Original Article

A Cross-Sectional Study on Reference Ranges of Normal Oral Temperatures Among Students in Singapore

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Abstract

Introduction: During the 2003 Severe Acute Respiratory Syndrome (SARS) outbreak, all schools in Singapore implemented twice-daily temperature monitoring for students to curtail the spread of the disease. Students were not allowed to attend school if their temperature readings were >37.8°C for students ≤12 years old, or ≥37.5°C for students >12 years old. These values had been arbitrarily determined with professional inputs. The aim of this study is to determine the reference ranges of normal oral temperatures of students in Singapore and recommend the cut-off values for febrile patients. This may be used in another similar outbreak of an infectious disease with fever. Materials and Methods: Four co-ed primary schools and 4 co-ed secondary schools were selected for this study. Four thousand and two hundred primary 1 to secondary 3 students responded (96.8%) and participated in this cross-sectional study. The mean ages of the students in the lowest (primary 1) and highest educational levels (secondary 3) were 7.4 years old and 15.3 years old, respectively. Twelve oral temperature readings per student (i.e. measurements taken 4 times a day in 3 consecutive days) were collected. Forty-six thousand seven hundred and eighty-three (92.8%) out of 50,400 temperature readings were used for the analysis as missing data were excluded. A quantile regression model was applied to estimate reference ranges of normal oral temperatures for students with adjustment for potential confounding factors. Results: The age-specific reference ranges of normal oral temperature from this study for students ≤12 years old and >12 years old were 35.7°C to 37.7°C and 35.6°C to 37.4°C, respectively. Temperatures of 37.8°C and 37.5°C are therefore recommended as the oral temperature cut-offs for those ≤12 years old and >12 years old, respectively. Conclusion: This study has provided empirical data on normal oral temperature cut-offs which could be used during temperature screening in schools.

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Key words: Cut-offs, Infectious diseases, SARS

Introduction

Severe acute respiratory syndrome (SARS), an infection caused by the SARS Coronavirus (SARS-CoV), was imported into Singapore in late February 2003 by a local resident who came back to Singapore from a holiday in Hong Kong. The 2003 SARS outbreak in Singapore began on 1 March 2003 and the last case was isolated on 11 May 2003.[1,2] The WHO surveillance case definition of SARS for a suspect case includes a history of high fever (>38°C), one or more respiratory symptoms, including cough, shortness of breath and difficulty breathing, and close contact within 10 days before onset of symptoms with a person who has been diagnosed with SARS or with a history of travel within 10 days before onset of symptoms to an area with reported foci of SARS transmission.[3]

During the SARS outbreak in Singapore, there was much concern that febrile but otherwise asymptomatic children infected with SARS may unknowingly spread the disease within their schools. All schools in Singapore had implemented mandatory body temperature monitoring for all their students twice daily during the period of 30 April 2003 to 25 July 2003. Students were issued with personal oral digital thermometers to measure their body temperature, and they were not allowed to attend school if their temperature reading was >37.8°C for students ≤12 years old or ≥37.5°C for students >12 years old.[4,5] With

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this screening procedure in place, some students who may be asymptomatic could not attend school due to high temperatures screened.[6]

These screening cut-off values had been arbitrarily determined with professional inputs based on the clinical experience and common understanding of what constitutes the normal range of temperatures for a healthy school-age child.[7,8] Due to a lack of support of empirical evidence from any local studies, there is a need to conduct a local study to determine the appropriate cut-off for normal body temperature using local data for school-age children. There are some known internal and external factors, which have been shown in studies to affect oral temperature readings. These include variation in body core temperature, age, sex, ethnicity, pharmacologic agents, exercise, ambient temperature and humidity, intake of foods and fluids.[9-11]

The objectives of this study are to determine the reference ranges of normal oral temperatures of school-going children in Singapore adjusting for internal factors (i.e. sex, age, ethnicity, body mass index) and external factors (ambient temperature, the time of day) that can confound oral temperature readings and to recommend the body temperature cut-off values to be used by schools for determining whether their students should be allowed to attend school in the event of another outbreak of SARS or other infectious diseases with fever.

Materials and Methods

This study was a joint collaborative study conducted by the Health Promotion Board, Ministry of Education, Ministry of Health and National University Hospital during the 2nd and 3rd week of November 2003. Four co-ed primary schools and 4 co-ed secondary schools were pre-selected to represent typical schools from the 4 geographical zones of Singapore and these schools were located within the neighbourhoods of the community. Three classes were randomly chosen from each educational level from primary 1 to primary 6 in the 4 primary schools and from secondary 1 to secondary 3 in the 4 secondary schools to take part in this study. A total of 72 classes and 36 classes were selected from the 4 primary and 4 secondary schools, respectively. All students in the selected classes were invited to participate in the study. Four thousand three hundred and thirty-seven students responded.

Before the study fieldwork started, letters were sent to the school principals to inform them of the study. Teachers of the selected classes were briefed by school nurses on the study procedures and the aims of the study. Specific instructions were given to the teachers to ensure that all precautions had been taken for accuracy of temperatures taken. Teachers ensured that the students had not eaten, drunk, exercised or played or been in a hot environment for at least 30 minutes prior to temperature taking. The temperatures were taken on the following schedules: before recess, before physical education (PE), at least 30 minutes after recess, at least 30 minutes after PE, and at least 30 minutes after students had settled in their respective classrooms in the morning as well as in the afternoon. Standard instruction sheets were also given to the selected classes' teachers with standardised procedures of temperature-taking and recordings by the students in school.

Letters were also sent to parents to explain to them about the aims of the study and that participation is voluntary. Parents who agreed to participate in the study were requested to complete a health questionnaire on the students and to supervise temperature-taking and recording of readings by the students at home. These parents also received the same written instructions on supervision of temperature-taking and recording as the class teachers. The health questionnaire to be completed by the parents included information on their child's date of birth, gender, ethnicity and information on any medical history of chronic medical illness as well as a history of regular medication. The health questionnaires were collected by the teachers-in-charge a few days prior to the commencement of the temperature taking exercise.

Each student who participated was issued with a new oral digital thermometer and was instructed to take 4 oral temperature readings within each day for 3 consecutive days. The time periods for these 4 temperature readings were from 8.30am to 9.30am (morning), 11.30am to 2.00pm (noon), 3.30pm to 5.00pm (afternoon), and 8.00pm to 9.30pm (night), respectively. To ensure that temperatures are taken and recorded correctly, School Health Service (SHS) nurses briefed the teachers-in-charge of all classes as well as demonstrated the procedure on how to take temperatures during their pre-study visit to the schools. In addition, during the temperature-taking exercise, nurses were in the schools in the classrooms to help the teachers-in-charge supervise the students during the temperature taking exercises. The temperature readings were also verified by the class teacher when the temperature readings were taken in school, and by the parent or guardian when taken at home. Instructions were given to the students to record the temperature readings taken in schools and at home on forms provided. The distribution and collection of all forms were done through the class teachers who then returned them to the school nurses.

Height and weight measurements of the students in the selected classes were taken by the school nurses a day before the 3-day temperature-taking period started. During the 3-day study period, students with temperatures above 37.5°C were reviewed by the school nurse who would screen the students for common symptoms related to acute febrile illness, that is, runny nose, cough, vomiting, diarrhoea,

rash, body pain and sore throat. The presence and absence of these symptoms were captured by nurses in specified forms. Students with persistently elevated temperatures were referred for further medical assessment.

Statistical Analyses

All the students' temperature recording forms and health questionnaires were checked by the school nurses who conducted follow-up with students and parents to verify any doubtful or incomplete information provided in the returned forms and questionnaires. The study data collected were entered into the MS Access databases. Chi-squared test and t-test were used to test the associations and differences of temperature readings among the internal and external independent factors whichever appropriate.

The reference ranges of normal oral temperature for school students were estimated from predicted 1st and 99th percentiles by using a multivariate quantile regression model[12] with adjustment for potential internal and external factors that could affect the temperature readings. Furthermore, in order to obtain robust statistical significance of estimates, the standard errors of regression estimates were obtained using the Bootstrapping method with 100 re-samples.

The cut-off temperature values determined by the predicted 99th percentile values were estimated using the quantile regression model as described above. All analyses were based only on the data from students who were well. The "well students" are defined as those students without chronic medical illness reported, not on regular medication, not feeling sick, and without any one of the following symptoms, that is, runny nose, cough, vomiting, diarrhoea, rash, body pain and sore throat at the time of the study. In all the analyses, *P* values of less than 0.01 were considered to indicate statistical significance to account for possible deflation of standard errors arising from repeated measurements within students. All statistical analyses were conducted using statistical software Stata version 8.0.

Results

Study Population

A sample of 4,337 students was originally selected from the master list. Of these students selected to take part in the study, an eventual total of 4,200 students participated in the study.

Out of the total enrolment of 4,337 students from the selected 72 primary classes and 36 secondary classes, an eventual total of 4,200 (96.8%) students participated in the study. The non-participants were students who were absent from school during the period of study. The numbers of participating students per class in the primary schools and in the secondary schools ranged from 30 to 42 students and from 25 to 43 students, respectively.

Table 1. Distribution of Students by Sex and Ethnic Group

	Sex		
	Male	Female	Total
Ethnic group	N (%)	N (%)	No (%)
Chinese	1,629 (84.6)	1,960 (86.2)	3,589 (85.5)
Malay	203 (10.5)	225 (9.9)	428 (10.2)
Indian	74 (3.8)	61 (2.7)	135 (3.2)
Other	18 (0.9)	27 (1.2)	45 (1.1)
Missing	2 (0.1)	1 (0.0)	3 (0.1)
Total	1,926 (45.9)	2,274 (54.1)	4,200 (100)

Table 2. Mean and Range of Student's Age (in Years) by Educational Level

Educational level	Mean	Minimum	Maximum
Primary 1	7.4	6.9	8.0
Primary 2	8.4	7.9	9.2
Primary 3	9.4	8.3	11.0
Primary 4	10.4	8.9	13.7
Primary 5	11.4	10.9	13.5
Primary 6	12.4	11.9	16.6
Secondary 1	13.4	12.9	16.7
Secondary 2	14.4	13.9	17.9
Secondary 3	15.3	14.9	18.7

Of the participants, 54.1% (2,274 students) were females. The majority of the participants were Chinese (85.5%), followed by Malays (10.2%), Indians (3.2%) and other ethnic groups (1.1%). Three students with missing ethnicity data were excluded from the data analyses (Table 1).

In this study, the mean ages of students in the lowest educational level (primary 1) and highest educational level (secondary 3) were 7.4 years old and 15.3 years old, respectively (Table 2).

Oral Temperature Readings

In the data analysis of the temperature readings, a total of 46,783 (about 92.8%) out of 50,400 (4,200 students x 12 readings per student) temperature readings were used as missing data were excluded from the data analyses.

The means and standard deviations of oral temperature readings by class ranged from 36.5°C to 37.2°C and from 0.3°C to 0.5°C, respectively (Table 3). The 50th percentiles (i.e. medians) and 99th percentiles ranged from 36.5°C to 37.2°C and from 37.2°C to 39.3°C, respectively (Table 4).

Factors Affecting Oral Temperature Readings

As shown in Table 5, multiple quantile regression analyses demonstrated that there were some statistically significant associations between both 50th and 99th percentiles of oral temperature readings, and sex, ethnic group, body mass index and study time of day in our study-females were observed to have higher oral temperature readings when compared with their male counterparts. Malays, Indians and other ethnic groups had higher oral temperature readings when compared with the Chinese and oral temperature readings were linearly associated with body mass index (BMI).

In addition, the analysis showed that there was an inverted "V-shaped" relationship between temperature and the study time of day-the oral temperature readings increased from morning and peaked at noon and/or afternoon and declined at night. Comparing the readings taken over the 3 study days, there were no statistically significant differences observed in temperature readings at the 99th percentile readings. At the 50th percentile, there was a significant difference in temperature readings measured on Day 3 when compared with Day 1.

Reference Ranges and the Recommended Temperature Cut-offs

By inspecting observed students' oral temperature readings with the predicted 1st, 50th and 99th percentile curves obtained by fitting quantile regression models with adjustment for age, sex, race, BMI and time of the day, the declining trends of oral temperature readings as age increased were shown (data not shown).

As shown in Table 6, the age-specific reference ranges of oral temperature for the school students aged 12 years and below (or equivalently studying in primary 1 to 6)

Table 3. Mean and Standard Deviation (SD) of All Students' Oral Temperature Readings (in Degrees Celsius) by School, Educational Level and Class *

		Primary schools											
		Pr Sch A			Pr Sch B			Pr Sch C			Pr Sch D		
Educational level		Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
Primary 1	Mean	36.9	37.0	37.0	36.8	36.8	36.9	36.8	37.0	37.0	37.2	37.1	36.9
	SD	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.5
Primary 2	Mean	36.9	36.9	36.9	36.8	36.9	36.8	36.7	36.8	36.8	36.9	37.0	36.8
	SD	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Primary 3	Mean	37.1	36.9	36.8	36.9	36.7	36.6	36.8	36.8	37.1	37.0	36.8	37.0
	SD	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4
Primary 4	Mean	36.9	36.9	36.7	36.8	36.8	36.7	36.7	36.8	36.7	36.8	37.0	36.8
	SD	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.4	0.4
Primary 5	Mean	36.8	36.9	36.9	36.7	36.7	36.7	36.8	36.6	36.7	36.8	36.9	36.9
	SD	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4
Primary 6	Mean	36.8	36.7	36.6	36.7	36.7	36.7	36.7	36.6	36.6	36.7	36.8	36.9
	SD	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.4	0.4	0.3	0.3

		Secondary schools											
		Sec Sch E			Sec Sch F			Sec Sch G			Sec Sch H		
		Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
Secondary 1	Mean	36.7	36.7	36.8	36.8	36.7	36.7	36.6	36.7	36.6	36.7	36.7	36.7
	SD	0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3
Secondary 2	Mean	36.8	36.6	36.7	36.7	36.7	36.7	36.7	36.6	36.6	36.6	36.7	36.7
	SD	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.3	0.3
Secondary 3	Mean	36.6	36.8	36.7	36.6	36.8	36.7	36.5	36.5	36.5	36.5	36.6	36.7
	SD	0.3	0.3	0.4	0.4	0.4	0.3	0.4	0.4	0.3	0.5	0.3	0.3

* The study schools have been renamed as "Pr Sch A" to "Pr Sch D" for the primary schools, and "Sec Sch E" to "Sec Sch H" for the secondary schools, respectively. The 3 selected study classes within the schools have been renamed as "Class 1" to "Class 3".

Table 4. Median and 99th (P99) Percentile of All Students' Oral Temperature Readings (in Degrees Celsius) by School, Educational Level and Class*

		Primary schools											
		Pr Sch A			Pr Sch B			Pr Sch C			Pr Sch D		
Educational level		Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
Primary 1	Median	37.0	37.0	37.0	36.9	36.9	37.0	36.9	37.0	37.0	37.2	37.1	36.9
	P99	37.8	37.9	37.8	37.6	37.8	37.8	37.6	37.6	37.9	38.1	38.0	37.8
Primary 2	Median	37.0	37.0	37.0	36.8	36.9	36.8	36.7	36.8	36.8	37.0	37.0	36.9
	P99	37.8	37.8	37.6	38.0	37.8	37.6	37.4	37.7	37.5	37.8	37.8	37.6
Primary 3	Median	37.1	36.8	36.8	36.9	36.8	36.6	36.9	36.9	37.0	37.0	36.9	37.0
	P99	38.0	37.6	37.5	37.7	37.6	37.4	37.7	37.6	38.4	37.7	37.7	37.8
Primary 4	Median	36.9	36.9	36.8	36.8	36.9	36.8	36.6	36.9	36.7	36.8	37.0	36.9
	P99	37.8	37.5	37.6	37.6	37.6	37.5	37.3	37.5	37.3	37.4	39.3	37.4
Primary 5	Median	36.8	36.9	37.0	36.8	36.8	36.8	36.8	36.6	36.8	36.9	37.0	37.0
	P99	37.6	37.7	37.7	37.5	37.6	37.6	37.4	37.5	37.7	37.6	37.7	37.6
Primary 6	Median	36.8	36.8	36.7	36.7	36.7	36.7	36.6	36.5	36.6	36.8	36.8	36.9
	P99	37.5	37.4	37.2	37.4	37.3	38.2	37.6	37.3	37.6	37.7	37.5	37.5
		Secondary schools											
		Sec Sch E			Sec Sch F			Sec Sch G			Sec Sch H		
		Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
Secondary 1	Median	36.7	36.7	36.8	36.8	36.7	36.7	36.6	36.7	36.7	36.7	36.8	36.7
	P99	37.4	37.4	37.6	37.6	37.4	37.4	37.4	37.3	37.3	37.3	37.3	37.3
Secondary 2	Median	36.8	36.6	36.7	36.8	36.8	36.8	36.7	36.6	36.6	36.7	36.8	36.8
	P99	37.5	37.5	37.5	37.3	37.3	37.3	37.5	37.5	37.3	37.2	37.4	37.2
Secondary 3	Median	36.6	36.8	36.8	36.7	36.8	36.7	36.6	36.5	36.5	36.6	36.6	36.7
	P99	37.2	37.4	37.4	37.2	37.4	37.3	37.3	37.3	37.2	37.3	37.2	37.4

* The study schools have been renamed as "Pr Sch A" to "Pr Sch D" for the primary schools, and "Sec Sch E" to "Sec Sch H" for the secondary schools, respectively. The 3 selected study classes within the schools have been renamed as "Class 1" to "Class 3".

were 35.7°C to 37.7°C. The students aged above 12 years (or studying in secondary 1 to secondary 3) were 35.6°C to 37.4°C. These ranges were based on predicted percentile values which were estimated from the fitted quantile regression models with adjustment for sex, age, race, BMI and time of the day. Based on these reference ranges, the recommended oral temperature cut-offs for students in our study could be set at 37.8°C for those who are ≤12 years old and 37.5°C for those who are >12 years old (Table 6).

Discussion

During the SARS outbreak in 2003, there was large-scale nationwide temperature screening in all Singapore schools. If a student had an elevated temperature based on the temperature reading cut-offs provided by the Ministry of Health, he/she would be isolated immediately and not allowed to attend school. Those students with persistently elevated temperatures were referred for further medical evaluation. Chng and colleagues[5] reported that only 9.0% of the school children referred had an identifiable pathological cause.[5] The pathologies were mild, ranging from dental to respiratory infections. In this study, less than 3% of school students had any chronic medical illness and on any regular medication, and less than 1% of school students had any 1 symptom during the study period (data not shown).

Heat is generated in our body through chemical reactions of metabolism. The higher the metabolic rate, the more heat is generated. Young children have higher metabolic rates than adults. The metabolic rate in our body is influenced by hormones (such as growth hormone and thyroid hormones), physical activity levels, diurnal rhythms, food consumption and for females, by their menstrual cycle.[13] Taking these points into consideration, specific precautions had been taken to ensure that factors such as food consumption

Table 5. Regression Model Analyses of Variable Associated with Oral Temperature Readings at 50th And 99th Percentiles

	Dependent variable used in two separate models					
	Oral temperature readings at 50th percentile			Oral temperature readings at 99th percentile		
Independent variables	**Coefficient**	**t-statistic#**	***P* value***	**coefficient**	**t-statistic#**	***P* value***
Age	-0.0575	-6.25	0.000	-0.0630	-2.83	0.005
Age2 (squared term of Age)	0.0008	2.00	0.045	0.0003	0.30	0.765
Sex						
Male vs Female	-0.0310	-6.43	0.000	-0.0447	-3.75	0.000
Ethnic groups						
Malay vs Chinese	0.1226	19.77	0.000	0.1257	5.16	0.000
Indian vs Chinese	0.0485	4.12	0.000	0.0682	2.84	0.004
Other vs Chinese	0.0502	2.56	0.010	0.1246	1.89	0.059
Body mass index (BMI) (kg/m2)	0.0040	6.07	0.000	0.0044	2.23	0.026
Study day						
Day 2 vs Day 1	0.0041	0.81	0.415	-0.0046	-0.29	0.775
Day 3 vs Day 1	0.0223	4.01	0.000	0.0183	1.42	0.156
Study time						
Noon vs Morning	0.1884	31.45	0.000	0.1073	6.69	0.000
Afternoon vs Morning	0.1828	27.88	0.000	0.1368	6.59	0.000
Night vs Morning	0.0621	7.94	0.000	0.0148	0.80	0.42

The standard errors of estimates were obtained by using the bootstrap re-sampling method with 100 replications.

Table 6. Age-specific Normal Reference Ranges for Normal High Fever (based on predicted percentile values which were estimated from the fitted quantile regression models with adjustment for sex, age, race, BMI and time of the day)

Age (y)	**Educational level**	**Age-specific normal reference ranges in ˚C (1st – 99th percentile)**	**Recommended* normal high temperature cut-offs (in ˚C)**
7	Primary 1	35.7–37.7	37.8
8	Primary 2	35.7–37.7	37.8
9	Primary 3	35.7–37.6	37.8
10	Primary 4	35.7–37.6	37.8
11	Primary 5	35.7–37.5	37.8
12	Primary 6	35.7–37.5	37.8
13	Secondary 1	35.6–37.4	37.5
14	Secondary 2	35.6–37.4	37.5
15	Secondary 3	35.6–37.3	37.5

* the 99th percentile values were used as the cut-offs.

and physical activity did not interfere with temperature readings taken during the study. The class teachers also helped to ensure that the students had not eaten, drunk, exercised, played or been in a hot environment for at least 30 minutes prior to temperature-taking and they also complied with step-to-step instructions provided on printed instruction sheets which aimed to standardise procedures of temperature-taking and recordings by the students in the school. Similar instructions were provided for parents who supervised the temperature-taking process at home.

In our study, it was shown that internal factors such as age, sex and ethnic groups, and external factors such as time of day when the temperature readings were taken, had some influence on body temperature readings. In a study by Linda S Smith, she examined variables affecting temperature measurement in adults and she reported that the temperature readings varied by age and race. The greater the age, the lower the temperature readings.[10,11] It was observed from our study that girls have higher temperatures than boys.[11] This could possibly be explained by the physiologic changes to body temperature that occurs in females during their menstrual cycle where a rise in progesterone production around ovulation causes a sustained rise in body temperature of around 0.5 degrees. The influence of race on temperature readings was also noted in other investigations by Gillum and McGann et al.[11,14] As quoted in these studies, there is a need to have more in-depth investigation and research to better understand the influence of factors such as ethnicity, sex and age on oral temperature readings.

There is currently a lack of information from studies on normal temperature ranges among school children especially in tropical countries such as Singapore. Kojiri Ishii reported the range of normal body temperature among school boys in his investigation into the problem of low temperature in Japanese students.[15] In Ishii's study of oral temperature in Japanese boys, he reported that the range of oral temperature readings of 4th to 6th year elementary school boys were from 35.30^{o}C to 37.40^{o}C, the range of oral temperature readings of 1st to 3rd year junior high school boys were from 35.45^{o}C to 37.14^{o}C, and the range of oral temperatures of senior high school boys were from 35.40^{o}C to 36.72^{o}C.[14] In our study, the analysis from the fitted quantile regression models (adjusted for the confounding factors), showed the age-specific normal oral temperature range for younger school children in primary schools aged 7 to 12 years old were from 35.7^{o}C to 37.7^{o}C and for the older school children in secondary schools aged 13 to 15 years old, from 35.6^{o}C to 37.4^{o}C. The temperature ranges for the Singapore school children were higher than the Japanese boys. This could be due to the differences in the study conditions such as the differences in climate.

To our knowledge, this is the first local study conducted with the aim of determining the reference ranges for oral temperature readings for school children in Singapore. From the information on reference ranges among the students in our study, the normal high temperature cut-offs can be derived, that is, 37.8^{o}C for ≤12 year olds and 37.5^{o}C for >12 year olds in this study group. This supports the cut-offs that were used for the temperature screening in schools during the 2003 SARS outbreak in Singapore.

Although the reference ranges and the recommended normal high temperature cut-offs are useful tools in deciding which school children should not be allowed to attend school or should be referred for further evaluation, we must exercise caution if the tool is to be applied clinically. For any given febrile or unwell student, it is also important to take into account associated risk factors, co-existing and biologically plausible medical conditions through careful history-taking and medical assessment.[8] The recommended temperature ranges and cut-offs serve as a general guideline, and the decision to classify him/her with a potential of being infected with SARS or any febrile-related infectious disease, should only be made upon further medical evaluation.[16-18]

There are some limitations to this study which include the possible selection bias from the convenience of selection of schools and classes to be included in the study. Another limitation is the recall bias from information reported in the health questionnaires by parents. Measurement bias may also occur as oral temperature readings are taken and recorded by the students under the close supervision of the class teachers. Nurses assigned to each participating school conducted checks during the study period to ensure that all procedures of temperature taking and recording were compiled by the study participants. One aspect which might need to be further investigated is the effect of ambient temperature on body temperature although in tropical countries such as Singapore, there is not much variation in the climate unlike in temperate countries. Another aspect which would also influence the body temperature measurement that we did not consider in this study is some environmental factors, such as whether the body temperature was taken in a very cold air-conditioned room or immediately after doing exercise. However, in order to minimise effects of the latter, teachers would ensure that students had not eaten, drunk, exercised, played or been in a hot environment for at least 30 minutes prior to temperature-taking.

There was also another consideration for our study, that is, whether oral temperature was the best way for determining body temperature. The Community Paediatrics Committee of the Canadian Paediatric Society recommends the oral or sublingual route for temperature readings for children above 5 years old.[19] In an evidence-based review by El-Radhi and Barry on pediatric thermometry, it was concluded that the oral temperature was more accurate than the axillary

site.[20-23] The disadvantages in this method includes factors which would affect the reading as stated earlier (e.g. exercise, hot and cold drinks, etc). There is variation in the temperature recorded from the sublingual area depending on exactly where the bulb of the thermometer is placed.[23] There have been recent studies which have shown tympanic temperatures to be accurate.[20,24,25] This option was not used for the study due to cost consideration as compared to oral thermometers.

Conclusion

In the context of temperature screening among school children in Singapore during an infectious disease outbreak such as SARS, this study has provided empirical data on normal temperature cut-offs which can support the decisions on which school children are to be isolated and further evaluated medically. In conclusion, the normal high temperature cut-offs obtained from this study, that is, 37.8°C for ≤12 year olds and 37.5°C for >12 year olds support the cut-offs that were used for the temperature screening in schools during the 2003 SARS outbreak in Singapore. The study also highlights some factors that could influence the temperature readings such as sex, ethnic group, body mass index, and study time of day. Although the reference ranges and the recommended normal high temperature cut-offs are useful tools in screening school children for febrile conditions, it is important to conduct a full clinical evaluation before classifying the child with a potential of being infected with any febrile-related infectious disease.

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