# Efficiency and Accessibility in Occupational Health: The Promise of Automated Monitoring Technologies

A comparison study of remote Health Surveillance technology versus traditional gold standard methods

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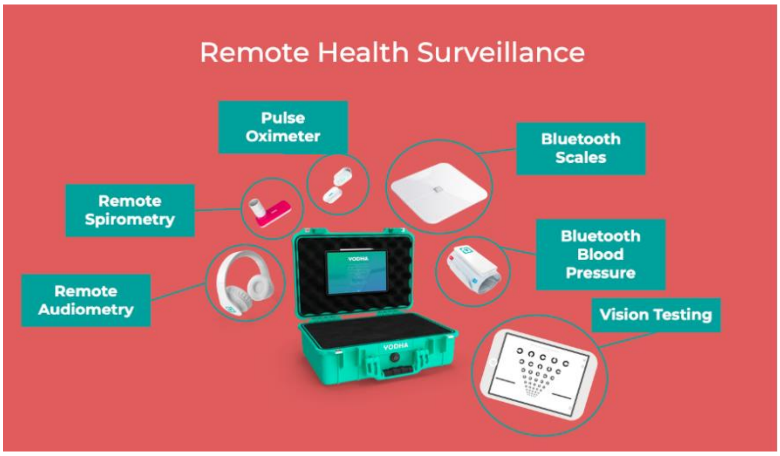
## Introduction

This paper aims to assess the viability of employing recently developed automated health monitoring technology for remote occupational health surveillance, particularly in comparison to traditional, assessor-operated methods. Specifically, it seeks to evaluate the efficacy, reliability, and user acceptability of these newer methods, which are administered by the user in-person, compared to established practices. The study will determine whether these remote monitoring technologies can deliver accurate health status measures while being user-friendly and time efficient. Recent studies by Boente et al. (2024) have shown the feasibility and acceptability of home spirometry for rural patients with interstitial lung disease. Their study highlighted the significant barriers faced by rural patients, such as lack of local specialty care, long distances to expert centres, and the high cost and time associated with travel.

Additionally, it aims to explore the potential of remote technology to enhance access to rapid health surveillance screening, addressing limitations such as staffing costs, assessment time, and employee travel distances to screening venues. Furthermore, this research will investigate the potential of remote technology to overcome these barriers and improve access to health monitoring, while also considering the challenges related to cost and reimbursement (Boente et al., 2024). Ultimately, this paper will contribute to the understanding of whether automated, user-administered health monitoring technologies can effectively replace traditional methods and provide a sustainable solution for occupational health surveillance.



## Purpose

The purpose of this paper is to compare two sets of data collected from the same 100 employees, each attending two appointments. The first appointment involves in-person assessment by a technician using the current gold standard health surveillance devices, while the second appointment is unassisted and utilises the YODHA remote health surveillance box.

## Overall Objectives

The primary objective involves analysing data from both visits conducted as part of the project. Specifically, the aim is to compare outcomes obtained using newly developed technology integrated into the YODHA mobile screening kit and software with those from the old technology. This analysis will evaluate the reliability of outcome measures obtained from different technologies, determining whether the new technology can produce consistent results comparable to the old technology. Additionally, the goal is to assess data collected by end-users and analyse its reliability compared to data collected in person by a nurse. Finally, the objective is to investigate whether data collected in workplace conditions using the new technology aligns with results obtained in controlled environments. Through these analyses, valuable insights will be provided to address the project's objectives.

## Methodology

Study Design: This study aimed to compare the efficacy, reliability, and user acceptability of newly developed automated health monitoring technologies with traditional assessor-operated methods. Specifically, the focus was on remote occupational health surveillance using the YODHA remote health surveillance box versus established gold standard devices. The study involved 100 employees who each attended two separate health assessment appointments.

Participants: Participants were selected from a diverse pool of employees, ensuring a representative sample. The gender distribution included 73 males and 27 females, with ages ranging from 18 to 67 years (mean age = 39.7 years, SD = 14.2).

## Experimental Procedure

### Appointment 1: In-Person Assessment by Technician

Participants were greeted by a technician at the onset of the study, where they were introduced to the study's purpose and procedures. The importance of their informed consent was emphasised, ensuring they understood their participation and any associated risks. Following the consent process, demographic data, including age and gender, were collected from each participant. This information helped in ensuring a diverse and representative sample for the study.

Subsequently, participants underwent audiometric testing to assess their hearing thresholds. Utilising a gold standard audiometric device (Amplivox), operated by the technician, measurements were taken at various frequencies of 500Hz, 1000Hz, 2000Hz, 3000Hz, 4000Hz, 6000Hz, and 8000Hz. Attention was paid to ensuring the proper placement of headphones and the accurate administration of the test for consistent and reliable results.

Spirometry was then conducted to evaluate pulmonary function. Participants were guided to perform spirometry measurements, including Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), and Peak Expiratory Flow (PEF), using the Mirobank spirometer. The technician provided instructions on taking a deep breath and exhaling forcefully into the spirometer, ensuring correct technique for accurate data collection.

Finally, blood pressure and pulse rate were measured using an Omron blood pressure monitor. Participants were instructed to sit quietly for five minutes before the measurements were taken to ensure accurate readings, thus contributing to the reliability of the collected data throughout the study.

### Appointment 2: Unassisted Remote Assessment

Participants were provided with the YODHA remote health surveillance box and given instructions on its use. These instructions were delivered either via written guidelines and images or a brief video tutorial, ensuring clarity and ease of understanding.

Subsequently, participants engaged in self-administered audiometric testing utilising the YODHA device, mirroring the frequency spectrum examined during their initial appointment. They adhered to on-screen instructions to ensure precise placement of headphones and calibration of the device, thereby facilitating consistent and dependable measurements.

Following audiometric testing, participants progressed to conduct self-administered spirometry using the YODHA device. They followed on-screen prompts to execute spirometry measurements, including the correct positioning of a new mouthpiece onto the spirometer and its subsequent disposal after use.

These instructions were meticulously designed to uphold proper technique and mitigate the potential for contamination, thereby ensuring the reliability of the acquired data.

Furthermore, participants employed the YODHA device to autonomously measure their blood pressure and pulse rate. Preceding the acquisition of measurements, participants were instructed to observe a period of quiet rest for five minutes, thereby ensuring uniformity and precision in the obtained readings.

Ethical approval was obtained from the institutional review board. Informed consent was collected from all participants. Data privacy and confidentiality were strictly maintained throughout the study. This methodology ensures a robust comparison between traditional and remote health monitoring technologies, providing valuable insights into their potential application in occupational health surveillance.

## Data Analysis

Descriptive and inferential statistical analyses were conducted using JASP software. The dataset included variables such as gender, age, hearing test results, spirometry measures, and blood pressure readings. Descriptive statistics were calculated to summarise the data, including frequencies, percentages, means, medians, modes, standard deviations, interquartile ranges, and ranges. For gender, frequency tables and distribution plots were created. Age statistics included measures of central tendency and dispersion, while visual representations were provided using distribution plots and bar charts.

Paired samples t-tests were employed to compare the differences between the Gold and Yodha hearing test measures at various frequencies (e.g., 1000Hz, 2000Hz). Normality assumptions for these tests were checked using the Shapiro-Wilk test, with significant results indicating deviations from normality. Similarly, paired samples t-tests and normality checks were conducted for spirometry measures (e.g., FVC, FEV1) and blood pressure readings (systolic, diastolic, pulse).

Correlation analyses were performed using Spearman's rank-order correlation to assess the relationship between hearing test results across different frequencies. Significance levels were reported, with p-values less than 0.05 considered statistically significant. These analyses provided insights into the reliability and consistency of the measures across different devices and conditions.

## Results

### Demographic Characteristics of the Sample: Gender Distribution and Age Profile

The gender distribution of the sample shows a significant imbalance, with 73% of participants identified as male and 27% as female, out of a total of 100 subjects (see Tables 1, 2; Figures 1, 2 3, 4 for details). The age characteristics reveal a diverse range, with the mode at 34 years, median at 39 years, and mean age of 39.7 years. The standard deviation (SD) is 14.2 years, indicating a moderate spread around the mean, with ages spanning from a minimum of 18 to a maximum of 67 years. The interquartile range (IQR) is 25 years, highlighting substantial variability within the middle 50% of the age distribution. The 25th percentile age is 27 years, showing that a quarter of the participants are younger than this age. The 50th percentile (median) age is 39 years, indicating that half of the participants are younger than this age. The 75th percentile is at 52 years, showing that 75% of the participants are younger than 52 years.

Table 1: Frequency Tables Gender

Frequencies for Gender

| Gender | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| M | 73 | 73.000 | 73.000 | 73.000 |
| F | 27 | 27.000 | 27.000 | 100.000 |
| Total | 100 | 100.000 | | |

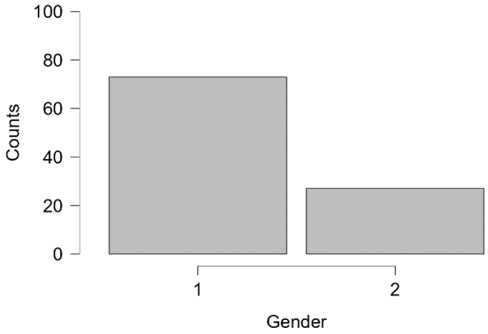


Figure 1: Distribution Plots (1: male, 2: female)

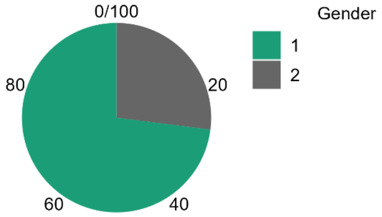


Figure 2: Pie chart Gender

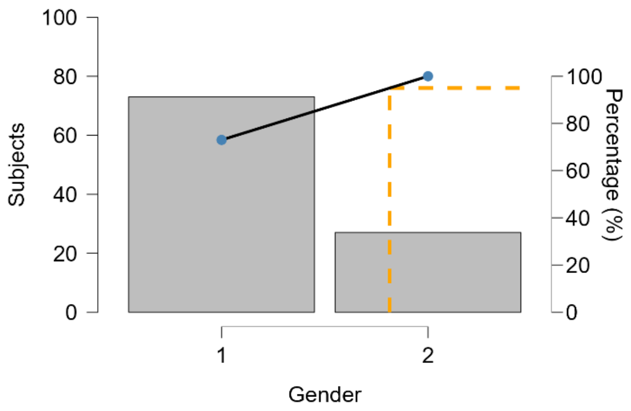


Figure 3: Pareto Plots Gender

Table 2: Descriptive Statistics Age

Descriptive Statistics

| | Mode | Median | Mean | Std. Deviation | Coefficient of variation | IQR | Range | Minimum | Maximum | 25th percentile | 50th percentile | 75th percentile |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | 34.000 [a] | 39.000 | 39.700 | 14.237 | 0.359 | 25.000 | 49.000 | 18.000 | 67.000 | 27.000 | 39.000 | 52.000 |

[a] The mode is computed assuming that variables are discreet.

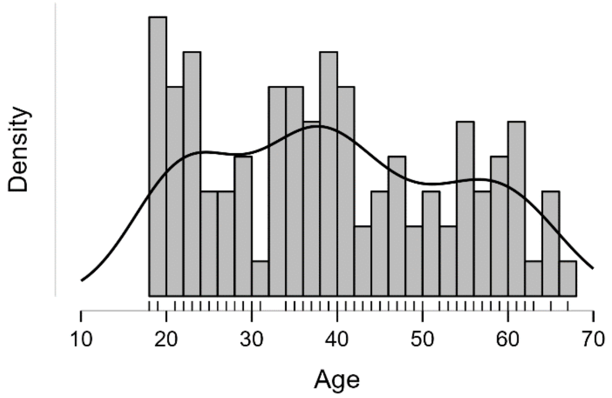


Figure 4: Distribution Plots for Age

## Comparative Analysis of Hearing Test Results between Gold standard in person testing and YODHA Remote Health Surveillance Technology

The Paired Samples T-Test results for the hearing test between gold standard in person testing and YODHA remote health surveillance technology indicated significant differences at several frequencies (see Tables 3,4,5; Figures 5,6 for details). For instance, at 1000Hz in the left ear, the mean for gold standard in person testing was 8.4 dB (SD = 7.551), compared to YODHA's 8.7 dB (SD = 7.372), resulting in a t-value of-2.514 and a p-value of 0.014. Similarly, at 2000Hz in the left ear, the mean difference was more pronounced, with gold standard in person testing at 6.15 dB (SD = 7.973) and YODHA at 6.95 dB (SD = 8.131), yielding a t-value of-4.342 and a p-value of <0.001. Other significant differences were observed at 3000Hz in the left ear (t =-2.602, p = 0.011) and at 4000Hz in the right ear (t =-2.514, p = 0.014).

On the other hand, several frequencies showed no significant differences between gold standard in person testing and YODHA. For example, at 6000Hz in the left ear, the mean for gold standard in person testing was 26.0 dB (SD = 11.481) compared to YODHA's 25.85 dB (SD = 11.238), resulting in a t-value of 0.686 and a p-value of 0.494. Similarly, at 8000Hz in the left ear, the mean values were nearly identical (Gold standard in person testing: 18.8 dB, SD = 10.228; YODHA: 18.85 dB, SD = 10.270), with a t-value of-0.445 and a p-value of 0.657. Other non-significant differences were found at 500Hz in the right ear (t =-1.421, p = 0.158) and at 6000Hz in the right ear (t = 1.750, p = 0.083). Additionally, due to the variance in the difference being equal to zero, the comparison at 500Hz in the left ear and at 8000Hz in the right ear could not be performed, indicating no variability in the differences at these frequencies.

## Table 3: Hearing Test Paired Samples T-Test

Paired Samples T-Test

| Measure 1 | | Measure 2 | t | df | P |
|---|---|---|---|---|---|
| 1000Hz_Left_Gold_Visit1 | - | 1000Hz_ Left_YODHA_Visit2 | -2.514 | 99 | 0.014 |
| 2000Hz_Left_Gold_Visit1 | - | 2000Hz_ Left_YODHA_Visit2 | -4.342 | 99 | < .001 |
| 3000Hz_Left_Gold_Visit1 | - | 3000Hz_ Left_YODHA_Visit2 | -2.602 | 99 | 0.011 |
| 4000Hz_Left_Gold_Visit1 | - | 4000Hz_ Left_YODHA_Visit2 | -1.828 | 99 | 0.070 |
| 6000Hz_Left_Gold_Visit1 | - | 6000Hz_ Left_YODHA_Visit2 | 0.686 | 99 | 0.494 |
| 8000Hz_Left_Gold_Visit1 | - | 8000Hz_ Left_YODHA_Visit2 | -0.445 | 99 | 0.657 |
| 500Hz_Right_Gold_Visit1 | - | 500Hz_ Right_YODHA_Visit2 | -1.421 | 99 | 0.158 |
| 1000Hz_Right_Gold_Visit1 | - | 1000Hz_ Right_YODHA_Visit2 | -2.031 | 99 | 0.045 |
| 2000Hz_Right_Gold_Visit1 | - | 2000Hz_ Right_YODHA_Visit2 | -4.180 | 99 | < .001 |
| 4000Hz_Right_Gold_Visit1 | - | 4000Hz_ Right_YODHA_Visit2 | -2.514 | 99 | 0.014 |
| 6000Hz_Right_Gold_Visit1 | - | 6000Hz_ Right_YODHA_Visit2 | 1.750 | 99 | 0.083 |

## Table 4: Assumption Checks

Test of Normality (Shapiro-Wilk)

| | | | W | p |
|---|---|---|---|---|
| 1000Hz_Left_Gold_Visit1 | - | 1000Hz_ Left_YODHA_Visit2 | 0.252 | < .001 |
| 2000Hz_Left_Gold_Visit1 | - | 2000Hz_ Left_YODHA_Visit2 | 0.440 | < .001 |

Test of Normality (Shapiro-Wilk)

| | | | W | p |
|---|---|---|---|---|
| 3000Hz_Left_Gold_Visit1 | - | 3000Hz_ Left_YODHA_Visit2 | 0.385 | < .001 |
| 4000Hz_Left_Gold_Visit1 | - | 4000Hz_ Left_YODHA_Visit2 | 0.372 | < .001 |
| 6000Hz_Left_Gold_Visit1 | - | 6000Hz_ Left_YODHA_Visit2 | 0.171 | < .001 |
| 8000Hz_Left_Gold_Visit1 | - | 8000Hz_ Left_YODHA_Visit2 | 0.277 | < .001 |
| 500Hz_Right_Gold_Visit1 | - | 500Hz_ Right_YODHA_Visit2 | 0.123 | < .001 |
| 1000Hz_Right_Gold_Visit1 | - | 1000Hz_ Right_YODHA_Visit2 | 0.195 | < .001 |
| 2000Hz_Right_Gold_Visit1 | - | 2000Hz_ Right_YODHA_Visit2 | 0.426 | < .001 |
| 4000Hz_Right_Gold_Visit1 | - | 4000Hz_ Right_YODHA_Visit2 | 0.252 | < .001 |
| 6000Hz_Right_Gold_Visit1 | - | 6000Hz_ Right_YODHA_Visit2 | 0.161 | < .001 |

*Note.* Significant results suggest a deviation from normality.

## Table 5: Descriptives

Descriptives

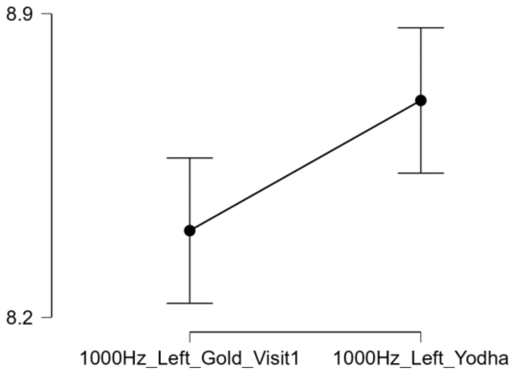
| | N | Mean | SD | SE | Coefficient of variation |
|---|---|---|---|---|---|
| 1000Hz_Left_Gold_Visit1 | 100 | 8.400 | 7.551 | 0.755 | 0.899 |
| 1000Hz_ Left_YODHA_Visit2 | 100 | 8.700 | 7.372 | 0.737 | 0.847 |
| 2000Hz_Left_Gold_Visit1 | 100 | 6.150 | 7.973 | 0.797 | 1.296 |
| 2000Hz_ Left_YODHA_Visit2 | 100 | 6.950 | 8.131 | 0.813 | 1.170 |
| 3000Hz_Left_Gold_Visit1 | 100 | 19.350 | 17.021 | 1.702 | 0.880 |
| 3000Hz_ Left_YODHA_Visit2 | 100 | 19.750 | 16.898 | 1.690 | 0.856 |
| 4000Hz_Left_Gold_Visit1 | 100 | 21.400 | 14.548 | 1.455 | 0.680 |
| 4000Hz_ Left_YODHA_Visit2 | 100 | 21.750 | 14.964 | 1.496 | 0.688 |
| 6000Hz_Left_Gold_Visit1 | 100 | 26.000 | 11.481 | 1.148 | 0.442 |
| 6000Hz_ Left_YODHA_Visit2 | 100 | 25.850 | 11.238 | 1.124 | 0.435 |
| 8000Hz_Left_Gold_Visit1 | 100 | 18.800 | 10.228 | 1.023 | 0.544 |
| 8000Hz_ Left_YODHA_Visit2 | 100 | 18.850 | 10.270 | 1.027 | 0.545 |
| 500Hz_Right_Gold_Visit1 | 100 | 8.700 | 8.751 | 0.875 | 1.006 |
| 500Hz_ Right_YODHA_Visit2 | 100 | 8.800 | 8.620 | 0.862 | 0.980 |
| 1000Hz_Right_Gold_Visit1 | 100 | 6.850 | 8.398 | 0.840 | 1.226 |
| 1000Hz_ Right_YODHA_Visit2 | 100 | 7.050 | 8.412 | 0.841 | 1.193 |
| 2000Hz_Right_Gold_Visit1 | 100 | 7.150 | 12.003 | 1.200 | 1.679 |
| 2000Hz_ Right_YODHA_Visit2 | 100 | 7.900 | 11.660 | 1.166 | 1.476 |
| 4000Hz_Right_Gold_Visit1 | 100 | 22.550 | 16.307 | 1.631 | 0.723 |

Descriptives

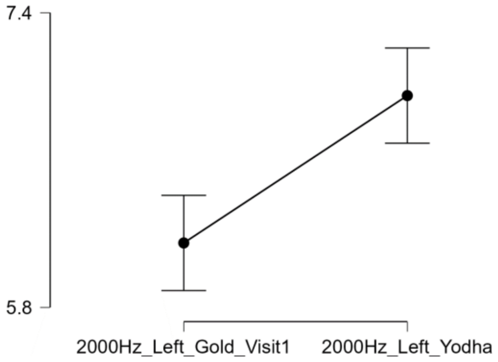
| | N | Mean | SD | SE | Coefficient of variation |
|---|---|---|---|---|---|
| 4000Hz_ Right_YODHA_Visit2 | 100 | 22.850 | 16.225 | 1.623 | 0.710 |
| 6000Hz_Right_Gold_Visit1 | 100 | 28.750 | 14.220 | 1.422 | 0.495 |
| 6000Hz_ Right_YODHA_Visit2 | 100 | 28.600 | 14.144 | 1.414 | 0.495 |

## Figure 5: Descriptives Plots

### 1000Hz_Left_Gold_Visit1 - 1000Hz_Left_Yodha



### 2000Hz_Left_Gold_Visit1 - 2000Hz_Left_Yodha



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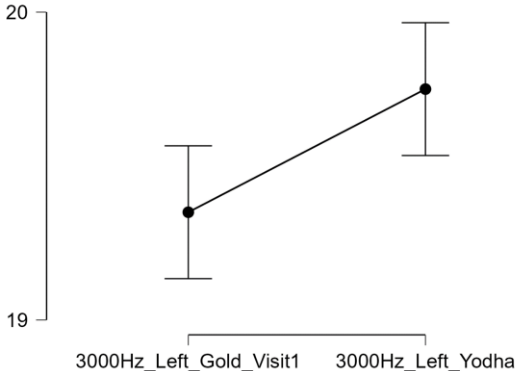

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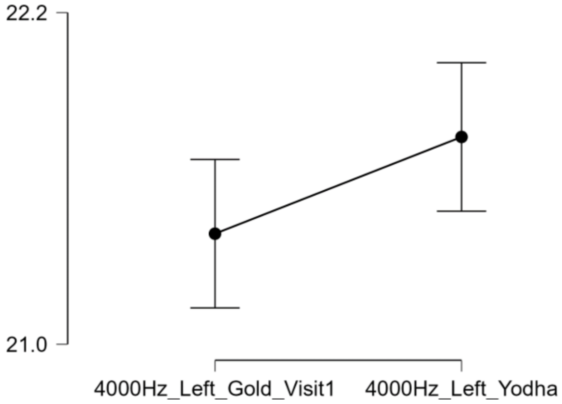
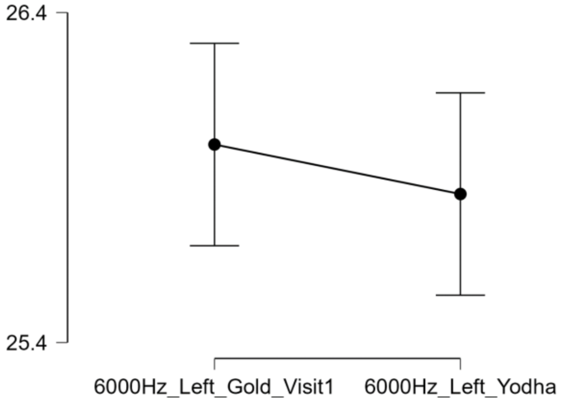
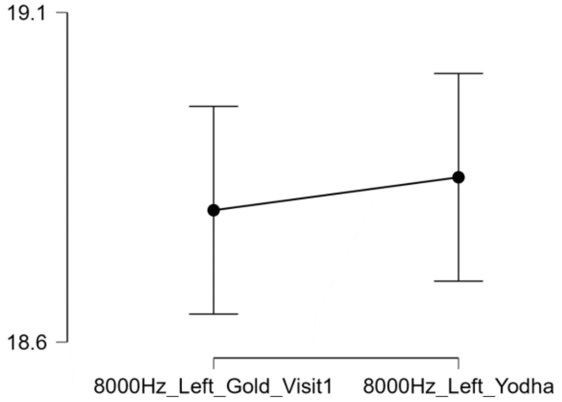


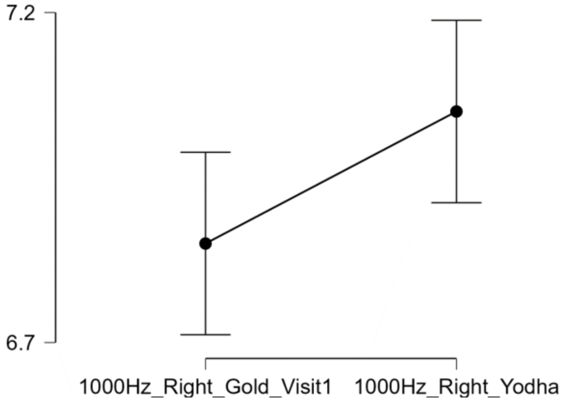
6000Hz_Left_Gold_Visit1 - 6000Hz_Left_Yodha



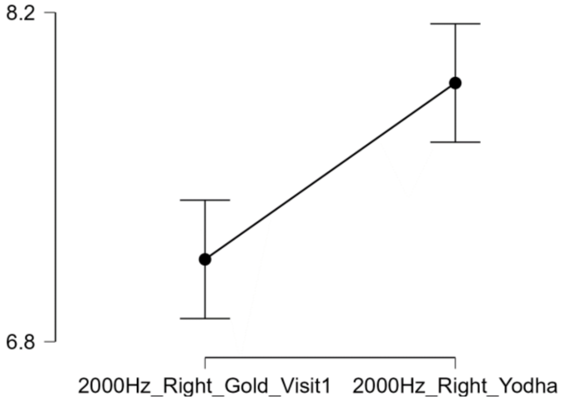
8000Hz_Left_Gold_Visit1 - 8000Hz_Left_Yodha



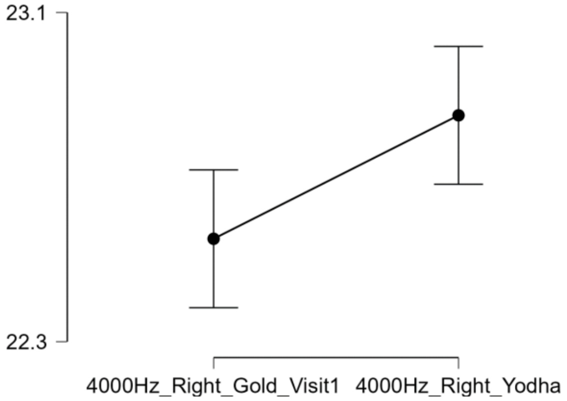
1000Hz_Right_Gold_Visit1 - 1000Hz_Right_Yodha



2000Hz_Right_Gold_Visit1 - 2000Hz_Right_Yodha



4000Hz_Right_Gold_Visit1 - 4000Hz_Right_Yodha



6000Hz_Right_Gold_Visit1 - 6000Hz_Right_Yodha

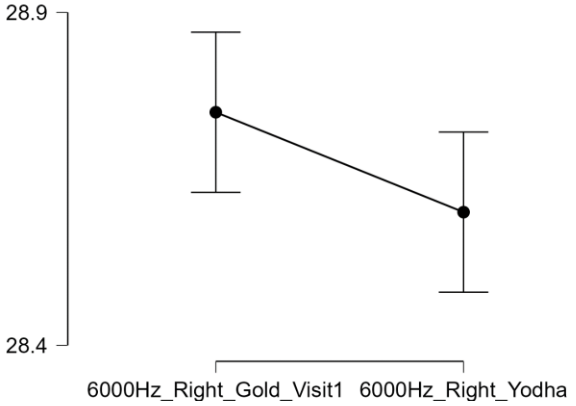
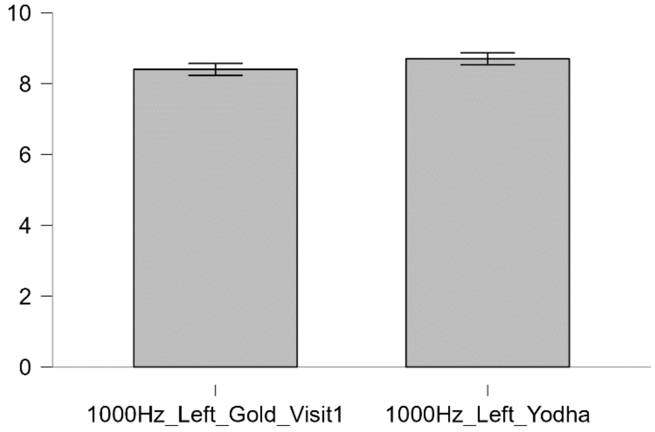
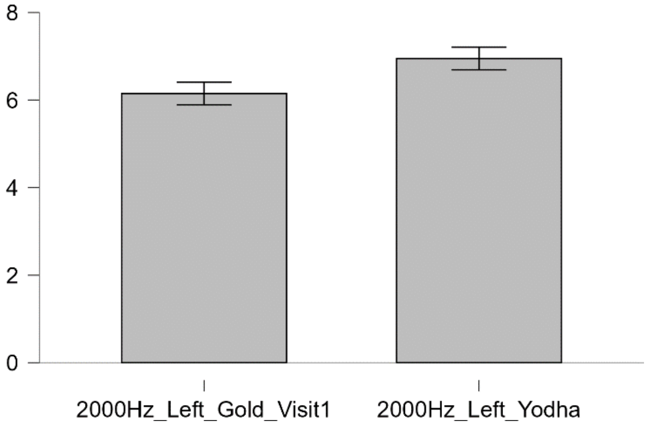


Figure 6: Bar Plots

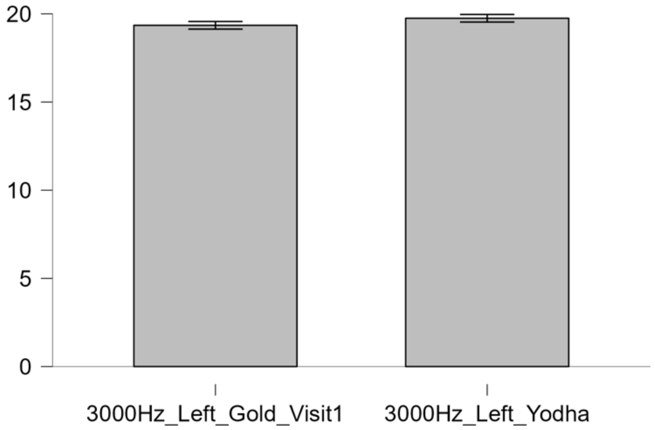
1000Hz_Left_Gold_Visit1 - 1000Hz_Left_Yodha



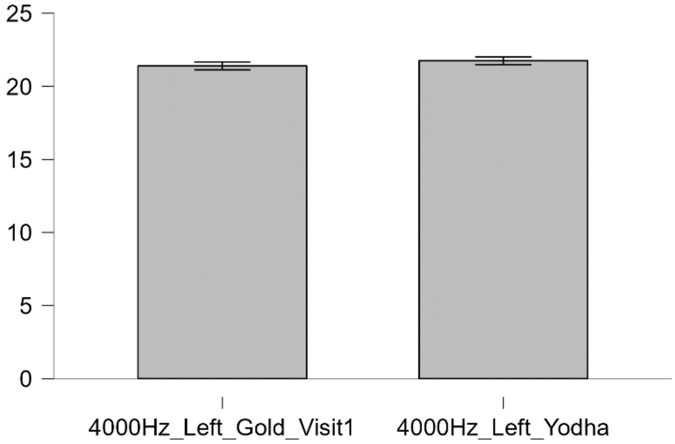
2000Hz_Left_Gold_Visit1 - 2000Hz_Left_Yodha



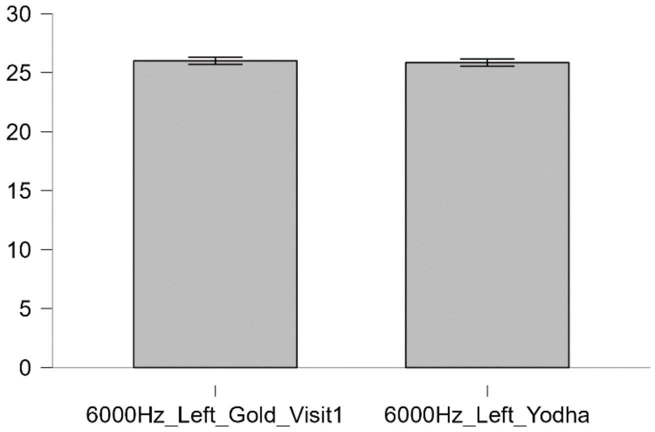
3000Hz_Left_Gold_Visit1 - 3000Hz_Left_Yodha



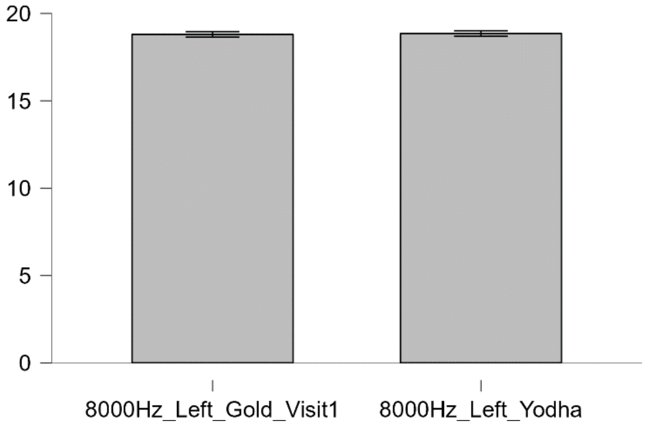
4000Hz_Left_Gold_Visit1 - 4000Hz_Left_Yodha



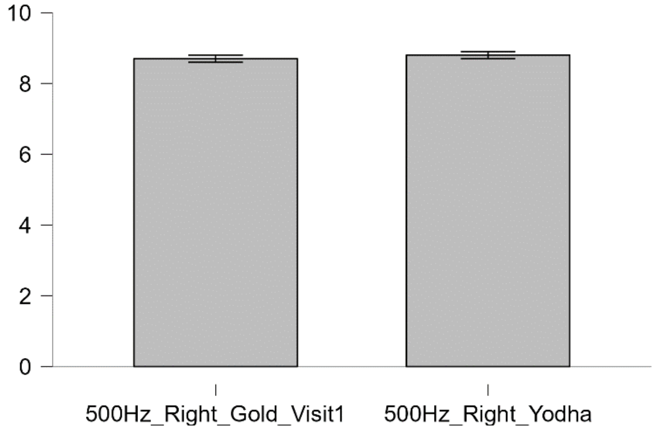
6000Hz_Left_Gold_Visit1 - 6000Hz_Left_Yodha



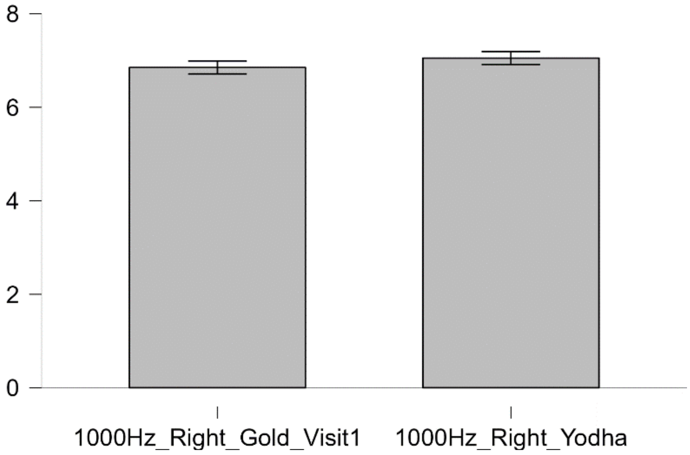
### 8000Hz_Left_Gold_Visit1 - 8000Hz_Left_Yodha



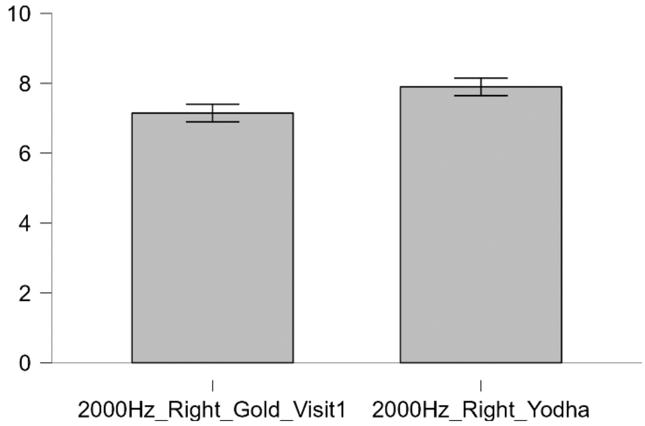
### 500Hz_Right_Gold_Visit1 - 500Hz_Right_Yodha



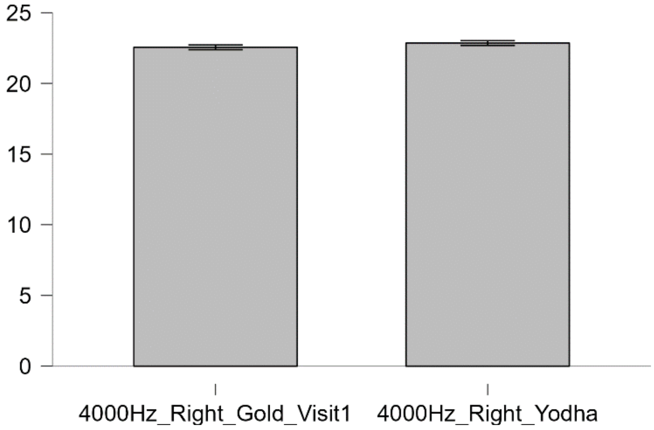
### 1000Hz_Right_Gold_Visit1 - 1000Hz_Right_Yodha



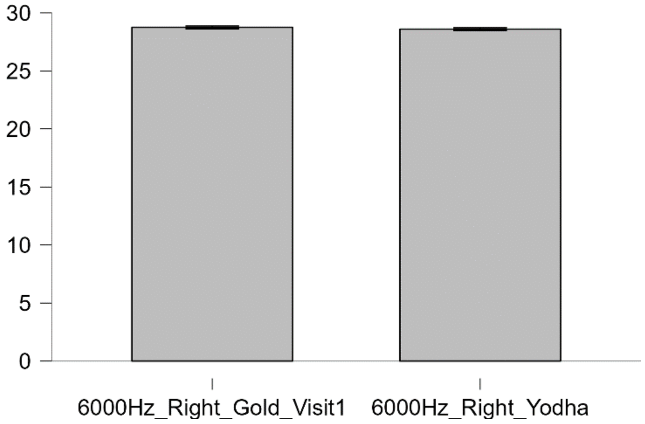
2000Hz_Right_Gold_Visit1 - 2000Hz_Right_Yodha



4000Hz_Right_Gold_Visit1 - 4000Hz_Right_Yodha



6000Hz_Right_Gold_Visit1 - 6000Hz_Right_Yodha



### Comparative Analysis of Spirometry Measures between Mirobank and YODHA Devices

The descriptive statistics for spirometry measures between Mirobank and YODHA indicate some differences in pulmonary function test results (see Tables 6,7,8; Figures 7,8 for details). For FVC, the mean for Mirobank was 4.705 L (SD = 1.289), with an IQR of 1.557 L. The range spanned from 0.750 L to 7.290 L, with the 25th percentile at 4.058 L, the median at 4.430 L, and the 75th percentile at 5.615 L. YODHA's FVC had a slightly higher mean of 4.836 L (SD = 1.327), an IQR of 1.656 L, and a range from 0.767 L to 7.592 L. The 25th percentile for YODHA FVC was 4.144 L, the median 4.483 L, and the 75th percentile 5.801 L. Both distributions exhibited significant deviations from normality, as indicated by Shapiro-Wilk test results (W = 0.941, p < 0.001).

For FEV1, the mean for Mirobank was 3.762 L (SD = 1.056), with an IQR of 1.630 L. The FEV1 values ranged from 0.750 L to 5.670 L, with the 25th percentile at 3.132 L, the median at 3.560 L, and the 75th percentile at 4.763 L. YODHA’s FEV1 mean was slightly higher at 3.867 L (SD = 1.087), with an IQR of 1.682 L, and a range from 0.767 L to 5.800 L. The 25th percentile for YODHA FEV1 was 3.225 L, the median 3.682 L, and the 75th percentile 4.907 L. FEV1 distributions also showed significant deviations from normality (W = 0.937, p < 0.001 for Mirobank; W = 0.937, p < 0.001 for YODHA).

Additionally, PEF had a mean of 8.194 L/min (SD = 2.695) for Mirobank, with an IQR of 2.443 L/min and a range from 2.080 L/min to 13.790 L/min. The 25th percentile was 7.025 L/min, the median 7.985 L/min, and the 75th percentile 9.468 L/min. YODHA’s PEF mean was 8.425 L/min (SD = 2.775), with an IQR of 2.618 L/min, and a range from 2.149 L/min to 14.245 L/min. The 25th percentile for YODHA PEF was 7.067 L/min, the median 8.258 L/min, and the 75th percentile 9.685 L/min. Both PEF distributions deviated significantly from normality (W = 0.959, p = 0.004 for Mirobank; W = 0.962, p = 0.006 for YODHA).

Moreover, FEV1/FVC ratio also displayed differences, with Mirobank having a mean of 80.206 (SD = 7.764) and YODHA having a higher mean of 82.992 (SD = 3.526). The IQR for Mirobank was 7.450, while for YODHA it was 3.100. The range for Mirobank's FEV1/FVC was from 50.900 to 100.000, and for YODHA from 72.200 to 93.200. Both ratios deviated significantly from normality (W = 0.914, p < 0.001 for Mirobank; W = 0.947, p < 0.001 for YODHA). Additionally, the variance in the difference between Mirobank and YODHA for both predicted FVC and predicted FEV1 is equal to zero, suggesting no variability in the observed differences between the two visits.

Table 6: Descriptive Statistics Spirometry

Descriptive Statistics

| | Mean | Std. Deviation | IQR | Shapiro-Wilk | P-value of Shapiro-Wilk | Range | Minimum | Maximum | 25th percentile | 50th percentile | 75th percentile |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mirobank FVC | 4.705 | 1.289 | 1.557 | 0.956 | 0.002 | 6.540 | 0.750 | 7.290 | 4.058 | 4.430 | 5.615 |
| YODHA FVC | 4.836 | 1.327 | 1.656 | 0.960 | 0.004 | 6.824 | 0.767 | 7.592 | 4.144 | 4.483 | 5.801 |
| Mirobank FEV1 | 3.762 | 1.056 | 1.630 | 0.957 | 0.002 | 4.920 | 0.750 | 5.670 | 3.132 | 3.560 | 4.763 |

Descriptive Statistics

| | Mean | Std. Deviation | IQR | Shapiro-Wilk | P-value of Shapiro-Wilk | Range | Minimum | Maximum | 25th percentile | 50th percentile | 75th percentile |
|---|---|---|---|---|---|---|---|---|---|---|---|
| YODHA FEV1 | 3.867 | 1.087 | 1.682 | 0.958 | 0.003 | 5.033 | 0.767 | 5.800 | 3.225 | 3.682 | 4.907 |
| Mirobank PEF | 8.194 | 2.695 | 2.443 | 0.959 | 0.004 | 11.710 | 2.080 | 13.790 | 7.025 | 7.985 | 9.468 |
| YODHA PEF | 8.425 | 2.775 | 2.618 | 0.962 | 0.006 | 12.096 | 2.149 | 14.245 | 7.067 | 8.258 | 9.685 |
| Mirobank FEV1/FVC | 80.206 | 7.764 | 7.450 | 0.914 | < .001 | 49.100 | 50.900 | 100.000 | 76.900 | 81.700 | 84.350 |
| YODHA Pred FEV1/FVC | 82.992 | 3.526 | 3.100 | 0.947 | < .001 | 21.000 | 72.200 | 93.200 | 81.200 | 82.700 | 84.300 |

## Table 7: Assumption Checks Spirometry

Test of Normality (Shapiro-Wilk)

| | | | W | p |
|---|---|---|---|---|
| Mirobank FVC | - | YODHA FVC | 0.941 | < .001 |
| Mirobank FEV1 | - | YODHA FEV1 | 0.937 | < .001 |
| Mirobank Pred FEV1 | - | YODHA FEV1 | 0.934 | < .001 |
| Mirobank PEF | - | YODHA PEF | 0.930 | < .001 |
| Mirobank Pred PEF | - | YODHA Pred FEV1 | 0.853 | < .001 |
| Mirobank FEV1/FVC | - | YODHA FEV1/FVC | 0.923 | < .001 |

*Note.* Significant results suggest a deviation from normality.

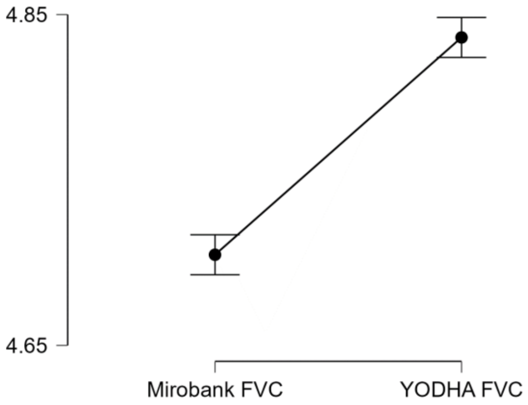
## Table 8: Descriptives Spirometry Data

Descriptives

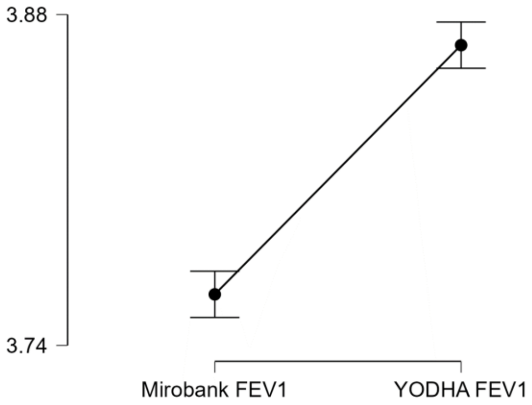
| | N | Mean | SD | SE | Coefficient of variation |
|---|---|---|---|---|---|
| Mirobank FVC | 100 | 4.705 | 1.289 | 0.129 | 0.274 |
| YODHA FVC | 100 | 4.836 | 1.327 | 0.133 | 0.274 |
| Mirobank FEV1 | 100 | 3.762 | 1.056 | 0.106 | 0.281 |
| YODHA FEV1 | 100 | 3.867 | 1.087 | 0.109 | 0.281 |
| Mirobank Pred FEV1 | 100 | 4.313 | 0.640 | 0.064 | 0.148 |
| Mirobank PEF | 100 | 8.194 | 2.695 | 0.269 | 0.329 |
| YODHA PEF | 100 | 8.425 | 2.775 | 0.277 | 0.329 |
| Mirobank Pred PEF | 100 | 9.261 | 1.264 | 0.126 | 0.137 |
| YODHA Pred FEV1 | 100 | 4.313 | 0.640 | 0.064 | 0.148 |
| Mirobank FEV1/FVC | 100 | 80.206 | 7.764 | 0.776 | 0.097 |
| YODHA FEV1/FVC | 100 | 82.465 | 8.216 | 0.822 | 0.100 |

Figure 7: Descriptives Plots

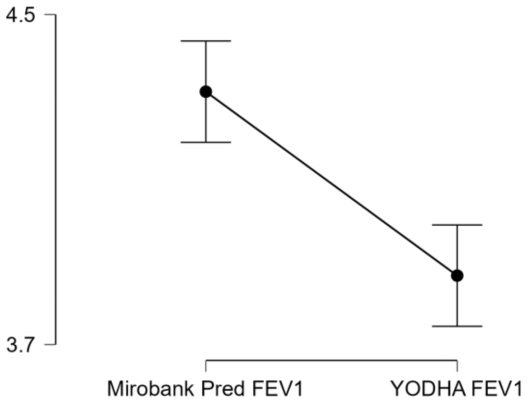
Mirobank FVC - YODHA FVC



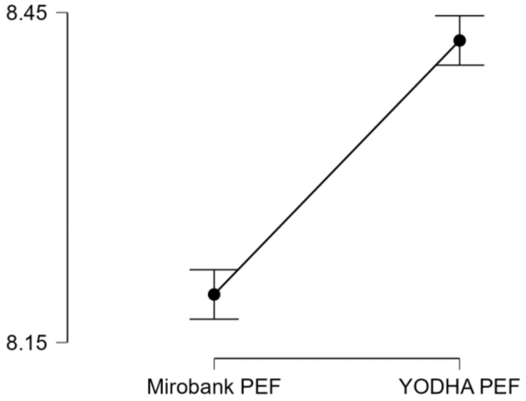
Mirobank FEV1 - YODHA FEV1



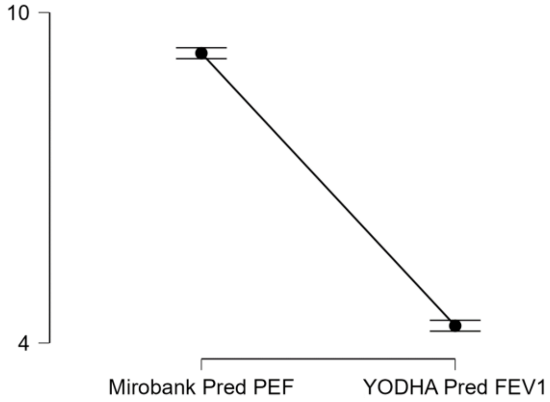
Mirobank Pred FEV1 - YODHA FEV1



Mirobank PEF - YODHA PEF



Mirobank Pred PEF - YODHA Pred FEV1



Mirobank FEV1/FVC - YODHA FEV1/FVC

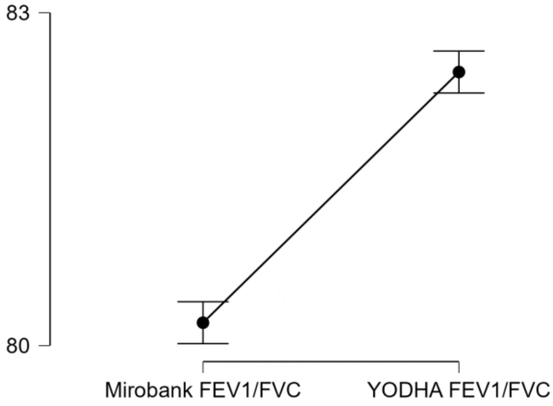
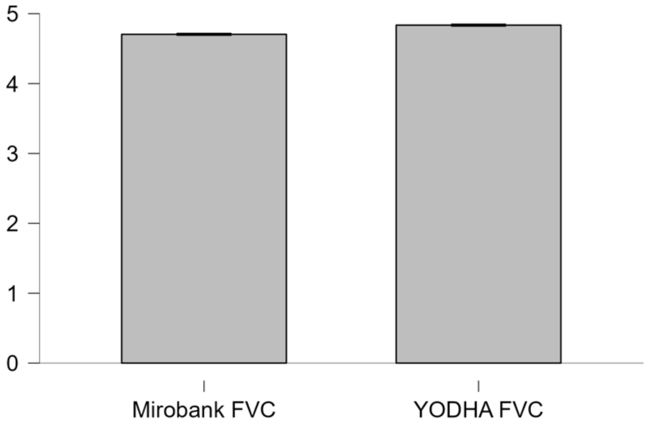
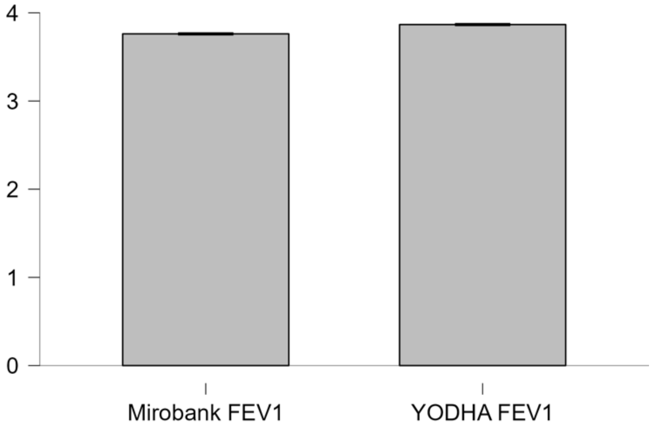


Figure 8: Bar Plots

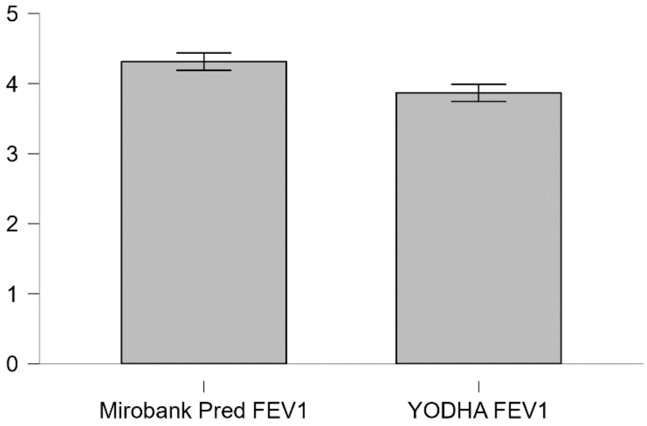
Mirobank FVC - YODHA FVC



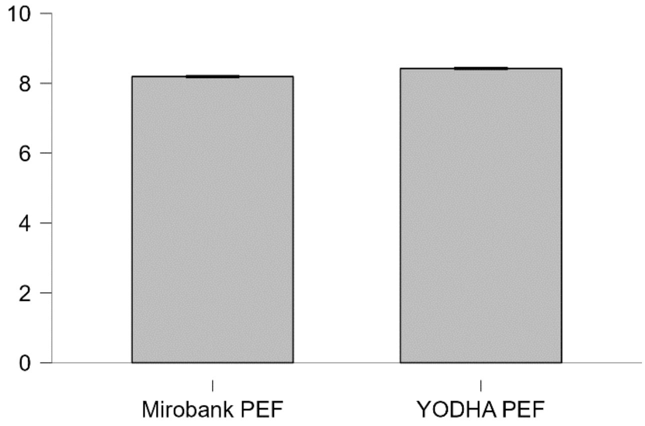
Mirobank FEV1 - YODHA FEV1



Mirobank Pred FEV1 - YODHA FEV1

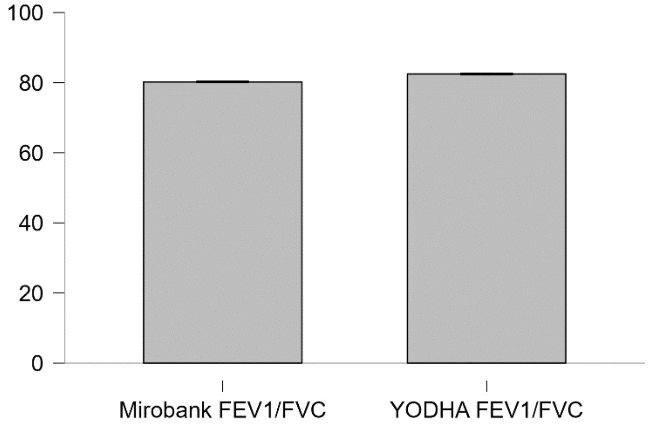


Mirobank PEF - YODHA PEF



Mirobank Pred PEF - YODHA Pred FEV1

Mirobank FEV1/FVC - YODHA FEV1/FVC



### Comparative Analysis of Blood Pressure and Pulse Rate Measurements between Omron and YODHA Devices

The Omron and YODHA devices show similarities and differences in blood pressure measurements (see Tables 10, 11, 12; Figures 9,10 for details), with Omron having a mode of 148.000 and YODHA slightly lower at 139.200. However, the median and mean values for both devices are quite close, with Omron having a mean of 135.000 and YODHA 135.240. The SD for both is also similar, with Omron at 13.581 and YODHA at 13.802. The IQR is comparable as well, with Omron at 21.250 and YODHA at 20.857. However, while the Shapiro-Wilk test indicates significant deviations from normality for both devices (W = 0.933, p < .001 for Omron; W = 0.980, p = .124 for YODHA), the range of systolic blood pressure values is wider for YODHA (ranging from 109.312 to 168.000) compared to Omron (ranging from 110.000 to 160.000).

Both Omron and YODHA devices show similar median and mean values for diastolic blood pressure, with Omron at 82,000 and YODHA at 82.110. The SD for diastolic pressure is comparable as well, with Omron at 8.540 and YODHA at 8.893. However, the mode for Omron is 78.000, slightly lower than YODHA's mode of 76.128. Both devices display significant deviations from normality according to the Shapiro-Wilk test (W = 0.931, p < .001 for Omron; W = 0.983, p = .230 for YODHA).

The mean pulse rate for Omron is 79.500, with a SD of 14.107, while for YODHA it is 79.737, slightly higher than the SD of 14.332. The Shapiro-Wilk test indicates significant deviations from normality for both devices (W = 0.945, p < .001 for Omron; W = 0.983, p = .233 for YODHA). Both devices exhibit similar patterns in terms of mean, SD, and normality of pulse rate measurements.

Table 9: Descriptive Statistics Blood Pressure

Descriptive Statistics

| | Mode | Median | Mean | Std. Deviation | IQR | Shapiro-Wilk | P-value of Shapiro-Wilk | Range | Minimum | Maximum | 25th percentile | 50th percentile | 75th percentile |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Omron BP Systolic | 148.000[a] | 135.000 | 134.190 | 13.581 | 21.250 | 0.970 | 0.024 | 50.000 | 110.000 | 160.000 | 124.000 | 135.000 | 145.250 |
| YODHA BP Systolic | 139.200[a] | 135.240 | 134.736 | 13.802 | 20.857 | 0.980 | 0.124 | 58.688 | 109.312 | 168.000 | 123.300 | 135.240 | 144.157 |
| Omron BP Diastolic | 78.000[a] | 82.000 | 81.850 | 8.540 | 12.250 | 0.986 | 0.363 | 36.000 | 63.000 | 99.000 | 75.750 | 82.000 | 88.000 |
| YODHA BP Diastolic | 76.128[a] | 82.110 | 82.215 | 8.893 | 11.752 | 0.983 | 0.230 | 39.540 | 63.360 | 102.900 | 76.363 | 82.110 | 88.115 |

Descriptive Statistics

| | Mode | Median | Mean | Std. Deviation | IQR | Shapiro-Wilk | P-value of Shapiro-Wilk | Range | Minimum | Maximum | 25th percentile | 50th percentile | 75th percentile |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Omron BP Pulse | 89.000 [a] | 79.500 | 79.580 | 14.107 | 20.250 | 0.978 | 0.089 | 57.000 | 50.000 | 107.000 | 70.000 | 79.500 | 90.250 |
| YODHA BP Pulse | 72.633 [a] | 79.737 | 79.931 | 14.332 | 17.399 | 0.983 | 0.233 | 60.465 | 48.000 | 108.465 | 72.135 | 79.737 | 89.534 |

[a] The mode is computed assuming that variables are discreet.

## Table 10: Paired Samples T-Test Blood Pressure

Paired Samples T-Test

| Measure 1 | | Measure 2 | t | df | p |
|---|---|---|---|---|---|
| Omron BP Systolic | - | YODHA BP Systolic | -1.319 | 99 | 0.190 |
| Omron BP Diastolic | - | YODHA BP Diastolic | -1.447 | 99 | 0.151 |
| Omron BP Pulse | - | YODHA BP Pulse | -1.412 | 99 | 0.161 |

*Note.* Student's t-test.

## Table 11: Assumption Checks

Test of Normality (Shapiro-Wilk)

| | | | W | p |
|---|---|---|---|---|
| Omron BP Systolic | - | YODHA BP Systolic | 0.933 | < .001 |
| Omron BP Diastolic | - | YODHA BP Diastolic | 0.931 | < .001 |
| Omron BP Pulse | - | YODHA BP Pulse | 0.945 | < .001 |

*Note.* Significant results suggest a deviation from normality.

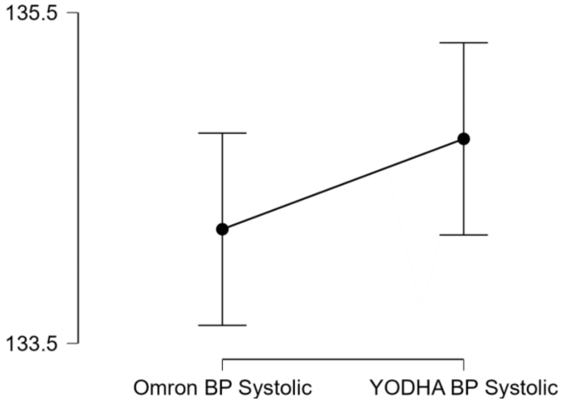
## Table 12: Descriptives

Descriptives

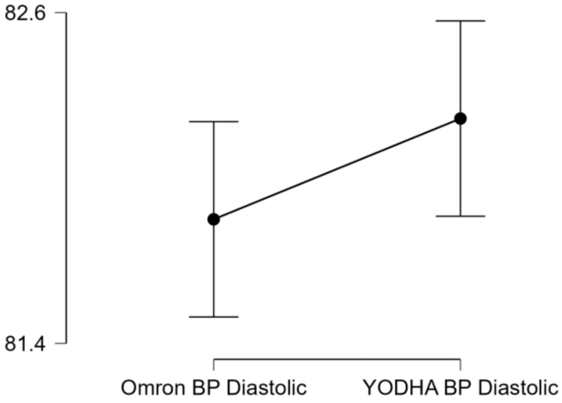
| | N | Mean | SD | SE | Coefficient of variation |
|---|---|---|---|---|---|
| Omron BP Systolic | 100 | 134.190 | 13.581 | 1.358 | 0.101 |
| YODHA BP Systolic | 100 | 134.736 | 13.802 | 1.380 | 0.102 |
| Omron BP Diastolic | 100 | 81.850 | 8.540 | 0.854 | 0.104 |
| YODHA BP Diastolic | 100 | 82.215 | 8.893 | 0.889 | 0.108 |
| Omron BP Pulse | 100 | 79.580 | 14.107 | 1.411 | 0.177 |
| YODHA BP Pulse | 100 | 79.931 | 14.332 | 1.433 | 0.179 |

Figure 9: Descriptives Plots

Omron BP Systolic - YODHA BP Systolic



Omron BP Diastolic - YODHA BP Diastolic



Omron BP Pulse - YODHA BP Pulse

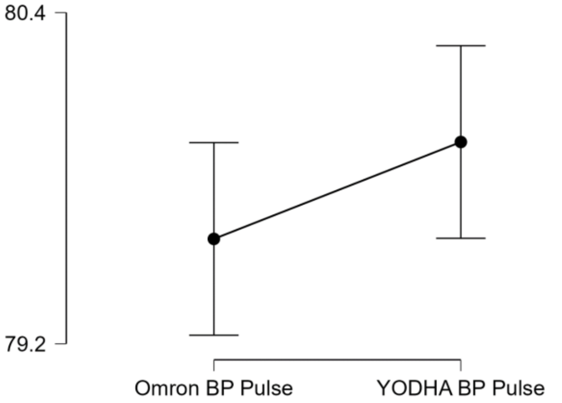
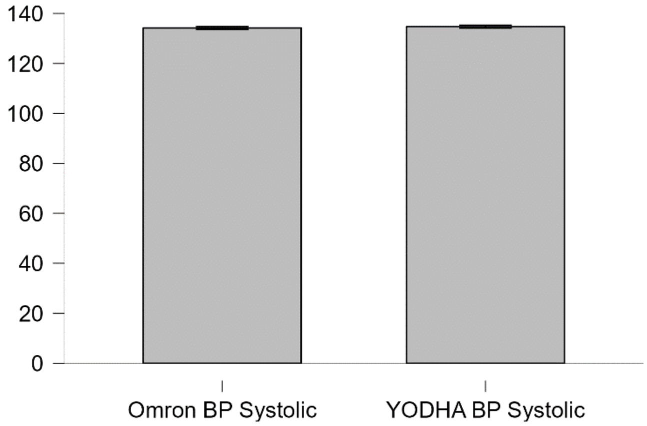
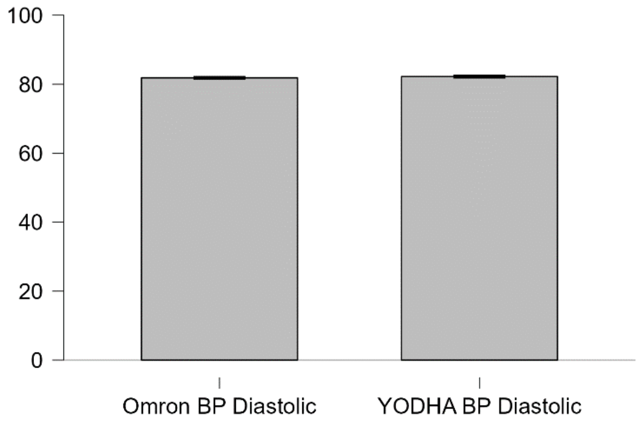


Figure 10: Bar Plots

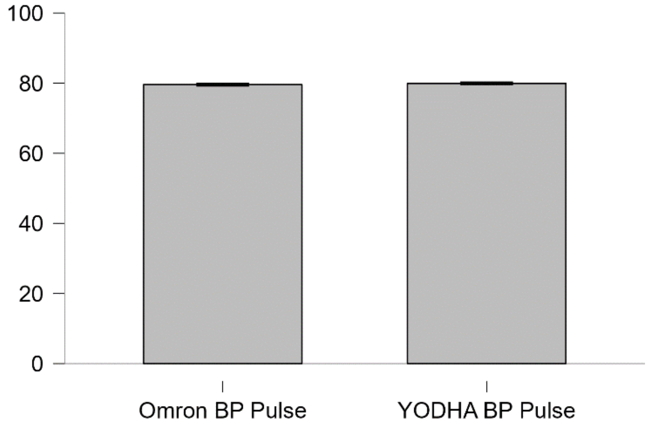
Omron BP Systolic - YODHA BP Systolic



Omron BP Diastolic - YODHA BP Diastolic



Omron BP Pulse - YODHA BP Pulse



### Comparative Analysis of Hearing Test Results between Gold standard in person testing and YODHA Devices across Various Frequencies

The Spearman's correlation coefficients indicate significant associations between the hearing test results obtained from gold standard in person testing and YODHA devices across various frequencies (see details for each frequency in Table 13). At 500Hz in the left ear, there was a perfect positive correlation (Spearman's rho = 1.000, p < .001), suggesting a strong agreement between the measurements from both devices at this frequency. Similar strong positive correlations were observed at 1000Hz (Spearman's rho = 0.958, p < .001), 2000Hz (Spearman's rho = 0.939, p < .001), 3000Hz (Spearman's rho = 0.990, p < .001), 4000Hz (Spearman's rho = 0.990, p < .001), 6000Hz (Spearman's rho = 0.991, p < .001), and 8000Hz (Spearman's rho = 0.989, p < .001) in the left ear, indicating consistent correlation patterns across these frequencies.

In the right ear, similar strong positive correlations were observed at all frequencies tested: 500Hz (Spearman's rho = 0.998, p < .001), 1000Hz (Spearman's rho = 0.991, p < .001), 2000Hz (Spearman's rho = 0.973, p < .001), 3000Hz (Spearman's rho = 0.967, p < .001), 4000Hz (Spearman's rho = 0.996, p < .001), 6000Hz (Spearman's rho = 0.997, p < .001), and 8000Hz (Spearman's rho = 1.000, p < .001).

### Table 13: Hearing Correlation

Spearman's Correlations

| Variable | | 500Hz_Left_Gold_Visit1 | 500Hz_Left_ YODHA_Visit2 |
|---|---|---|---|
| 1. 500Hz_Left_Gold_Visit1 | Spearman's rho | — | |
| | p-value | — | |
| 2. 500Hz_Left_ YODHA_Visit2 | Spearman's rho | 1.000 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | 1000Hz_Left_Gold_Visit1 | 1000Hz_Left_ YODHA_Visit2 |
|---|---|---|---|
| 1. 1000Hz_Left_Gold_Visit1 | Spearman's rho | — | |
| | p-value | — | |
| 2. 1000Hz_Left_ YODHA_Visit2 | Spearman's rho | 0.958 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | 2000Hz_Left_Gold_Visit1 | 2000Hz_Left_ YODHA_Visit2 |
|---|---|---|---|
| 1. 2000Hz_Left_Gold_Visit1 | Spearman's rho | — | |
| | p-value | — | |
| 2. 2000Hz_Left_ YODHA_Visit2 | Spearman's rho | 0.939 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | 3000Hz_Left_Gold_Visit1 | 3000Hz_Left_ YODHA_Visit2 |
|---|---|---|---|

Spearman's Correlations

| Variable | | 2000Hz_Left_Gold_Visit1 | 2000Hz_Left_ YODHA_Visit2 |
|---|---|---|---|
| 1. 3000Hz_Left_Gold_Visit1 | Spearman's rho | — | |
| | p-value | — | |
| 2. 3000Hz_Left_ YODHA_Visit2 | Spearman's rho | 0.990 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | 4000Hz_Left_Gold_Visit1 | 4000Hz_Left_ YODHA_Visit2 |
|---|---|---|---|
| 1. 4000Hz_Left_Gold_Visit1 | Spearman's rho | — | |
| | p-value | — | |
| 2. 4000Hz_Left_ YODHA_Visit2 | Spearman's rho | 0.990 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | 6000Hz_Left_Gold_Visit1 | 6000Hz_Left_ YODHA_Visit2 |
|---|---|---|---|
| 1. 6000Hz_Left_Gold_Visit1 | Spearman's rho | — | |
| | p-value | — | |
| 2. 6000Hz_Left_ YODHA_Visit2 | Spearman's rho | 0.991 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | 8000Hz_Left_Gold_Visit1 | 8000Hz_Left_ YODHA_Visit2 |
|---|---|---|---|
| 1. 8000Hz_Left_Gold_Visit1 | Spearman's rho | — | |
| | p-value | — | |
| 2. 8000Hz_Left_ YODHA_Visit2 | Spearman's rho | 0.989 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | 500Hz_Right_Gold_Visit1 | 500Hz_Right_ YODHA_Visit2 |
|---|---|---|---|
| 1. 500Hz_Right_Gold_Visit1 | Spearman's rho | — | |
| | p-value | — | |
| 2. 500Hz_Right_ YODHA_Visit2 | Spearman's rho | 0.998 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | 1000Hz_Right_Gold_Visit1 | 1000Hz_Right_ YODHA_Visit2 |
|---|---|---|---|
| 1. 1000Hz_Right_Gold_Visit1 | Spearman's rho | — | |
| | p-value | — | |
| 2. 1000Hz_Right_ YODHA_Visit2 | Spearman's rho | 0.991 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | 2000Hz_Right_Gold_Visit1 | 2000Hz_Right_ YODHA_Visit2 |
|---|---|---|---|
| 1. 2000Hz_Right_Gold_Visit1 | Spearman's rho | — | |
| | p-value | — | |
| 2. 2000Hz_Right_ YODHA_Visit2 | Spearman's rho | 0.973 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | 3000Hz_Right_Gold_Visit1 | 3000Hz_Right_ YODHA_Visit2 |
|---|---|---|---|
| 1. 3000Hz_Right_Gold_Visit1 | Spearman's rho | — | |
| | p-value | — | |
| 2. 3000Hz_Right_ YODHA_Visit2 | Spearman's rho | 0.967 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | 4000Hz_Right_Gold_Visit1 | 4000Hz_Right_ YODHA_Visit2 |
|---|---|---|---|
| 1. 4000Hz_Right_Gold_Visit1 | Spearman's rho | — | |
| | p-value | — | |
| 2. 4000Hz_Right_ YODHA_Visit2 | Spearman's rho | 0.996 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | 6000Hz_Right_Gold_Visit1 | 6000Hz_Right_ YODHA_Visit2 |
|---|---|---|---|
| 1. 6000Hz_Right_Gold_Visit1 | Spearman's rho | — | |
| | p-value | — | |
| 2. 6000Hz_Right_ YODHA_Visit2 | Spearman's rho | 0.997 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | 8000Hz_Right_Gold_Visit1 | 8000Hz_Right_ YODHA_Visit2 |
|---|---|---|---|
| 1. 8000Hz_Right_Gold_Visit1 | Spearman's rho | — | |
| | p-value | — | |
| 2. 8000Hz_Right_ YODHA_Visit2 | Spearman's rho | 1.000 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

## Comparative Analysis of Spirometry Measurements between Mirobank and YODHA Devices

Spearman's correlation coefficients show significant associations between spirometry measurements from Mirobank and YODHA devices (see details in Table 14). For FVC, there is a strong positive correlation between Mirobank and YODHA measurements (Spearman's rho = 0.994, p < .001), indicating consistent FVC values between the two devices. Similarly, a perfect positive correlation exists between predicted FVC values obtained from Mirobank and YODHA devices (Spearman's rho = 1.000, p < .001), confirming precise predicted FVC outcomes.

Regarding FEV1, a strong positive correlation is evident between Mirobank and YODHA measurements (Spearman's rho = 0.995, p < .001), ensuring reliable FEV1 values. The correlation between predicted FEV1 values obtained from Mirobank and YODHA devices was also perfect, with a Spearman's rho of 1.000 (p < .001), also indicating complete agreement in the predicted FEV1 outcomes.

However, for PEF, while a significant correlation was observed between Mirobank and YODHA measurements (Spearman's rho = 0.628, p < .001), the correlation coefficient suggests a moderate level of agreement between the two devices for PEF values. Similarly, there is a perfect positive correlation between predicted PEF values obtained from Mirobank and YODHA devices (Spearman's rho = 1.000, p < .001), ensuring exact predicted PEF outcomes. Regarding the FEV1/FVC ratio, a strong positive correlation exists between Mirobank and YODHA measurements (Spearman's rho = 0.966, p < .001), demonstrating consistent FEV1/FVC ratios. The correlation between predicted FEV1/FVC ratios from Mirobank and YODHA devices is perfect (Spearman's rho = 1.000, p < .001), confirming precise predicted FEV1/FVC ratio outcomes.

### Table 14: Spirometry Correlation

Spearman's Correlations

| Variable | | Mirobank FVC | YODHA FVC |
|---|---|---|---|
| 1. Mirobank FVC | Spearman's rho | — | |
| | p-value | — | |
| 2. YODHA FVC | Spearman's rho | 0.994 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | Mirobank Pred FVC | YODHA Pred FVC |
|---|---|---|---|
| 1. Mirobank Pred FVC | Spearman's rho | — | |
| | p-value | — | |
| 2. YODHA Pred FVC | Spearman's rho | 1.000 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | Mirobank FEV1 | YODHA FEV1 |
|---|---|---|---|
| 1. Mirobank FEV1 | Spearman's rho | — | |
| | p-value | — | |
| 2. YODHA FEV1 | Spearman's rho | 0.995 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | Mirobank Pred FEV1 | YODHA Pred FEV1 |
|---|---|---|---|
| 1. Mirobank Pred FEV1 | Spearman's rho | — | |
| | p-value | — | |
| 2. YODHA Pred FEV1 | Spearman's rho | 1.000 *** | — |

Spearman's Correlations

| Variable | | Mirobank Pred FEV1 | YODHA Pred FEV1 |
|---|---|---|---|
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | Mirobank PEF | YODHA Pred PEF |
|---|---|---|---|
| 1. Mirobank PEF | Spearman's rho | — | |
| | p-value | — | |
| 2. YODHA Pred PEF | Spearman's rho | 0.628 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | Mirobank Pred PEF | YODHA Pred PEF |
|---|---|---|---|
| 1. Mirobank Pred PEF | Spearman's rho | — | |
| | p-value | — | |
| 2. YODHA Pred PEF | Spearman's rho | 1.000 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | Mirobank FEV1/FVC | YODHA FEV1/FVC |
|---|---|---|---|
| 1. Mirobank FEV1/FVC | Spearman's rho | — | |
| | p-value | — | |
| 2. YODHA FEV1/FVC | Spearman's rho | 0.966 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | Mirobank Pred FEV1/FVC | YODHA Pred FEV1/FVC |
|---|---|---|---|
| 1. Mirobank Pred FEV1/FVC | Spearman's rho | — | |
| | p-value | — | |
| 2. YODHA Pred FEV1/FVC | Spearman's rho | 1.000 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

### Correlations Between Omron and YODHA Devices for Blood Pressure Measurements

Spearman's correlation coefficients indicate strong associations between Omron and YODHA devices (see details in Table 15), with a high positive correlation for systolic blood pressure (Spearman's rho = 0.956, p < .001), indicating consistent readings. Diastolic blood pressure measurements also show a strong correlation (Spearman's rho = 0.957, p < .001), confirming agreement between the two devices. Pulse rate values display an even higher correlation (Spearman's rho = 0.983, p < .001), further demonstrating consistency.

### Table 15: Blood Pressure Correlation

Spearman's Correlations

| Variable | | Omron BP Systolic | YODHA BP Systolic |
|---|---|---|---|
| 1. Omron BP Systolic | Spearman's rho | — | |
| | p-value | — | |
| 2. YODHA BP Systolic | Spearman's rho | 0.956 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | Omron BP Diastolic | YODHA BP Diastolic |
|---|---|---|---|
| 1. Omron BP Diastolic | Spearman's rho | — | |
| | p-value | — | |
| 2. YODHA BP Diastolic | Spearman's rho | 0.957 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

Spearman's Correlations

| Variable | | Omron BP Pulse | YODHA BP Pulse |
|---|---|---|---|
| 1. Omron BP Pulse | Spearman's rho | — | |
| | p-value | — | |
| 2. YODHA BP Pulse | Spearman's rho | 0.983 *** | — |
| | p-value | < .001 | — |

* p < .05, ** p < .01, *** p < .001

## Gender Differences in Auditory Thresholds Across Frequencies and Visits

Gender differences in auditory thresholds reveal nuanced variations across frequencies and visits (see details in Table 16). For instance, at 500Hz during the gold standard in person testing, males displayed a mean threshold of 9.521 dB (SD = 8.214 dB), slightly lower than females with a mean threshold of 9.815 dB (SD = 8.932 dB). Similarly, at 1000Hz, males showed a mean threshold of 8.493 dB (SD = 7.532 dB), while females had a mean threshold of 8.148 dB (SD = 7.740 dB). The trend indicates that males generally have slightly lower mean thresholds than females, but this difference varies across frequency bands. Gender differences in mean thresholds vary at different frequencies, with males showing marginally lower thresholds at 500Hz and 1000Hz, and more pronounced at 3000Hz and 4000Hz.

### Table 16: Gender Differences Descriptive Statistics

Descriptive Statistics

| | | Valid | Mean | Std. Deviation | IQR | Shapiro-Wilk | P-value of Shapiro-Wilk | Range | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|
| 500Hz_Left_Gold_Visit1 | 1 | 73 | 9.521 | 8.214 | 10.000 | 0.780 | < .001 | 35.000 | 0.000 | 35.000 |
| 500Hz_Left_Gold_Visit1 | 2 | 27 | 9.815 | 8.932 | 10.000 | 0.796 | < .001 | 35.000 | 0.000 | 35.000 |
| 1000Hz_Left_Gold_Visit1 | 1 | 73 | 8.493 | 7.532 | 10.000 | 0.757 | < .001 | 30.000 | 0.000 | 30.000 |
| 1000Hz_Left_Gold_Visit1 | 2 | 27 | 8.148 | 7.740 | 5.000 | 0.756 | < .001 | 30.000 | 0.000 | 30.000 |

Descriptive Statistics

| | | Valid | Mean | Std. Deviation | IQR | Shapiro-Wilk | P-value of Shapiro-Wilk | Range | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|
| 2000Hz_Left_Gold_Visit1 | 1 | 73 | 6.096 | 7.784 | 5.000 | 0.736 | < .001 | 35.000 | -5.000 | 30.000 |
| 2000Hz_Left_Gold_Visit1 | 2 | 27 | 6.296 | 8.615 | 5.000 | 0.801 | < .001 | 35.000 | -5.000 | 30.000 |
| 3000Hz_Left_Gold_Visit1 | 1 | 73 | 19.589 | 16.827 | 20.000 | 0.842 | < .001 | 55.000 | 0.000 | 55.000 |
| 3000Hz_Left_Gold_Visit1 | 2 | 27 | 18.704 | 17.845 | 20.000 | 0.825 | < .001 | 55.000 | 0.000 | 55.000 |
| 4000Hz_Left_Gold_Visit1 | 1 | 73 | 21.575 | 14.479 | 15.000 | 0.852 | < .001 | 45.000 | 5.000 | 50.000 |
| 4000Hz_Left_Gold_Visit1 | 2 | 27 | 20.926 | 15.002 | 15.000 | 0.833 | < .001 | 45.000 | 5.000 | 50.000 |
| 6000Hz_Left_Gold_Visit1 | 1 | 73 | 26.027 | 11.606 | 15.000 | 0.905 | < .001 | 40.000 | 10.000 | 50.000 |
| 6000Hz_Left_Gold_Visit1 | 2 | 27 | 25.926 | 11.354 | 12.500 | 0.914 | 0.028 | 40.000 | 10.000 | 50.000 |
| 8000Hz_Left_Gold_Visit1 | 1 | 73 | 18.425 | 9.856 | 10.000 | 0.824 | < .001 | 40.000 | 5.000 | 45.000 |
| 8000Hz_Left_Gold_Visit1 | 2 | 27 | 19.815 | 11.307 | 5.000 | 0.869 | 0.003 | 40.000 | 5.000 | 45.000 |
| 500Hz_Right_Gold_Visit1 | 1 | 73 | 8.356 | 8.419 | 10.000 | 0.931 | < .001 | 30.000 | -5.000 | 25.000 |
| 500Hz_Right_Gold_Visit1 | 2 | 27 | 9.630 | 9.700 | 17.500 | 0.910 | 0.023 | 30.000 | -5.000 | 25.000 |
| 1000Hz_Right_Gold_Visit1 | 1 | 73 | 6.781 | 8.595 | 5.000 | 0.825 | < .001 | 35.000 | -5.000 | 30.000 |
| 1000Hz_Right_Gold_Visit1 | 2 | 27 | 7.037 | 7.998 | 5.000 | 0.734 | < .001 | 35.000 | -5.000 | 30.000 |
| 2000Hz_Right_Gold_Visit1 | 1 | 73 | 6.438 | 12.061 | 15.000 | 0.818 | < .001 | 45.000 | -5.000 | 40.000 |
| 2000Hz_Right_Gold_Visit1 | 2 | 27 | 9.074 | 11.851 | 15.000 | 0.869 | 0.003 | 45.000 | -5.000 | 40.000 |
| 3000Hz_Right_Gold_Visit1 | 1 | 73 | 18.219 | 15.509 | 20.000 | 0.800 | < .001 | 55.000 | 5.000 | 60.000 |
| 3000Hz_Right_Gold_Visit1 | 2 | 27 | 17.593 | 16.015 | 20.000 | 0.780 | < .001 | 55.000 | 5.000 | 60.000 |
| 4000Hz_Right_Gold_Visit1 | 1 | 73 | 22.534 | 16.732 | 30.000 | 0.914 | < .001 | 55.000 | 0.000 | 55.000 |
| 4000Hz_Right_Gold_Visit1 | 2 | 27 | 22.593 | 15.403 | 20.000 | 0.933 | 0.080 | 55.000 | 0.000 | 55.000 |
| 6000Hz_Right_Gold_Visit1 | 1 | 73 | 28.151 | 13.681 | 20.000 | 0.850 | < .001 | 50.000 | 10.000 | 60.000 |
| 6000Hz_Right_Gold_Visit1 | 2 | 27 | 30.370 | 15.746 | 22.500 | 0.878 | 0.004 | 50.000 | 10.000 | 60.000 |
| 8000Hz_Right_Gold_Visit1 | 1 | 73 | 22.192 | 9.574 | 15.000 | 0.903 | < .001 | 30.000 | 10.000 | 40.000 |
| 8000Hz_Right_Gold_Visit1 | 2 | 27 | 22.778 | 10.316 | 15.000 | 0.851 | 0.001 | 30.000 | 10.000 | 40.000 |
| 500Hz_Left_YODHA_Visit2 | 1 | 73 | 9.521 | 8.214 | 10.000 | 0.780 | < .001 | 35.000 | 0.000 | 35.000 |
| 500Hz_Left_YODHA_Visit2 | 2 | 27 | 9.815 | 8.932 | 10.000 | 0.796 | < .001 | 35.000 | 0.000 | 35.000 |
| 1000Hz_Left_YODHA_Visit2 | 1 | 73 | 8.836 | 7.337 | 10.000 | 0.747 | < .001 | 30.000 | 0.000 | 30.000 |
| 1000Hz_Left_YODHA_Visit2 | 2 | 27 | 8.333 | 7.596 | 5.000 | 0.737 | < .001 | 30.000 | 0.000 | 30.000 |
| 2000Hz_Left_YODHA_Visit2 | 1 | 73 | 6.986 | 8.154 | 5.000 | 0.753 | < .001 | 40.000 | -5.000 | 35.000 |
| 2000Hz_Left_YODHA_Visit2 | 2 | 27 | 6.852 | 8.221 | 5.000 | 0.803 | < .001 | 35.000 | -5.000 | 30.000 |
| 3000Hz_Left_YODHA_Visit2 | 1 | 73 | 20.000 | 16.667 | 20.000 | 0.855 | < .001 | 60.000 | 0.000 | 60.000 |
| 3000Hz_Left_YODHA_Visit2 | 2 | 27 | 19.074 | 17.815 | 20.000 | 0.831 | < .001 | 55.000 | 0.000 | 55.000 |
| 4000Hz_Left_YODHA_Visit2 | 1 | 73 | 21.781 | 14.822 | 15.000 | 0.857 | < .001 | 55.000 | 5.000 | 60.000 |
| 4000Hz_Left_YODHA_Visit2 | 2 | 27 | 21.667 | 15.628 | 15.000 | 0.848 | 0.001 | 50.000 | 5.000 | 55.000 |
| 6000Hz_Left_YODHA_Visit2 | 1 | 73 | 26.164 | 11.563 | 15.000 | 0.904 | < .001 | 40.000 | 10.000 | 50.000 |
| 6000Hz_Left_YODHA_Visit2 | 2 | 27 | 25.000 | 10.470 | 15.000 | 0.922 | 0.043 | 40.000 | 10.000 | 50.000 |
| 8000Hz_Left_YODHA_Visit2 | 1 | 73 | 18.493 | 9.884 | 5.000 | 0.833 | < .001 | 40.000 | 5.000 | 45.000 |
| 8000Hz_Left_YODHA_Visit2 | 2 | 27 | 19.815 | 11.392 | 5.000 | 0.884 | 0.006 | 45.000 | 0.000 | 45.000 |

Descriptive Statistics

| | | Valid | Mean | Std. Deviation | IQR | Shapiro-Wilk | P-value of Shapiro-Wilk | Range | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|
| 500Hz_Right_Yodha | 1 | 73 | 8.493 | 8.236 | 10.000 | 0.927 | < .001 | 30.000 | -5.000 | 25.000 |
| 500Hz_ Right_YODHA_Visit2 | 2 | 27 | 9.630 | 9.700 | 17.500 | 0.910 | 0.023 | 30.000 | -5.000 | 25.000 |
| 1000Hz_ Right_YODHA_Visit2 | 1 | 73 | 7.055 | 8.613 | 5.000 | 0.837 | < .001 | 35.000 | -5.000 | 30.000 |
| 1000Hz_ Right_YODHA_Visit2 | 2 | 27 | 7.037 | 7.998 | 5.000 | 0.734 | < .001 | 35.000 | -5.000 | 30.000 |
| 2000Hz_ Right_YODHA_Visit2 | 1 | 73 | 7.192 | 11.726 | 10.000 | 0.832 | < .001 | 45.000 | -5.000 | 40.000 |
| 2000Hz_ Right_YODHA_Visit2 | 2 | 27 | 9.815 | 11.476 | 15.000 | 0.871 | 0.003 | 45.000 | -5.000 | 40.000 |
| 3000Hz_ Right_YODHA_Visit2 | 1 | 73 | 18.767 | 14.925 | 20.000 | 0.824 | < .001 | 55.000 | 5.000 | 60.000 |
| 3000Hz_ Right_YODHA_Visit2 | 2 | 27 | 19.074 | 17.155 | 20.000 | 0.778 | < .001 | 65.000 | 5.000 | 70.000 |
| 4000Hz_ Right_YODHA_Visit2 | 1 | 73 | 22.808 | 16.562 | 30.000 | 0.920 | < .001 | 55.000 | 0.000 | 55.000 |
| 4000Hz_ Right_YODHA_Visit2 | 2 | 27 | 22.963 | 15.582 | 20.000 | 0.933 | 0.081 | 60.000 | 0.000 | 60.000 |
| 6000Hz_ Right_YODHA_Visit2 | 1 | 73 | 28.014 | 13.610 | 20.000 | 0.863 | < .001 | 50.000 | 10.000 | 60.000 |
| 6000Hz_ Right_YODHA_Visit2 | 2 | 27 | 30.185 | 15.657 | 20.000 | 0.872 | 0.003 | 50.000 | 10.000 | 60.000 |
| 8000Hz_ Right_YODHA_Visit2 | 1 | 73 | 22.192 | 9.574 | 15.000 | 0.903 | < .001 | 30.000 | 10.000 | 40.000 |
| 8000Hz_ Right_YODHA_Visit2 | 2 | 27 | 22.778 | 10.316 | 15.000 | 0.851 | 0.001 | 30.000 | 10.000 | 40.000 |

### Pulmonary Function Measures: A Comparative Analysis between Mirobank and YODHA Groups

The Mirobank group had a FVC mean was 4.797 L (SD = 1.282) for male participants and 4.456 L (SD = 1.300) for female participants (see details in Table 17). Similarly, the predicted FVC mean was 5.295 L (SD = 0.719) for males and 4.964 L (SD = 0.869) for females. Interestingly, a slight decrease in mean values for FVC and predicted FVC was observed from Visit 1 to Visit 2, although the SDs remained relatively consistent. Moreover, a similar trend was observed for FEV1 and PEF measures.

Comparatively, the YODHA group exhibited similar patterns in pulmonary function measures across visits, albeit with some variations. For example, the FVC mean for male participants was 4.950 L (SD = 1.324) and for female participants was 4.527 L (SD = 1.308). Likewise, the predicted FVC mean was 5.295 L (SD = 0.719) for males and 4.964 L (SD = 0.869) for females. Despite these similarities, subtle differences in mean values between the Mirobank and YODHA groups were noted, suggesting potential group-specific differences in pulmonary function. Additionally, the FEV1/FVC ratio showed consistent trends across visits, with slightly higher mean values in the YODHA group compared to the Mirobank group, indicating potential differences in airway obstruction or pulmonary restriction between the two groups.

Table 17: Descriptive Statistics on Pulmonary Function

Descriptive Statistics

| | | Valid | Mean | Std. Deviation | IQR | Shapiro-Wilk | P-value of Shapiro-Wilk | Range | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|
| Mirobank FVC | 1 | 73 | 4.797 | 1.282 | 1.690 | 0.961 | 0.022 | 6.540 | 0.750 | 7.290 |
| Mirobank FVC | 2 | 27 | 4.456 | 1.300 | 0.670 | 0.919 | 0.037 | 5.730 | 1.390 | 7.120 |
| Mirobank Pred FVC | 1 | 73 | 5.295 | 0.719 | 0.920 | 0.914 | < .001 | 3.480 | 2.800 | 6.280 |
| Mirobank Pred FVC | 2 | 27 | 4.964 | 0.869 | 0.845 | 0.879 | 0.005 | 4.140 | 2.100 | 6.240 |
| Mirobank FEV1 | 1 | 73 | 3.840 | 1.043 | 1.540 | 0.950 | 0.006 | 4.840 | 0.750 | 5.590 |
| Mirobank FEV1 | 2 | 27 | 3.549 | 1.081 | 0.800 | 0.949 | 0.208 | 4.670 | 1.000 | 5.670 |
| Mirobank Pred FEV1 | 1 | 73 | 4.386 | 0.598 | 0.670 | 0.863 | < .001 | 2.910 | 2.350 | 5.260 |
| Mirobank Pred FEV1 | 2 | 27 | 4.116 | 0.718 | 0.310 | 0.819 | < .001 | 3.060 | 1.920 | 4.980 |
| Mirobank PEF | 1 | 73 | 8.342 | 2.743 | 2.610 | 0.954 | 0.010 | 11.080 | 2.710 | 13.790 |
| Mirobank PEF | 2 | 27 | 7.794 | 2.565 | 2.295 | 0.970 | 0.593 | 11.270 | 2.080 | 13.350 |
| Mirobank Pred PEF | 1 | 73 | 9.374 | 1.175 | 1.070 | 0.807 | < .001 | 5.700 | 5.190 | 10.890 |
| Mirobank Pred PEF | 2 | 27 | 8.956 | 1.460 | 0.855 | 0.805 | < .001 | 5.650 | 5.240 | 10.890 |
| Mirobank FEV1/FVC | 1 | 73 | 80.505 | 8.267 | 7.300 | 0.914 | < .001 | 49.100 | 50.900 | 100.000 |
| Mirobank FEV1/FVC | 2 | 27 | 79.396 | 6.269 | 7.450 | 0.883 | 0.005 | 27.700 | 59.200 | 86.900 |
| Mirobank Pred FEV1/FVC | 1 | 73 | 83.473 | 3.584 | 3.200 | 0.939 | 0.002 | 21.000 | 72.200 | 93.200 |
| Mirobank Pred FEV1/FVC | 2 | 27 | 81.693 | 3.060 | 4.050 | 0.927 | 0.060 | 14.500 | 76.400 | 90.900 |
| YODHA FVC | 1 | 73 | 4.950 | 1.324 | 1.703 | 0.961 | 0.023 | 6.824 | 0.767 | 7.592 |
| YODHA FVC | 2 | 27 | 4.527 | 1.308 | 0.778 | 0.932 | 0.078 | 5.727 | 1.436 | 7.163 |
| YODHA Pred FVC | 1 | 73 | 5.295 | 0.719 | 0.920 | 0.914 | < .001 | 3.480 | 2.800 | 6.280 |
| YODHA Pred FVC | 2 | 27 | 4.964 | 0.869 | 0.845 | 0.879 | 0.005 | 4.140 | 2.100 | 6.240 |
| YODHA FEV1 | 1 | 73 | 3.963 | 1.076 | 1.623 | 0.951 | 0.006 | 4.987 | 0.767 | 5.754 |
| YODHA FEV1 | 2 | 27 | 3.606 | 1.092 | 0.967 | 0.961 | 0.395 | 4.767 | 1.033 | 5.800 |
| YODHA Pred FEV1 | 1 | 73 | 4.386 | 0.598 | 0.670 | 0.863 | < .001 | 2.910 | 2.350 | 5.260 |
| YODHA Pred FEV1 | 2 | 27 | 4.116 | 0.718 | 0.310 | 0.819 | < .001 | 3.060 | 1.920 | 4.980 |
| YODHA PEF | 1 | 73 | 8.611 | 2.832 | 3.008 | 0.957 | 0.015 | 11.473 | 2.772 | 14.245 |
| YODHA PEF | 2 | 27 | 7.920 | 2.596 | 2.397 | 0.973 | 0.679 | 11.508 | 2.149 | 13.657 |
| YODHA Pred PEF | 1 | 73 | 9.374 | 1.175 | 1.070 | 0.807 | < .001 | 5.700 | 5.190 | 10.890 |
| YODHA Pred PEF | 2 | 27 | 8.956 | 1.460 | 0.855 | 0.805 | < .001 | 5.650 | 5.240 | 10.890 |
| YODHA FEV1/FVC | 1 | 73 | 83.106 | 8.685 | 7.517 | 0.915 | < .001 | 52.929 | 52.071 | 105.000 |
| YODHA FEV1/FVC | 2 | 27 | 80.730 | 6.626 | 7.450 | 0.903 | 0.016 | 29.695 | 59.555 | 89.250 |
| YODHA Pred FEV1/FVC | 1 | 73 | 83.473 | 3.584 | 3.200 | 0.939 | 0.002 | 21.000 | 72.200 | 93.200 |
| YODHA Pred FEV1/FVC | 2 | 27 | 81.693 | 3.060 | 4.050 | 0.927 | 0.060 | 14.500 | 76.400 | 90.900 |

## Gender-Specific Blood Pressure Measurements: A Comparative Analysis between Omron and YODHA Devices

The descriptive statistics offer valuable insights into the blood pressure measurements recorded using Omron and YODHA devices, with distinct patterns observed between male and female participants (see details in Table 18). In terms of systolic blood pressure measured by Omron devices, male participants exhibited a slightly higher mean of 134.877 mmHg (SD = 13.559) compared to female participants, who had a mean of 132.333 mmHg (SD = 13.720). Similarly, for diastolic blood pressure measured by Omron, males had a mean of 82.000 mmHg (SD = 8.342), slightly higher than females with a mean of 81.444 mmHg (SD = 9.208). However, when examining pulse rate, females showed a slightly higher mean of 81.630 bpm (SD = 11.610) compared to males with a mean of 78.822 bpm (SD = 14.927).

Contrastingly, the YODHA group displayed comparable patterns in blood pressure measures between male and female participants. For systolic blood pressure, males had a mean of 135.133 mmHg (SD = 13.857) and females had a mean of 133.664 mmHg (SD = 13.854). Likewise, diastolic blood pressure showed similar trends, with males exhibiting a mean of 82.187 mmHg (SD = 8.726) and females with a mean of 82.293 mmHg (SD = 9.502). Interestingly, the pulse rate among YODHA participants showed a slightly higher mean for females, with 82.493 bpm (SD = 12.105), compared to males with 78.984 bpm (SD = 15.039).

Table 18: Descriptive Statistics on Blood Pressure Measurements

Descriptive Statistics

| | | Valid | Mean | Std. Deviation | IQR | Shapiro-Wilk | P-value of Shapiro-Wilk | Range | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|---|
| Omron BP Systolic | M | 73 | 134.877 | 13.559 | 23.000 | 0.968 | 0.059 | 50.000 | 110.000 | 160.000 |
| Omron BP Systolic | F | 27 | 132.333 | 13.720 | 19.500 | 0.961 | 0.394 | 49.000 | 110.000 | 159.000 |
| Omron BP Diastolic | M | 73 | 82.000 | 8.342 | 12.000 | 0.985 | 0.556 | 36.000 | 63.000 | 99.000 |
| Omron BP Diastolic | F | 27 | 81.444 | 9.208 | 11.500 | 0.957 | 0.323 | 33.000 | 65.000 | 98.000 |
| Omron BP Pulse | M | 73 | 78.822 | 14.927 | 24.000 | 0.967 | 0.053 | 57.000 | 50.000 | 107.000 |
| Omron BP Pulse | F | 27 | 81.630 | 11.610 | 15.500 | 0.969 | 0.571 | 44.000 | 61.000 | 105.000 |
| YODHA BP Systolic | M | 73 | 135.133 | 13.857 | 19.704 | 0.981 | 0.350 | 58.688 | 109.312 | 168.000 |
| YODHA BP Systolic | F | 27 | 133.664 | 13.854 | 19.554 | 0.972 | 0.647 | 52.983 | 111.264 | 164.247 |
| YODHA BP Diastolic | M | 73 | 82.187 | 8.726 | 11.536 | 0.973 | 0.117 | 37.917 | 63.360 | 101.277 |
| YODHA BP Diastolic | F | 27 | 82.293 | 9.502 | 11.307 | 0.972 | 0.651 | 35.755 | 67.145 | 102.900 |
| YODHA BP Pulse | M | 73 | 78.984 | 15.039 | 19.290 | 0.971 | 0.088 | 56.860 | 48.000 | 104.860 |
| YODHA BP Pulse | F | 27 | 82.493 | 12.105 | 14.016 | 0.966 | 0.510 | 46.977 | 61.488 | 108.465 |

## Discussion

### Exploring the Potential of Remote Health Assessment Technologies: A Comparative Analysis and Demographic Considerations

Recent research by Semaan et al. (2023) and Bardram (2023) highlights the promising accuracy of remote health assessment technologies, such as remote photoplethysmography imaging and telemedicine, which rival traditional in-person methods for measuring vital signs and conducting physical examinations. Specifically, Semaan et al. (2023) demonstrated excellent agreement between remote and standard measurements for vital signs like respiratory rate, while Bardram (2023) found telemedicine to be effective in children for various examinations, including otoscopy and lung auscultations. Moreover, Wagner et al. (2023) found that digital applications have facilitated accurate remote hearing assessments, supporting decentralised hearing services. These findings underscore the potential of remote health assessment technologies to enhance employee wellbeing by providing reliable measurements of blood pressure, hearing, and lung function, thus offering a viable alternative to traditional in-person methods.

However, it's noteworthy that the sample in the study displayed a notable skew towards older ages, with a quarter falling between 52 and 67 years old. This suggests potential demographic trends or sampling biases within the study. This demographic variability is critical, as age and gender can influence health parameters such as auditory and pulmonary function (Ftouh et al., 2018; World Health Organisation, 2020). Thus, the comparison of automated health monitoring technologies with traditional in-person methods entails significant methodological considerations, especially given the predominantly male sample (73%) with a diverse age range (mean age 39.7 years, SD = 14.2).

### Comparative Analysis of Hearing Test Results: Evaluating Variations Between Gold standard in person testing and YODHA Assessments

Examining the Paired Samples T-Test results for the hearing test between gold standard in person testing and YODHA reveals significant differences at specific frequencies, such as 1000Hz and 2000Hz in the left ear, and 4000Hz in the right ear, indicating variations in hearing thresholds between the two visits. Conversely, several frequencies, including 6000Hz and 8000Hz in the left ear, and 500Hz and 6000Hz in the right ear, showed no significant differences, suggesting consistent hearing thresholds and stable auditory performance for these frequencies between the two testing conditions. Additionally, the inability to perform comparisons at 500Hz in the left ear and 8000Hz in the right ear due to zero variance highlights specific issues in variability that should be further investigated.

Thus, the study identified significant differences in hearing thresholds between the two visits, highlighting potential variability in remote hearing tests and challenges in maintaining consistent noise levels (Füllgrabe et al., 2015). Despite these differences, strong positive correlations across all tested frequencies suggest that the relative ranking of individuals remains stable, indicating crucial monitoring over time. Furthermore, considering the limitations of standard audiometry protocols, such as the standard 7029:2017, which does not adequately address variations across individual sexes and age groups, there is a need for extended high-frequency audiometry to ensure comprehensive hearing assessment (Škerková et al., 2022). Additionally, the reliability of alternative methods, such as the Amplivox hearing test, especially in assessing hearing status through distortion-product otoacoustic emission measurements, underscores the importance of exploring diverse assessment approaches. These approaches can provide more accurate and detailed insights into auditory function, as evidenced in our study comparing gold standard in-person testing and YODHA results (Burke et al., 2010).

## Comparative Analysis of Spirometry Results Between Mirobank and YODHA Devices: Insights into Pulmonary Function Assessment

Comparing spirometry results between Mirobank and YODHA reveals slight differences, with YODHA generally showing slightly higher mean values for FVC, FEV1, and PEF. However, both sets of measures exhibit significant deviations from normality, consistent with prior research highlighting variability in spirometry measures due to factors such as user proficiency and environmental conditions (Miller, 2005). The FEV1/FVC ratio suggests a potential improvement in pulmonary function with YODHA measurements. The lack of variability in predicted FVC and FEV1 between Mirobank and YODHA suggests the need for further investigation into comparability issues, especially in women and patients with less severe airflow limitations (Aggarwal et al., 2006).

Notably, spirometers are considered the gold standard for COPD diagnosis, yet technical factors can lead to inaccuracies, especially in outpatient settings (Fan et al., 2020). Moreover, although our study did not directly assess sensitivity and specificity, the notable distinctions observed between gold standard in person testing and YODHA imply efficacy in detecting alterations in hearing thresholds. This aligns with the documented high accuracy rates of hearing screeners like pure-tone screening and HearCheck, which exhibited a sensitivity of at least 89% and specificity of at least 78% (Fortnum et al., 2016). Additionally, Barth et al. (2024) found reasonable concordance between clinic and home spirometry in patients with interstitial lung disease, confirming the reliability of remote spirometry measurements and endorsing their potential for accurate health monitoring. This further supports the conclusions drawn from our study.

## Consistency of Blood Pressure Measurements Between Omron and YODHA Devices: Implications for Clinical Monitoring

Our investigation into the correlation of blood pressure data between Omron and YODHA devices revealed robust positive correlations for systolic (Spearman's rho = 0.956, p < .001), diastolic (Spearman's rho = 0.957, p < .001), and pulse rate (Spearman's rho = 0.983, p < .001), indicating a high level of consistency between the devices. The significant deviations from normality observed in both devices align with previous research suggesting that blood pressure measurements may vary due to factors such as cuff placement, user technique, and device calibration (Parati et al., 2014). In contrast, a study by Juraschek et al. (2023) examining device agreement for home and office blood pressure measurements using the Omron HEM-907XL found a failure rate of 22.4%, with Omron devices exhibiting a failure rate of 19.1% compared to 27.6% for non-Omron devices. This study underscores that more than one-fifth of home devices failed to meet the accuracy protocol set by the American Medical Association, underscoring the importance of office-based comparisons to ensure the accuracy of home devices. The high correlation coefficients (Spearman's rho > 0.95) suggest that YODHA can deliver reliable blood pressure readings comparable to conventional methods, which is essential for monitoring chronic diseases (O'Brien et al., 2013) and may potentially meet the accuracy standards observed in clinical settings, alike the reliable performance of Omron devices (Juraschek et al., 2023).

### Gender-Specific Variations in Auditory Thresholds Across Frequencies and Visits: Implications for Auditory Sensitivity Assessment

Gender differences in auditory thresholds manifest as nuanced variations across frequencies and visits, with males generally exhibiting slightly lower mean thresholds than females, particularly at higher frequencies. These findings underscore the intricate interplay between gender and auditory sensitivity, hinting at frequency-specific factors influencing these disparities. Further investigation is warranted to unravel the underlying mechanisms driving these differences.

Supporting our observations, previous research by Von Gablenz et al. (2020) highlights the variability of gender differences in auditory thresholds across studies and regions. For instance, German studies revealed that 15.5% of participants had a pure-tone average exceeding 25 dB HL at 0.5, 1, 2, and 4 kHz in the better ear, with 8.6% exhibiting a PTA of at least 35 dB HL. Comparisons with Dutch and Swedish studies generally corroborated our findings, although some disparities were evident. Notably, discrepancies emerged when comparing with US-American results, indicating regional disparities in age-related hearing impairment. Specifically, there was less pronounced age-related hearing impairment in Europe compared to the US, potentially attributable to lower rates of hearing impairment in males as observed in European studies.

### Gender-Specific Analysis of Spirometry Measurements and Implications for Pulmonary Function Assessment

The study findings reveal a high level of agreement in spirometry measurements across male and female participants, particularly for FVC and FEV1. However, measurements of PEF exhibit a moderate level of consistency. Both genders demonstrate similar levels of reliability in spirometry measurements across both Mirobank and YODHA devices. Male participants exhibit more consistent results across visits compared to female participants in both groups. Despite subtle variations between the two groups, trends in pulmonary function measures remain relatively consistent, with slight decreases in mean values observed from Visit 1 to Visit 2.

The results on spirometry from the Mirobank and YODHA groups aligns with existing research by Li et al. (2023) on pulmonary function in patients with chronic obstructive pulmonary disease (COPD). Consistent with prior findings, disparities in lung function measures are observed between male and female participants. Males generally exhibit higher mean FVC and predicted FVC values compared to females in both groups. Interestingly, a slight decline in these mean values is noted from Visit 1 to Visit 2, despite consistent standard deviations. While our study primarily focuses on pulmonary function measures across visits, Li et al. (2023) have explored differences in COPD-related comorbidities and all-cause mortality between men and women. Although not directly examined in our study, these previous findings highlight the broader context of sex-based disparities in COPD outcomes.

In terms of spirometry, the YODHA group demonstrates similar trends to the Mirobank group, suggesting comparable patterns in lung function measures. However, subtle variations in mean values between the two groups imply potential differences in disease severity or progression. Furthermore, consistent trends in the FEV1/FVC ratio across visits, with slightly higher mean values in the YODHA group, may indicate distinctions in airway obstruction or pulmonary restriction between the two groups. These findings underscore the significance of sex-based differences in pulmonary function measures and emphasise the need for further investigation into their clinical implications.

### Gender-Specific Analysis of Blood Pressure Correlations and Implications for Clinical Interpretation

The analysis demonstrates strong correlations between Omron and YODHA devices across all blood pressure metrics, indicating consistent results. Notably, there are no significant differences in consistency observed between male and female participants. While both devices provide valuable insights into blood pressure measurements, the YODHA group shows greater consistency between male and female participants across visits, whereas the Omron group displays slightly more variability. These findings emphasise the need to consider device-specific factors and potential gender biases when interpreting blood pressure measurements for clinical assessment and intervention strategies. Further research is necessary to elucidate the underlying mechanisms contributing to gender-specific variations in blood pressure measurements recorded by different devices.

This study's findings on gender-specific patterns in blood pressure measurements align with the research by Kiss et al. (2024), which identified differences in cardiovascular risk factors between men and women. While our study focuses on blood pressure measurements obtained using Omron and YODHA devices, Kiss et al. (2024) highlighted disparities in the measurement and management of cardiovascular risk factors. Specifically, they noted that among individuals with elevated blood pressure, women were less likely than men to receive lipid-lowering medications (RR 0.87, 95% CI: 0.79-0.95) but more likely to achieve adequate blood pressure control with treatment (RR 1.17, 95% CI: 1.09-1.25). These findings underscore the importance of considering gender differences in cardiovascular health management, which complements our investigation into gender-specific variations in blood pressure measurements.

## Implications for Occupational Health Surveillance

The use of remote health monitoring technology, such as the YODHA mobile screening kit, can significantly enhance accessibility to occupational health services, particularly in industries with dispersed or remotely located workers. This technology allows employees to perform health assessments at their convenience, reducing the need for travel and minimising work schedule disruptions. Remote health technologies also facilitate continuous and real-time monitoring of workers' health, enabling early detection of health issues, prompt interventions, and better overall management of occupational health risks (Khanijahani et al., 2022). Although the study identifies some discrepancies between new and traditional technologies, the strong positive correlations across various health metrics indicate that remote monitoring can provide reliable data, essential for long-term health monitoring and informed decision-making regarding workplace safety and employee health. Furthermore, remote assessments yielding comparable results to in-person evaluations can reduce the need for physical appointments, saving time and resources and minimising human error and bias associated with technician-administered tests.

## Conclusion:

The study showed that the YODHA remote health surveillance system can be considered a viable method of health surveillance, based on all results for hearing, lung function and blood pressure being within a 5% variance across both self-serve results and technician assisted results using the current gold standard hardware and software. These results are within the expected variability in health surveillance results from appointment to appointment with the same patient with the same methodology.

The variance in audiometric thresholds, typically within ±5 dB, is well-documented:

1. British Society of Audiology (BSA)- Recommended Procedure for Pure-Tone Audiometry:

- This document outlines the expected variability in audiometric results due to factors such as biological variation and testing conditions. It specifies that a ±5 dB variation in hearing thresholds is normal.
- Reference: British Society of Audiology (2018). *Recommended Procedure: Pure-Tone Air-Conduction and Bone-Conduction Threshold Audiometry with and without Masking.* www.thebsa.org.uk

2. Occupational Safety and Health Administration (OSHA) - Hearing Conservation Program Guidelines:

- OSHA highlights that audiometric testing has inherent variability and mentions ±5 dB as a typical range for normal test-to-test variation in hearing threshold measurements.
- Reference: OSHA (2002). *Hearing Conservation Program Guidelines.* Available at: www.osha.gov

3. International Standards Organization (ISO) 8253-1:

- This ISO standard covers audiometric test methods, emphasising factors contributing to variability, including environmental noise and patient conditions. It supports the ±5 dB threshold variation as standard for repeatability.
- Reference: ISO 8253-1:2010. *Acoustics — Audiometric Test Methods — Part 1: Basic Pure Tone Air and Bone Conduction Threshold Audiometry.* Available at ISO.org.

4. Health and Safety Executive (HSE)- Controlling Noise at Work:

- The HSE notes the variability in audiometric test results and emphasises the need for repeat testing to establish consistent trends rather than relying on single measurements.
- Reference: HSE (2005). *Noise at Work: Guidance for Employers on the Control of Noise at Work Regulations 2005.* ISBN: 978-0-7176-6165-7.

Blood pressure measurements are influenced by various factors, leading to expected variability even when using the same equipment and methodology.

Normal Variance:

- Variability between readings is typically ±5 mmHg for systolic and diastolic blood pressure when measurements are taken under similar conditions.

**Factors Influencing Variance:**

- Biological Factors: Stress, anxiety (white coat syndrome), caffeine, smoking, physical activity, or hydration can cause fluctuations.
- Technical Factors: Improper cuff size, placement errors, and operator technique can contribute to differences.
- Time of Day: Blood pressure tends to be lower in the morning and higher in the afternoon or evening.

**Reference:**

- British and Irish Hypertension Society (BIHS). *Practical Guidance on Measuring Blood Pressure in the Clinic and Home Settings* (2017).
- Source: www.bihsoc.org

Spirometry, used to measure lung function, can also show variability due to technique, effort, and biological factors.

**Normal Variance:**

- Forced Vital Capacity (FVC): ±5% or ±0.15 L (whichever is greater).
- Forced Expiratory Volume in 1 Second (FEV1): ±5% or ±0.15 L (whichever is greater).
- FEV1/FVC Ratio: Variability is less prominent as it is a ratio, but effort and lung condition can cause small fluctuations.

**Factors Influencing Variance:**

- Patient Effort: Spirometry is effort-dependent, and inconsistent effort can lead to higher variability.
- Biological Variations: Diurnal changes, respiratory conditions (e.g., asthma), or exposure to environmental irritants.
- Equipment Calibration: Poor calibration of the spirometer can introduce errors.

**Reference:**

- American Thoracic Society (ATS) and European Respiratory Society (ERS). *Standardization of Spirometry 2019 Update*.

- Source: ATS/ERS Task Force on Spirometry, available at www.thoracic.org

Expected variance summary table:

| Metric | Expected Variance | Reference |
|---|---|---|
| Blood Pressure | ±5 mmHg (systolic/diastolic) | British and Irish Hypertension Society (BIHS), 2017 |
| Spirometry (FVC, FEV1) | ±5% or ±0.15 L | ATS/ERS *Standardization of Spirometry 2019 Update* |
| Spirometry (FEV1/FVC) | Minimal Variance | ATS/ERS, 2019 |
| Hearing Assessment | ±5 dB at specific frequencies | British Society of Audiology (BSA), 2018; OSHA Hearing Conservation Program |

Although instructions and video tutorials were provided for using the YODHA device, the reliability of self-administered tests depends on the user's ability to follow instructions correctly. Future research should focus on improving the user interface and providing comprehensive training to ensure consistent and accurate data collection by non-professionals. Additionally, maintaining consistent conditions for remote health assessments, such as controlling ambient noise levels during audiometric testing, poses potential challenges. Future studies should explore ways to mitigate environmental variables that could impact the accuracy of remote health measurements. The sample in the study was predominantly male and had a diverse age range, but it did not reflect an even gender distribution. Future research should aim to include a more balanced demographic representation to ensure that the findings are generalisable across different populations. Longitudinal studies are necessary to fully understand the long-term implications of remote health monitoring, tracking health outcomes over extended periods to assess the effectiveness and reliability of remote technologies in maintaining occupational health standards. Furthermore, the successful implementation of remote health monitoring requires seamless integration with existing occupational health systems. Future research should explore how these technologies can be integrated with current health records, data management systems, and compliance frameworks to enhance overall efficiency and efficacy.

In conclusion, the study demonstrates the potential of remote health monitoring technologies, such as the YODHA remote health surveillance system, to enhance occupational health surveillance by improving accessibility, enabling continuous monitoring, and providing reliable data. Despite the identified challenges related to technological variability, user training, environmental factors, demographic considerations, and integration with existing health systems, the findings underscore the need for ongoing refinement and comprehensive longitudinal research. Addressing these considerations will be crucial to fully harness the benefits of remote health monitoring and ensure its effective implementation in diverse occupational settings.

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