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An abstract of
a thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
of the requirements of the degree of
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Abstract

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The post-acute sequelae of SARS-CoV-2 (PASC) present a significant challenge in healthcare post-pandemic with cardiovascular and autonomic symptoms being among the most commonly reported. Consumer health wearables offer a promising solution for remote monitoring and management of these symptoms, particularly in real life, outside of clinic settings. However, the accuracy and reliability of these wearables remain uncertain which hinders widespread adoption and clinical integration.

This narrative synthesis presents findings from a systematic umbrella review aimed at characterizing the accuracy, reliability, acceptability, and clinical utility of consumer health wearables for cardiovascular biomarker monitoring in the context of PASC. A comprehensive literature search was conducted, resulting in the inclusion of 12 articles in the narrative synthesis.

The study reported variations in levels of accuracy and reliability among different wearable brands and models. Apple Watch emerged as a top-performing device, demonstrating reliable heart rate measurement, heart rate variability, and atrial fibrillation (AF) detection. Fitbit devices showed medium to good accuracy, while wristwatches from various brands such as Garmin, Polar, and so on demonstrated promising results for heart rate measurement. Huawei and Samsung devices exhibited high sensitivity and specificity rates for AF detection.

These findings highlight the potential of consumer health wearables in remote monitoring of cardiovascular health in patients with PASC but also emphasize the need for standardized validation methods and regulatory oversight.

In conclusion, this narrative synthesis contributes to our understanding of the accuracy and reliability of consumer health wearables in cardiovascular monitoring, providing valuable insights for healthcare providers, researchers, consumers, and policymakers.

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Table of Contents

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Introduction

As many as one in five adults who have had SARS-CoV-2 are now reporting symptoms of post-acute sequelae of SARS-CoV-2 (PASC) (CDC 2022). Although PASC can vary widely in its presentation and severity, several of the most frequently reported symptoms are cardiovascular and/or autonomic, such as tachycardia (rapid heart rate), palpitations, dyspnea on exertion, and chest pain (Biasccia et al. 2021, Raman et al. 2022). Ongoing myocardial inflammation has been reported after recovery from COVID-19 for both mildly symptomatic and asymptomatic patients (Proal and VanElzakker 2021). Although the causes of PASC are likely multifactorial and as of yet largely unknown, it is hypothesized that SARS-CoV-2 infection induces Cardiovascular Autonomic Dysfunction (CVAD) which can lead to dysfunctional heart rate control and abnormal vascular dynamics by hypovolemia, brainstem involvement, and autoimmunity (Shah et al. 2019, Bisaccia et al. 2021). With a direct impact on the heart and heart muscle contraction, PASC has raised the concerns of controlling and keeping track of changes in cardiovascular health in not only patients with pre-existing cardiovascular diseases but also people who have new onset symptoms after SARS-CoV-2 infection.

While some PASC patients are referred to cardiology clinics for evaluation and long-term monitoring, many patients (particularly those who have minor symptoms, are younger in age, and have fewer cardiovascular risk factors) are managed by primary care providers and instructed to self-monitor and manage symptoms at home (Whiteson et al. 2022). Consumer health wearables, defined as commercially available sensors (e.g., smartwatches, chest straps, smart jewelry) that provide wearers with real-time cardiovascular and autonomic measures, may provide patients and providers with valuable tools to manage symptoms and monitor improvements. In terms of cardiovascular health care, there is evidence to support the use of wearable devices in cardiovascular risk assessment and cardiovascular disease prevention, diagnosis, and management (Bayoumy et al. 2021). It has been suggested that wearables have huge potential for health monitoring such as cardiovascular health, medical education, and health data access (Niknejad et al. 2020, Sultan 2015).

However, the field of consumer health wearables also has several challenges. One problem is that most consumer health wearables are federally unregulated, which means that there are limited checks in place to evaluate the veracity of claims made by the companies that manufacture them. Major challenges and barriers to using wearables in cardiovascular care are device accuracy, reliability, and consistency. Some reviews of wearables have suggested that the accuracy of heart rate measurement varies across skin tone, activity conditions, level of exercise ("signal crossover effect"), and devices (Bent et al. 2020, Duncker et al. 2021). However, this evidence has not yet been aggregated. Another problem is that wearables have low adoption and adherence in some populations because users may not get the expected benefits or find devices to be difficult to use, but little research has synthesized and investigated differences in acceptability and usability (Niknejad et al. 2020). In summary, despite a rapid increase in interest in consumer health wearables, there have been few systematic attempts to aggregate existing evidence for their accuracy, reliability, and clinical utility in the context of tracking PASC symptoms (and symptoms of syndromes like it).

The objective of the Honors Thesis

Since January 2023 I have been a research assistant on a CTSA-funded systematic umbrella review project that aims to aggregate existing literature to characterize the accuracy, reliability, acceptability, and clinical utility of consumer health wearables in the context of PASC. I participated in the abstract screening, full-text review, and data extraction. I screened about 800 abstracts, reviewed about 50 full texts, and extracted 6 articles. My honors thesis involved conducting preliminary analyses of review results to date to address the research question: *how accurate are consumer health wearables at measuring cardiovascular data, and what is the quality of that evidence?*

The Importance of this Study in the Field of Biology

In the biological system, the heart rate and heart rhythm are controlled by the sympathetic nervous system and the parasympathetic nervous system. Heart rate is the number of contractions of the heart per minute, and rhythm is the pattern of the electrical impulses that cause the heartbeat. The heart rate is controlled by the membrane potential which is mediated by the movement of ions in and out of the cell membrane. The ion movement is controlled by the binding of acetylcholine and norepinephrine and the surface receptors. A healthy heartbeat should be around 70-75/min at rest. A constant heart rate of over 100 and below 60 if you are not an athlete at rest would be considered an unhealthy heart rate. Tachycardia is a common symptom in a lot of PASC patients, caused by an elevation in acute cardiac troponin from ischemic causes. The increase in acute cardiac troponin can be possibly explained by a direct effect on myocardial cells via ACE2 receptor, cytokine storm, and hypoxia-induced apoptosis as well as myocarditis, Takotsubo syndrome, and pulmonary embolism (Sherif et al. 2023).

One of the common PASC symptoms involves heart palpitation (fast and pounding heartbeats) and brain fog which happens with a frequency of about 10.3%. SARS-CoV 2 infection induces Cardiovascular Autonomic Dysfunction (CVAD) which can lead to dysfunctional heart rate control and abnormal vascular dynamics by hypovolemia, brainstem involvement, and autoimmunity (Shah et al. 2019, Bisaccia et al. 2021). Many of the PASC patients experience a significant blood pressure elevation, considerable sinus tachycardia burden, and increased indexed left-ventricular end-diastolic volume (LVEDVi) by echocardiogram (Mahmoud et al. 2022).

Cardiovascular disease is the leading cause of mortality in the US, so it is important to track heart rate and heart rhythm outside of the clinic. Being able to track heart rate and heart rhythm helps patients with cardiovascular diseases to monitor their recovery progress and to seek clinical intervention in case of recurrence. It is also important for healthy people to keep track of changes in their heart rate and heart rhythm. Heart rate vs rhythm can be different in different contexts such as in relaxed and stressed states, and wearables allow people to follow the patterns of their heart rate and rhythm.

This study focused on three cardiovascular biomarkers that are related to PASC symptoms: heart rate, heart rate variability, and atrial fibrillation (AF) detection. In terms of heart rate, PASC patients may experience fluctuations in heart rate as ongoing symptoms. Studies showed that patients with long COVID experienced and were diagnosed with inappropriate sinus tachycardia (Fedorowski et al. 2024). Tachycardia, or increased heart rate, can be a response to various physiological stresses or dysfunctions within the body, including ongoing inflammation or autonomic nervous system dysregulation, which are believed to be associated with PASC (Fedorowski et al., 2024). Heart rate variability serves as an indicator of the autonomic nervous system's activity and regulation of the heart. Lower HRV can be indicative of physiological stress or dysfunction. According to some studies, patients with PASC showed a lower HRV than normal, suggesting sympathovagal imbalances and impaired cardiovagal reflex (Marques et al., 2023). Atrial fibrillation is a cardiac arrhythmia associated with rapid and irregular heartbeats. While AF can occur in individuals without a history of COVID-19, AF is the most commonly reported arrhythmia following COVID-19 infection, and COVID-19 can increase the risk of AF, particularly in severe cases or those with pre-existing cardiovascular conditions (Lavelle et al., 2022). AF can contribute to symptoms such as palpitations, shortness of breath, and fatigue, which may overlap with the symptoms experienced by PASC patients.

Method

1. Literature Search Strategy

This project follows a systematic umbrella review methodology. A systematic umbrella review is a systematic review of all existing systematic reviews on a topic, intending to aggregate findings across reviews of many different patient populations (Aromataris et al., 2015).

1.1 Databases:

We focused on peer-reviewed research articles and publications from PubMed and Medline to conduct a comprehensive systematic review of the accuracy and clinical utility of consumer wearables in tracking heart rate and rhythm.

1.2 Keywords:

Working closely with the Emory Library Research Team, we created a search strategy that includes terms and keywords related to the research topic.

The search terms will include the following terms but are not limited to: “Consumer”, “Wearable”, “Wearable sensor”, “Health wearable”, “Smartwatch”, “Smart ring”, “Smart jewel”, “Smart cloth”, “Smart wear”, “Fitness tracker”, “Activity tracker”, “Activity monitor”, “AliveCor”, “Apple watch”, “Fitbit”, “Garmin”, “Google Pixel”, “Kardia”, “Oura”, “Samsung Galaxy”, “Suunto”, “Whoop”, “Actigraph”, “Actiwatch”.

1.3. Inclusion and Exclusion Criteria:

These search terms resulted in 3,998 articles. In terms of exclusion and inclusion criteria for the paper, please refer to the following description for reference.

For Article Typle, the article must be a review of the empirical literature, including systematic review, narrative review, meta-analysis, bibliometric analysis, and other types of “reviews.” We excluded articles that report primary study outcomes of a single study, articles that review only theories, concepts, or positions/opinions, and articles where review is not the main purpose.

For Types of Devices Reviewed, we included only commercially available consumer wearables. The technologies must be commercially available for purchase by anyone in the US and designed to be worn externally on the body. We excluded devices that are medical/ experimental, nearables (designed for use near but not on one’s person), implantables (designed for internal use), self-reported tracking apps, and technologies worn for a small part of the day.

In terms of the Review Aim, the review aim must be to evaluate the technology. The articles included must evaluate one or more of the following: accuracy, validity, reliability, feasibility and acceptability, and clinical utility. We excluded the articles with review aims that belong to the following: research-only application, protocol papers, product review or marketing data, evaluating outcomes that are not relevant to PASC, focusing on an intervention other than just the wearables, and articles where wearable is instrumental.

For the Type of sensor data, sensor data review must have relevance to symptoms of PASC. Review data types must include heart rate (HR), heart rate variability (HRV), oxygen saturation (O2sat), skin temperature, electrodermal activity (EDA), sleep-relevant metrics (sleep stage monitoring, sleep onset latency, sleep quantity, sleep quality), physical activity assessed through accelerometry (steps taken, flights of stairs climbed), ambulatory blood pressure, arrhythmias: atrial fibrillation, bradycardia, tachycardia, and EKG. We excluded papers that primarily focused on data analytic techniques and those that had low relevance to PASC symptoms.

For the population, we only included adults, meaning 18 years of age or older. The population may be medically healthy OR have **any kind of medical condition**.

2. Study Selection:

2.1 Abstract Screening:

The initial screening of articles was based on the screening of titles and abstracts using the criteria above and the platform COVIDENCE, which is a web-based platform used for screening and extracting data for systematic review. Each article was evaluated by two trained research assistants from the HEAT Lab based on the inclusion and exclusion criteria. Any disagreements were resolved through discussion, and if necessary, other reviewers were consulted. After the abstract screening, 104 articles were deemed eligible for full-text review for further evaluation.

2.2. Full-Text Review:

Articles that passed the initial screening will undergo a full-text assessment to ensure they meet the inclusion criteria. Two reviewers independently assessed the full text of the articles. Conflicts were resolved through discussion and other reviewers' consultation if needed. After a full-text review, 42 articles were deemed eligible for inclusion in data extraction and synthesis.

3. Data Extraction and Analytic Strategy:

A standard data extraction form was created for use as a template for this process to collect relevant information selected from the articles. Quality and Risk of Bias are also being assessed using the AMSTAR 2.0 checklist. The template included the following points of relevance to my honors thesis: authors and publication details, study design and methodology, characteristics of the study population, type and model of consumer wearables used, measurement parameters, Reported accuracy (sensitivity and specificity) reliability, and clinical utility data, and key finding and conclusions. For measurement parameters, we looked at heart rate, heart rate variability, oxygen saturation, V02 max, arrhythmia detection, and ECG. In terms of reported accuracy (sensitivity and specificity) reliability, and clinical utility data, we looked at variability by demographics, variability by setting, and variability by clinical morbidity characteristics (e.g., diagnoses).

Because this is a narrative synthesis, there are no *a priori* hypotheses. Narrative synthesis refers to the approach for systematic review and combining results from various studies, primarily utilizing words to summarize and explain the synthesis findings (Popay et al., 2006). My honors thesis reported preliminary results of the reviews that report comparisons of wearables to clinical-grad equipment, overall estimated accuracy (sensitivity and specificity) for the following: heart rate, heart rate variability, and atrial fibrillation (AF) detection, and the comparative performance of devices included in the review. The final evaluation of the performance of the wearables was decided based on aggregated data and evaluation recorded in the extraction files as well as the evidence from the original papers. An all-around best device decision was made based on performance in all variables.

TABLE 1. *Details of reviews included in the reported analyses.*

Author/ Year Citation	Number of Included Studies	Name of Devices	Variables
Alharbi et al. 2019	20	Fitbit Charge HR, MagIC	Heart Rate, Heart Rate Variability
Avila et al. 2021	9	Polar V800	Heart Rate Variability
Elbey et al. 2021	9	Apple Watch, Fitbit SW, Samsung Gear Fit2, Samsung Simband	AF Detection
Fuller et al. 2020	158	Apple Watch, Fitbit Charge 2, Garmin Vivosmart HR+	Heart Rate
Germini et al. 2022	65	Apple Watch, Fitbit Blaze, Fitbit Charge 2,	Heart Rate

		Fitbit Charge HR, Fitbit Charge HR 2	
Irwin et al. 2022	8	Fitbit Charge 2	Heart Rate
Khundaqji et al. 2021	31	Apple Watch, Huawei Honor Band 4, Huawei Watch GT, Samsung GearFit 2	AF Detection
Lui et al. 2022	19	Apple Watch 1, Apple Watch Series 3, Apple Watch	Heart Rate, Heart Rate Variability, AF Detection
Nazarian et al. 2021	18	Apple Watch, Honor Band 4, Honor Watch, Huawei Watch GT, Samsung GearFit 2	AF Detection
Patel et al. 2021	14	Apple Watch, Fitbit	Heart Rate Variability
Sanchis-Gomar et al. 2021	Non-specified	Apple Watch	AF Detection
Zhang et al. 2020	44	Garmin, Microsoft, Mio, Omron, Philips, PulseOn, Tempo, TomTom, and Wavelet	Heart Rate

Results:

Out of the initial 6838 articles screened during abstract screening, 100 reviews progressed to full-text reviews. Out of the 100 articles, 25 articles were excluded for the wrong review aim; 13 articles were excluded for the wrong type of device reviewed; 8 articles were excluded for the wrong type of sensor data, and 4 articles were excluded for the wrong review criteria. 4 articles were excluded for the wrong article type. 2 articles were excluded for the wrong setting. 1 was excluded for the wrong intervention. After abstract screening and full-text review, 42 papers made it into extraction and were included in the study. Out of the 42 articles, 12 articles were included in this analysis as they reported on the accuracy of heart rate and heart variability measurement specifically; the non-included articles reported on the accuracy of measurement of other biomarkers that were included in the overarching project. Out of the

12 papers included, four reviews only reported heart rate data (Fuller et al., 2020; Germini et al., 2022; Irwin et al., 2022; Zhang et al., 2020); two reviews (Avila et al., 2021; Patel et al., 2021) only reported heart rate variability data, and one paper (Alharbi et al., 2019) reported both heart rate and heart rate variability data. Four papers (Elbey et al., 2021; Khundaqji et al., 2021; Sanchis-Gomar et al., 2021; Nazarian et al., 2021) reported only AF detection data, and one paper (Lui et al., 2022) reported all biometrics of interest: heart rate, heart rate variability, and AF detection.

1. Heart Rate Measurement:

Wearable devices included in this review were found to offer differing levels of accuracy and reliability for heart rate measurement. This review identified accuracy and reliability information for devices from the following brands: Apple, Fitbit, and Garmin; other wristwatches studied are Garmin, Microsoft, Mio, Omron, Philips, PulseOn, Tempo, TomTom, and Wavelet. In total, there were 6 studies included in this section.

Apple Watch:

This review identified review-level evidence for the following Apple Watch Devices: Apple Watch 1, Apple Watch 2, Apple Watch 3, and Apple Watch 4 based on 3 review articles. One review (Germini et al., 2022) reported the accuracy of Apple Watch against clinical device benchmarking. The reviews concluded that the Apple Watch had relatively high performance among clinical devices with specificity scores ranging from 0.68 to 0.95 ES. A review (Fuller et al., 2020) mentioned Apple Watch's significant accuracy of ±3% of the true heart rate 71% of the time, outcompeting other wearables such as the Fitbit or Garmin wristwatch. According to one of the reviews (Lui et al., 2022), Apple Watch, including Apple Watch Series 3 and Apple Watch Series 4, showed acceptable accuracy and better results than its peers considering increased errors in case of movement and overestimation. Specifically, the Apple Watch 4 performed considerably well during exercise. However, although this review found that the Apple Watch 4 attained high levels of accuracy during exercise, it found that the Apple Watch Series 1 demonstrated only medium accuracy as variability increased as the magnitude of heart rate increased (Lui et al., 2022).

Fitbit Devices:

This review identified review-level evidence from 4 papers for the following Fitbit Devices: Blaze, Charge, Charge 2, and Charge HR series. In comparison to the Apple Watch, Fitbit devices showed a wider range of mean absolute percentage errors (MAPE) ranging from 2.4% to 17% (Germini et al., 2022). While compared to Apple Watch and Garmin, Fitbit devices appeared to underestimate heart rates (Fuller et al., 2020). Despite inconsistencies across activity levels and diminished performance during hand movement tasks, Fitbit Charge 2 showed medium to good accuracy compared to ECG with a wide interval of error results at low-to-moderate-intensity levels. Fitbit Charge 2's measurement of heart rate fluctuated with intensity with higher accuracy at lower-intensity activity levels. Yet, in terms of inter-device reliability in healthy older adults, Fitbit Charge 2 showed good reliability during treadmill and overground bouts according to the paper's conclusion (Fuller et al., 2020; Irwin et al., 2022). Fitbit Charge HR also exhibits medium accuracy as they showed heart rate measurements that are slightly lower than continuous ECG monitoring in the real world and not as accurate as pulse-oximetry-derived HRs (Alharbi et al., 2019; Germini et al., 2022). On the other hand, Fitbit Blaze showed low accuracy in heart rate measurement with MAPE values ranging from 6%-16% (Germini et al., 2022).

Garmin:

There was one paper review of the Garmin Vivosmart HR+ for heart rate accuracy. In terms of validity, Garmin showed low to medium accuracy as the errors were within ±3% for 49% of the time (Fuller et al., 2020). Garmin Vivosmart HR+ was concluded to demonstrate good reliability across various tasks and lower limits of agreement than Fitbit (Fuller et al., 2020). Although specific accuracy metrics were not conclusively discussed, its reliability suggests suitability for continuous heart rate monitoring.

Other brands of Wristwatches:

There was one paper in the review that included the information for the review of wristwatches from other brands. Wristwatches from brands, including Garmin, Microsoft, Mio, Omron, Philips, PulseOn, Tempo, TomTom, and Wavelet, demonstrated good accuracy in comparison to ECG or chest-strap telemetry with non-statistically significant mean differences (beats per min, bpm) in most common activity settings: −0.40 bpm (95 confidence interval (CI) −1.64 to 0.83) during sleep, −0.01 bpm (−0.02 to 0.00) during rest, −0.51 bpm (−1.60 to 0.58) during treadmill activities (walking to running), 1.30 bpm (−1.21 to 3.81) during post- exercise and −1.30 bpm (−3.76 to 1.16) during daily living activities. However, the mean was larger and statistically significant for resistance training (−7.26 bpm, −10.46 to −4.07) and cycling (−4.55 bpm, −7.24 to −1.87) (Zhang et al., 2020). However, the individual performance of each brand might differ.

2. Heart Rate Variability:

Wearable devices included in this review were found to offer differing levels of accuracy and reliability. This review identified accuracy and reliability information for devices from the following brands: Apple, Fitbit, MagIC, and Polar. In total, there were 4 studies included in this section.

Apple Watch:

This review identified review-level evidence from 2 papers for the following Apple Watch Devices: Apple Watch 1, Apple Watch 3, and Apple Watch 4. Apple Watch performance was evaluated as having good accuracy in measuring heart rate variability compared with ECG (Lui et al., 2022). Apple Watch electrocardiogram readings had medium to good accuracy with 71% of the reading within 3% of electrocardiogram readings in controlled settings (Patel et al., 2021). This means the Apple Watch can reliably capture fluctuations in heart rate, providing useful insights into changes in cardiovascular health.

MagIC (Maglietta Interattiva Computerizzata)

MagIC is a textile-based wearable system that is composed of a vest with textile sensors for detecting ECG and respiratory activity and a portable electronic board for motor detection, signal preprocessing, and wireless data transmission (Rienzo et al., 2005). In static conditions, MagIC was accurate in monitoring cardiac rhythm and comparable to that obtained by a traditional one-lead ECG recorder (Alharbi et al., 2019). This shows insights into the potential of textile-based technology beyond more common wearables such as wristwatches or wristbands.

Fitbit:

In comparison to continuous electrocardiography monitoring, Fitbit-based continuous electrocardiogram monitoring showed good accuracy and reliability with 73% of the readings within 5 BPM of the electrocardiogram value, indicating it is reliable in capturing heart rate variability (Patel et al., 2021). The specific device series was not mentioned.

Polar:

One paper (Avila et al., 2021) reviewed the Polar V800 for heart rate measurement. Polar V800 showed relatively good accuracy as it showed similar changes in HRV domains and could detect a similar therapeutic response to the 2-lead ECG in patients with failed back surgery syndrome compared to the 2-lead ECG, indicating its reliability in capturing heart rate variability.

3. Atrial Fibrillation (AF) Detection:

Wearable devices included in this review were found to offer differing levels of accuracy and reliability for AF detection. This review identified accuracy and reliability information for the devices from the following brands: Apple, Huawei, and Samsung. In total, there were 5 articles included in this section.

Apple Watch:

This review identified review-level evidence from 4 articles for the following Apple Watch Devices: Apple Watch 1, Apple Watch 2, Apple Watch 3, and Apple Watch 4. Apple Watch was effective in detecting AF with varying degrees of sensitivity and specificity. Apple Watch showed high sensitivity rates above 93%, indicating the device can accurately identify AF episodes (Elbey et al., 2021). Additionally, Apple Watch demonstrated high accuracy and specificity with values over 90% in the majority of studies, suggesting the device's ability to distinguish AF from normal sinus rhythm (Sanchis-Gomar et al., 2021; Khundaqji et al., 2021; Nazarian et al., 2021). Yet, one review suggested Apple Watch's AF detection was lower with only medium accuracy, and the Apple Watch Series 4 specifically was rated by this review with accuracy from medium to good (Lui et al., 2022).

Combined with KardiaBand and Cardiogram, it enhanced Apple Watch's AF detection capabilities. Apple Watch with KardiaBand demonstrated reliable AF detection with sensitivity values from 93.0% to 98.4%. Cardiogram integration also yielded high sensitivity and specificity values, especially in sedentary populations (Khundaqji et al., 2021).

Huawei Devices:

This review identified review-level evidence for the following Huawei Devices: Honor Band 4, Honor Watch, and Watch GT based on 2 articles. The three Huawei series included were reported to have a sensitivity rate of 100% and a specificity rate exceeding 98% (Khundaqji et al., 2021; Nazarian et al., 2021). Huawei devices exhibited effectiveness and reliability in AF detection, allowing them to monitor atrial fibrillation.

Samsung Devices:

This review identified review-level evidence from 3 review papers for the following Samsung Devices: Gear Fit2, Gear S3, and Simband. These devices were found to be reliable in AF detection and useful in monitoring cardiovascular health. Both devices exhibited high sensitivity rates (over 93%) and specificity rates (over 98%) (Elbey et al., 2021; Khundaqji et al., 2021). The Gear S3 also showed high accuracy in AF detection while tested against an ECG patch (Nazarian et al., 2021).

Discussion

A significant number of SARS-CoV-2 patients suffer from post-acute sequelae of SARS-CoV-2 (PASC) symptoms. Despite differences in severity and variety of symptoms, cardiovascular and autonomic symptoms are the most frequently reported symptoms of PASC. Considering the recency of the pandemic and the prevalence of consumer health wearables, there is a need to characterize the accuracy and reliability of consumer health wearables in monitoring cardiovascular biomarkers that may indicate changes or abnormalities in the cardiovascular health of people who have PASC. Understanding their performance in measuring cardiovascular changes would provide insight into the potential and utility of wearables for patients and healthcare providers in remote care and hospital settings.

The narrative synthesis highlights several findings regarding the accuracy and reliability of a variety of consumer health wearables. Overall, wearables demonstrated acceptable accuracy and reliability for cardiovascular metrics. However, there are certain challenges in achieving accuracy and reliability in real-life settings. One of the significant issues from the study is the variation in accuracy across different levels of activities, meaning across low to moderate to intense activity levels, which should be addressed to maximize accuracy and reliability.

In terms of accuracy, the definition of medium and good accuracy was based on the evaluation of the reviews that were included in this umbrella review. The results of this review suggest that the Apple Watch was the top-performing device for the assessment of heart rate, heart rate variability, and atrial fibrillation detection. According to the studies included, the Apple Watch was reported to provide reliable heart rate data, including when benchmarked to clinical grade (meaning FDA-approved) devices, indicating its effectiveness and validity for monitoring the cardiovascular biomarkers described here. Fitbit devices were found to perform with medium to good accuracy for heart rate and heart rate variability, suggesting that they may less reliably pick up on changes or abnormalities in these biomarkers. A wide range of wristwatches from brands, including Garmin, Microsoft, Mio, Omron, Philips, PulseOn, Tempo, TomTom, and Wavelet, demonstrated good accuracy in measuring heart rate in comparison to ECG or chest-strap telemetry. Huawei and Samsung devices demonstrated high sensitivity and specificity rates for AF detection. Several smartwatches included in this review were found to be comparable in reliability for AF detection to ECG traditional monitoring strategies. However, with variations in software and hardware as well as among different groups, consumer wearables can not replace medical-grade devices, yet they can be used to supplement medical-grade devices in a daily life setting.

The findings can be used for significant implications in research and practice. They highlight the current development and possible limitations in common consumer health wearables. This calls for the refinement of sensor technology and data algorithms to enhance the accuracy and reliability of wearables. The study also provides insight into the need for validation of wearable devices against clinical benchmarking. The study should serve as a reference to the performances of different wearables for heart rate data, which can help serve consumers in their decision of wearables that best fit their needs. Healthcare providers can use findings from the study to validate and consider the use of wearable devices for remote patient health tracking and clinical monitoring in hospital settings for therapeutic purposes.

The results provide valuable insights into the potential utility of consumer health wearables in monitoring PASC-related symptoms, particularly cardiovascular and autonomic dysregulation. By assessing the accuracy and reliability of these devices in capturing cardiovascular biomarkers, the study contributes to the growing understanding and the development of accessible and non-invasive solutions tailored to PASC symptoms for patients to keep track of their health daily. Moreover, healthcare providers and physicians can make use of the data collected using wearables to better understand the effect of PASC on patients and to develop suitable treatment plans for patients with PASC. Wearables serve as accessible and affordable tools for PASC patients to monitor and measure the parameters related to their persistent symptoms. The findings provide PASC patients with guidance and insight into common consumer health wearables, which can benefit them in integrating wearables into more effective management of their symptoms outside of the clinics.

In terms of limitations, the study is based on existing literature, which can include inherent biases and limitations such as limited scope, outdated information, selective reporting, and potential conflicts of interest among authors or funding sources. In addition, the analyses reported here do not include differences in accuracy and reliability based on population characteristics noted by the included reviews (e.g., race/skin tone, age, medical comorbidities, and medications), which are known to impact accuracy and reduce the accuracy and useful of these devices for some groups. More detailed research is necessary to tackle these limitations and provide a more extensive and comprehensive understanding of the accuracy and validity of wearables in the measurement of cardiovascular data.

Future research should go in the direction of identifying existing challenges and limitations to optimize the acceptability and clinical utility of consumer health wearables. This research could be used to create a gold-standard reference and guide the development of the industry. The study should also focus on differences in accuracy based on various settings and populations. Longitudinal studies should be carried out to assess long-term reliability and clinical outcomes with the use of wearables. This future research can improve the integration of wearables into healthcare and patient health monitoring.

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