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Original Article

Comparative Evaluation of a Camera-based Monitoring Solution for Heart Rate, Heart Rate Variability, Respiratory Rate, Oxygen Saturation, and Blood Pressure Measurement vis-à-vis Regulated Contec Multipara Patient Monitor CMS 8000

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Abstract

This study aimed to evaluate the accuracy and reliability of a camera-based monitoring solution, vital scan, in measuring vital signs compared to established regulated medical devices. The study design involved simultaneous measurement of heart rate, respiratory rate, oxygen saturation, systolic blood pressure (BP), and diastolic BP using multiple devices, including smartphones and an HP laptop with a Logitech webcam. A total of 626 participants from diverse backgrounds were recruited for the study. Vital scan demonstrated a high correlation with the FDA-regulated Contec Multipara Patient Monitor CMS 8000 for all measured vital signs. The results suggest that the camera-based monitoring solution is feasible and accurate for assessing vital signs, potentially offering a non-invasive and convenient alternative in health-care settings. Further research and validation studies are needed to explore its integration into clinical practice and assess its cost-effectiveness and patient comfort benefits.

Key words: Blood pressure, Camera-based monitoring solution, Comparative evaluation, Heart rate, Oxygen saturation, Regulated medical devices, Respiratory rate

INTRODUCTION

Accurate and timely monitoring of vital signs, including heart rate (HR), respiratory rate (RR), oxygen saturation (SpO_2), and blood pressure (BP), is essential in health-care settings for effective patient care and early detection of critical conditions. Conventionally, regulated medical devices such as electrocardiograms (ECGs), pulse oximeters, and sphygmomanometers have been used to measure these vital signs. However, advancements in technology have introduced camera-based monitoring solutions that claim to provide non-invasive and convenient alternatives for vital sign measurement.[1-5]

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The camera-based monitoring solution utilizes computer vision algorithms and image processing techniques to analyze physiological parameters from video recordings or images captured by a standard camera. This technology has the potential to revolutionize vital sign monitoring by enabling remote and continuous measurements without the need for direct physical contact with the patient.[6-13]

This evaluation aims to critically assess the effectiveness and reliability of a camera-based monitoring solution in accurately measuring HR, RR, SpO_2, and BP when compared to established regulated medical devices. The evaluation will focus on evaluating the accuracy, precision, and consistency of the camera-based solution's measurements and comparing them to the gold standard provided by regulated medical devices.[1,4-9,14]

By conducting a comparative evaluation, health-care professionals and researchers can gain insights into the feasibility and potential limitations of adopting camera-

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based monitoring solutions in clinical practice. The results of this evaluation will inform decision-making processes regarding the integration of this technology into health-care settings, potentially improving patient monitoring efficiency, reducing health-care costs, and enhancing patient comfort.[1-6,10,12-14]

Contec CMS 8000

The Contec CMS 8000 is a multiparameter patient monitor commonly used in medical settings to continuously monitor the vital signs and other parameters of patients. It is designed to provide health-care professionals with real-time information about a patient's condition, allowing for timely interventions and improved patient care.

The Contec CMS 8000 typically monitors several key parameters, which may include in the study:

1. ECG: Measures the electrical activity of the heart, detecting irregularities and abnormalities in HR and rhythm.
2. SpO_2 (Peripheral SpO_2): Measures the SpO_2 level of hemoglobin in the blood, indicating how well oxygen is being carried to the body's tissues.
3. Non-invasive BP: Measures BP using a cuff on the patient's arm without the need for invasive procedures.
4. Respiration rate: Monitors the number of breaths per minute, helping assess respiratory function.
5. Temperature (TEMP): Measures the patient's body TEMP.
6. Pulse rate (PR): Monitors the HR by counting the number of pulses per minute.
7. Optional CO_2 monitoring ($EtCO_2$): Some versions of the CMS 8000 may also offer end-tidal carbon dioxide monitoring, which helps assess how well a patient is ventilating.

The patient monitor typically features a display screen that shows the real-time readings of the monitored parameters. Alarms and alerts are incorporated to notify health-care providers if any of the measured values fall outside preset safe ranges, allowing them to promptly respond to any critical changes in the patient's condition.

Hypotheses

1. The camera-based monitoring solution will provide measurements of HR comparable to those obtained from regulated medical devices.
2. The camera-based monitoring solution will accurately measure RR in line with the readings of regulated medical devices.
3. The camera-based monitoring solution will yield SpO_2 measurements similar to those obtained from regulated medical devices.
4. The camera-based monitoring solution will produce BP measurements that align with the readings of regulated medical devices.

By testing these hypotheses, we can determine the accuracy and reliability of the camera-based monitoring solution and its potential as a viable alternative for vital sign measurements.

Research Design

The study design involved simultaneous measurement of five vital signs: HR, RR, SpO_2, systolic BP (SBP), and diastolic BP (DBP). Multiple devices were utilized, including an HP laptop with a Logitech webcam, as well as smartphones (Samsung S23, OnePlus 11, iPhone 13, 14 Pro, and iPad Pro). This device diversity aimed to demonstrate that the results were not biased by a particular technology and could function effectively across different operating systems such as Android, iOS, Windows, and macOS.

To ensure standardized measurements, the devices were positioned 60 cm away from the subject's face and mounted on a tripod with a ring light source positioned in front of the subject, providing a minimum illumination of 250 lux. Reference measurements for HR and RR were obtained using Massimo mightiest devices, while OMRON/CIRCA MICRO LIFE/NIDEK multi-parameter monitors and pulse oximeters were used to obtain reference measurements for the other vital signs. Participants were instructed to remove glasses or any facial coverings and sit in a chair during the scans. They were advised to maintain stillness and gaze directly at the camera throughout the entire 60-s scan duration. All vital signs were measured once using the medical devices.

Participants

In this study, a total of 626 participants were recruited, consisting of 313 females and 313 males. The age range of the participants was 27–57 years, and they represented diverse skin colors, ethnicities, and medical statuses.

Data Collection

Prior to data collection, participants provided informed consent and underwent a brief orientation to the devices and the measurement protocol. Simultaneous measurements were conducted by positioning participants comfortably and ensuring adequate lighting conditions. For HR, RR, and SpO2 measurements, participants wore the necessary sensors as instructed by each device's manufacturer. Blood pressure measurements were obtained using appropriate cuffs and calibration techniques.

Data collection sessions were conducted in controlled settings by trained research assistants.At Actofit HQ. Each participant underwent two rounds of measurements, with a

resting period between rounds to minimize potential order effects. The order of device usage was counterbalanced to mitigate bias.

MATERIALS AND METHODS

This study aimed to assess the accuracy of remote health screening technology, specifically Vastmindz's 3.0 SDK, in measuring HR, RR, BP, and SpO_2. The objective was to compare the accuracy of these measurements obtained using Vastmindz's technology against gold standard vital signs monitors, which served as the reference method. It is important to acknowledge that the reference instruments themselves have inherent error, with possible deviations of up to ±3 units per parameter. This factor will be taken into consideration when interpreting the results.

The study methodology consisted of two main components: Onsite data collection and subsequent analysis. Data collection took place at hospitals, ensuring that the process was free from any external interference. The data collection device employed in this study was equipped with an app utilizing Vastmindz's technology. The app interface facilitated various functions such as face detection, landmark placement, and the creation of regions of interest (ROIs). Within each frame, the app collected the blue-green-red (BGR) components of each ROI, representing visual information. These BGR samples were securely stored in a cloud database for further analysis. Figures 1 and 2 provide an overview of the methodology employed in this study.

To analyze the collected data, a pipeline was developed to systematically process the samples. The pipeline involved parsing the samples, converting the BGR components into a 1D signal, and extracting the relevant physiological parameters. Subsequently, the extracted results were compared to the ground truth values obtained from medical devices.

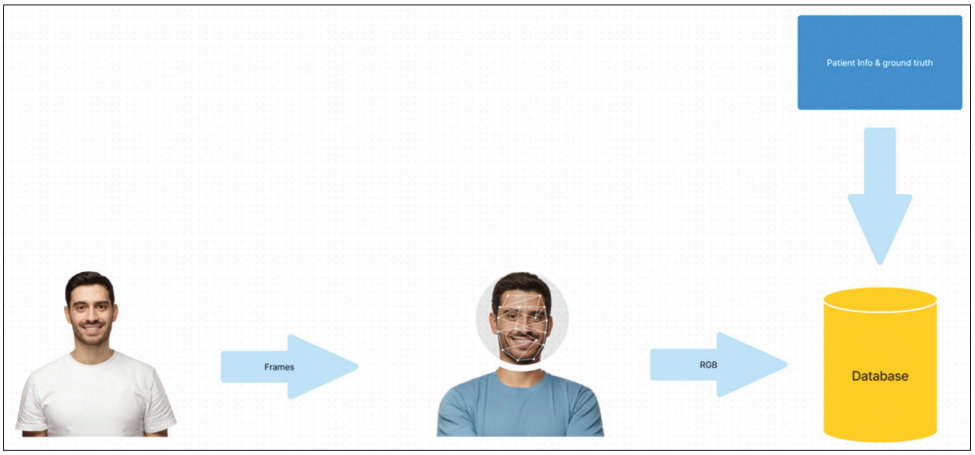


Figure 1: Study methodology: Data collection. RGB: red, green, and blue

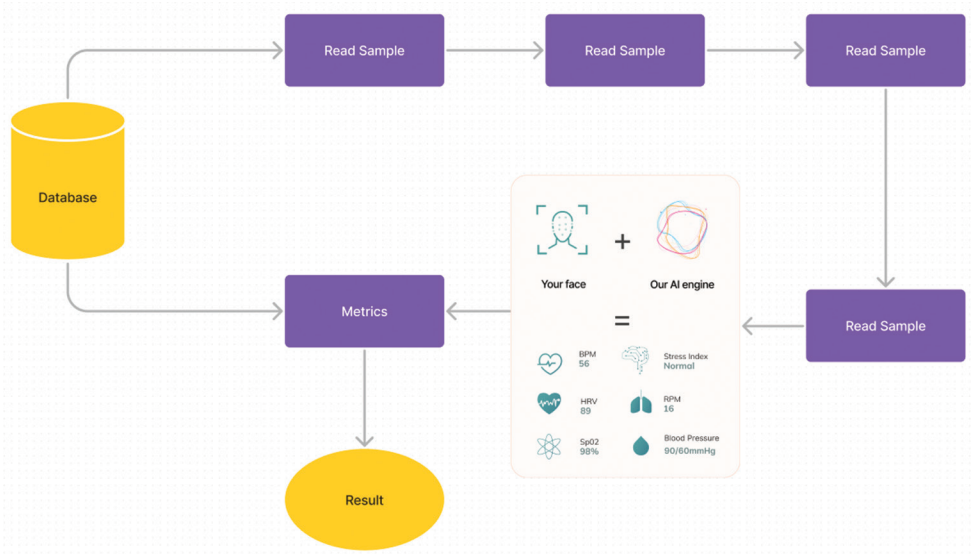


Figure 2: Study methodology: Analysis. BGR: Blue, green, and red, 1D: One-dimensional, rPPG: Remote photoplethysmography

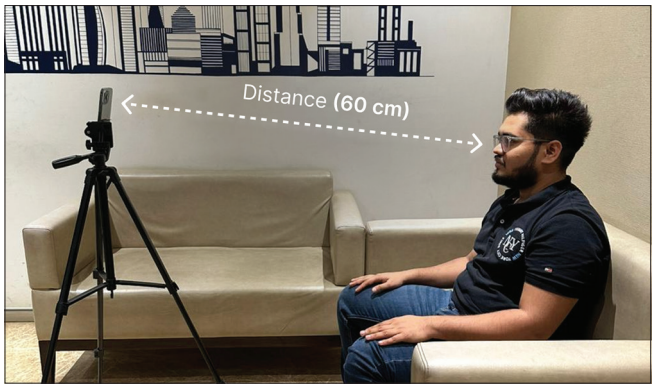


Figure 3: Study methodology: Protocol

To assess the accuracy of the estimated values, several metrics were calculated, including the mean error, mean absolute error, root mean squared error, and root mean squared percentage error (RMSPE %). These metrics provide quantitative measures of the disparity between the estimated values and the ground truth values. Figure 3 provides a visual representation summarizing the workflow employed in this study.

RESULTS

In addition to assessing the technology across patients with diverse demographic characteristics, it is crucial to analyze individuals with varying baseline parameters, including resting PR, RR, BP, SpO_2, and HR variability (HRV). These baseline parameters provide reference values for comparison and evaluation. The summary of reference values is shown in Table 2.

Reference values were compared to estimated values using facial scanning. Table 7 presents sample sizes, ME, MAE, RMSE, and RMSPE for each vital sign. Results are categorized into three groups. Visual insights are available in Graphs 13 and 14, offering histograms of errors for RR, SpO2, HR, and BP (SBP, DBP) [Table 7].

Considering the comprehensive analysis of the results, graph 17 examines the effect of age on errors, while graph 18 explores the impact of height and weight. These figures provide insights into the relationships between these factors and the observed errors.

Additionally, acknowledging the presence of potential outliers that could influence statistical outcomes, this study employs box plots. These plots effectively illustrate quartile ranges and highlight outliers for each vital sign. Refer to graph 19 for a visual representation of these distributions [Graphs 1-20] and [Tables 1 and 3-6].

Table 1: Demographic characteristics of the data[1-4]

Characteristics	Mean (minimum-maximum)
Age	40.94 (27–57)
Height	168.38 (155–180)
Weight	70.38 (58–82)
BMI	24.79 (21.7–28)

BMI: Body mass index

Table 2: Vital scan ground truth[4-7]

Vital scan	Mean
Systolic BP (mmHg)	121.6
Diastolic BP (mmHg)	78.6
SpO2 (%)	97.45
Heart rate (bpm)	74.40
Respiratory rate (breaths/min)	15.35
HRV (ms)	68.15

HRV: Heart rate variability

Table 3: Mean and standard deviation graph of male, vital scan versus Contec Multipara Patient Monitor CMS 8000[4-7]

Device	Parameter	Mean	Standard deviation
Vital scan	Systolic BP (mmHg)	121.1789	3.68
	Diastolic BP (mmHg)	78.23323	2.94
	SpO_2 (%)	97.48243	1.02
	Heart rate (bpm)	74.05112	3.85
	Respiratory rate (breaths/min)	15.3099	1.01
	HRV (ms)	68.05751	1.92
Contec Multipara Patient Monitor CMS 8000	Systolic BP (mmHg)	121.130	4.40
	Diastolic BP (mmHg)	78.20	4.01
	SpO_2 (%)	97.408	2.28
	Heart rate (bpm)	74.00	4.00
	Respiratory rate (breaths/min)	15.30	1.22
	HRV (ms)	68.06	2.87

HRV: Heart rate variability

DISCUSSION

The discussion for graph mean and standard deviation graph of male, vital scan vs Contec Multipara Patient monitor Cms 8000 as follows:

For the vital scan software the parameter systolic BP (mmHg) has mean of 121.17 and standard deviation of 3.68 whereas for the device Contec multipara patient monitor the parameter of systolic BP (mmHg) has 121.13 and standard deviation of 4.40. For the vital scan software the parameter diastolic BP (mmHg) has mean of 78.23 and standard deviation of 2.94 whereas for the device Contec multipara patient monitor the parameter of diastolic BP (mmHg) has 78.20 and standard deviation of 4.01. For the

Table 4: Mean and standard deviation graph of female, vital scan versus Contec Multipara Patient Monitor CMS 8000[17-23]

Device/software	Parameter	Mean	Standard deviation
Vital scan	Systolic BP (mmHg)	121.9201	3.68
	Diastolic BP (mmHg)	78.83706	2.94
	SpO_2 (%)	97.35463	1.02
	Heart rate (bpm)	74.63578	3.85
	Respiratory rate (breaths/min)	15.39936	1.01
	HRV (ms)	68.24281	1.92
Contec Multipara Patient Monitor CMS 8000	Systolic BP (mmHg)	121.76	4.4
	Diastolic BP (mmHg)	78.82	4.02
	SpO_2 (%)	97.25	2.28
	Heart rate (bpm)	74.61	4.01
	Respiratory rate (breaths/min)	15.40	1.22
	HRV (ms)	68.15	2.87

HRV: Heart rate variability

Table 5: Correlation of vital scan versus Contec Multipara Patient Monitor CMS 8000 in female[7–11]

Parameter	Correlation value
Systolic BP (mmHg)	0.8707623141
Diastolic BP (mmHg)	0.8675261043
SpO_2 (%)	0.9370792407
Heart rate (bpm)	0.9303930157
Respiratory rate (breaths/min)	0.8940214791
HRV (ms)	0.9366756366

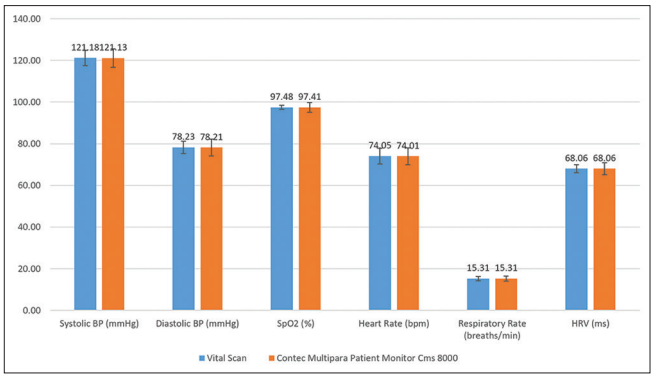
HRV: Heart rate variability

Table 6: Correlation of vital scan versus Contec Multipara Patient Monitor CMS 8000 in male

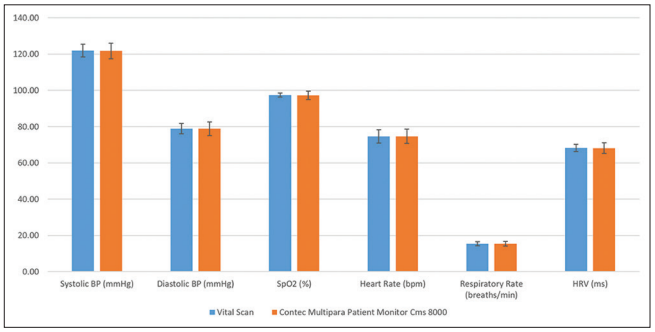
Parameter	Correlation value
Systolic BP (mmHg)	0.8726272693
Diastolic BP (mmHg)	0.896333088
SpO_2 (%)	0.9002112073
Heart rate (bpm)	0.9383255394
Respiratory rate (breaths/min)	0.9007170485
HRV (ms)	0.9229622818

HRV: Heart rate variability

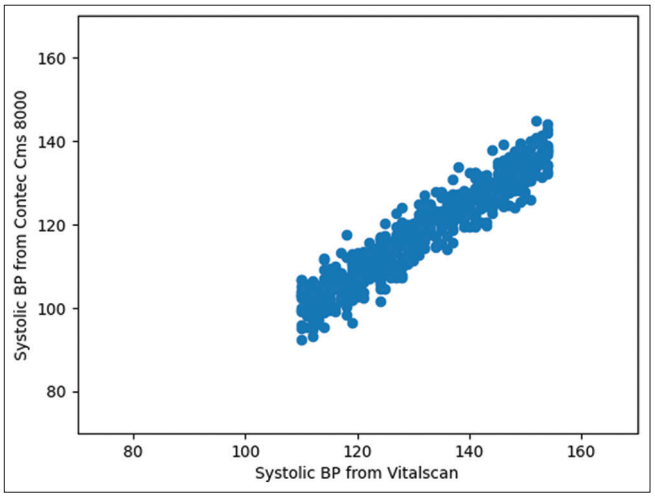
vital scan software the parameter SpO2 has mean of 97.48 and standard deviation of 1.02 whereas for the device Contec multipara patient monitor the parameter of SpO2 has mean of 97.40 and standard deviation of 2.28. For the vital scan software the parameter of heart rate (bpm) has mean of 74.05 and standard deviation of 3.85 whereas for the device Contec multipara patient monitor the parameter of heart rate (bpm) has mean of 74.00 and standard deviation of 4.00 . For the vital scan software the parameter of respiratory rate (breaths/min) has mean of 15.30 and standard deviation of 1.01 whereas for the device Contec multipara patient monitor the parameter of respiratory rate (breaths/min)



Graph 1: Mean and standard deviation graph of male, vital scan versus Contec Multipara Patient Monitor CMS 8000[4-7]



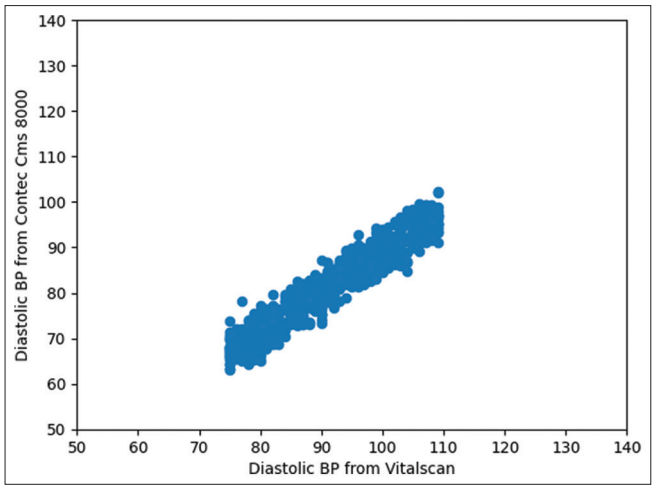
Graph 2: Mean and standard deviation graph of female, vital scan versus Contec Multipara Patient Monitor CMS 8000[4-7]



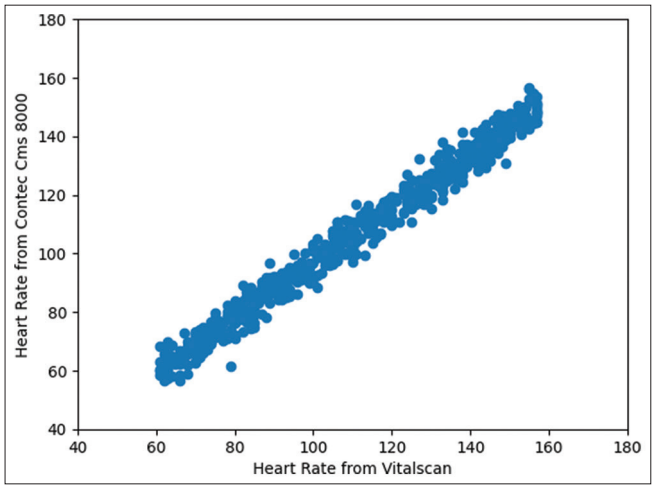
Graph 3: Systolic blood pressure female (Pearson correlation coefficient (r)=0.87, standard deviation=3.56)[7-11]

has mean of 15.30 and standard deviation of 1.22. For the vital scan software the parameter of HRV (ms) has mean of 68.05 and standard deviation of 1.92 whereas for the device Contec multipara patient monitor the parameter of HRV (ms) has mean of 68.06 and standard deviation of 2.87.

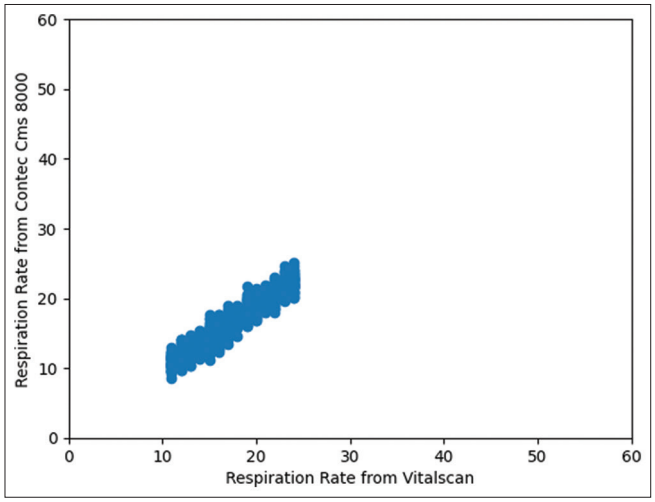
The discussion for graph mean and standard deviation graph of Female, vital scan vs Contec Multipara Patient monitor Cms 8000 as follows:



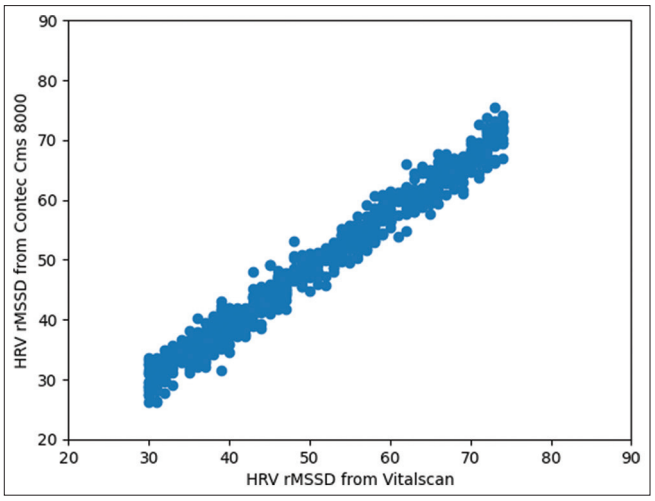
Graph 4: Diastolic blood pressure female (Pearson correlation coefficient (r) = 0.86 standard deviation = 2.80)[7-11]



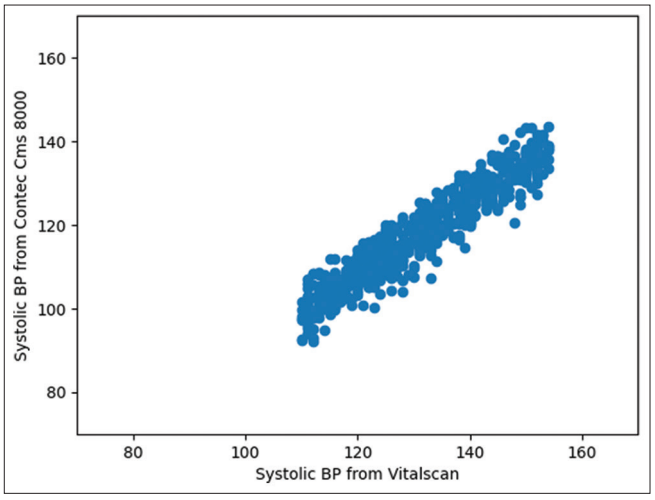
Graph 5: Heart rate female (Pearson correlation coefficient (r) = 0.93 standard deviation = 3.71)[4-9]



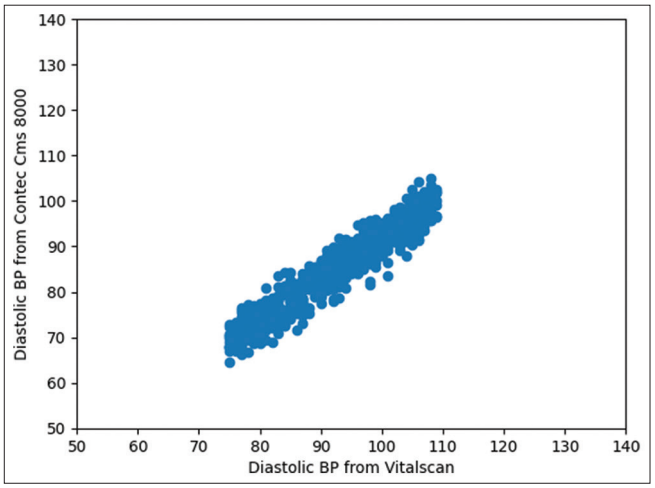
Graph 6: Respiration rate female (Pearson correlation coefficient (r) = 0.89 standard deviation = 1.09)[5-10]



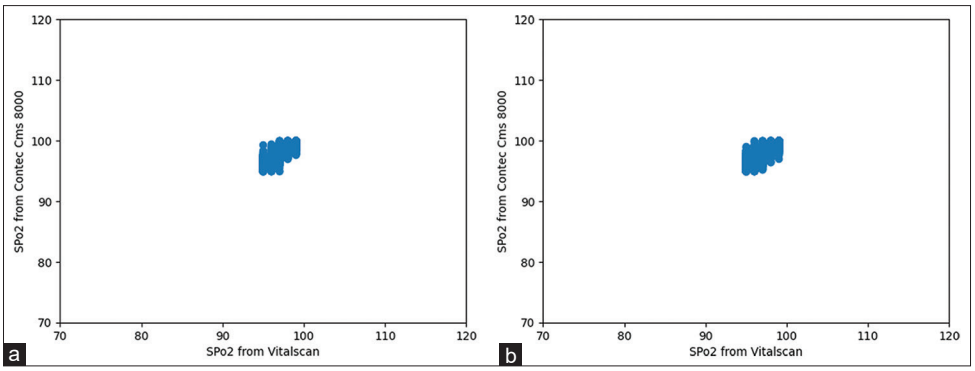
Graph 7: Heart rate variability rMSSD female (Pearson correlation coefficient (r) = 0.93 standard deviation = 1.95)[12-15]



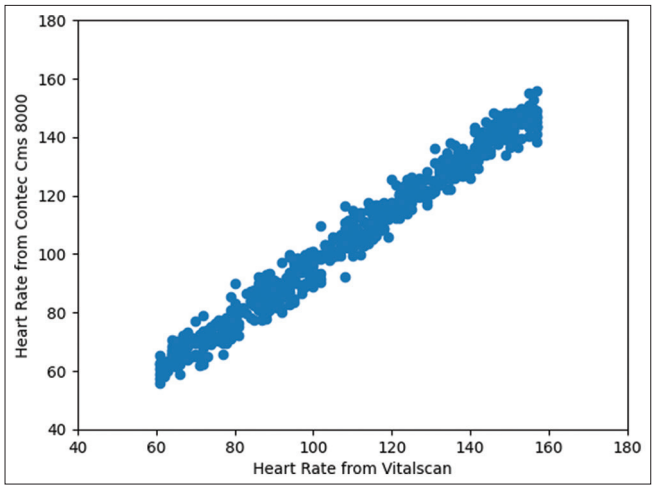
Graph 8: Systolic blood pressure male (Pearson correlation coefficient (r) = 0.87, standard deviation = 3.68)[7]



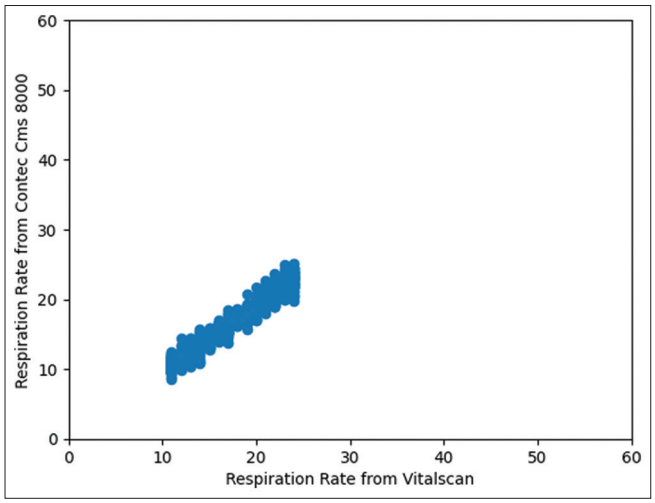
Graph 9: Diastolic blood pressure (Pearson correlation coefficient (r) = 0.98 standard deviation = 2.94)[7]



Graph 10: (a) SPO_2 female (Pearson correlation coefficient (r) = 0.93 standard deviation = 1.10) (b) SPO_2 male (Pearson correlation coefficient (r) = 0.90 standard deviation = 1.02)[17-25]

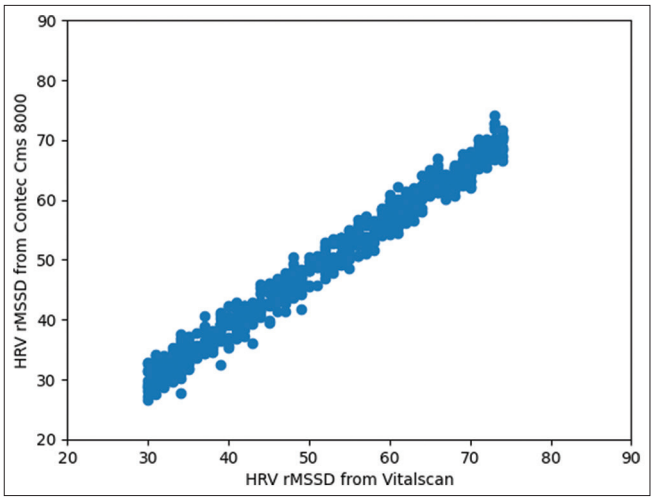


Graph 11: Heart rate male (Pearson correlation coefficient (r) = 0.93 standard deviation = 3.86)[17]



Graph 12: Respiration rate male (Pearson correlation coefficient (r) = 0.90 standard deviation = 1.01)[4]

For the vital scan software the parameter systolic BP (mmHg) has mean of 121.92 and standard deviation of 3.68 whereas for the device Contec multipara patient monitor the parameter of systolic BP (mmHg) has 121.76

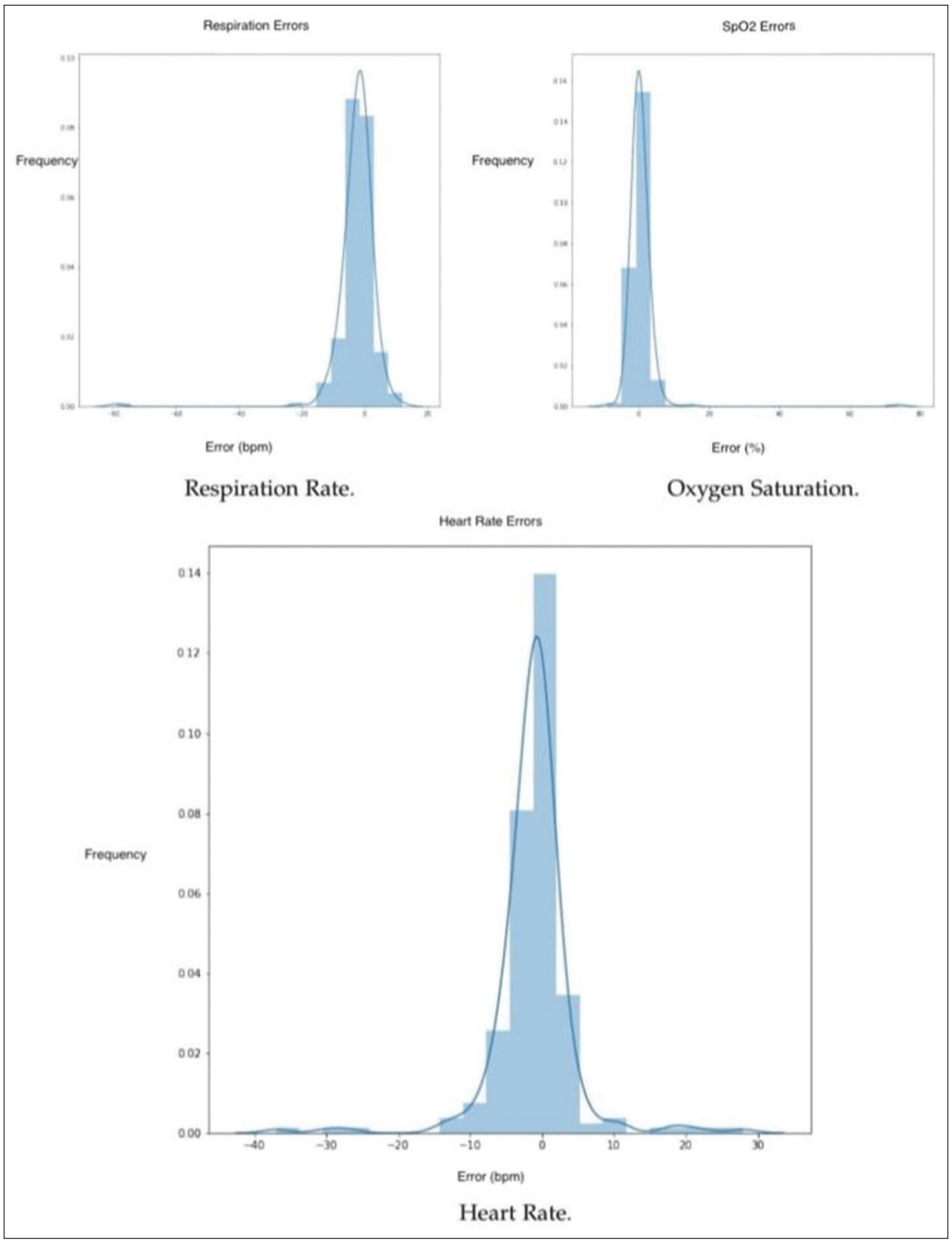


Graph 13: Heart rate variability rMSSD male (Pearson correlation coefficient (r) = 0.92 standard deviation = 1.93)[17]

Table 7: Differences between Reference and Estimated Values for Vital Signs

Vital Scan	Sample Size	ME	MAE	RMSE	RMSPE (%)
Heart rate (HR)	626	-1.19	3.09	5.72	7.43
HR≤60	46	1.94	2.88	5.51	10.48
60<HR≤100	501	-1.17	3.01	5.31	7.12
HR>100	79	-3.90	4.00	8.86	7.39
Oxygen saturation (SpO2)	608	0.30	1.21	1.77	1.85
90<SpO2≤95	78	3.64	3.64	3.80	4.06
SpO2>95	530	-0.15	0.88	1.26	1.29
Respiratory rate (RR)	576	-2.11	3.39	4.65	25.82
RR≤10	16	6.17	6.17	7.13	81.94
10<RR≤18	337	-0.48	2.02	2.70	17.94
RR>18	223	-5.41	5.46	6.58	28.22
Systolic blood pressure	613	-5.27	18.15	22.77	17.59
SBP≤90	3	38.33	38.33	38.48	45.62
90<SBP≤130	414	3.55	14.35	17.60	15.59
SBP>130	196	-22.13	24.69	29.68	19.93
Diastolic blood pressure	613	-3.95	10.49	13.71	17.38
DBP≤60	28	20.29	20.29	22.13	41.18
60<DBP≤90	509	-2.17 |	8.31	10.76	14.05
DBP>90	76	-20.68	20.68	23.10	23.47

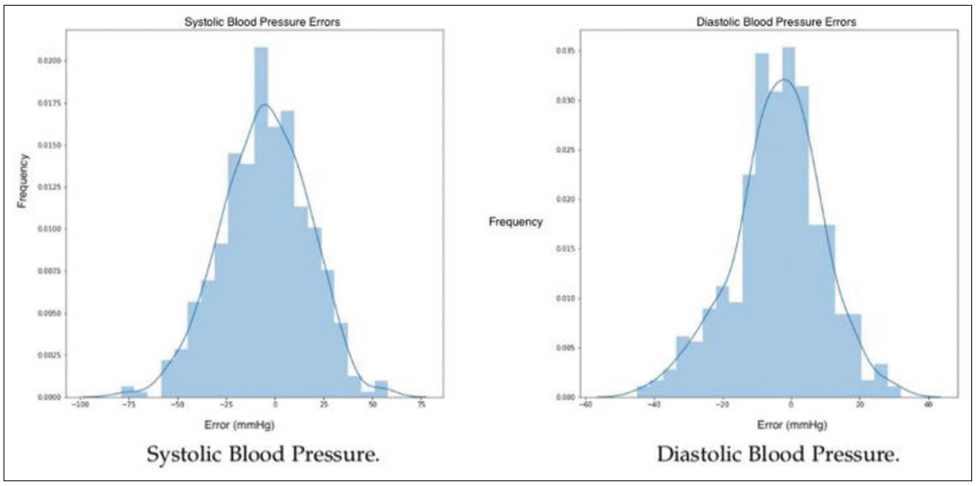
ME: mean error; MAE: mean absolute error; RMSE: root mean squared error; RMSPE: root mean squared percentage error



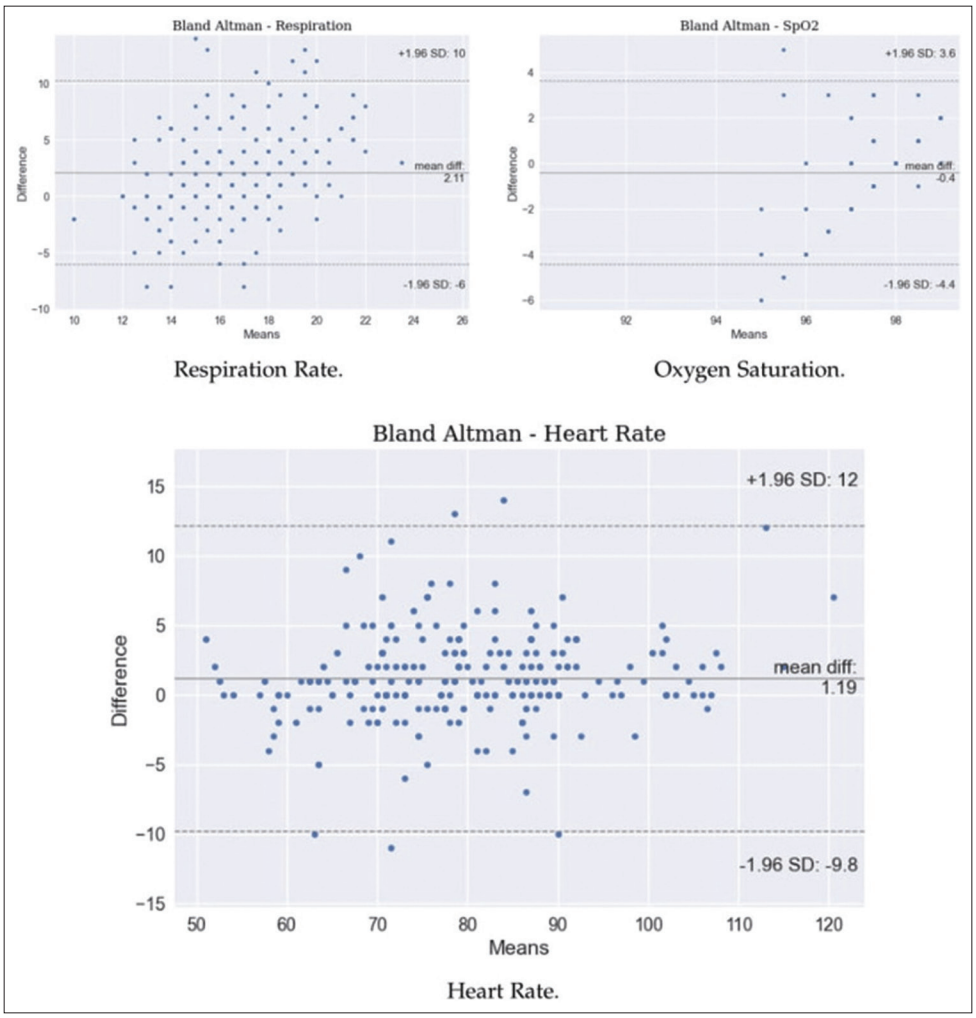
Graph 14: Histograms showing errors. (a) Respiration rate (RR), (b) oxygen saturation (SpO2), and (c) heart rate (HR)[17]

and standard deviation of 4.4. For the vital scan software the parameter diastolic BP (mmHg) has mean of 78.83 and standard deviation of 2.94 whereas for the device Contec multipara patient monitor the parameter of diastolic BP (mmHg) has 78.82 and standard deviation of 4.02. For the vital scan software the parameter SpO2 has mean of 97.35 and standard deviation of 1.02 whereas for the device Contec multipara patient monitor the parameter of SpO2 has mean of 97.25 and standard deviation of 2.28. For the vital scan software the parameter of heart rate (bpm) has mean of 74.63 and standard deviation of 3.85 whereas for the device Contec multipara patient monitor the parameter of heart rate (bpm) has mean of 74.61 and standard deviation of 4.01 . For the vital scan software the parameter of respiratory rate (breaths/min) has mean of 15.39 and standard deviation of 1.01 whereas for the device Contec multipara patient monitor the parameter of respiratory rate (breaths/min) has mean of 15.40 and standard deviation of 1.22 . For the vital scan software the parameter of HRV (ms) has mean of 68.24 and standard deviation of 1.92 whereas for the device Contec multipara patient monitor the parameter of HRV (ms) has mean of 68.15 and standard deviation of 2.87 .

The discussion for the graph of correlation of Vital Scan vs Contec Multipara Patient Monitor Cms 8000 in Female is as follows:

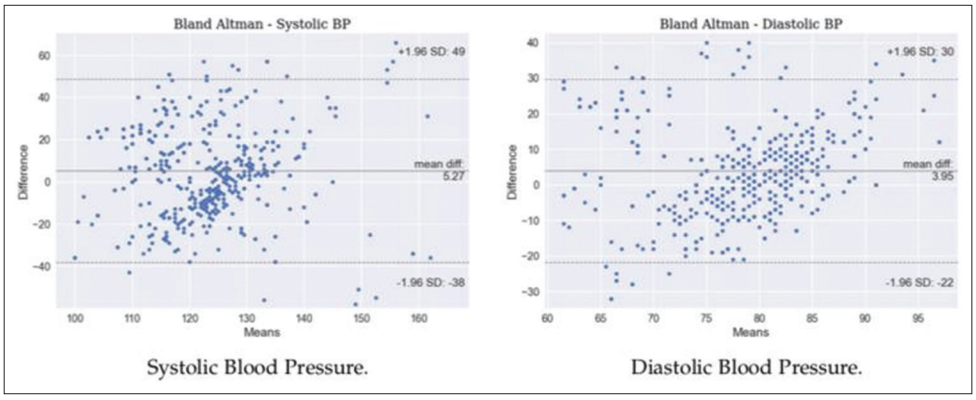


Graph 15: Histograms showing errors in blood pressure. In addition to histograms displaying error distribution, Bland-Altman plots provide an alternative evaluation method. These plots illustrate mean value versus difference for each data point. Graph 15 and graph 16 depict these plots for all vital signs[17]

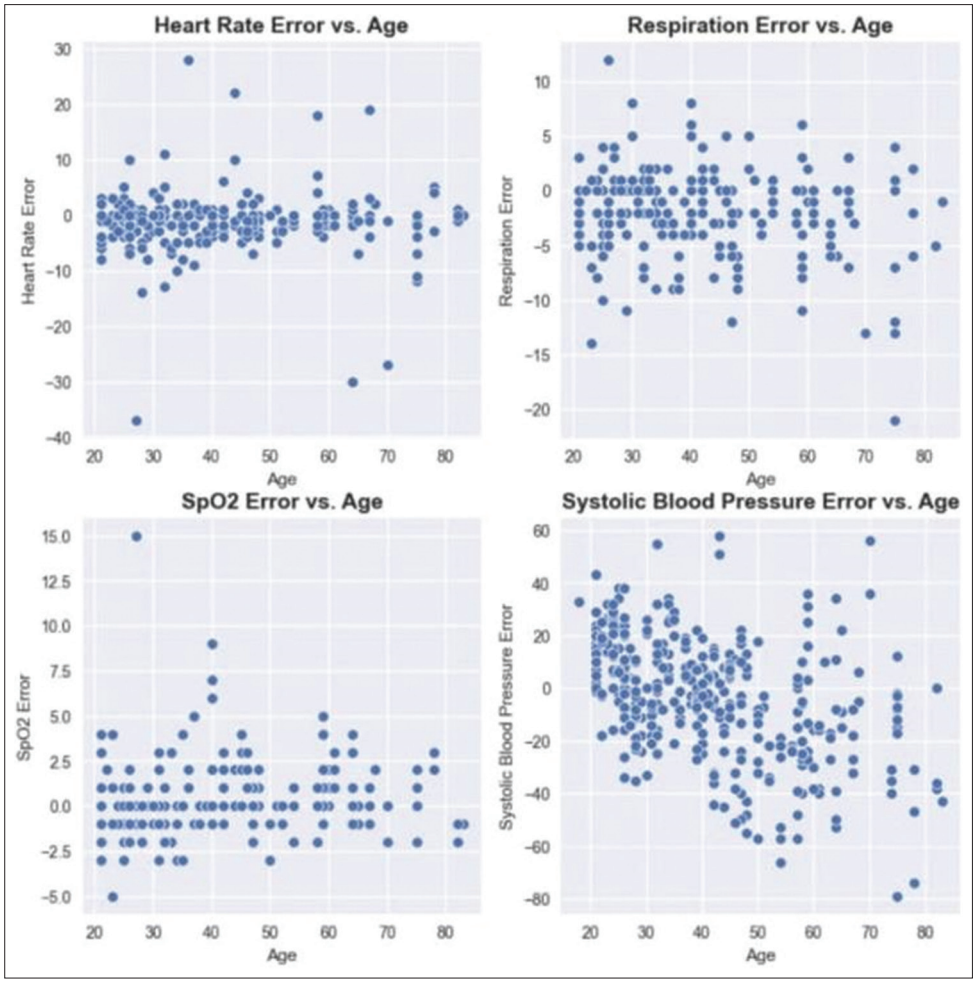


Graph 16: Bland-Altman plots. (a) Respiration rate, (b) oxygen saturation, and (c) heart rate[4]

The correlation value for systolic BP (mmHg) is 0.87.
The correlation value for diastolic BP (mmHg) is 0.86.
The correlation value for SpO2 is 0.937
The correlation value for Heart rate(bpm) is 0.930
The correlation value for Respiratory Rate (breaths/min) is 0.89
The correlation value for HRV (ms) is 0.93.



Graph 17: Bland-Altman plots. (a) Systolic blood pressure (SBP) and (b) diastolic blood pressure (DBP)[7]



Graph 18: Impact of age on vitals errors for heart rate, respiration, SpO2, and systolic blood pressure[5]

The discussion for the graph of correlation of Vital Scan vs Contec Multipara Patient Monitor Cms 8000 in Male is as follows:

The correlation value for systolic BP (mmHg) is 0.872

The correlation value for diastolic BP (mmHg) is 0.89.

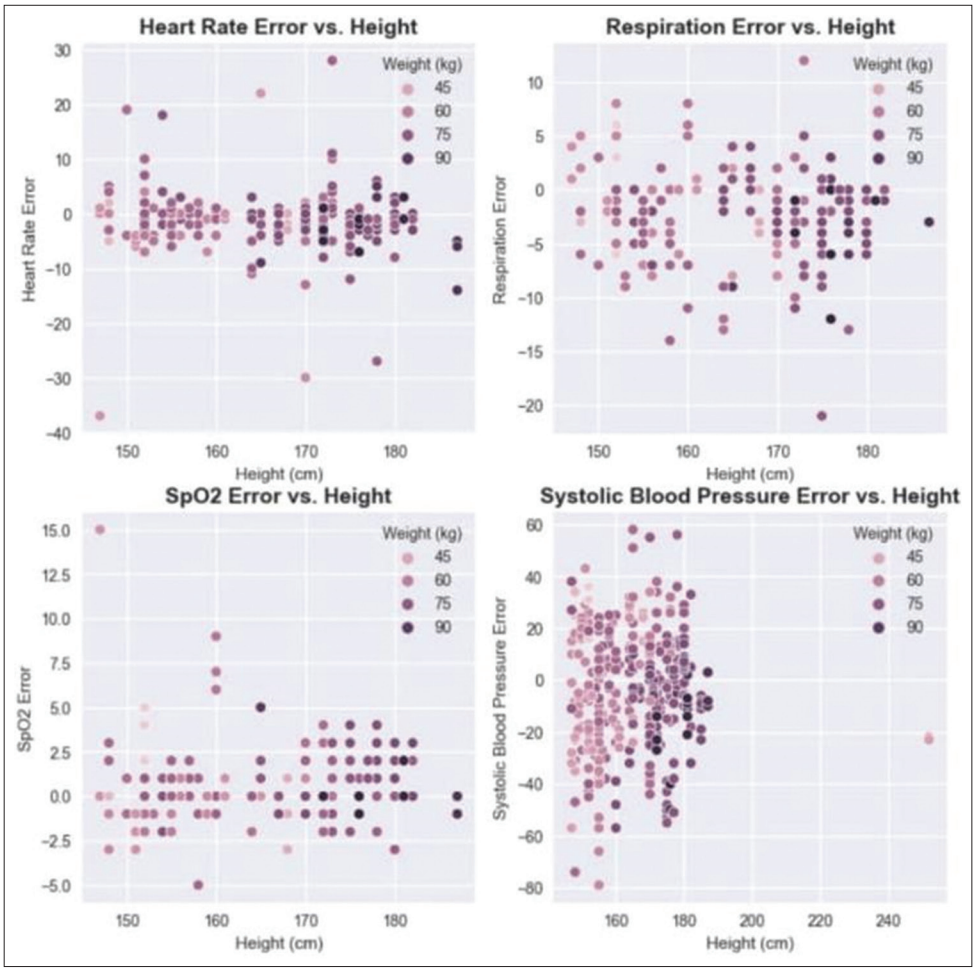
The correlation value for SpO2 is 0.90

The correlation value for Heart rate(bpm) is 0.938

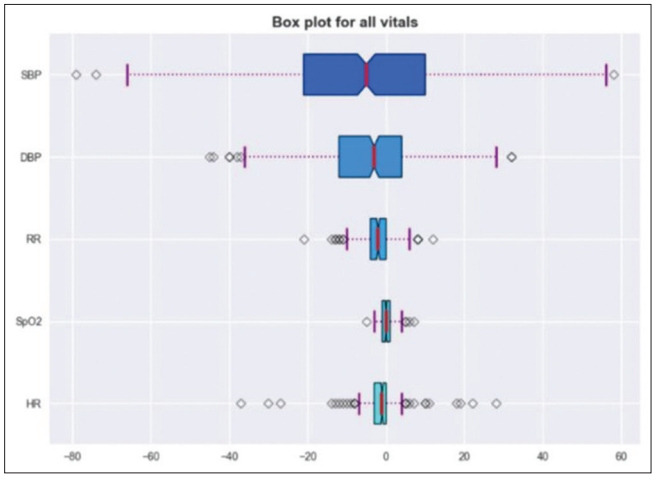
The correlation value for Respiratory Rate (breaths/min) is 0.90

The correlation value for HRV (ms) is 0.92 .

In the context of this study, the primary goal was to assess the performance of visual technology in comparison to established medical devices. It's important to note that



Graph 19: Impact of height and weight on vitals errors for heart rate, respiration, SpO2, and systolic blood pressure[4]



Graph 20: Box plot for all vitals. SBP: systolic blood pressure; DBP: diastolic blood pressure; RR: respiratory rate; SpO2: oxygen saturation; HR: heart rate[17]

the technology utilized in this investigation undergoes frequent software updates to enhance its capabilities. Consequently, recent studies are anticipated to exhibit improved performance compared to earlier ones. The study involved data collection from 626 participants, although complete vital sign data was not available for every individual. Notably, blood pressure (BP) was consistently measured for all participants, while other parameters were obtained from approximately 240 patients.[24,25]

The overall findings indicate a favorable agreement between camera-based visual monitoring technology (Vital Scan) and reference instruments. Specifically, heart rate (HR), respiratory rate (RR), and oxygen saturation (SpO2) all satisfied the preset hypothesis criteria of ±3 units in Mean Error (ME) for each parameter. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) also adhered to the requirement of ±10 units in ME. However, cautious interpretation is warranted due to the substantial standard deviation of errors among the results.[26]

An analysis of alternative metrics reveals that most algorithms maintained similar outcomes when using Mean Absolute Error (MAE), with the exception of SBP, which exhibited a significant absolute difference increase. The application of a quadratic function, such as Root Mean Square Error (RMSE), exposed errors that might be smoothed out by mean values. RMSE results indicated

acceptable performance in HR and SpO2, both in the average and within distinct groups. Nevertheless, RR, SBP, and DBP displayed the influence of pronounced errors when assessed through quadratic metrics.[27]

Notably, the HR estimation emerged as one of the most robust algorithms, maintaining the ±3 criteria across averages and within low and normal ranges. Instances of extremely high or low HR posed greater estimation challenges, potentially due to motion artifacts linked to stress and anxiety during image acquisition.

Regarding oxygen saturation (SpO2), a satisfactory agreement of 90% to 100% was observed, with a minimal ME of 0.3%. While there were limited instances of SpO2 below 90%, typically occurring in critical or high-altitude scenarios, future research aims to include more participants with hypoxia to validate performance at such low levels. It's worth noting that the technology's current scope is more aligned with preventive rather than diagnostic usage in such conditions.[28]

For respiratory rate (RR), optimal performance was within the normal range of 10 to 18 breaths per minute, exhibiting a mean error of -0.48. The most notable bias was apparent at very low rates of less than 10 breaths per minute.

However, blood pressure (BP), particularly SBP and DBP, posed the most intricate challenge. While the technology demonstrated favorable outcomes within its results and sample distribution, difficulties were prominent in extreme values, notably SBP higher than 150 mmHg and DBP higher than 90 mmHg.[29]

Histogram analyses highlight a tendency of results clustering around errors close to zero, implying frequent instances of low-level errors. However, the impact of outliers on statistical results must be acknowledged. Notably, the HR histogram displayed a classic normal distribution pattern.[30]

Bland-Altman plots, offering a robust perspective, indicate mean value vs. difference relationships. HR demonstrated a mean difference of 1.19 beats per minute, with a wider standard deviation of +12 to -10. RR exhibited a narrower standard deviation, although with a higher mean difference and more scattered errors. SpO2, as expected, revealed fewer data points due to grouped results, resulting in a lower mean difference. In the case of BP, consistent patterns of erroneous predictions were observed in extreme cases.[31]

Age did not exhibit a significant correlation with error across vital signs, suggesting the absence of age bias. Additionally, neither height nor weight appeared to influence outcomes, indicating that body weight and height relationships had minimal effect. The technology's performance remained unbiased in relation to demographic characteristics such as age, gender, height, or weight.[32]

A box plot analysis illustrated error distribution in quartiles and identified outliers. HR, RR, and SpO2 displayed narrow interquartile ranges, in contrast to DBP and SBP with broader ranges, aligning with the initial observation that BP exhibited a higher standard deviation. Outliers were observed in HR estimation, potentially impacting statistical outcomes, yet acceptable results were achieved even in their presence.[33]

Ethical Considerations

The consent was taken from the 626 participants who were recruited in this study, comprising 313 females and 313 males. The age range of the participants was 27–57 years, and they represented diverse skin colors, ethnicities, and medical statuses.

Limitations

Here are some limitations that can be identified for the given comparative evaluation:

1. Sample size: The study may have a limited sample size, which could affect the generalizability of the findings to a broader population.
2. Participant variation: While the study recruited a diverse group of participants, individual variations in physiology and health conditions could impact the accuracy of measurements for certain individuals or specific health conditions.
3. Device limitations: The camera-based monitoring solution may have its own limitations, such as the need for proper lighting conditions, distance from the camera, and potential inaccuracies in certain scenarios, which could affect the overall performance.
4. External factors: The study might not have accounted for all external factors that could influence the measurements, such as environmental conditions, movement artifacts, or interference from other electronic devices.
5. Controlled setting: The measurements were likely conducted in a controlled setting, which may not fully represent real-world situations and challenges that could arise in different health-care environments.
6. Interference: The presence of other people or objects in the camera's field of view might have introduced potential interferences, affecting the accuracy of measurements.
7. Specific vital signs: The accuracy of the camera-based solution could vary for different vital signs, and the study might not have explored this variation comprehensively.
8. Comparison devices: The performance of the

regulated medical devices used for comparison could also have their own limitations, which might influence the evaluation.

9. Duration of monitoring: The study might not have examined the long-term reliability of the camera-based solution for continuous vital sign monitoring over extended periods.
10. Scope of measurements: The study focused on specific vital signs; however, there are other vital signs and health parameters that the camera-based solution may not have been evaluated for.

It is essential to consider these limitations when interpreting the results and conclusions of the evaluation to ensure a comprehensive understanding of the camera-based monitoring solution's capabilities and potential applications in health-care settings.

CONCLUSION

The study encompassed comprehensive measurements of vital scan including heart rate (HR), respiratory rate (RR), oxygen saturation (SpO2), systolic blood pressure (SBP), and diastolic blood pressure (DBP) using a diverse range of devices such as smartphones (Samsung M32, OnePlus 9, iPhone 11, iPad 9) and an HP laptop with a Logitech webcam. This device diversity aimed to underscore the versatility of the results across various operating systems, avoiding technological bias. The utilization of Vital Scan software and the Contec Multipara Patient Monitor Cms 8000 device yielded valuable insights.

Through meticulous comparative analysis, Vital Scan demonstrated a strong correlation with the FDA-regulated Contec Multipara Patient Monitor CMS 8000, particularly concerning heart rate, respiratory rate, oxygen saturation, and blood pressure measurements. These findings affirm the precision and viability of camera-based monitoring for assessing crucial vital scan . However, the divergence observed in certain blood pressure readings underscores the need for further investigation.

With a dataset of 626 readings drawn from diverse demographics across facilities in India, the study substantiated the technology's ability to achieve acceptable agreement levels for mean error in HR, RR, SpO2, and BP measurements. Notably, while deviations were observed in some blood pressure readings, the overall acceptability of camera-based monitoring solutions for general health and wellness evaluation was evident.

As the study demonstrates the potential of this technology, its integration into clinical practice merits additional research and validation studies. Such endeavors could shed light on its cost-effectiveness, patient comfort, and broader utility. In essence, this study paves the way for a promising avenue of health assessment that leverages visual technology, fostering greater accessibility and insights into individual well-being.

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