Reliability and Accuracy of Digital Thermometers Used by Veterinary Professionals to Determine Temperatures of Animals

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Abstract

The purpose of this study was to determine the accuracy and reliability of thirty two different thermometers used to measure animal's rectal temperature. Thermometers are important in all medical fields, both human and veterinary alike. Accuracy and reliability of these tools are critical to determine the best treatment options for ill patients. A statistical analysis was run using SigmaPlot 12.5 to determine thermometer reliability while simple mean calculations measured accuracy. In total thirty two thermometers were tested in three water baths set at 35°C, 38°C, and 40°C. These temperatures represent a hypothermic state, normal animal body temperature and a hyperthermic state respectively. Each thermometer was tested seven times per temperature and compared to a true temperature measured by a National Institute of Standards and Technology (NIST) thermometer. There is a strong correlation between accuracy and reliability and all thermometers that were the most accurate were found to be the most reliable. A used Walgreens brand thermometer model VT801SWT was the most reliable and accurate overall. Results also show that new thermometers are more accurate than used ones with a few exceptions. A Reli-On two-second thermometer lot 4414 was the most unreliable with widely skewed results. Significant differences were not detected between human and animal thermometers. This experiment demonstrated that some thermometers are more reliable than others and that health care professionals should not trust thermometers that read temperatures in two seconds.

Introduction

Thermometers are common tools utilized in the medical field to determine the temperatures in response to the severity of an injury or illness or deviation from homeostasis. Routine human medical examinations begin by asking patients to describe ways in which they feel ill, any abnormal activities they participated in, and/or their current level of pain. Doctors use the information provided to determine the probable diagnosis of patients. Veterinary medicine is unique in that the patents are unable to communicate their problem and pain level. Owner's descriptions of behavioral changes or any other abnormal activities the animal displays are the only communications about the patient veterinarians are able to utilize. This communication gap leaves a broad window for interpretation of symptoms. Internal body temperatures are taken in veterinary as well as human medicine to help diagnose the problem correctly. In non-critical human medicine, patient descriptions are often more helpful than a thermometer reading at diagnosing the problem. Veterinary medicine relies heavily on the animal's temperature due to the wide variety of animal behavior changes. Similar to humans, all animals react to pain differently and without the ability to communicate with the patient, veterinarians are unable to pinpoint the problem with the owner's description alone.

Accuracy and reliability of thermometers are critical properties for diagnosis in veterinary medicine. Although an animal may display symptoms of an illness, many illnesses are not considered severe unless the patient is febrile. In research studies, animals undergo tests and are treated only after the set critical temperature is reached. Therefore, accuracy and reliability are of the utmost importance. Accuracy is freedom from mistake or error and reliability is the ability to yield the same results from repeated trials (Merriam

Webster, n.d.). Medical professionals should be confident the thermometer utilized displays readings close to the real temperature and is representative of true temperature fluctuation. If a thermometer displays an extreme hyperthermic or hypothermic reading, the animal requires immediate medical attention. Hyperthermia is a febrile state in which an animal is unable to dissipate heat and can be caused by exposure to high environmental temperatures, stress, or other factors (Ford & Mazzaferro, 2012). Hypothermia occurs in response to prolonged exposure to cold environmental conditions such as cold water or snow, or during surgical procedures when anesthetics are in the bloodstream. A hypothermic state drops the animals' core body temperature and requires immediate treatment usually with a heating pad and/or administering warm fluid via a catheter (Ford). Extreme hyperthermia (41-43°C) and hypothermia (28°C) are rare occurrences and many thermometers read 'Hi' or 'Lo' respectively indicating the temperature is not within the calibrated range (Ford). Mild hyperthermia (40°C) and hypothermia (35°C) are more common and are used by veterinarians to diagnose various infections, diseases, and other illnesses (Ettinger & Feldman, 2010). Normal temperature (38°C) can be misleading and either causes a lack of treatment or could provide support that the problem is minor, thus a less aggressive treatment approach may be used (Ettinger).

A wide variety of thermometers are commercially available and calibrated for human use. There also is a smaller commercial market for thermometers calibrated for small animals like dogs and cats. Due to the higher normal temperature (38°C) compared to humans normal (37°C) the companies selling animal thermometers claim they provide a more accurate and reliable reading for animal temperatures than human thermometers (Kushimotoo et al., 2014). The purpose of the current experiment was to test different

digital thermometers in a constant 35°C, 38°C, and 40°C water bath to determine the most accurate and reliable thermometer.

Materials and Methods

New thermometers were purchased in local drug stores and retail chains located in Stillwater, Oklahoma. Used thermometers were borrowed from veterinary students at Oklahoma State University. The number of uses and dates of purchase for all used thermometers varied and data was not available. In total, thirty two thermometers were tested representing twelve brands and twenty two different models. Brands included: Lumiscope, Reli-On, Vicks, Nexcare, Walgreens, American Red Cross, Nutri-Vet, Best Choice, Flents, Medline, Vet-One, and Jor-Vet. Thermometer readings were recorded in Fahrenheit and later converted to Celsius using a standard formula in Microsoft Excel. Some thermometers did not allow a Celsius reading to be obtained so Fahrenheit was used overall for consistency of results. The ranges of thermometers were converted into Celsius using the same formula in Microsoft Excel but the accuracy uncertainty values remained in Fahrenheit. Range of the thermometers averaged 32.3-43.2°C, all emitted an audible beep when reading was complete and displayed 0.1 degree resolution. Temperatures tested were set for mild hypothermia (35°C), normal temperature (38°C), and mild hyperthermia (40°C)(Ettinger). Extreme hypothermia and hyperthermia were unable to be tested due to the thermometers temperature range limitations. Accuracy of thermometers for temperatures averaged ±0.36°F for 35°C, ±0.20°F for 38°C, ±0.25°F for 40°C and ±0.27°F overall. A Thermo Scientific Isotemp 202 water bath with two liter capacity and ±0.5°C stability was used. The National Institute of Standards and Technology (United States Department of Commerce (USDOC), 2012) traceable glass thermometer was used as the

indicator of true temperature in the water bath in accordance with United States national standard for temperature (USDOC, 2012). This thermometer ranged from -20°C to 110°C with 95 percent certainty of ±0.045°C uncertainty. Water in the bath was stirred continually during the experiment using a metal stirring rod to ensure a uniform temperature reading. All experimental testing was performed in the same room with air temperature fluctuation between 21.3°C to 21.9°C.

The water bath was set up per the manual and filled until the water level reached two inches below the rim. To account for heat lost to the environment, the bath was set to a temperature higher than desired. The lid remained on the bath to help maintain temperature equilibrium. After the desired temperature was reached, as measured by the NIST thermometer, a timer was set for 30 minutes to ensure the temperature was constant and maintained equilibrium. Once the time passed, the NIST thermometer was placed in different locations of the water and if the reading remained constant, the thermometers began testing. Each thermometer probe was placed in the same location in the water bath and the readings were recorded after an audible beep. Once the sound occurred the thermometer was removed from the bath, dried on a paper towel and left to cool for a minimum of fifteen seconds. All thirty two thermometers were tested in the same manner seven times for each temperature.

Results

Table 1 displays the thirty two new and used thermometers tested including their brands. Once readings were recorded, data was analyzed for accuracy and reliability using different statistical methods. Accuracy was determined by utilizing simple means of each temperature reading by subtracting the true temperature, measured by the NIST

thermometer, from the mean of the measured temperature for each thermometer. The lowest difference between the true temperature and mean of the measured temperature determined the most accurate thermometer for each of the three constant temperatures. To determine the most accurate thermometer overall, the three constant temperatures were averaged. Previous means of each constant temperature were also averaged for each thermometer. These two means were compared to determine the most accurate thermometer overall. Analyzing the difference of the measured temperature from the actual temperature for each reading tested reliability. Using SigmaPlot statistical software a one way Analysis of Variance was run followed by a multiple comparison procedure of the data to isolate the groups that differ (SigmaPlot User Guide, 2013).

Each thermometer was assigned a number for easier representation as shown in Table 1. Numbers were assigned grouping brands together with new and old at random. The order tested differs from the number on this table.

Table 1: Thermometers Tested

Thermometer #	Brand	New/Used	Model #	Lot #	Human / Pet
Thermometer 1	Lumiscope	Used	L2013	SEP110MS	Human
Thermometer 2	Lumiscope	Used	L2013	KJM292MS	Human
Thermometer 3	Nexcare	Used	524036		Human
Thermometer 4	Nexcare	Used	524036		Human
Thermometer 5	Nexcare	New	524036		Human
Thermometer 6	American Red Cross	Used	Y7078		Human
Thermometer 7	American Red Cross	Used	Y7078		Human
Thermometer 8	Walgreens	New	VT-801BWT	1106	Human
Thermometer 9	Walgreens	New	VT-801BWT	1106	Human
Thermometer 10	Walgreens	Used	160-602-000	12250810	Human
Thermometer 11	Walgreens	Used	VT801SWT	806	Human
Thermometer 12	Walgreens	New	268694	1407	Human
Thermometer 13	Walgreens	New	268691	1501	Human
Thermometer 14	Vicks	Used	V966US	29711onb	Human
Thermometer 15	Vicks	Used	V912US	03013onb	Human
Thermometer 16	Vicks	Used	V912US	20812onb	Human
Thermometer 17	Vicks	Used	V912US	20812onb	Human
Thermometer 18	Vicks	Used	V912US	03013onb	Human
Thermometer 19	Vicks	New	V966US	32714onb	Human
Thermometer 20	Reli-on 60-sec	Used	GN2874.57059	4774201113	Human
Thermometer 21	Reli-on	Used	144-736-000	12250412	Human
Thermometer 22	Reli-on 60-sec	New	GN2874.57059	4774201014	Human
Thermometer 23	Reli-on 20-sec	New	GN2874.85447	4774200115	Human
Thermometer 24	Reli-on 8-sec	New	6429	1312-16485	Human
Thermometer 25	Reli-on 2-sec	New		4414	Human
Thermometer 26	Best Choice	New		1406	Human
Thermometer 27	Best Choice	New		912	Human
Thermometer 28	Medline	Used	MD59852B	1212651-5	Human
Thermometer 29	Vetone	Used	V1601013	KJP336MS	Pet
Thermometer 30	Jorvet	New	J134f		Human
Thermometer 31	Nutrivet	New			Pet
Thermometer 32	Flents	New	67358	2269	Human

Using the statistical analysis detailed above the most accurate thermometer for 35°C readings was the used Walgreens thermometer model VT801SWT with a mean difference of 0.45°C. The most accurate for 38°C was a new Reli-On two second thermometer with a mean difference of 0.08°C. The most accurate thermometer in 40°C

was Reli-On eight second thermometer with a mean difference of 0.76°C. Overall the most accurate thermometer was the used Walgreens thermometer model VT801SWT with a mean difference of 0.65°C. These results are represented in Table 2 below.

Table 2: Accuracy of Each Temperature and Overall

Difference between Mean Measured Temperature and True Temperature (°C)				
	35°C	**38°C**	**40°C**	**Overall**
Thermometer 1	0.65	0.80	0.90	0.78
Thermometer 2	0.58	0.83	0.84	0.75
Thermometer 3	0.85	1.10	1.16	1.03
Thermometer 4	0.78	1.05	1.04	0.95
Thermometer 5	0.77	0.99	1.12	0.96
Thermometer 6	0.67	0.86	0.94	0.83
Thermometer 7	0.57	0.83	0.91	0.77
Thermometer 8	0.67	0.80	0.89	0.79
Thermometer 9	0.74	0.82	0.90	0.82
Thermometer 10	0.60	0.88	0.96	0.81
Thermometer 11	**0.45**	0.72	0.78	**0.65**
Thermometer 12	0.59	0.89	0.90	0.79
Thermometer 13	0.56	0.78	0.79	0.71
Thermometer 14	1.45	1.08	1.17	1.23
Thermometer 15	1.45	1.12	1.21	1.26
Thermometer 16	1.45	1.06	1.21	1.24
Thermometer 17	1.44	1.06	1.17	1.22
Thermometer 18	1.45	1.16	1.21	1.28
Thermometer 19	1.44	1.12	1.20	1.25
Thermometer 20	0.66	0.71	1.04	0.80
Thermometer 21	0.69	0.79	0.94	0.80
Thermometer 22	0.60	0.80	0.89	0.76
Thermometer 23	0.60	0.77	0.87	0.75
Thermometer 24	0.56	0.96	**0.76**	0.76
Thermometer 25	2.08	**0.09**	1.06	1.08
Thermometer 26	0.57	0.83	1.00	0.80
Thermometer 27	0.48	0.75	0.85	0.69
Thermometer 28	0.61	0.81	1.04	0.82
Thermometer 29	0.56	0.71	0.87	0.71
Thermometer 30	0.57	0.88	0.98	0.81
Thermometer 31	0.66	0.83	1.13	0.88
Thermometer 32	0.56	0.89	0.98	0.81

Reliability tests were run to determine if the thermometers had a significant variation from the true temperature and to compare each temperature variance for every

thermometer tested. Temperature variance was conducted using each temperature grouping and the overall temperature grouping mean temperatures. The Shapiro-Wilk normality test failed for every group, indicating $P<0.05$ so a Kruskal-Wallis One Way Analysis of Variance on Ranks (ANOVA) was run and data analyzed; for 35°C the most reliable thermometer was thermometer 11 and the least reliable, 25. In the 38°C test the most reliable thermometer was number 25 and least reliable numbers 18 and 19. The 40°C test resulted in thermometer 24 as the most reliable and 15, 16 and 18 all as the least reliable at this temperature. Overall the most reliable thermometer was thermometer 25 at 38°C and least reliable was 25 at 35°C. When the overall results were averaged so each thermometer was compared independently for all three temperatures thermometer 11 was the most reliable. Results are presented using Box and Whisker Plots generated from SigmaPlot 12.5 in Figure 1, 2, 3, and 4 below.

Figure 1: Box Plot of Thermometers One-Way ANOVA results for 35°C Water Bath Temperature

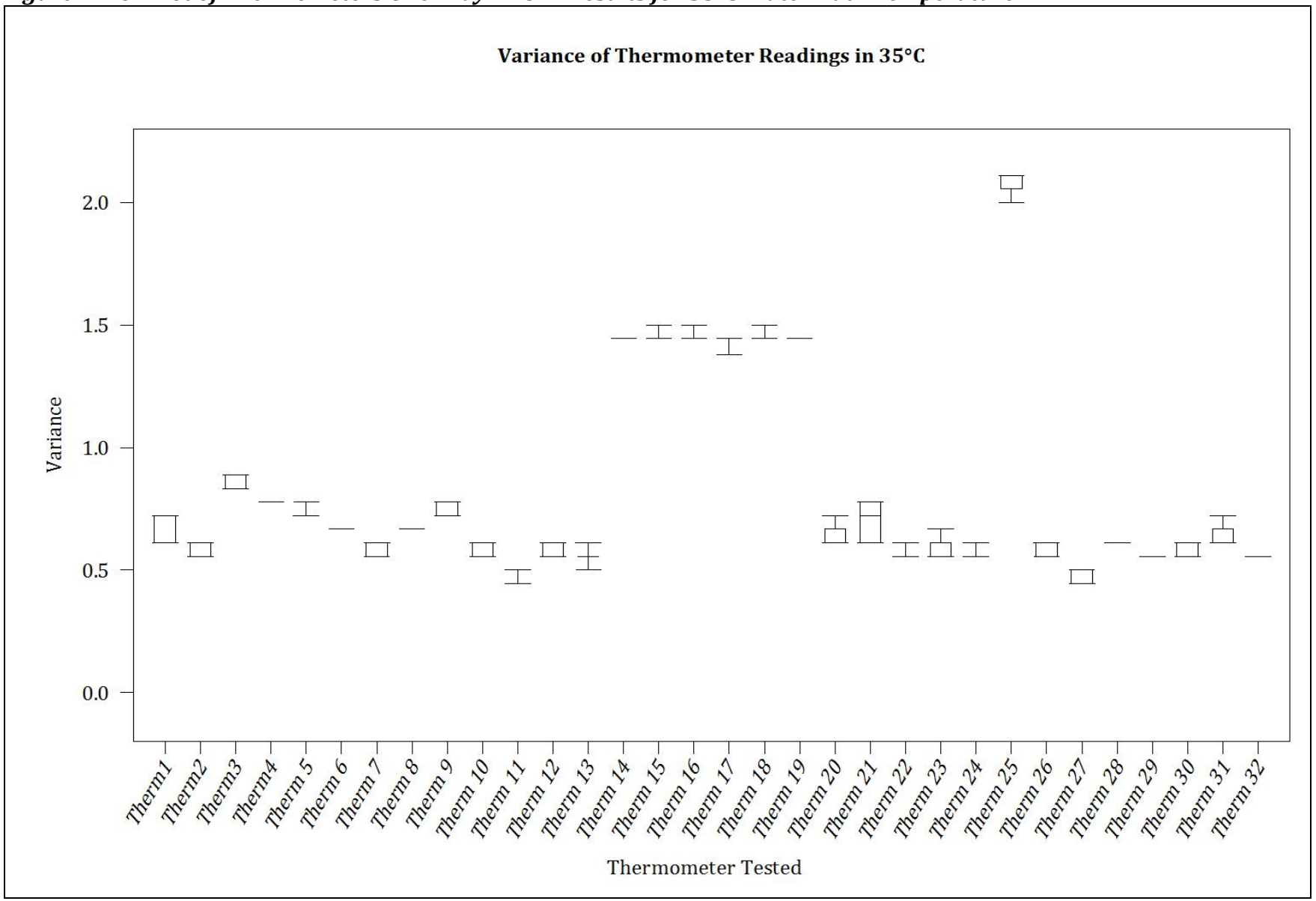


Figure 2: Box Plot of Thermometers One-Way ANOVA results for 38°C Water Bath Temperature

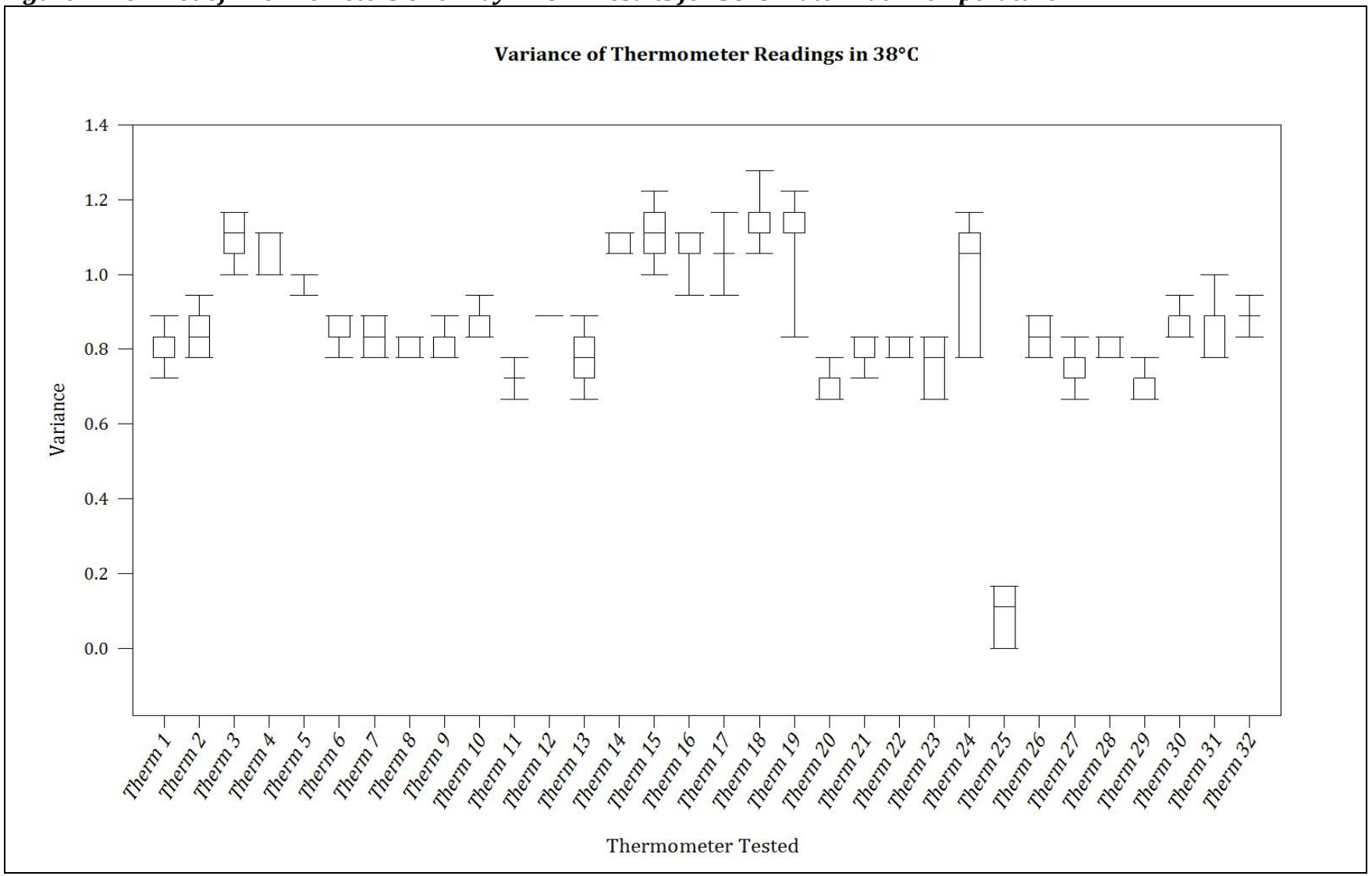


Figure 3: Box Plot of Thermometers One-Way ANOVA results for 40°C Water Bath Temperature

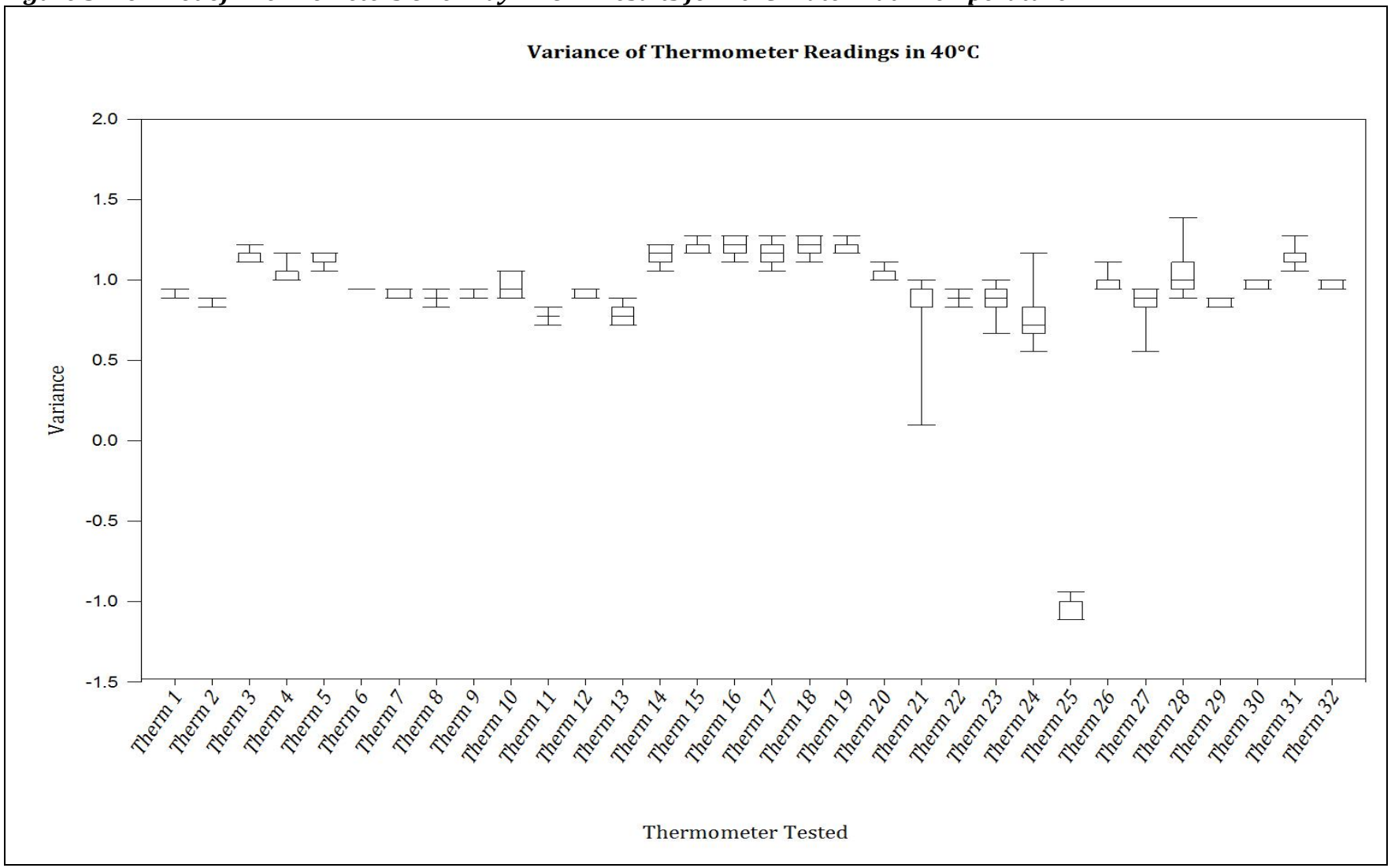
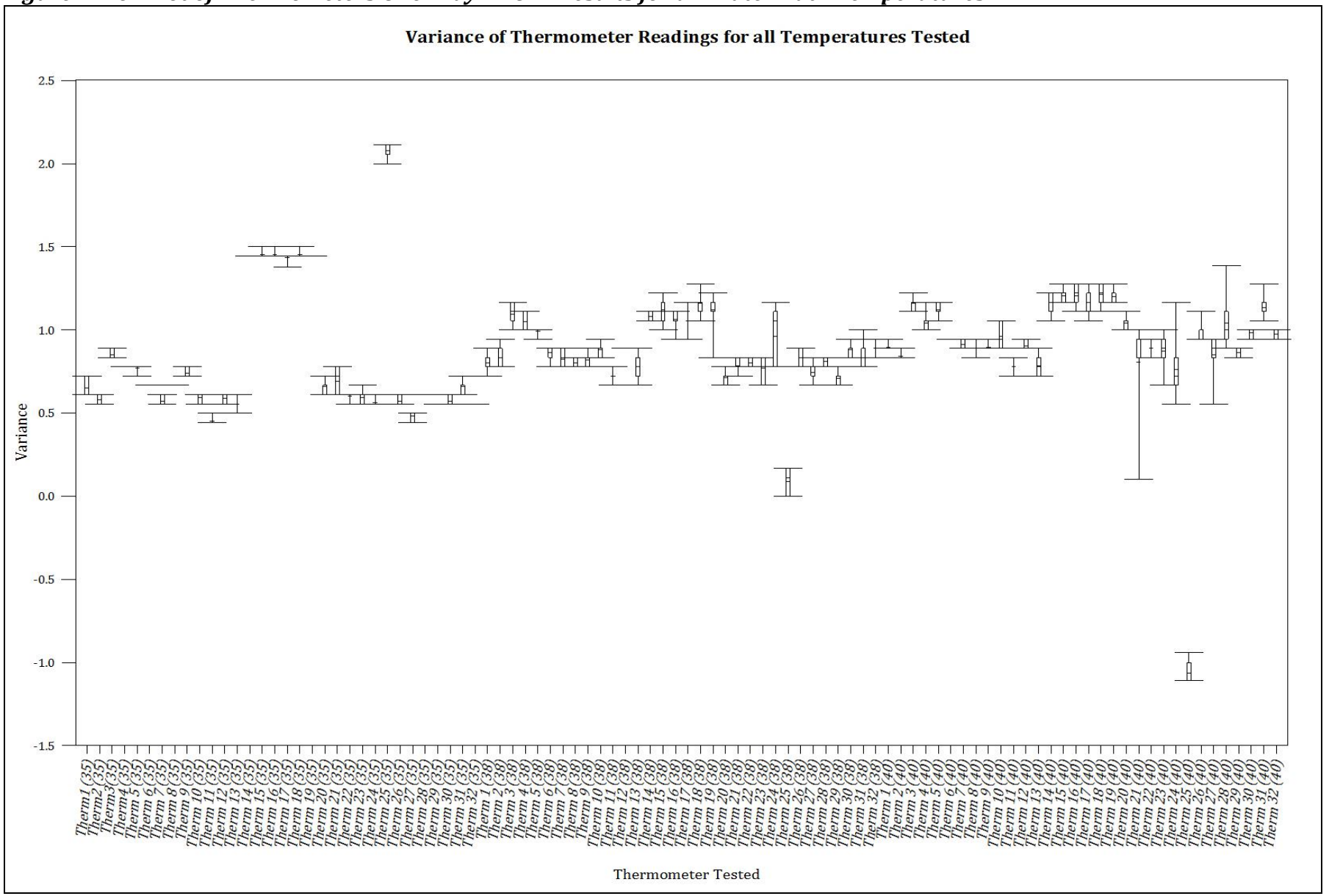


Figure 4: Box Plot of Thermometers One-Way ANOVA results for all Water Bath Temperatures



The ANOVA demonstrated all temperature groups were significantly different therefore, an analysis was conducted to determine which thermometers differed significantly from the others. This analysis was a multiple comparisons Tukey test run by SigmaPlot 12.5 statistical program. The thermometer with the wider range of significant differences for 35°C grouping was thermometer 25. The thermometer with the wider range of significant differences for 38°C grouping was thermometer 18. In the 40°C grouping thermometers 15, 16 and 18 all had the same range width of significantly different thermometers. Overall thermometer 25 at 35°C had the highest range of significantly different thermometers. These results are shown respectively in Table 3, 4, 5, and 6.

Table 3: Tukey Test Results for 35°C

Thermometers Significantly Different at 35°C (P<0.001)										
Therm 3	**Therm 4**	**Therm 5**	**Therm 9**	**Therm 14**	**Therm 15**	**Therm 16**	**Therm 17**	**Therm 18**	**Therm 19**	**Therm 25**
				2	2	2		2	2	2
				7	7	7	7	7	7	7
										10
11	11	11	11	11	11	11	11	11	11	11
										12
				13	13	13	13	13	13	13
										22
										23
				24	24	24	24	24	24	24
				26	26	26	26	26	26	26
27	27	27	27	27	27	27	27	27	27	27
				29	29	29	29	29	29	29
				30	30	30	30	30	30	30
				32	32	32	32	32	32	32

Table 4: Tukey Test Results for 38°C

Thermometers Significantly Different at 38°C (P<0.001)										
Therm 3	**Therm 4**	**Therm 5**	**Therm 12**	**Therm 14**	**Therm 15**	**Therm 16**	**Therm 17**	**Therm 18**	**Therm 19**	**Therm 24**
								1		
								8		
11	11	11		11	11	11	11	11	11	
					13			13	13	
20	20	20		20	20	20	20	20	20	
					21			21		
								22		
					23			23	23	
25	25	25	25	25	25	25	25	25	25	25
27	27			27	27	26	27	27	27	
29	29	29		29	29	27	29	29	29	

Table 5: Tukey Test Results for 40°C

Thermometers Significantly Different at 40°C (P<0.001)										
Therm 3	**Therm 4**	**Therm 5**	**Therm 14**	**Therm 15**	**Therm 16**	**Therm 17**	**Therm 18**	**Therm 19**	**Therm 20**	**Therm 31**
2		2	2	2	2	2	2	2		2
				8	8		8			
11		11	11	11	11	11	11	11		11
13		13	13	13	13	13	13	13		13
				22	22		22			
24			24	24	24	24	24	24		24
25	25	25	25	25	25	25	25	25	25	25
				27	27		27	27		
29			29	29	29	29	29	29		

Table 6: Tukey Test Results for all Temperatures

Thermometers Significantly Different at all Temperatures Tested (P<0.001)															
Therm 14 (35°C)	**Therm 15 (35°C)**	**Therm 16 (35°C)**	**Therm 17 (35°C)**	**Therm 18 (35°C)**	**Therm 19 (35°C)**	**Therm 25 (35°C)**	**Therm 3 (38°C)**	**Therm 4 (38°C)**	**Therm 5 (38°C)**	**Therm 14 (38°C)**	**Therm 15 (38°C)**	**Therm 16 (38°C)**	**Therm 17 (38°C)**	**Therm 18 (38°C)**	**Therm 19 (38°C)**
1 (35)	1 (35)	1 (35)	1 (35)	1 (35)	1 (35)	1 (35)									
2 (35)	2 (35)	2 (35)	2 (35)	2 (35)	2 (35)	2 (35)					2 (35)			2 (35)	
6 (35)	6 (35)	6 (35)	6 (35)	6 (35)	6 (35)	6 (35)									
7 (35)	7 (35)	7 (35)	7 (35)	7 (35)	7 (35)	7 (35)					7 (35)			7 (35)	
8 (35)	8 (35)	8 (35)	8 (35)	8 (35)	8 (35)	8 (35)									
						9 (35)									
10 (35)	10 (35)	10 (35)	10 (35)	10 (35)	10 (35)	10 (35)								10 (35)	
11 (35)	11 (35)	11 (35)	11 (35)	11 (35)	11 (35)	11 (35)	11 (35)	11 (35)		11 (35)	11 (35)	11 (35)	11 (35)	11 (35)	11 (35)
12 (35)	12 (35)	12 (35)	12 (35)	12 (35)	12 (35)	12 (35)								12 (35)	
13 (35)	13 (35)	13 (35)	13 (35)	13 (35)	13 (35)	13 (35)	13 (35)				13 (35)			13 (35)	13 (35)
20 (35)	20 (35)	20 (35)	20 (35)	20 (35)	20 (35)	20 (35)									
21 (35)	21 (35)	21 (35)	21 (35)	21 (35)	21 (35)	21 (35)									
22 (35)	22 (35)	22 (35)	22 (35)	22 (35)	22 (35)	22 (35)								22 (35)	
23 (35)	23 (35)	23 (35)	23 (35)	23 (35)	23 (35)	23 (35)								23 (35)	
24 (35)	24 (35)	24 (35)	24 (35)	24 (35)	24 (35)	24 (35)	24 (35)				24 (35)			24 (35)	24 (35)
26 (35)	26 (35)	26 (35)	26 (35)	26 (35)	26 (35)	26 (35)					26 (35)			26 (35)	
27 (35)	27 (35)	27 (35)	27 (35)	27 (35)	27 (35)	27 (35)	27 (35)	27 (35)		27 (35)	27 (35)	27 (35)	27 (35)	27 (35)	27 (35)
28 (35)	28 (35)	28 (35)	28 (35)	28 (35)	28 (35)	28 (35)									
29 (35)	29 (35)	29 (35)	29 (35)	29 (35)	29 (35)	29 (35)	29 (35)			29 (35)	29 (35)			29 (35)	29 (35)
30 (35)	30 (35)	30 (35)	30 (35)	30 (35)	30 (35)	30 (35)					30 (35)			30 (35)	
31 (35)	31 (35)	31 (35)	31 (35)	31 (35)	31 (35)	31 (35)									
32 (35)	32 (35)	32 (35)	32 (35)	32 (35)	32 (35)	32 (35)	32 (35)			32 (35)	32 (35)			32 (35)	32 (35)
						11 (38)									
						20 (38)									
25 (38)	25 (38)	25 (38)	25 (38)	25 (38)	25 (38)	25 (38)	25 (38)	25 (38)		25 (38)	25 (38)	25 (38)	25 (38)	25 (38)	25 (38)
29 (38)	29 (38)	29 (38)		29 (38)	29 (38)	29 (38)									
25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)

Table 6: continued...

Thermometers Significantly Different at all Temperatures Tested (P<0.001) ***continued***												
Therm 3 (40°C)	**Therm 4 (40°C)**	**Therm 5 (40°C)**	**Therm 14 (40°C)**	**Therm 15 (40°C)**	**Therm 16 (40°C)**	**Therm 17 (40°C)**	**Therm 18 (40°C)**	**Therm 19 (40°C)**	**Therm 20 (40°C)**	**Therm 26 (40°C)**	**Therm 28 (40°C)**	**Therm 31 (40°C)**
2 (35)		2 (35)	2 (35)	2 (35)	2 (35)	2 (35)	2 (35)	2 (35)				2 (35)
7 (35)		7 (35)	7 (35)	7 (35)	7 (35)	7 (35)	7 (35)	7 (35)				7 (35)
10 (35)			10 (35)	10 (35)	10 (35)	10 (35)	10 (35)	10 (35)				
11 (35)	11 (35)	11 (35)	11 (35)	11 (35)	11 (35)	11 (35)	11 (35)	11 (35)	11 (35)			11 (35)
12 (35)			12 (35)	12 (35)	12 (35)	12 (35)	12 (35)	12 (35)				12 (35)
13 (35)		13 (35)	13 (35)	13 (35)	13 (35)	13 (35)	13 (35)	13 (35)				13 (35)
22 (35)			22 (35)	22 (35)	22 (35)	22 (35)	22 (35)	22 (35)				
23 (35)			23 (35)	23 (35)	23 (35)	23 (35)	23 (35)	23 (35)				
24 (35)		24 (35)	24 (35)	24 (35)	24 (35)	24 (35)	24 (35)	24 (35)				24 (35)
26 (35)		26 (35)	26 (35)	26 (35)	26 (35)	26 (35)	26 (35)	26 (35)				26 (35)
27 (35)	27 (35)	27 (35)	27 (35)	27 (35)	27 (35)	27 (35)	27 (35)	27 (35)	27 (35)			27 (35)
			28 (35)	28 (35)	28 (35)		28 (35)	28 (35)				
29 (35)		29 (35)	29 (35)	29 (35)	29 (35)	29 (35)	29 (35)	29 (35)				29 (35)
30 (35)		30 (35)	30 (35)	30 (35)	30 (35)	30 (35)	30 (35)	30 (35)				30 (35)
32 (35)		32 (35)	32 (35)	32 (35)	32 (35)	32 (35)	32 (35)	32 (35)				32 (35)
25 (38)	25 (38)	25 (38)	25 (38)	25 (38)	25 (38)	25 (38)	25 (38)	25 (38)	25 (38)	25 (38)	25 (38)	25 (38)
25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)	25 (40)

Discussion

For all temperature groupings, accuracy and reliability had strong correlation thus the most reliable thermometers were also the most accurate. Thermometer 25, a new Reli-On two-second thermometer provided the most interesting data to analyze. When tested in the 35°C water bath the readings were an average +2.1°C above the true temperature, in the 38°C bath it was most accurate with an average +0.1°C above the true temperature and the 40°C water bath the reading was below the true temperature by -1.1°C. This thermometer is noticeable on the Box and Whisker plots as well due to the inaccurate readings. Results demonstrated that this Reli-On thermometer was the least accurate and reliable to use. Results determined thermometer 11 was the most accurate and reliable out of all 32 thermometers tested. This was surprising due to its worn appearance and it being a used thermometer. Due to the obvious correlation between accuracy and reliability, reliability was used to determine results for the following analysis. Of all new thermometers tested, numbers 13 and 27 were most accurate and reliable. Analyzing the used thermometers number 11 was most accurate and reliable as stated before followed by number 29. When the differences were averaged, overall the most accurate and reliable thermometers were new thermometers. New thermometers had a mean difference of 0.85°C from the real temperature while used had a 0.94°C mean difference. In general new thermometers are more accurate and reliable than used, however, some used are just as dependable as new. All thermometers were higher than the true temperature on all readings except thermometer 25 at 40°C. This could be due to the process in which thermometers measure temperature. Further analysis on the data can provide better insight on the most reliable thermometer brands. Analysis performed in this study

demonstrated that no major difference was found to correlate temperatures measured between human and animal thermometers and as previously mentioned; new thermometers were more reliable over all temperature groupings.

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