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Comparison of commercial smart watch and universal pulse oximeter on heart rate, oxygen saturation, and distance covered using the 6-minute walk test: A cross-sectional study

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Abstract
Commercial smartwatches offer the ability to measure vital signs such as heart rate (HR) and oxygen saturation (SpO2), and track physical activity, including distance covered. However, the accuracy of these devices compared to clinical tools, such as pulse oximeters, remains in question. This study aims to find correlation between commercial smartwatches against universal pulse oximeters in measuring HR, SpO2, and distance covered during the 6-minute walk test (6MWT). A total of 35 healthy subjects aged 18-25 years participated in the study. HR and SpO2 were measured using both a universal pulse oximeter and a commercial smartwatch, which were worn on the same side of the body. Measurements were taken both before and after the 6MWT. Distance covered during the 6MWT was measured manually and compared with the smartwatch reading. As the data did not follow a normal distribution, non-parametric tests were employed for statistical analysis. The intra-class correlation coefficient (ICC) was calculated to determine the level of agreement between the devices for each parameter. The results indicated that the ICC for heart rate measurements between the smartwatch and pulse oximeter was above 0.70, suggesting good agreement. However, the ICC for SpO2 and distance measurements was less than 0.70, indicating poor reliability of the smartwatch in measuring these parameters compared to the pulse oximeter and manual distance measurement. The findings suggest that while commercial smartwatches can be a reliable tool for measuring heart rate during activities such as the 6MWT, their accuracy in measuring SpO2 and distance covered is limited.

Keywords: Wearable technology, heart rate monitoring, SPO2, smartwatch, 6-minute walk test

1. Introduction
Currently, wearable technology has developed the vision of new possibilities for health care. [1] Routine monitoring of vital signs such as heart rate or SPO2 using wearable devices is an emerging trend in health monitoring outside the clinic and in-home care with a multi-billion-dollar potential [2, 3]. Smartwatch as wearable technology which is included in the E-health system to improve the quality of health services. This development makes it possible to provide people with information of sensing early symptoms of the disease or precaution of a diseased and keep track of the patient's condition [4]. Previous research has showed the efficacy of detecting accurate heart rate, oxygen saturation and step count. [5, 6] Pulse oximetry, a means of indirectly measuring peripheral blood oxygen saturation (SpO2), is a relatively new metric in smartwatches allowing simple SpO2 monitoring at home or, with certain constraints due to mobility, outdoors without the need for a universal pulse oximeter. Furthermore, the smartwatch's SpO2 sensor does not need to be linked to a finger, which complicates daily activities. This may be advantageous not only for athletes in training or mountaineers in high altitudes, but also for patients suffering from cardiovascular disorders and lung diseases such as chronic obstructive pulmonary disease (COPD) [7, 8]. Previous research has demonstrated that while wearable devices can provide valid HR and SpO2 measurements at rest, their reliability during physical activity remains unclear [5, 6]. The evidence is sparse regarding whether these wearables can accurately track other key parameters such as distance covered, especially during activities like the 6-Minute Walk Test (6MWT). Addressing this gap is crucial for determining whether smart watches are viable tools for routine health monitoring in

daily life. The aim of the current study was to compare the accuracy of a commercially available smartwatch (Apple Watch Series 9) and a universal pulse oximeter in measuring HR, SpO2, and distance covered during the 6MWT in healthy individuals.

2. Materials and Methods

This cross sectional study was conducted at the Department of Musculoskeletal Physiotherapy, Vikas college of Physiotherapy campus, Mangaluru, India. Ethical clearance was obtained from the Institutional Ethics Committee of Vikas College of Physiotherapy. After receiving the ethical clearance, 35 healthy participants, aged 18-25 years, were recruited for the study. The participants were selected from a population of healthy young adults with no known cardiovascular or respiratory conditions. Written informed consent was obtained from all the participants, and they were explained about the testing procedures.

2.1. Study Procedure

Both devices (Apple Watch Series 9 and Universal Pulse Oximeter) were used on the same side of the body (left hand) to measure HR and SpO2. The participants were asked to complete the 6MWT, a common submaximal exercise test that measures the distance an individual can walk in six minutes on a flat surface.

2.2. Outcome Measures

Heart Rate and SpO2 were measured before and after the 6MWT using both the Apple Watch Series 9 and Universal pulse oximeter.

Distance Covered during the 6MWT was measured manually and compared with the distance calculated by the Apple Watch Series 9.

3. Statistical Analysis

The data were analyzed using the SPSS software version 29.0.10. The significance level was set at 5%. The Shapiro-Wilk test was used to find the normality of the data. The Wilcoxon signed rank test was used to compare the outcome measures between smartwatch and universal pulse oximeter. The spearman's ratio was used to find out the correlation between the smartwatch and universal pulse oximeter.

4. Results

The comparison of HR measurements before and after the 6MWT showed a significant difference between the Apple Watch and the pulse oximeter. The median pre-walk HR measured by the pulse oximeter was 89 beats per minute (bpm) with an interquartile range (IQR) of 81-113 bpm, while the Apple Watch recorded a median of 99 bpm (IQR: 87-109 bpm), with a p-value of 0.010. Post-walk, the pulse oximeter recorded a median HR of 141 bpm (IQR: 116-161 bpm), and the Apple Watch measured 159 bpm (IQR: 136-175 bpm), with a p-value of < 0.001. [Table 1]

SpO2 readings were also significantly different between the two devices. Pre-walk, the pulse oximeter recorded a median of 98% (IQR: 98-99%), while the Apple Watch showed 97% (IQR: 95-99%), with a p-value of 0.017. Post-walk, the pulse oximeter recorded 99% (IQR: 97-99%), while the Apple Watch recorded 97% (IQR: 96-98%), with a p-value of < 0.001. [Table 1]

The distance measured by the Apple Watch was consistently lower than the manually recorded distance. The median manual measurement was 700 meters (IQR: 640-740 meters), whereas the Apple Watch recorded a median of 650 meters (IQR: 610-690 meters), with a p-value of 0.011. [Table 1]

Table 1: Comparison of HR, SPO_2, and distance between the actual and apple watch data

		Actual		Apple watch		"Z"	p value
		Median	IQR	Median	IQR		
HR	Pre	89	81 to 113	99	87 to 109	-2.56	0.010*
	Post	141	116 to 161	159	136 to 175	-5.10	< 0.001*
SPO_2	Pre	98	98 to 99	97	95 to 99	-2.38	0.017*
	Post	99	97 to 99	97	96 to 98	-4.17	< 0.001*
Distance (m)		700	640 to 740	650	610 to 690	-2.54	0.011*

("Z" = Wilcoxon signed rank test; * Significant; IQR = Inter Quartile Range)

- **Heart Rate:** Spearman's correlation coefficient for pre-walk HR was 0.861 ($p < 0.001$), and post-walk HR was 0.901 ($p < 0.001$). The ICC values for HR were 0.961 (pre) and 0.953 (post), indicating strong agreement between the Apple Watch and the pulse oximeter. [Table 2]
- **SpO2:** The correlation coefficient for pre-walk SpO2 was 0.460 ($p = 0.005$), and post-walk SpO2 was 0.374 ($p = 0.027$). The ICC values were 0.545 (pre) and 0.310 (post), showing poor agreement for Spo2. [Table 2]
- **Distance:** The correlation for distance was 0.491 ($p = 0.003$), with an ICC of 0.567, indicating moderate agreement. [Table 2]

Table 2: Agreement between actual data apple watch data

		Correlation between actual data and apple watch data		Agreement between actual data and apple watch data	
		Spearman's ratio	p value	ICC	95% C. I
HR	Pre	0.861	< 0.001*	0.961	0.92 to 0.98*
	Post	0.901	< 0.001*	0.953	0.91 to 0.98*
SPO_2	Pre	0.460	0.005*	0.545	0.10 to 0.77*
	Post	0.374	0.027*	0.310	-0.37 to 0.65
Distance (m)		0.491	0.003*	0.567	0.14 to 0.78*

(* Significant; ICC = Intraclass correlation coefficient; C. I = Confidence Interval)

5. Discussion

The current study compared the Commercial smartwatch (Apple watch Series 9) and universal pulse oximeter on heart rate, oxygen saturation and distance covered in normal healthy individuals, as there is no existing literature reporting on the correlation between smartwatch and universal pulse oximeter during physical activity. The study included 35 healthy individuals aged between 18 – 25 years. The results of this study indicates that the Apple Watch Series 9 can reliably measure HR during moderate physical activity like the 6MWT, with an ICC greater than 0.70, which is consistent with other research supporting the accuracy of wearable devices for HR monitoring [5]. This suggests that the Apple Watch could be a useful tool for tracking cardiovascular fitness in both clinical and non-clinical settings.

However, the study revealed limitations in the Apple Watch's accuracy for measuring SpO2 and distance. The ICC for SpO2 was below 0.70, which could be due to factors such as

skin tone, ambient light [5], and motion affecting the device's optical sensors. Similarly, distance measurements using the Apple Watch were less accurate, potentially due to the reliance on GPS and step-count algorithms [9], which may be influenced by environmental conditions and sensor placement. Study conducted by Jakub Rafl *et al*. (2021), they evaluated the accuracy of the Apple Watch Series 6 for SpO2 measurement [6]. Their findings indicated that while the smartwatch could reliably detect reduced blood oxygen levels below 90%, variability existed when comparing it to medical-grade pulse oximeters, whereas in present study we did not find significant correlation of Spo2 measurement before and after performing 6-minute walk test activity for Apple smart watch series 9.

The result of this study also resembles with systematic review done by Fuller D *et al*. (2020) on the reliability and validity of commercially available wearable devices and found that the commercially wearable devices are accurate for measuring heart rate in laboratory based settings [5].

6. Limitations

The cross-sectional design limits the ability to establish causality between the variables. Additionally, the small sample size may affect the generalizability of the findings. Moreover, only one smartwatch model (Apple watch series 9) was tested, and the results may vary with other brands or models.

Future studies should consider larger sample sizes, multiple models of wearable devices, and a wider range of physical activities to provide a more comprehensive evaluation of wearable technology's accuracy.

7. Conclusion

This study supports the use of the Apple Watch Series 9 as a reliable tool for heart rate monitoring during moderate physical activity like the 6MWT. However, its accuracy for SpO2 and distance measurements is limited, indicating the need for further refinement and validation of commercial smartwatches to ensure clinical relevance.

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