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S.O.S. for COVID-19 (Subjective and Objective Screening): Are Asymptomatic Cases Truly Without Warning Signs?

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Abstract

Purpose

The purpose of this study is to 1) investigate the usefulness of five (5) objective early warning signs; 2) evaluate the relationships between objective signs with symptoms of COVID-19, and 3) assess the accuracy of ambient infrared forehead temperature with tympanic temperature.

Methods

Cross sectional data were collected at Wayne State University during the 2020-2021 semester. Blood oxygen levels and blood pressure were measured via automated pulse oximeters and blood pressure cuff, respectively. Body temperature was measured with an infrared thermometer via contact with the temple (temporal temp) and non-contact with the forehead (infrared temp). The smell test was conducted with two non-toxic scented markers. Participants were asked to identify each smell from a provided list.

Results

Twenty-nine participants (nineteen in the Fall 2020 semester and ten in the Winter 2021 semester) consented to participate in vital sign testing. None of our participants confirmed a positive COVID-19 test. Therefore, only relationships between vital sign measurements were reported for these analyses (i.e. no COVID-19 positive versus COVID-19 negative analyses could be performed, as per the original study design). No significant intra-variable correlations were revealed upon statistical analysis. Infrared and temporal temperatures were not correlated

with p=-0.252 and r=0.2196. A slight correlation between the fall and winter cohort was found for heart rate only with $p=0.51$. Three participants had an oxygen saturation (O2) reading $\leq 90\%$, without any associated symptoms. There were (non-significant) trends for those three participants with low O2 saturation levels to have higher heart rate (94±25bpm vs. 79±14bpm; $p=0.11$) and lower systolic blood pressure (111±21 vs. 120±12mmHg; $p=0.27$) compared with those participants with O2 readings >90% (low O2 vs. normal O2 saturations, respectively).

Conclusion

Non-contact infrared thermometers are inaccurate at or above 99.5ºF; thus, they are an ineffective way to screen for fever associated with COVID-19. Blood pressure is another ineffective method for screening due to the lack of research on how COVID-19 affects blood pressure without preexisting conditions. Heart rate could be another screening method; however, it is unknown how SARS-CoV-2 affects the heart due to lack of research. Participants with low oxygen saturation levels tended to have lower systolic blood pressures and higher heart rates, indicating physiological disruptions unrelated to a positive COVID-19 test and requires further investigation. Finally, smell may be a reliable method to screen for COVID-19 due to the high prevalence of anosmia and early presentation when infected.

Introduction

The coronavirus disease 2019 pandemic has plagued the world and is characterized by mass shutdown, social isolation, conspiracy theories, and unprecedented vaccine development. First reported in Wuhan provenance in mainland China, SARS-CoV-2, the novel coronavirus, has been responsible for over 100 million positive cases and over 2.2 million deaths worldwide (WHO Coronavirus Disease dashboard, n.d). SARS-CoV-2 affects the respiratory system causing coronavirus disease 2019 (COVID-19), characterized by mild to severe symptoms (Hu et al., 2020). The easy transmissibility via expired respiratory droplets containing SARS-CoV-2 has led to a rapid global spread leading the World Health Organization to declare it a pandemic (Ghebreyesus Adhanom, 2020). Two distinct categories of infection have emerged, symptomatic cases and asymptomatic cases. Despite this, subtle physiological changes have suggested a spectrum of COVID-19 pathophysiology ranging from seemingly asymptomatic to severe.

SARS-CoV-2 has four spike proteins on its outer envelope that allow it to bind to and infiltrate host cells (Indwiani Ysragil, 2020). Attracted to angiotensin-converting enzyme two receptor (ACE2), SARS-CoV-2 is prone to infect cells of the lower respiratory system (Rabi et al., 2020). A myriad of symptoms is caused by COVID-19 ranging from abnormal vital signs (Tobin et al., 2020; Wang 2020) to a loss of olfaction (Whitcroft & Hummel, 2020) and gustation (Luers et al., 2020). Due to the objective presentation of symptoms, screening patrons for entry to public spaces have become popular. Low blood oxygen saturation levels have been a commonly reported clinical sign leading to happy hypoxia without any dyspnea (Tobin et al., 2020). Further, SARS-CoV-2 can directly affect the heart by binding to the ACE2 receptors on the myocardium leading to myocarditis (Topol, 2020) and arrhythmias (Goha et al., 2020). The virus also affects blood pressure by dysregulating the renin-angiotensin-aldosterone system (Topol, 2020). Each of these signs has an easy, non-invasive way to measure and report.

Screening via self-report of symptoms, travel disclosure, and non-contact forehead temperature checks has become widespread. However, self-report measures and ambient forehead thermometers have been shown to be inaccurate (Althubaiti, 2016; Niven, 2015). As such, the aims of this study are to 1) investigate the usefulness of five (5) objective early warning signs; 2) evaluate the relationships between objective signs with symptoms of COVID-19, and 3) assess the accuracy of ambient infrared forehead temperature with tympanic temperature.

As the United States surpasses 571,000 deaths, the coronavirus pandemic remains an emergent health crisis. As such, we hypothesize that elevations in heart rate and blood pressure, with or without reductions in oxygen saturation and smell, may help identify “asymptomatic” SARS-CoV-2 cases. Implementing simple, non-invasive screening methods can allow for the prediction and early detection of COVID-19.

Increased screening methods are becoming more important as people who recover are left with severe, lasting symptoms. Persistent symptoms for three weeks after recovery is known as post-acute COVID-19 (Greenhalgh et al., 2020), often referred to as “long-COVID.” Any symptoms present past that window are referred to as chronic-COVID (Chan et al., 2020). Long- and chronic-COVID affect those who had severe symptoms, as well as those with mild symptoms. A US study concluded that symptoms cease in a 14-to-21-day window for only 65% of people infected with COVID-19 (Tenforde et al., 2020). The most-reported post-acute symptoms are cough, low-grade fever, and fatigue on the mild end of the spectrum (Nalbandian et al., 2021). Toward the more severe end, patients have presented with neurocognitive difficulties, gastrointestinal problems, and metabolic disruption (Dasgupta et al., 2020).

Methods

The present study is of cross-sectional design. Prospective data were to be collected once a week for in-person Life Fitness Activities (LFA) classes at Wayne State University in Detroit, MI, on a voluntary basis during the fall 2020 semester. However, due to the increasing status of the pandemic, data was only collected twice. Cross-sectional data were collected at Wayne State University Campus Health Center COVID-19 testing sites on a voluntary basis during the winter 2021 semester. All participants signed written informed consent before testing began for this IRB approved project (IRB-20-08-2665).

Blood oxygen saturation (O2) levels and blood pressure were measured via automated pulse oximeters (Clinical Guard, Atlanta, GA, USA) and a blood pressure cuff (Omron, Model BP785N, Lake Forest, IL) respectively. Body temperature was measured using a dual infrared thermometer via contact with the temple (temporal temp) and non-contact with the forehead (infrared temp) (Mesanfit, Shenzhen, China). The smell test was conducted with two non-toxic scented markers Crayola Silly Scents Sweet and Smelly Markers, Easton, PA, USA). Participants were asked to identify each smell from a provided list. Participants were contacted via email after testing to follow up for positive test results.

The blood pressure cuff was placed on the participant, and the pulse oximeter was placed on the index finger of the opposite hand. Temperature was taken first via non-contact with the forehead then with contact to the temple. After blood pressure and O2 saturation were recorded, participants were asked to pull their masks below their noses and identify the scent of two markers. Extra precautions were taken to prevent the stead of COVID-19. Researchers wore non-latex disposable gloves and a mask. After data was collected, all equipment was disinfected using a chlorine-based surface disinfectant.

Results

Twenty-nine participants (nineteen in the Fall 2020 semester and ten in the Winter 2021 semester) consented to participate in vital sign testing. None of our participants confirmed a positive COVID-19 test. Therefore, only relationships between vital sign measurements were reported for these analyses (i.e., no COVID-19 positive versus COVID-19 negative analyses could be performed, as per the original study design).

The present study aimed to determine the usefulness of five non-invasive vital signs (blood pressure, oxygen saturation, pulse, heart rate, and smell), evaluate the relationship with subjective symptoms and objective signs and finally assess the accuracy of infrared temperature checks with temporal temperature checks. Statistical analysis was performed on all data. Descriptive statistics of the data set (n=29) are provided in table 1. An outlier in oxygen saturation (56%) was found to be more than three standard deviations from the mean and subsequently was removed from the results.

Infrared temp has a mean of 96.8±1.49º, n=29. Temporal temp averaged 98.47±1.57º, n=29. Systolic blood pressure and diastolic blood pressure averaged 119.17±13.26mmHg, n=29 and 73.52±7.8mmHg, n=29, respectively. The heart rate mean is reported as 80.69±15.53bpm, n=29. O2 saturation with the outlier has a median of 95.17±8.13%. n=29. One outlier was identified (O2 of 56%) and when removed from the data set, the median became 96.57±3.11%. Relationships between each variable were run for correlations. No significant intra-variable relationships were found.

Table 1. Descriptive statistics of data set. One O2 saturation outlier was removed due to being more than two standard deviations outside of the mean.

Variable	Valid N	Mean	Minimum	Maximum	Std.Dev.
Infrared Temp.	29	96.8379	92.3	98.6	1.48647
Temporal Temp.	29	98.4724	95.6	103.5	1.57001
SBP	29	119.1724	88	157	13.26399
DBP	29	73.5172	56	90	7.80394
HR	29	80.6897	55	121	15.52901
O2 Saturation	29	95.1724	56	99	8.12874
O2 Saturation_NO OUTLIER	28	96.5714	84	99	3.10828

Diastolic blood pressure (DPB) and systolic blood pressure (SBP) were not significantly related with a p=0.253, r=0.2192, n=29. Infrared temperature and temporal temperature are not significantly correlated with p=0.252, r=0.2196, n=29. Heart rate (HR) and O2 saturation were not related with p=-0.543, r=-0.0119, n=28. HR and SBP are not related with p=0.956, r=-0.0108, n=29. HR and DBP are not related with p=0.487, r=0.1343, n=29. This data is available in table 2.

Table 2 Statistical analysis to show relationships. No relationships between variables were significant. Marked correlations are significant at p < 0.05000.

Variable	Infrared Temp.	Temporal Temp.	SBP	DBP	HR	O2 Saturation_NO OUTLIER
Infrared Temp.	1 N=29 p= ---	0.2196 N=29 p=.252	-0.1503 N=29 p=.436	-0.1446 N=29 p=.454	0.1918 N=29 p=.319	0.103 N=28 p=.602
Temporal Temp.	0.2196 N=29 p=.252	1 N=29 p= ---	-0.0775 N=29 p=.690	-0.2337 N=29 p=.222	0.2661 N=29 p=.163	0.2667 N=28 p=.170
SBP	-0.1503 N=29 p=.436	-0.0775 N=29 p=.690	1 N=29 p= ---	0.2192 N=29 p=.253	-0.0108 N=29 p=.956	-0.1845 N=28 p=.347
DBP	-0.1446 N=29 p=.454	-0.2337 N=29 p=.222	0.2192 N=29 p=.253	1 N=29 p= ---	0.1343 N=29 p=.487	-0.3391 N=28 p=.078
HR	0.1918 N=29 p=.319	0.2661 N=29 p=.163	-0.0108 N=29 p=.956	0.1343 N=29 p=.487	1 N=29 p= ---	-0.1199 N=28 p=.543
O2 Saturation_NO OUTLIER	0.103 N=28 p=.602	0.2667 N=28 p=.170	-0.1845 N=28 p=.347	-0.3391 N=28 p=.078	-0.1199 N=28 p=.543	1 N=28 p= ---

Table 3 shows statistics between Fall 2020 cohort and Winter 2021 cohort. Heart rate was the only factor that has a slight correlation. Group 1 is the Fall 2020 cohort. Group 2 is the winter 2021 cohort.

Variable	Mean 2	Mean 1	t-value	df	p	Valid N 2	Valid N 1	Std.Dev. 2	Std.Dev. 1	F-ratio Variances	p Variances
Infrared Temp.	96.61	96.9579	-0.59207	27	0.558728	10	19	1.45255	1.52909	1.10818	0.913496
Temporal Temp.	98.01	98.7158	-1.15764	27	0.25715	10	19	1.3868	1.64055	1.39942	0.620907
SBP	115	121.3684	-1.24073	27	0.225377	10	19	13.40812	13.0009	1.06363	0.865038
DBP	71.4	74.6316	-1.06237	27	0.29748	10	19	7.21418	8.05682	1.24725	0.75988
HR	73	84.7368	-2.04101	27	0.051136	10	19	10.42433	16.45142	2.49064	0.163766
O2 Saturation	92.1	96.7895	-1.51003	27	0.14265	10	19	13.42841	2.14939	39.03177	0
O2 Saturation_NO OUTLIER	96.1111	96.7895	-0.53213	26	0.599154	9	19	4.67559	2.14939	4.73196	0.005933

Data for the fall and winter semesters were compared to identify any relationships between cohorts. No significant relationships were observed, as seen in table 3. There was a small relationship between cohorts seen in heart rate with a $p = 0.051$.

Table 4 shows high O2 saturation versus low O2 saturation. Valid data was found with an O2 saturation above 90%. No significant factors were found.

Variable	Mean 0	Mean 1	t-value	df	p	Valid N 0	Valid N 1	Std.Dev. 0	Std.Dev. 1	F-ratio Variances	p Variances
Infrared Temp.	96.7846	97.3	-0.56163	27	0.579001	26	3	1.55992	0.4	15.2085	0.126953
Temporal Temp.	98.5846	97.5	1.13898	27	0.264717	26	3	1.61089	0.7	5.2958	0.341802
SBP	120.115	111	1.13275	27	0.267279	26	3	12.4075	20.66398	2.7737	0.163344
DBP	72.8077	79.6667	-1.47109	27	0.152827	26	3	7.55258	8.73689	1.3382	0.560929
HR	79.1538	94	-1.61204	27	0.118583	26	3	14.03052	24.87971	3.1444	0.121033
O2 Saturation	97.3077	76.6667	6.62845	27	0	26	3	1.34964	18.14754	180.7995	0
O2 Saturation_NO OUTLIER	97.3077	87	8.98571	26	0	26	2	1.34964	4.24264	9.8818	0.008532

Table 4 shows the difference between data sets when separated by high and low oxygen saturation. When separated, minor changes were seen between groups. The low O2 saturation group showed systolic blood pressure and higher diastolic blood pressure.

Discussion

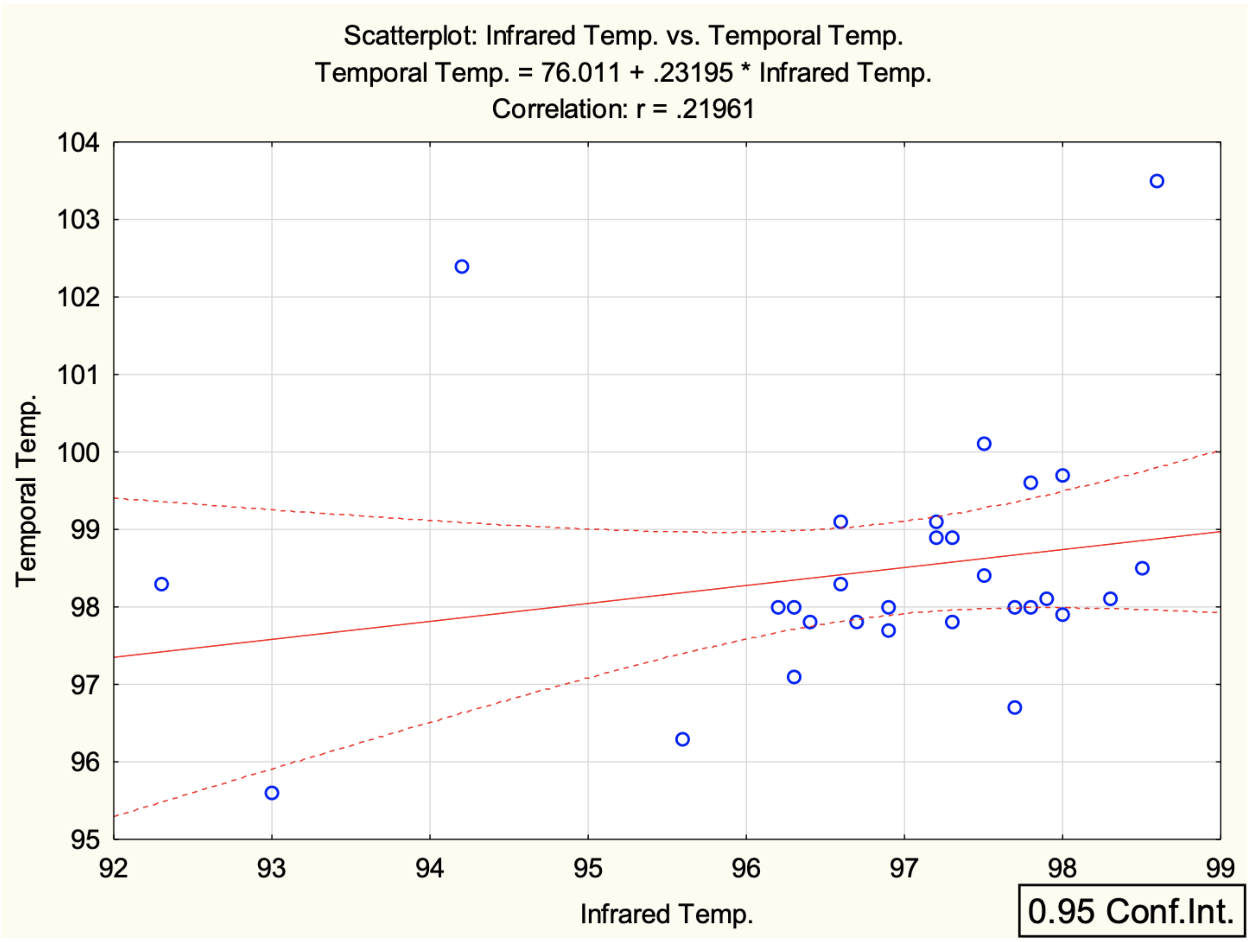
Infrared thermometers are not an effective tool for pre-screening

Infrared temperature measures of the forehead have become commonplace as a quick, non-invasive way to screen for potential COVID-19 symptoms. The increased use of these tools has brought their inaccuracies to light. The “gold standard” of body temperature measurement is the pulmonary artery catheter (Bridges & Thomas, 2009). During this procedure, a catheter is inserted via a large vein, then it is directed into the pulmonary vein, where the temperature of the blood is recorded; this is considered a true “core body temperature” reading (Wright & Mackowiak, 2020). When measuring via pulmonary artery catheter, the “normal” value can be expected to be about 98.6ºF (37ºC) (Bridges & Thomas, 2009). Other common ways to take temperature include oral, tympanic, temporal, axilla, and rectal. Each method has its strengths and shortcomings. While no study to date has determined the correlation between these methods, the clinical review board of the non-profit organization, HealthWise, determined that rectal and tympanic temperatures are 0.5°F (0.3°C) to 1°F (0.6°C) higher than an oral temperature (Blahd et al., 2020). The review board also reports that axillary and temporal are 0.5°F (0.3°C) to 1°F (0.6°C) below oral readings (Blahd et al., 2020).

A study in a neuroscience ICU concluded that measurements taken at the urinary bladder and temperatures taken via the pulmonary artery varied by 0.8ºC in 15% of patients. The study then compared tympanic temperature measurements to bladder measures and found that 35% had a difference of 0.8ºC or higher, with 10% of those with a variance having a discrepancy of 1.5° C or greater (Dunleavy, 2010). These variances lead Wright and Mackowiak (2021) to argue that a proper encompassing body temperature does not exist; instead, there are only the temperatures of individual body parts.

A more recent study published in the American Journal of Infection Control assessed the accuracy of non-contact infrared thermometers (NCIT) with temporal artery thermometers (TAT). Khan et al. (2020) found NCIT's to be related to TAT temperatures below 99.5ºF (37.5°C). When temperatures are at or above 99.5ºF (37.5°C), the mean differences widened considerably (Khan et al., 2020). In contrast with Khan et al., the current study found no correlation at any temperature, as seen in graph 1. The data collected during this study revealed no relationship between infrared temperature reading and temporal temperature reading. Also revealed upon statistical analysis is no correlation between fall and winter cohorts regarding temporal temperature ($p=0.2572$) and infrared temperature ($p=0.5587$), see figure 2. This concludes that both methods of temperature readings are not helpful for screening. Fall infrared temperature was expected to have been higher due to warmer weather and outside classes. This change was not observed. Increased inaccuracies due to ambient temperature (Shajkofci, 2021) further rendered infrared thermometers inadequate.

Figure 1 shows no relationship between temporal temperature and infrared temperature, p=0.252, n=29. Dashed lines represent upper and lower confidence intervals, while the solid line represents correlation.



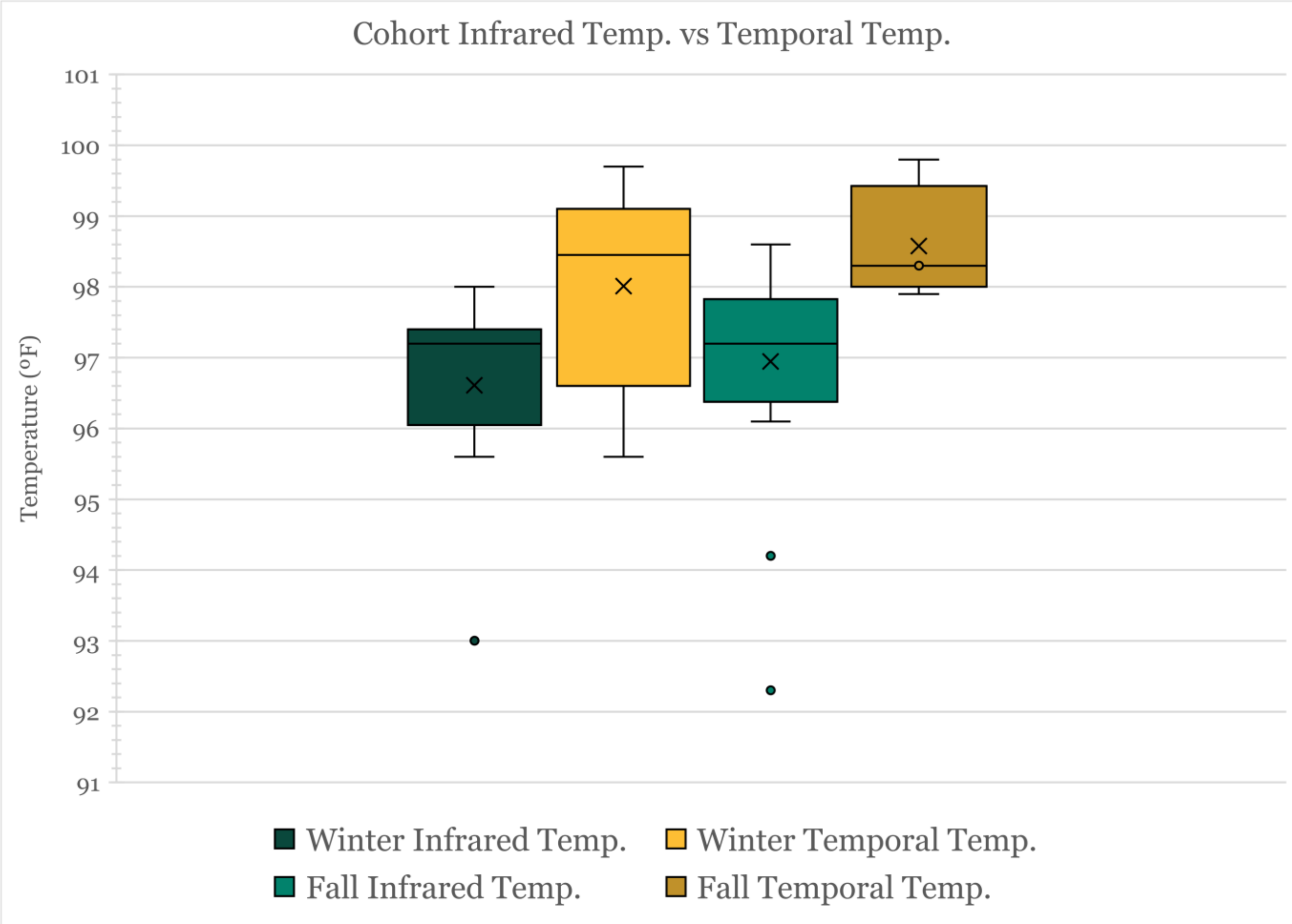


Figure 2 shows differences between cohorts. X represents the mean of each group. Fall vs. winter infrared temp. has a p of 0.5587 and temporal temp. has a p of 0.2572.

In the midst of a flu-like pandemic, accurate temperature checks have become a tool to protect and promote public health. The gold standard method to measure temperature remains an invasive procedure, not suitable for field testing. Another limiting factor affecting temperature checks is a lack of agreement surrounding an actual temperature (Chan, Kosik, & Wang, 2021). The US Center for Diseases Control and Prevention [CDC] (2017) lists the criterion of fever being a temperature reading of 100.4ºF or greater. As such, the errors in temperature readings above 99.5ºF render temperature measurements via non-contact infrared thermometers impractical for COVID-19 screening. The inaccuracies at temperatures at or above 99.5ºF for NCIT's raise significant problems for the COVID-19 pandemic.

Systolic blood pressure does not appear to be significantly linked to diastolic blood pressure

Blood pressure is a large part of cardiovascular health, which is an essential indicator of overall health. As such, blood pressure is a common vital used to assess such health due to its ease of use and low cost. The virus that causes COVID-19 targets the cardiovascular system via the ACE2 receptor (Rabi et al., 2020). Individuals with previous high blood pressure are at an increased risk for a severe reaction to COVID-19 (Shah et al., 2021). The stress placed on the body by SARS-CoV-2 would be expected to increase blood pressure due to its effect on the renin-angiotensin-aldosterone system. To date, no study has assessed the effect of COVID-19 on blood pressure. The opposite has been studied in-depth, i.e., how hypertension affects COVID-19 outcomes.

The linear relationship between systolic blood pressure (SBP) and diastolic blood pressure (DBP) is well studied and well understood (Pastor-Barriuso et al., 2003). SBP and DBP have been linked together in several studies, often demonstrating a systolic-versus-diastolic slope upon regression (Gavish, Ben-Dov, & Bursztyn, 2008). Both blood pressure readings coupled with pulse pressure have been shown to be highly related. These three factors are said to be so closely related that having two of the three provides enough data to determine the third. The present study found SBP and DBP are not significantly correlated with a $p=0.253$ and an $r=0.2192$, see figure 3.

Interestingly, the present article does not show a significant correlation; however, when SBP and DBP are plotted and tracked, the data shows SBP and DBP following each other in certain instances (see figure 4). Gavish, Ben-Dov, and Bursztyn (2008) explained this trend, citing that changes in DBP can be seen as more prominent changes in SBP. The present cohort did not show a high correlation; however, it did show similarities to previous studies in that regard.

As previously mentioned, no study to date has examined if COVID-19 causes changes in blood pressure. As such, there is no significant research to determine if blood pressure monitoring would be a good method to screen for COVID-19. However, if blood pressure were commonly measured, individuals would be more in tune with their health. If a person trends with high blood pressure, they would be able to take more precautions to prevent COVID-19 infection and potential strong adverse reactions.

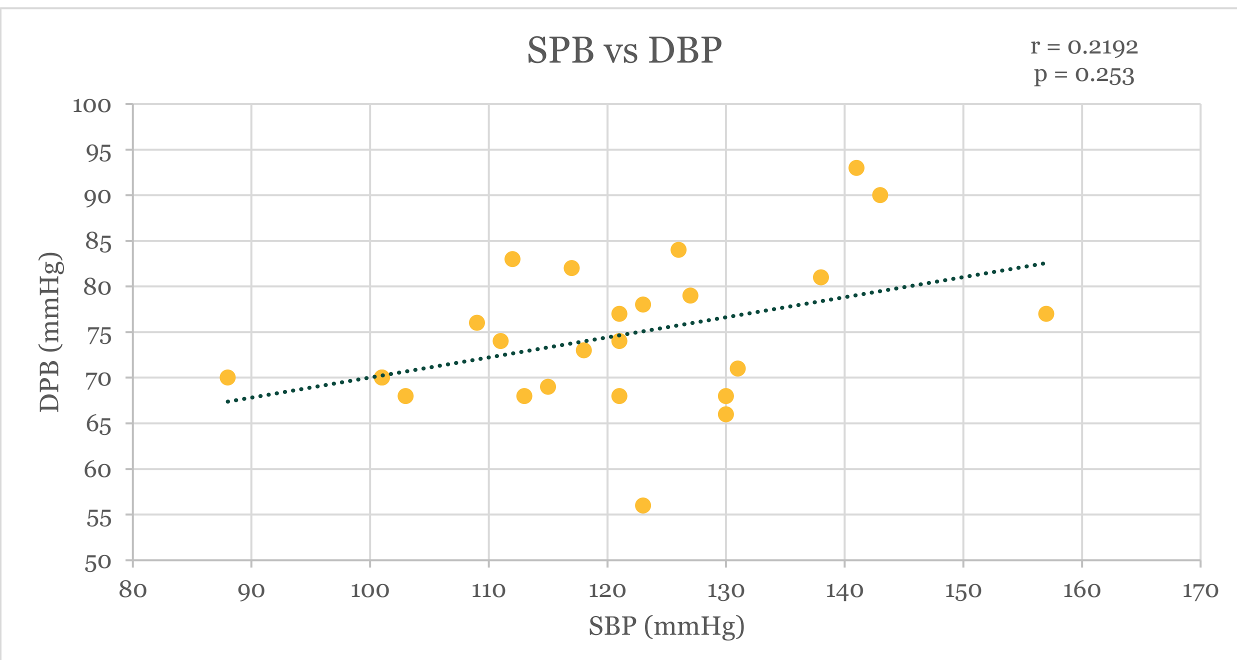


Figure 3 Systolic blood pressure and diastolic blood pressure typically share a linear relationship. Seen in the current study is a lack of linear relationship with p=0.2192

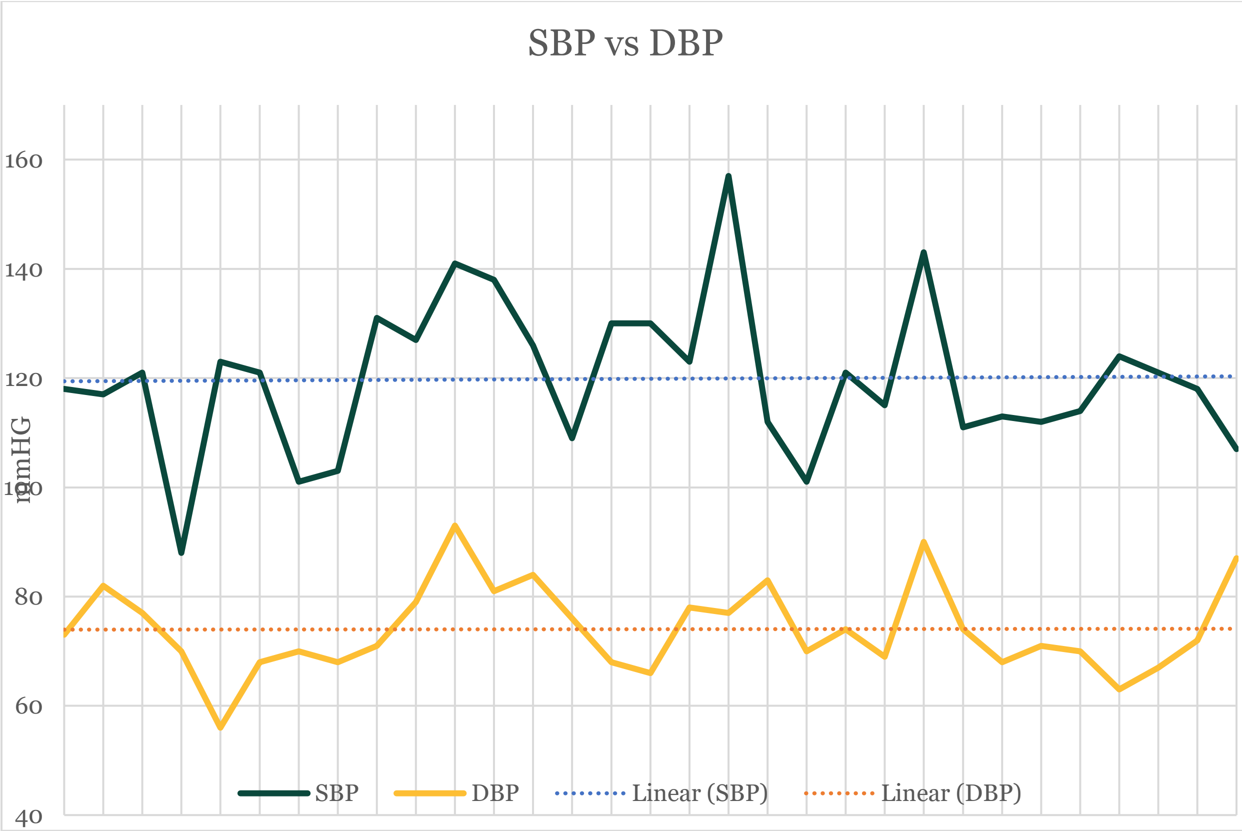


Figure 4 demonstrates some consistency of systolic blood pressure (SBP) to reflect changes in diastolic blood pressure (DBP).

O2 Stats

Oxygen (O2) saturation has been a perplexing piece of the SARS-CoV-2 puzzle. Hypoxia without any dyspnea has been seen in many patients and subsequently been given the term "happy hypoxia." Patients have been reporting to hospitals with blood oxygen levels as low as 50% (Tobin, Laghi, & Jubran, 2020), which is contradictory to life and would potentially lead to brain damage or cell death. It is hypothesized that when SARS-CoV-2 s attaches to ACE2 receptors, it affects the carotid body, where blood oxygen receptors are located (Tobin, Laghi, &

Jubran, 2020). The human body is more sensitive to decreases in levels of blood carbon dioxide levels, which is not seen in COVID-19 infection. Based on this fact, we may be able to determine a better way to monitor COVID-19 patients. A study published in the Journal for Laboratory Medicine found that in a small population, COVID-19 patients show lower levels of oxygen and higher carbon dioxide levels in the blood (Elezagic et al., 2020). The Elezagic et al. study results open the door for a new way to screen for COVID-19. More studies are needed to validate CO2 as an efficient screening method.

The FDA reports that pulse oximeters have inaccuracies that are not clinically significant at normal O2 saturation levels (Center for Devices and Radiological Health, 2021). When O2 saturation levels fall, the inaccuracies become more remarkable and more significant (Tobin, Laghi, & Jubran, 2020). Race has been revealed to play a factor in pulse oximetry inaccuracies as well. A 2020 study found that pulse oximeters over estimated O2 saturation in Black patients when arterial oxygen saturation was ≤88%, causing occult hypoxemia to be overlooked (Sjoding et al., 2020).

The present study found no relationship between O2 saturation and other tested variables. However, the data did reveal differences in other variables when O2 saturation was low. In those tested, there was a tendency to show changes in heart rate and blood pressure. While we could not verify COVID-19 infection, there was something physiological occurring in the population. Larger sample size may further highlight these changes due to the potential inclusion of SARS-CoV-2 positive individuals.

Other correlations expected to be present were between O2 saturation and blood pressure. Oxygen saturation has been shown to be correlated with systolic blood pressure above 80 mmHg (Hinkelbein, Genzwuerker, & Fiedler, 2005). However, the present study revealed a $p = 0.347$ and $r = -0.1845$. The negative r value is particularly interesting due to the inverse relationship between these two variables.

Using pulse oximetry for the screening of COVID-19 can be unreliable. Pulse oximeters show vast inaccuracies when O2 saturation is below 90%. COVID-19 patients can present with levels as low as 50%; thus, pulse oximeters are not helpful to detect new COVID-19 infections. Instead, using pulse oximeters for monitoring oxygen levels in those with a positive SARS-CoV-2 test could be a lifesaving tool. Home-bound COVID-19 patients can use a pulse oximeter to monitor their status and determine if they should seek medical attention or not. Further, many available pulse oximeters have not been approved by the FDA; thus, a more widely validated method for screening should be used. As previously mentioned, CO2 levels should be explored as a way to monitor infection.

Other potentially useful screening methods

The present study also attempted to validate smell as a potential screening method. All participants had the ability to determine a scent when asked; therefore, smell could not be validated. A smell test could be a quick and straightforward way to screen for COVID-19 due to nearly 60% of all COVID-19 patients presenting with hyposmia or anosmia (Whitcroft & Hummel, 2020). Loss of smell is more prevalent in COVID-19 patients than in other diseases (Printza & Constantinidis, 2020), and it is often one of the first symptoms to present, often appearing three days after infection; as such, it could be a proper screening method in the face of the pandemic. A hypothetical danger to using a smell test could be the need to pull a mask down below the nose. This opens the participant up to potential infection, or the participant could release infectious particles into the air for others to become infected.

Heart rate is another possible method for monitoring for COVID-19 infection. COVID-19 has demonstrated an ability to increase resting heart rate in a small perfect of COVID-19 patients (Quer et al., 2020). However, the study reported there was not a significant enough change to discern COVID-19 positive patients from negative patients. The effect COVID-19 has on heart rate needs to be further studied to gauge its usefulness in screening for SARS-CoV-2.

Further benefits from the present study

The COVID-19 pandemic has severely impacted general mental health. In the United States, 40% of adults report worse mental health status in June 2020 than in June 2019 (Czeisler et al., 2020). Implementing the extra safeguards tested in this study can lower these rates by allowing more people to interact. Thus, potential benefits from this study include an added level of protection during screening to allow for more in-person activities such as in-person classes.

Limitations

Potential limitations of the present study include small sample size, lack of follow-up, and lack of equilibration before taking blood pressure. Another significant limitation for the population is the requirement to be symptom-free. In order for students to be on campus, they must have been symptom-free for 48 hours and complete a questionnaire. Prospective investigations were hampered by cancelled classes, quarantines, and positive tests which shut down remaining testing through much of Fall 2020.

Conclusion

The ongoing COVID-19 pandemic has brought to light flaws in well-established medical testing devices. The most prominent example of these is the inaccuracies of non-contact infrared thermometers. NCIT's are inaccurate at temperatures at or above 99.5ºF; as such, they are an ineffective way to screen for fever associated with COVID-19. The present study revealed NCIT's show no relationship between temporal temperatures and non-contact forehead measures, further reducing their accuracy for application. Blood pressure is another ineffective method for screening due to the lack of research on how COVID-19 affects blood pressure without preexisting conditions. Pulse oximeters show reduced accuracy when blood oxygen levels fall below 80%. Therefore, O2 saturation is not an effective way to screen for COVID-19 infection due to the high prevalence of COVID-19 patients showing hypoxia as low as 50%. Heart rate could be another screening method; however, it is unknown how SARS-CoV-2 affects the heart due to lack of research. Finally, smell may be a reliable method to screen for COVID-19 due to the high prevalence of anosmia and early presentation when infected.

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I want to give a special thank you to Dr. Hew-Butler. She has been a fantastic mentor these past two years. I have learned a lot from her about exercise physiology and research and how challenging it can be. My college experience would not have been remotely close to what it was without her. I also want to thank Val and Matt for being a second guide when Dr. Hew was not there.

I look forward to continuing research with her and to furthering our relationship.

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