The small advantage of using the slow-slide technique with an electronic thermometer to avoid temperature drawdown may be offset by the need for instruction of personnel and patients (Mercury vs. electronic thermometers, 1972). Four to five seconds is a relatively short time, but it can seem lengthy both to the operator who is inserting the probe and to the person who is holding his mouth open during the procedure. During data collection, a number of subjects had to be reminded not to close their mouths as soon as they felt the probe, but to wait until told to do so. In the investigator's experience, personnel seldom have been observed to use the slow-slide technique, even when it was specified and clearly described in the instructions for use of the thermometer. Also, personnel who commonly have the task of temperature-taking delegated to them are often those with the least professional preparation.

Implications for Temperature Measurement. Several guidelines for oral temperature measurement can be drawn from this study. First, the preferred site for measuring oral temperature is in either the right or the left posterior sublingual pocket at the base of the tongue, and not in the area under the front of the tongue. Either pocket can be used, based on the operator's ease in placing the thermometer tip accurately and on the presence of any local oral discomfort or other factors that would contraindicate using one side. With electronic thermometers, use of the posterior pocket is essential. It is still preferred with mercury thermometers, although a satisfactory reading also can be obtained in the front area—at least when a registration time of approximately eight minutes is used. For research purposes, the posterior pocket should be used with either type of instrument.

Insertion technique is a second, but less important, consideration. For clinical purposes, placing the probe of an electronic thermometer directly into a posterior pocket is quite satisfactory, although the small advantage of prewarming the probe makes a slow-slide insertion the technique of choice for research.

A third guideline is to use the same reliable thermometer for making repeated temperature measurements. Variations associated with the use of different types and brands of instruments can be large enough to affect clinical assessment of temperature status, whereas successive readings with the same thermometer would be comparable with each other and could be correlated better with other clinical observations.

Factors known to influence oral temperature should be controlled insofar as is possible and practical, e.g., waiting about 30 minutes before taking a temperature measurement after a person has ingested hot or cold substances or smoked. That such variables are difficult to control in a busy clinical setting is acknowledged. For research, relatively tight controls should be imposed on extraneous variables that can modify oral temperature and confound study findings.

Oral temperature-taking is a common health assessment practice in both professional and home settings. Professional health personnel have an important educational function in teaching current oral thermometry guidelines. Likewise, manufacturers of temperature-taking instruments need to disseminate documented thermometry practice applicable to their products.

Other questions about oral temperature measurement remain to be answered. Recommendations for further study include determining whether local oral temperature and more central temperature measurements are affected by the presence of oxygen or other inhalation therapies, nasogastric or intestinal tubes, lower dentures or absence of teeth, and longer than transitory periods of mouth breathing. Study of variables that potentially can affect body temperature will extend the guidelines for oral thermometry practice and thereby facilitate obtaining valid temperature measurements for use in clinical practice and research endeavors. NR

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