COMPARISON OF ELECTRONIC AND GLASS THERMOMETERS: LENGTH OF TIME OF INSERTION AND TYPE OF BREATHING

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In current clinical practice, nurses assess oral temperatures with either a glass or an electronic thermometer. The research literature recommends optimum placement times at the sublingual site of 7-9 minutes (Boylan & Brown, 1985; Campbell, 1983; Clarke, 1979; Ketefian, 1975; Nichols & Kucha, 1972). Optimum placement time has been defined as the time required for 90% of the subjects' thermometers to reach maximum temperatures (highest readings) minus 0.2°F (0.1°C).

In actual clinical practice, the length of time of insertion is frequently a function of the time available and the number of nursing actions required. The length of time of actual insertion of a glass thermometer has been reported to vary from 30 seconds to ten minutes. The electronic thermometer requires only seconds. With the heavy demands on nursing personnel and the current staff shortages, this time-saving feature of electronic thermometers is a major advantage. However, there has been concern over the cost distribution and number of units required per ward. The list price for hospital purchase in Canada in 1989 was $850 for electronic thermometers and $0.66 for glass thermometers.

The required accuracy of any temperature recording for clinical practice implications should be considered. Statistical differences in methods do not always result in meaningful clinical implications. Precise temperature monitoring is important in certain situations such as pre-operative care, intensive care, or for patients receiving antibiotic treatments.

Discrepancies in the literature exist about the accuracy of comparative readings between electronic and glass thermometers. Campbell (1983) found that only 18% registered the same, whereas 58% of the electronic readings were higher and 24% were lower than glass thermometers readings. However, the reported average variance (0.22°C - 0.35°C) was small.

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With respect to whether a patient is mouth or nose breathing, temperature differences have been recorded (Erickson, 1976; Tate, Gohrke & Mansfield, 1970). Some reports suggest that the short calibration time for electronic thermometers does not allow for the drawdown effect when heat is transferred from the mouth to the cool tip of the thermometer (Durham, Swanson & Paulford, 1986; Tandler & Sklar, 1983). Mouth breathing is exhibited in various acute and chronic conditions including nasal congestion, nasal surgery and presence of nasal/oral tubes. It is interesting to note that the difference between oral and rectal readings for normal nose breathing subjects was 0.34°C - 0.53°C, while with tachypneic patients the difference was greater (0.72°C - 0.93°C). Extensive research has documented numerous other extraneous variables which could affect oral temperature readings (see Table 1).

The investigators were consulted about the clinical implications of the research literature for temperature taking practices using either electronic or glass thermometers. The Director of Nursing Research for a large Canadian university hospital wanted to revise clinical protocols to be consistent with the reported research and the hospital administration was considering whether to purchase electronic thermometers.

The following study hypotheses were formed after a review of the literature.

1. Electronic versus Glass Thermometers: The electronic thermometer will record significantly higher readings than the glass thermometer at three and five minutes of insertion time only.
2. Insertion Time of Glass Thermometers: The optimum placement time for a glass thermometer in the oral cavity will be eight minutes. Significant differences in oral temperature readings will exist only between three and five minutes and between five and eight minutes.
3. Mouth versus Nose Breathing: Mouth breathing will result in significantly lower oral temperature reading than nose breathing.

Methods

Subjects

Forty-eight university nursing students registered in a senior research course volunteered to participate as data collectors for the study. This represented a 95% participation rate from the class. Informed consent was obtained. The study had been approved by the ethics review committee at the School of Nursing. The convenience sample was randomly divided into two groups, mouth and nose breathing. No significant differences existed between the two respective groups for age ($M = 22.75, 23.96$ years), $t(46) = -1.28$, $p > .05$; for whether or not they had eaten breakfast before the experiment; whether or not they felt they were under high stress level; and whether

Table 1

Extraneous Variables Affecting Oral Temperature Readings

Variable	Source
Age	Erickson, 1980; Fox et al., 1973.
Body position (lying, sitting, standing)	Cranston, Gerbrandy & Snell, 1954.
Chewing gum	Lee & Atkins, 1972; Verhonick & Werley, 1963.
Denture wearing	Beck & Campbell, 1975; Erickson, 1976.
Emotional stress	Renbourn, 1963.
Environmental or room temperature	Campbell, 1983; Nichols & Kucha, 1972.
Exercise	Dubois, 1948.
Febrile patients	Nichols, 1972
Hormones	Blainey, 1974.
Immersion of one extremity in cold or hot water	Cranston, 1966.
Local inflammatory process	Renbourn, 1963.
Ingestion of cold or hot liquids	Beck & Campbell, 1975; Blainey, 1974; Forster, Adler & Davis, 1970; Lee & Atkins, 1972.
Intubation	
a) Nasogastric	Heinz, 1985.
b) Oral	Cashion & Cason, 1984.
Menstrual cycle	Cherniak & Feingold, 1973.
Oral placement site	Erickson, 1976; Tate, Gohrke & Mansfield, 1970; Wironen, 1975.
Oxygen administration	Dressler, Smejkal & Ruffala, 1983; Grass, 1974; Hasler & Cohen, 1982; Lim-Levy, 1982; Yonkman, 1982.
Salicylates and antibiotic therapy	Blainey, 1974.
Sex (male or female)	Nichols, 1968; Zuspan & Zuspan, 1974.
Slow-insertion technique	Erickson, 1980. Smoking Beck & Campbell, 1975; Verhonick & Werley, 1963; Woodman, Parry & Simms, 1967.
Submental fat pads	Beck & Campbell, 1975.
Tachypnea	Tandler & Sklar, 1983.
Time of day	Hardy, 1980.

they were in their first or second half of their menstrual cycle. No subjects were wearing dentures; had eaten, drunk, smoked or chewed gum in the preceding half hour; had vigorously exercised that morning; suffered from hyper- or hypo-thyroidism; had any type of mouth pathology; or were taking medications that could affect body temperature. All were afebrile.

Instruments

Thirty-nine new (New International) oral thermometers were supplied from the hospitals. They were tested for reliability prior to the experiment in a Precision-Scientific water bath. Canadian and American standards require thermometers to register within 0.2°F or 0.1°C of test range (Puritan & Bishop, 1969; Standard for thermometers: Clinical, 1971). Three thermometers were discarded from the experiment because they varied from 0.3°C, 0.2°C and 0.6°C, and one thermometer was broken during the experiment.

Twenty-five new IVAC 821 electronic thermometers with a range from 34°C to 44°C ± 0.1°C were used. This equipment had been calibrated by the company.

Design and procedure

A factorial design was used to examine the type of thermometer (electronic versus glass) and type of breathing (mouth versus nose) with repeated measures on the length of time the glass thermometer was inserted (3, 5, 8, 10, and 12 minutes). Room temperature was recorded as 74°F (24°C) before and after the experiment. The subjects had been seated quietly in the room for 30 minutes before the timed readings began. The slow-insertion technique for thermometers was demonstrated and practised. The students divided into groups of two. The role of the partner was to ensure proper and constant mouth or nose breathing; proper placement and insertion technique of the thermometers; and to double-check and record all readings.

As timing began, the electronic thermometer probe was inserted in the right sublingual pocket of the participant by the partner. At the audible sound of the electronic thermometer (beep), the reading was recorded. The glass thermometer was then shaken to 35°C, and inserted in the same right sublingual pocket using the slow-insertion technique. The temperatures were read at 3, 5, 8, 10, and 12 minutes from the starting time. Five seconds were alloted for the partner to read, double-check the temperature reading with the participant, and re-insert the thermometer. No disagreements in temperature readings existed between partners. A stop watch was used to monitor time intervals and the times were announced to the groups. This intermittent temperature recording method was adapted from Verhonick and Nichols

(1968) and has been used by others (Goodall, 1986). No significant difference was found in temperatures of afebrile subjects when the glass thermometer was inserted for 12 continuous minutes or for 12 minutes removed intermittently every one minute for five seconds. At the completion of the glass thermometer readings, another electronic thermometer temperature reading was taken. No discrepancies between the initial and latter electronic thermometer temperature readings existed. The experiment was repeated using reversed roles of participants. The same glass and electronic thermometer was used for a given subject. Each subject acted as his or her own control.

Results

Electronic versus glass thermometer

As predicted, the electronic thermometer recorded higher readings (M = 37.02°C) than the glass thermometer at 3 minutes (M = 36.83°C), $F(1,46) = 39.79$; $p < .05$, and at 5 minutes (M = 36.89°C), $F(1,46) = 23.81$, $p < .05$. However, significant differences between type of thermometer were also noted at 8, 10, and 12 minutes when mouth and nose breathing data were combined into one group, $p < .05$. The difference between the average electronic and glass thermometer reading was 0.12°C. The difference between the two types of thermometer for mouth breathing readings was 0.09°C and for nose breathing readings was 0.14°C (see Figure 1).

Insertion time of glass thermometer

The optimum placement times were found to be five minutes for mouth breathing subjects, and between five and eight minutes for nose-breathing subjects (see Figure 2). Note that after three minutes of insertion time, only 70.8% of the mouth-breathing subjects and 50.0% of the nose-breathing subjects had reached their optimum temperatures.

The main effect of insertion time of the glass thermometer on oral temperatures was significant, $F(4,184) = 23.99$, $p < .05$. All comparisons between times of insertion of glass thermometer indicated statistically significant differences. For example, the difference in oral temperatures between 3 and 5 minutes was 0.06°C, $t(47) = -3.81$, $p < .05$, and between 3 and 8 minutes was 0.09°C, $t(47) = -4.75$, $p < .05$. These small differences, ranging from 0.01 to 0.11°C, were statistically significant because of the small variance in temperatures (see Figure 3).

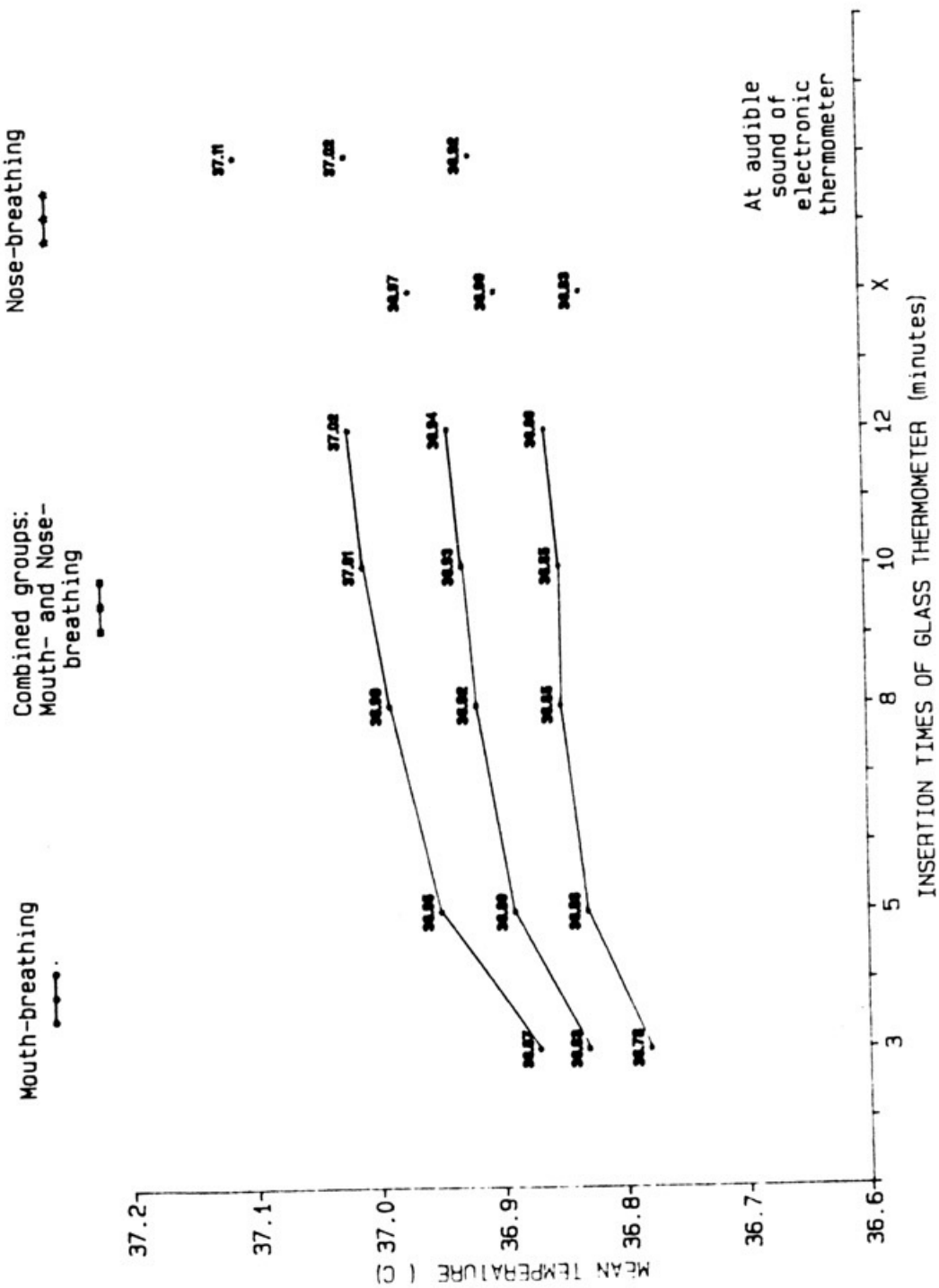

Figure 1
Comparison of mean oral temperatures at different insertion times using glass or electronic thermometers for mouth- and nose-breathing subjects

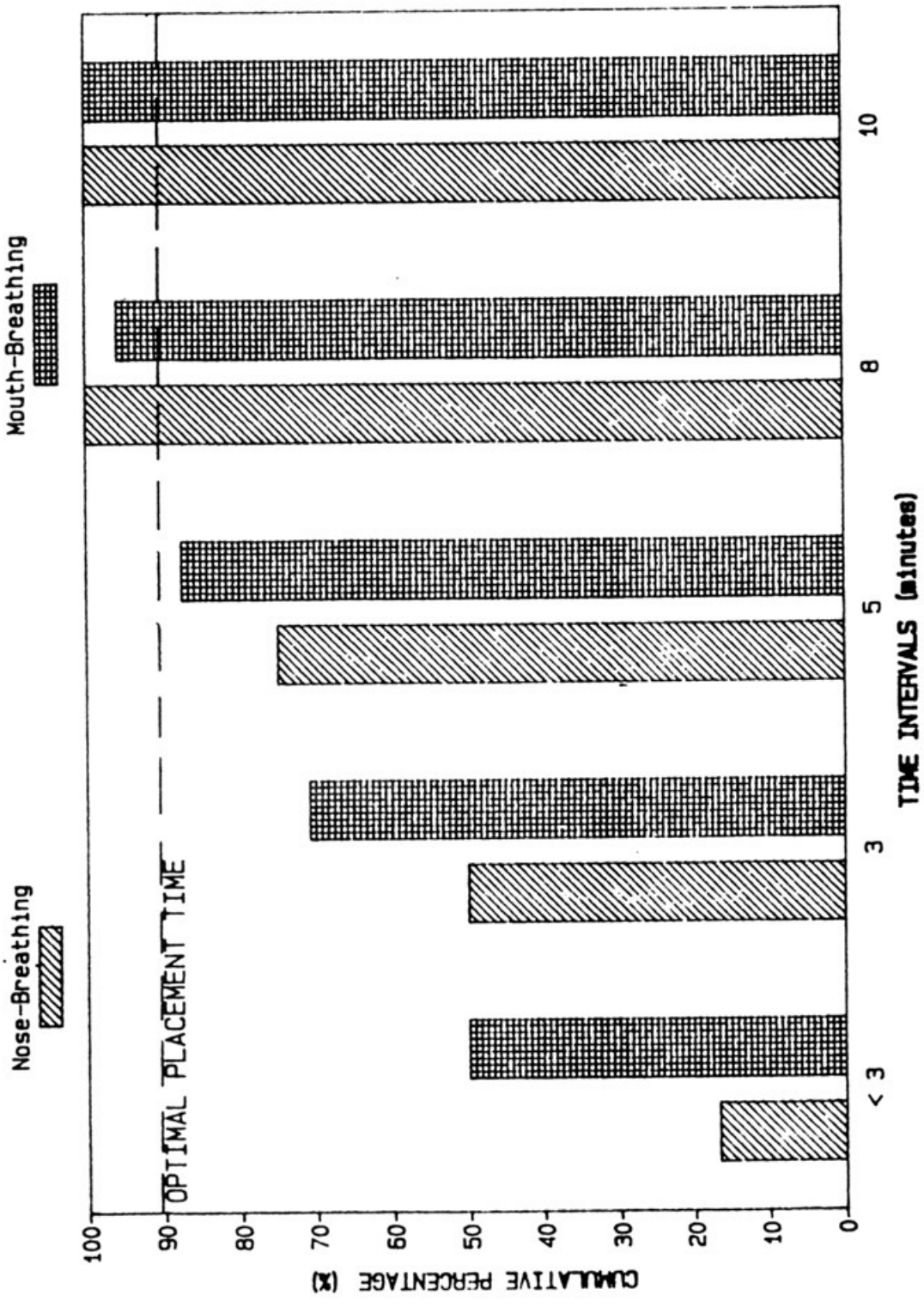

Figure 2
Cumulative percentage of optimal placement times using a glass thermometer for mouth- and nose-breathing subjects.

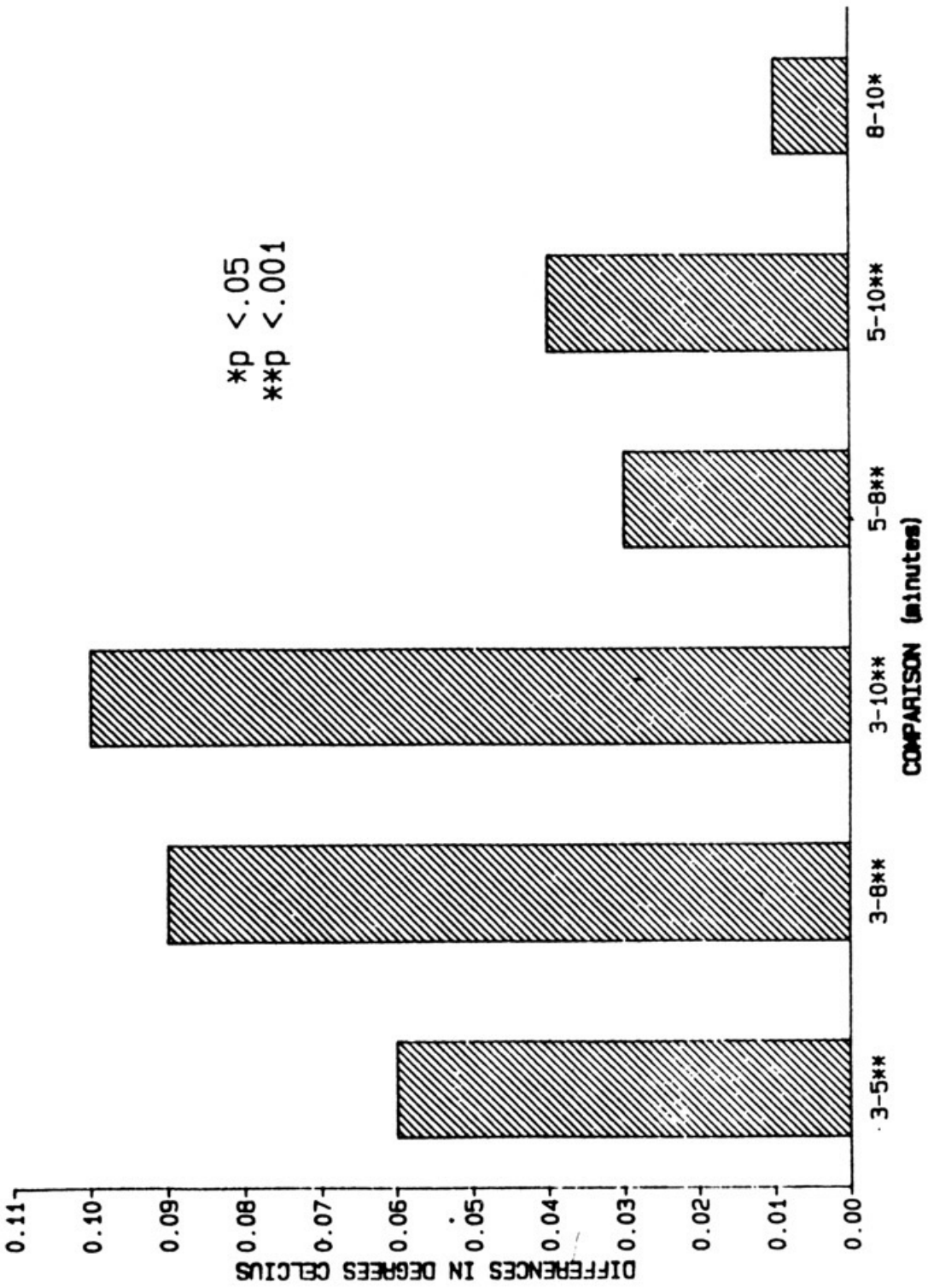

Figure 3
Differences between times of insertion of glass thermometers for mouth- and nose-breathing subjects.

Mouth versus nose breathing

In examining the other main effect of type of breathing, mouth-breathing subjects recorded 0.19°C and 0.14°C lower than nose-breathing subjects for electronic, and glass thermometers, respectively (see Figure 1). The F ratio of 4.26 (1,46) was statistically significant at the .05 level.

When controlling for the type of thermometer, type of breathing produced a statistical difference when using an electronic thermometer $F(1,46) = 5.49$, $p < .05$. For the glass thermometer, significant differences between mouth and nose breathing readings were found at 8 minutes, $F(1,46) = 4.58$, $p < .05$, 0.13°C, at 10 minutes, $F(1,46) = 5.23$, $p < .05$, 0.16°C, and at 12 minutes, $F(1,46) = 4.85$, $p < .05$, 0.16°C, but not at 3 and 5 minutes, $p > .05$.

Discussion

A key issue is to determine what degree of accuracy in measurement of temperature is clinically meaningful? Also, does the clinical context influence the requirements for precision? An isolated elevated temperature reading does not warrant a change in patient care. A pattern of increasing temperatures or consistently high temperatures of 38.5°C indicates a need for close monitoring. Failure of a thermometer to record an existing fever may mislead the nurse. Prescribed antipyretic medication or drawing of blood for cultures may be withheld. The physician's evaluation of the need to initiate or continue antibiotic therapy may also be misled. With interpretation of arterial blood gases, false temperature readings may not identify problems such as metabolic alkalosis related to fever.

In this study, conservative statistical tests indicating statistical significance did not imply clinical significance because of the existence of small variances among and within subjects. However, the electronic thermometer readings were always higher than those of the glass thermometer at all times of insertion. The 0.14°C mean difference between electronic and glass thermometer readings for nose-breathing subjects, and the 0.09°C mean difference for mouth-breathing subjects are not considered large enough to advocate changes in patient care or to warrant the use, or the purchase of electronic thermometers over glass thermometers.

The highest recorded difference, 0.24°C, between the electronic and the glass thermometer at three minutes of insertion time for the nose-breathing subjects could be considered clinically important only when the actual patient temperature is already high, 38.3°C for example. In the case of borderline temperatures, it is advised that the glass thermometer be left in place for at least five minutes or that an electronic thermometer be used.

The thermometers were checked for reliability before the study in a Precision water-bath. It is important to note that three of the brand new thermometers were not precise prior to the actual study. In practice we take for granted that new equipment is reliable. It is therefore recommended that hospital personnel have screening procedures to check for the accuracy of new and used thermometers.

When utilizing *optimum placement times* for glass thermometers, the findings of this study corresponded with Nichols & Kucha (1972). The optimum placement time for nose-breathing subjects was between five and eight minutes. The temperatures for mouth-breathing subjects were generally lower than those for the nose-breathing subjects; as such, the optimum placement time was shorter, and was determined as five minutes. However, looking at actual temperature differences among groups seems to be a more accurate way to determine whether patient care should be altered. Although each increment in temperature was statistically significant, the largest difference of 0.11°C between three and twelve minutes is hardly clinically important. Patient record forms in charts are coded in 0.1°C. Therefore, the 0.09°C difference between three and eight minutes of insertion time does not justify eight minutes as the optimum placement time. Three minutes is therefore sufficient insertion time for a glass thermometer, provided that proper placement is assured. This finding is very important as many conscientious nurses waste valuable time in leaving the glass thermometer for eight minutes. In addition, many nursing schools and agencies still advocate the eight minute optimal time for thermometer insertion.

It seems logical that mouth-breathing subjects would record lower temperature readings than nose-breathing subjects: because the tight lip-seal around the thermometer is broken and the oral cavity is thereby cooled by an evaporative process similar to panting. As expected, this study found mouth breathing produced lower temperatures than nose breathing. Mean differences of 0.14°C and 0.19°C were found when using a glass and electronic thermometer, respectively. One explanation for the results of some studies that found clinically significant temperature differences between mouth and nose breathing could be their classification of mouth-breathing subjects as tachypneic (Durham et al., 1986; Tandler & Sklar, 1983). The increased frequency in breathing among tachypneic subjects could have augmented the evaporative process of the oral cavity, consequently registering lower temperature readings. It is also possible that oral temperatures vary for lifelong mouth-breathing versus the temporary mouth-breathing subjects in this experiment.

The fast recording response of the electronic thermometer (15 to 30 seconds) did provide more precise readings for mouth-breathing subjects than the glass thermometer when the latter was inserted for only three or five

minutes. The 0.16°C difference found at ten and twelve minutes was nevertheless very small.

Recommendations

1. Health professionals can rely on the accuracy of oral temperature readings obtained from either a glass or electronic thermometer to guide their interventions.

2. For afebrile subjects, the recommended time to leave a glass thermometer at the sublingual site is three minutes.

3. When a patient's temperature is elevated or at borderline levels, a glass thermometer should be left in place for at least *five minutes* or an electronic thermometer should be used.

4. Electronic thermometers give more precise readings than glass thermometers for mouth-breathing subjects when the glass thermometer is left in the oral cavity for only three or five minutes.

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RÉSUMÉ

Comparaison entre les Thermomètres de Vitre et Electroniques: Le Temps d'Insertion et le Genre de Respiration

La litérature recommande de laisser un thermomètre de vitre au site sublingual pendant 7 à 9 minutes. Dans la pratique, le temps d'insertion varie entre 30 secondes et 10 minutes, et dépend du temps disponible et des demandes de l'infirmière. Le thermomètre électonique requiert seulement quelques secondes. Cependant, le thermomètre électronique est partagé par plusieurs infirmières et le coût d'achat est relativement élevé. Y a-t-il un avantage d'acquérir un thermomètre électronique surtout quand le traitement de certaines conditions cliniques exigent des températures exactes? Cette étude comparait les températures de 48 sujets afébriles respirant par la bouche et par le nez. Les lectures du thermomètre de vitre inséré pendant 3, 5, 8, 10 et 12 minutes ont été comparées aux lectures du thermomètre électronique.

Les recommendations de cette étude sont les suivantes: 1) Les décisions cliniques peuvent être guidées par les températures obtenues par un thermomètre de vitre ou électronique; 2) Les thermomètres électroniques offrent plus de précision que les thermomètres de vitre si ces derniers sont laissés seulement pendant 3 ou 5 minutes pour les sujets qui respirent par la bouche; 3) Le thermomètre de vitre doit être laiser pendant trois minutes au site sublingual; 4) Le thermomètre de vitre devrait être laissé en place pour au moins 5 minutes, ou un thermomètre électronique devrait être utilisé si les températures d'un patient sont élevées ou approchent la limite.