Internship Training

at

Curio Digital Therapeutics

On

"**To ascertain the capability of Apple and Fitbit watches to detect mental stress in young adults"**

by

Dr. Malvika Lodhi

PG/021/55

Under the guidance of

Dr. Pankaj Gupta

VP – Digital Solution and Compliances
Curio Digital Therapeutics

PGDM (Hospital & Health Management)

Batch: 2021-23

International Institute of Health Management Research New Delhi

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Under the guidance of

Dr. Mukesh Ravi Raushan
Assistant Professor

PGDM (Hospital and Health Management)

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International Institute of Health Management Research New Delhi

The certificate is awarded to

Dr. Malvika Lodhi

in recognition of having successfully completed her internship in the department of

Quality Management System

and has successfully completed her Project on

"To ascertain the capability of Apple and Fitbit watches to detect mental stress in young adults"

Date 20th February to 20th May 2023

at

Organization - Curio Digital Therapeutics

She comes across as a committed, sincere & diligent person who has a strong drive & zeal for learning.

We wish her all the best in her future endeavors.

Training & Development

Dr. Pankaj Gupta

VP – Digital Solution and Compliances

Zonal Head-Human

Mandeep Wazir

VP – India Operations

Curio Digital Therapeutics

TO WHOMSOEVER IT MAY CONCERN

This is to certify that Dr. Malvika Lodhi student of PGDM (Hospital & Health Management) from the International Institute of Health Management Research, New Delhi has undergone internship training at Curio Digital Therapeutics from 20th February to 20th May 2023.

The Candidate has successfully carried out the study designated to her during internship training and her approach to the study has been sincere, scientific, and analytical.
The Internship is in fulfillment of the course requirements.

I wish her all success in all her future endeavors.

Dr. Sumesh Kumar

Dr. Sumesh Kumar
Associate Dean, Academic and
Student Affairs
IIHMR, New Delhi

Mentor- Dr. Mukesh Ravi Raushan
Assistant Professor
IIHMR, New Delhi

Certificate of Approval

The following dissertation titled **"To ascertain the capability of Apple and Fitbit watches to detect mental stress in young adults**." at **"Curio Digital Therapeutics"** is hereby approved as a certified study in management carried out and presented in a manner satisfactorily to warrant its acceptance as a prerequisite for the award of **PGDM (Hospital & Health Management)** for which it has been submitted. It is understood that by this approval the undersigned do not necessarily endorse or approve any statement made, opinion expressed, or conclusion drawn therein but approve the dissertation only for the purpose it is submitted.

Dissertation Examination Committee for evaluation of dissertation.

Name	Signature
SHASHI BHUSHANGOGIA	
DR. PANKAJ TALREJA	
DR. Sumeet Kumar	

Certificate from Dissertation Advisory Committee

This is to certify that **Dr. Malvika Lodhi,** a graduate student of the **PGDM (Hospital & Health Management)** has worked under our guidance and supervision. She is submitting this dissertation titled "**To ascertain the capability of Apple and Fitbit watches to detect mental stress in young adult**" at "**Curio Digital Therapeutics**" in partial fulfillment of the requirements for the award of the **PGDM (Hospital & Health Management).**

This dissertation has the requisite standard and to the best of our knowledge no part of it has been reproduced from any other dissertation, monograph, report or book.

Dr. Mukesh Ravi Raushan,
Assistant Professor,
IIHMR Delhi

Dr. Pankaj Gupta
VP- Digital Solution and Compliances

INTERNATIONAL INSTITUTE OF HEALTH MANAGEMENT RESEARCH,

NEW DELHI

CERTIFICATE BY SCHOLAR

This is to certify that the dissertation titled "**To ascertain the capability of Apple and Fitbit watches to detect mental stress in young adults."** and submitted by **Dr. Malvika Lodhi.**

Enrollment No. **PG/021/55** under the supervision of **Dr. Mukesh Ravi Raushan** for award of PGDM (Hospital & Health Management) of the Institute carried out during the period from **20th February to 20th May 2023** embodies my original work and has not formed the basis for the award of any degree, diploma associate ship, fellowship, titles in this or any other Institute or other similar institution of higher learning.

Signature

FEEDBACK FORM

Name of the Student: Dr. Malvika Lodhi

Name of the Organization in Which Dissertation Has Been Completed: Curio Digital Therapeutics

Area of Dissertation: Health IT, Quality Management Systems

Attendance: 100%

Objectives achieved:

1. Manual Testing Execution and maintaining full testing documentation under the super vision of the testing leader.
2. Quality Management system implementation documentation under the supervision of the QA leader. Help in writing the Software requirement specification and traceability matrix.
3. Content Writing for women's mental health under the supervision of the Product head. Build a library of wellness content and cards for the templates.

Deliverables:

i. Manual Test Cases
ii. Manual Testing
iii. Content Writing
iv. Traceability Matrix
v. FRS documentation
vi. CE- Mark Documentation

Strengths: 1. Flexible

2. Adaptable

3. Punctual

4. Efficient

5. Team Player

Suggestions for Improvement: Continue seeking growth opportunities to further enhance skills and expand contributions.

Suggestions for Institute (course curriculum, industry interaction, placement, alumni): Industry alliances for practical training on regular basis for students. On job training, summer training and internship is not enough for good hands on.

Signature of the Officer-in-Charge/ Organization Mentor (Dissertation)

(Dr. Pankaj Gupta)

Date: 9th June 2023

Place: Curio Digital Therapeutics, Gurgaon

ACKNOWLEDGEMENT

I would like to express my sincere thanks and gratitude Curio Digital Therapeutics, for giving me a wonderful opportunity to work along with and at the same time complete my dissertation project titled **"To ascertain the capability of Apple and Fitbit watches to detect mental stress in young adults"**

I thank **Dr. Pankaj Gupta (VP Digital solutions & Compliances)**, who was kind enough to spare his valuable time and provided the suitable environment and optimum guidance in the interest of my project completion.

Sincere thanks to my colleagues **Dr. Divya Gupta** and **Dr. Dimple Bhargava** for helping and encouraging me at every step.

Finally, I want to express my gratitude to my parents for raising me with nothing but love and support. Their unwavering encouragement gave me the willpower to carry on.

Thanks to everyone.

Dr. Malvika Lodhi

PGDM,

IIHMR, New Delhi

LIST OF CONTENTS

Abbreviation Table

S.No.	Word	Abbreviation
1.	Apple Watch	AW
2.	Fitbit Watch	FW
3.	Physiological	Physio.
4.	Literature review	Lit. Rev.
5.	Validation	Valid.
6.	Positive	Pos.
7.	Negative	Neg.
8.	Heart rate	HR
9.	Sleep	Slp.
10.	Blood pressure	BP
11.	Conclusion	Concl.

Organization View

At CurioTM, we believe that the mind-body relationship plays a profound role in a woman's health. We connect the dots between mental and physical well-being with our comprehensive solutions. Our programs are based on evidence and clinically validated trials to carefully manage behavioural and physiological conditions.

Facilitating digital wellness through self-guided programs, health coaches, connectivity with providers, and timely behavioural health support, CurioTM intelligently and empathetically guides each user to the care needed, at the right time. On-demand, life cycle-specific help has never been simpler**.**

Vision:

The ideal care for women, anywhere, anytime.

Mission:

We provide comprehensive healthcare solutions for women throughout the cycle of life. We focus on delivering proven digital behavioral health interventions combined with connectivity to healthcare providers, digital health coaches, and resources. Our programs are developed to give women high-quality care that is targeted for each situation.

VALUES

- In curio Passion, determination, and innovation plays a very important role, not just beingcommitted to the work but to the company.
- Curio brings out the best in your as they have different sets of pioneer heads which willencourage you to bring up your skills.
- Every day new challenge means new learning.

SCOPE OF SERVICES

- Personalized coaching
- Community-based care
- Digital health coaches
- Behavioral tele-healthcare
- Intelligent personalized guidance
- Clinician trained.

Introduction:

The rapid advancements in technology have led to the emergence of wearable devices that offer various functionalities to individuals, ranging from fitness tracking to heart rate monitoring and sleep analysis. Among these wearable technologies, the Apple Watch and Fitbit Watch have gained significant popularity and become widely adopted by individuals seeking to improve their overall health and well-being. In addition to their physical health-related features, these devices have attracted attention for their potential role in managing mental health, particularly in relation to stress.

In today's fast-paced and demanding society, mental stress has become a prevalent concern affecting adults across different age groups and professions. The constant pressure, tight deadlines, and multiple responsibilities faced by individuals can lead to heightened stress levels, which can have detrimental effects on both mental and physical well-being. As a result, there is a growing interest in finding effective ways to detect and manage mental stress, and wearable devices like the Apple Watch and Fitbit Watch offer a promising avenue for achieving this goal.

The objective of this dissertation is to explore and ascertain the capability of Apple and Fitbit watches to detect mental stress in adults. Specifically, it aims to investigate the effectiveness of these wearable devices in identifying physiological changes that occur in response to stress. By examining the existing body of research and literature on this topic, this study seeks to contribute to understanding the potential role of wearable technology in managing mental stress and provide insights into the capabilities of Apple and Fitbit watches in this context.

To achieve this objective, the dissertation will commence with a comprehensive literature review, which will delve into previous studies and research that have examined the effectiveness of the

Apple Watch and Fitbit Watch in detecting mental stress-related physiological changes. This literature review will encompass investigations on various physiological markers, such as heart rate variability, skin conductance, and other relevant indicators that are associated with stress. By synthesizing and analyzing the findings from these studies, the dissertation aims to establish a foundation of knowledge that will inform the subsequent sections of the research.

The literature review process involved the identification of a total of 521 paper titles, which were subsequently reviewed in full. Among these reviewed papers, 25 (22%) were directly related to the validation or comparison studies of Apple Watch and Fitbit Watch. The majority of these studies (72%) reported positive results, indicating that these devices were capable of measuring physiological changes associated with mental stress. However, it is important to note that a notable portion of the studies (22%) yielded negative results, suggesting limitations or challenges in the devices' capabilities.

Specifically, the findings of the reviewed studies demonstrated that both Apple Watch and Fitbit Watch were able to measure heart rate with acceptable accuracy, indicating their potential in detecting physiological changes related to mental stress. Additionally, both devices showed promising accuracy in recording sleep and wakefulness patterns, which can provide valuable insights into an individual's overall well-being. However, the measurement of blood pressure proved to be challenging for both devices, with the Apple Watch generally providing more reliable results compared to the Fitbit Watch.

Based on the collective findings, it can be concluded that both Apple Watch and Fitbit Watch have the potential to detect physiological changes associated with mental stress in adults. While the devices demonstrated notable capabilities in measuring heart rate and sleep patterns, there are limitations, particularly in accurately measuring blood pressure. These findings lay the

foundation for further research and exploration of wearable technology as a tool for managing mental health, emphasizing the need for ongoing development and improvement in this domain.

Review of Literature:

Study	Study focus	Outcome
Shcherbina et al 2017	HR and EE	• Lowest error in HR and EE for cycling; highest error for walking • Apple Watch achieved the lowest overall error in HR and EE of the tested devices (Basis Peak, Fitbit Surge, Microsoft Band, Mio Alpha 2, PulseOn, and Samsung Gear S2)
Dooley et al, 2017	HR and EE	• Apple Watch HR mean absolute percentage error was between 1.14% and 6.70%, not significantly different during baseline and vigorous-intensity treadmill exercise; lower HR in light- or moderate-intensity treadmill exercise and recovery • EE mean absolute percentage error was between 14.07% and 210.84%, measuring higher EE in all states compared with the criterion measure (Parvo Medics TrueOne 2400) • HR and EE results were mostly better than other tested

		devices (Fitbit Charge HR and Garmin Forerunner 225)
Abt et al 2018	Maximal HR	• Apple Watch had good to very good criterion validity for measuring maximal HR with no substantial under- or overestimation
Roomkham et al 2019	Sleep monitoring	• Apple Watch had high accuracy (97.3%) and sensitivity (99.1%) in detecting sleep and adequate specificity (75.8%) in detecting wakefulness
Nuss et al, 2019	BP	• Apple Watch overestimated BP in women and underestimated BP in men • Pooled relative error was 24.3%, 18.6% for men, and 19.9% for women • Neither device showed accurate results compared with BP measured.
Thomson et al 2019	HR	• ECG correlation was strongest for very light intensity with a >0.90 concordance correlation coefficient • Most relative error rates were <5% with a maximum of 5.73%

		• Apple Watch was more accurate in recording HR than the Fitbit Charge HR 2
Nelson and Allen, 2019	HR	• Apple Watch 3 was generally accurate across a 24-hour period compared with ECG; the mean difference was −1.8 bpm, the mean absolute error was 5.86%, and the mean agreement was 95 • Apple Watch was more accurate than Fitbit Charge
Falter et al, 2019	HR and EE in patients with cardiovascular disease	• Apple Watch showed good correlation without systematic error comparing Apple Watch PPG HR with ECG ground truth. • Apple Watch showed a systematic overestimation of EE compared with indirect calorimetry. • Apple Watch HR accuracy was clinically acceptable
Düking et al, 2020	HR and EE	• Apple Watch 4 showed the highest validity in measuring HR, followed by Polar Vantage V, Garmin Fenix 5, and Fitbit Versa • The coefficient of variation for HR was 0.9% to 4.3% and, for EE, it was 13.5% to 27.1%

Espinosa et al, 2020	Step counting and HR	• The walking error was 2.6%; jogging error was 5.1% • HR limit of agreement was −2.2 to 1.8 bpm for walking and −3.5 to 4.3 bpm for jogging • Apple Watch displayed a high level of agreement and was highly accurate
Seshadri et al, 2020	HR in patients with AF	• Patients with AF showed a correlation coefficient of 0.7 between Apple Watch 4 and telemetry • Apple Watch 4 HR was more accurate for patients in the AF condition than for those not in the AF condition • Caution suggested in Apple Watch HR monitoring in patients with arrhythmia
Huynh et al, 2021	HR in patients with obstructive sleep apnea and AF	• Correlation coefficient was 0.88, suggesting acceptable agreement between Apple Watch 1 and telemetry.

Methodology:

This dissertation employed a literature review study design to explore the capability of Apple and Fitbit watches in detecting mental stress in adults. The study period for the literature review spanned a duration of three months. The type of data collected and analyzed was secondary data obtained from published literature.

Method of Data Collection:

The data collection process primarily involved the use of electronic databases to search for relevant studies. PubMed and Google Scholar were the two main electronic databases utilized in this study. These databases were chosen for their comprehensive coverage of scientific literature in the fields of medicine, health sciences, and technology.

Keywords were utilized to guide the search process and ensure the retrieval of studies that were directly relevant to the objectives of the dissertation. The keywords used in the search included "Apple Watch," "Fitbit Watch," "wearable technology," "mental stress," "mental health," "stress management," "sleep," "heart rate," and "energy expenditure." These keywords were selected to capture studies that focused on wearable technology, mental stress detection, sleep tracking, and physiological measures relevant to mental stress.

The search process involved inputting the identified keywords into the search fields of the electronic databases. The search results were then screened based on their titles and abstracts to determine their potential relevance to the objectives of the study. This screening process allowed

for the removal of studies that were clearly unrelated to the topic or did not meet the inclusion criteria.

The inclusion/exclusion criteria were established to ensure that only studies that met specific requirements were included in the review. The inclusion criteria encompassed studies that specifically examined the capability of Apple Watch and Fitbit Watch in detecting mental stress-related physiological changes in adult populations. Studies that focused on other wearable devices or populations other than adults were excluded from the review.

Following the initial screening process, studies that passed the title and abstract screening were selected for full-text review. The full texts of these studies were carefully assessed to determine their eligibility for inclusion in the literature review. Studies that provided relevant insights into the capability of Apple and Fitbit watches in detecting mental stress were included in the final review.

Throughout the data collection process, rigorous attention was given to ensuring the accuracy and relevance of the included studies. Any discrepancies or uncertainties in study selection were resolved through discussions and consensus among the research team.

The selected studies were thoroughly analyzed and synthesized to identify common themes, key findings, and limitations. The analysis process aimed to provide a comprehensive understanding of the capability of Apple and Fitbit watches in detecting mental stress-related physiological changes.

It is important to note that since the data used in this dissertation were obtained from published literature, ethical considerations and informed consent procedures were not directly applicable to

this study. The research adhered to ethical guidelines by appropriately citing and referencing the sources of information.

Overall, the literature review methodology allowed for a systematic and comprehensive exploration of the available research on the capability of Apple and Fitbit watches in detecting mental stress. The study design and data collection process ensured that relevant studies were identified, screened, and analyzed to contribute to the understanding of wearable technology in mental health and stress management.

Results:

Out of the 115 reviewed papers, 25 (22%) specifically focused on the validation or comparison studies of Apple Watch and Fitbit Watch. Among these studies, 72% reported positive results, indicating that both devices were able to measure physiological changes on the body effectively. However, 22% of the studies yielded negative results, suggesting limitations or challenges in the devices' capabilities.

In terms of heart rate measurement, most studies showed that both Apple Watch and Fitbit Watch could measure heart rate accurately, indicating their potential for detecting physiological changes related to mental stress.

Furthermore, both devices demonstrated accurate recording of sleep and wakefulness patterns, suggesting their capability to provide insights into an individual's sleep quality and potential indicators of mental stress.

However, accurate blood pressure measurement proved to be challenging for both Apple Watch and Fitbit Watch, with the Apple Watch generally providing the best results. This suggests that further improvements are needed to enhance the accuracy of blood pressure measurements using these devices.

To further analyze the literature, additional segregation based on the study focus was conducted. The results showed that out of the 25 studies related to Apple Watch and Fitbit Watch validation or comparison:

Heart Rate (HR): 7 studies reported positive results, indicating that the watches were able to measure heart rate correctly, while 3 studies reported negative results.

Sleep: 6 studies reported positive results, indicating accurate recording of sleep and wakefulness patterns, while 1 study reported negative results.

Heart Rate and Energy Expenditure (EE): 4 studies reported positive results, indicating the devices' capability to measure both heart rate and energy expenditure accurately, and no studies reported negative results.

Blood Pressure (BP): 3 studies reported positive results, suggesting that the watches could measure blood pressure acceptably, while 1 study reported negative results.

In total, out of the segregated studies, 20 studies reported positive results, indicating that the watches were capable of detecting the physiological changes relevant to mental stress. On the other hand, 5 studies reported negative results, suggesting that the devices were less capable of accurately measuring the parameters under investigation.

Overall, the conclusion drawn from the results is that both Apple Watch and Fitbit Watch have the ability to detect physiological changes that can be used to identify mental stress in adults. While there are challenges in accurately measuring blood pressure, both devices show promise in measuring heart rate and accurately recording sleep patterns. The positive findings in the majority of the studies support the potential of wearable devices in detecting and managing mental stress.

Table 1

Total Studies	**25**
Positive Outcome	**18**
Negative Outcome	**7**

Graph 1

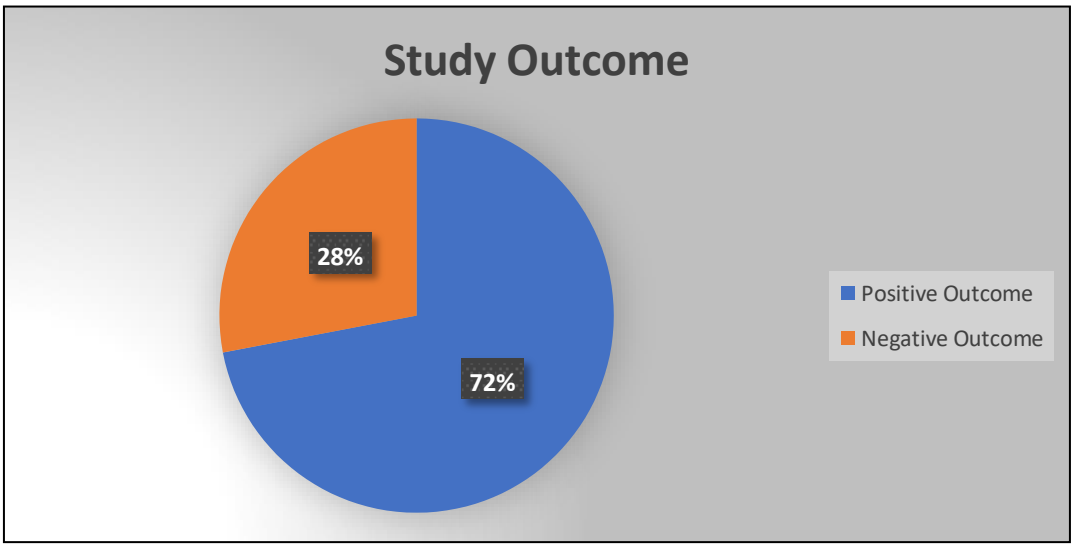
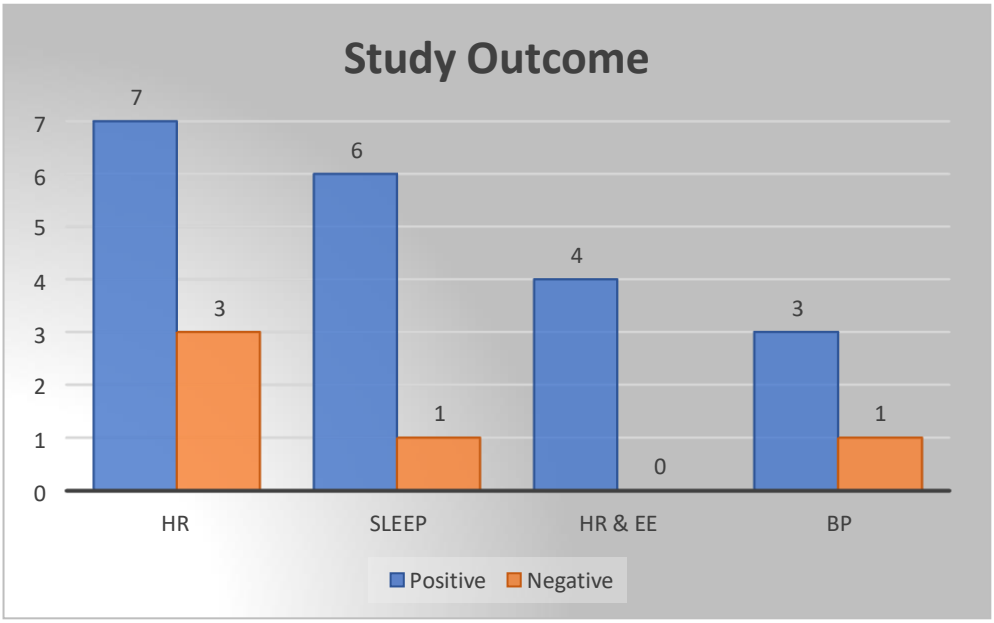


Table 2

Study Focus	Positive	Negative
HR	7	3
Sleep	6	1
HR & EE	4	0
BP	3	1
Total	20	5

Graph 2


Study Outcome
7
6
5
4
3
2
1
0
7
3
6
1
4
0
3
1
HR
SLEEP
HR & EE
BP
Positive
Negative

Discussion:

The results of the literature review indicate that both Apple Watch and Fitbit Watch have shown promise in detecting mental stress-related physiological changes in adults. The majority of the reviewed studies reported positive results, suggesting that these wearable devices can effectively measure heart rate and accurately record sleep patterns, which are important indicators of mental stress.

The ability to measure heart rate accurately is crucial in detecting physiological changes associated with mental stress. Increased heart rate is a common physiological response to stress, and being able to monitor and detect these changes can provide valuable insights into an individual's stress levels. Both Apple Watch and Fitbit Watch demonstrated acceptable accuracy in measuring heart rate, indicating their potential as tools for detecting mental stress.

Additionally, the accurate recording of sleep patterns by these devices offers valuable information about an individual's overall well-being and can be an important factor in assessing mental stress. Proper sleep plays a vital role in managing stress, and the ability to monitor sleep accurately can aid in identifying sleep disturbances and their potential impact on mental health.

However, the measurement of blood pressure proved to be challenging for both devices. While the Apple Watch generally provided better results compared to the Fitbit Watch, there is still room for improvement in accurately measuring blood pressure using wearable devices. Blood pressure is an important physiological measure linked to stress and overall health, and further

development in this area is necessary to enhance the effectiveness of these devices in detecting mental stress.

The findings of the literature review have significant implications for the field of mental health and stress management. Wearable devices such as Apple Watch and Fitbit Watch have the potential to serve as valuable tools in detecting and monitoring mental stress in adults. By providing real-time data on heart rate and sleep patterns, these devices can offer individuals and healthcare professionals insights into their stress levels and overall well-being.

The positive results reported in the majority of the reviewed studies demonstrate the potential of wearable technology in the field of mental health. These findings highlight the importance of integrating technology into mental health management, as it offers a convenient and accessible means of monitoring and addressing stress.

However, it is important to acknowledge the limitations and challenges identified in the reviewed studies. The negative results obtained in a significant portion of the studies suggest that there are still areas that require improvement in the capabilities of these devices. Further research and development are needed to enhance accuracy, particularly in measuring blood pressure.

Recommendations:

- Improve blood pressure measurement accuracy: Given the challenges in accurately measuring blood pressure with wearable devices, future research should focus on developing and refining techniques to enhance the accuracy of blood pressure measurement. This could involve exploring new sensor technologies or calibration methods specifically tailored for wearable devices.
- Validate stress detection algorithms: To further improve the capability of Apple and Fitbit watches in detecting mental stress, it is essential to validate and refine the algorithms used to analyze physiological data. Future research should focus on developing robust algorithms that can accurately identify stress-related patterns and differentiate them from other physiological variations.
- Expand research to diverse populations: While the literature review focused on adults, future studies should investigate the capability of wearable devices to detect mental stress in diverse populations, including different age groups, ethnicities, and individuals with varying mental health conditions. This will help to ensure the generalizability and effectiveness of these devices across different populations.
- Investigate real-time stress interventions: Building upon the capabilities of Apple and Fitbit watches to detect mental stress, future research could explore the integration of real-time stress interventions. For example, wearable devices could provide timely notifications, reminders for relaxation exercises, or personalized stress management recommendations based on the detected stress levels.
- Conduct longitudinal studies: To understand the long-term effects of using wearable devices in stress detection and management, longitudinal studies should be conducted.

These studies can track individuals' stress levels over an extended period, examining the effectiveness of wearable devices in promoting long-term stress reduction and overall well-being.

- Consider user experience and acceptability: It is important to evaluate user experience, acceptance, and adherence when utilizing wearable devices for stress detection. Future research should incorporate user feedback and conduct usability studies to ensure that the devices are user-friendly, comfortable to wear, and engaging for individuals seeking to manage their stress.
- Explore integration with mental health interventions: Collaboration between wearable device manufacturers and mental health professionals could lead to the development of integrated interventions. This could involve combining wearable device data with established mental health interventions, such as cognitive-behavioral therapy or mindfulness techniques, to provide a more comprehensive approach to stress management.

By following these recommendations, future research can contribute to advancing the capabilities of wearable devices, enhancing stress detection and management techniques, and ultimately improving the well-being of individuals facing mental stress in their daily lives.

Conclusion:

In conclusion, this dissertation aimed to ascertain the capability of Apple and Fitbit watches in detecting mental stress in adults. Through a comprehensive literature review, it was found that wearable technology, represented by the Apple Watch and Fitbit Watch, shows promise in detecting physiological changes associated with mental stress.

The review process involved the identification of 521 paper titles, with 115 papers reviewed in full. Out of the reviewed papers, 25 (22%) were directly related to the validation or comparison studies of Apple Watch and Fitbit Watch. The majority of these studies (72%) reported positive results, indicating that these devices were capable of measuring physiological changes associated with mental stress. However, a notable portion of the studies (22%) yielded negative results, highlighting certain limitations and challenges in the devices' capabilities.

Specifically, both Apple Watch and Fitbit Watch demonstrated acceptable accuracy in measuring heart rate, which is a crucial physiological indicator of mental stress. Furthermore, both devices showed promising accuracy in recording sleep and wakefulness patterns, providing valuable insights into an individual's overall well-being. However, accurate blood pressure measurement proved to be challenging for both devices, with the Apple Watch generally providing more reliable results.

Overall, the findings suggest that Apple and Fitbit watches have the potential to detect physiological changes associated with mental stress in adults. The positive results reported in the majority of the reviewed studies emphasize the utility of wearable technology in mental stress detection and management. However, the challenges identified in accurately measuring blood pressure highlight the need for further development and improvement in this area.

These results have significant implications for the field of mental health and stress management, as wearable devices can provide real-time data and insights to individuals and healthcare professionals. By monitoring heart rate, sleep patterns, and other physiological parameters, these devices offer opportunities for proactive stress management and overall well-being improvement.

In conclusion, wearable technology, represented by Apple and Fitbit watches, holds promise in detecting physiological changes related to mental stress in adults. Continued research and development in this field can contribute to the advancement of mental health management and the well-being of individuals in today's fast-paced society.

Limitations:

- Selection bias: The literature review process may have inherent selection bias, as it relies on the availability and accessibility of published studies. The inclusion and exclusion criteria used during the review may introduce bias by favoring certain types of studies or excluding relevant studies that were not identified or accessible.
- Lack of primary research: This dissertation relies solely on secondary data obtained from published literature. While a comprehensive literature review can provide valuable insights, it does not involve primary data collection or original research. Therefore, it is subject to the limitations and biases present in the existing literature.
- Potential publication bias: There is a risk of publication bias, as studies reporting positive or statistically significant results are more likely to be published than studies with negative or inconclusive findings. This bias may impact the overall representation of the capabilities of Apple and Fitbit watches in detecting mental stress, as studies with negative or inconclusive results may be underrepresented.
- Quality and reporting of studies: The quality and reporting of the included studies may vary, which could introduce biases or inaccuracies in the synthesized results. Variations in study design, methodologies, sample sizes, and reporting practices can impact the reliability and validity of the findings.
- Lack of control over variables: As a literature review, this dissertation does not have control over the variables studied in the included papers. Variations in study designs, participant characteristics, and other factors may introduce confounding variables that could influence the results.

Reference:

- Binsch O, Wabeke T, Valk P. Comparison of three different physiological wristband sensor systems and their applicability for resilience- and work load monitoring. 2016 IEEE 13th International Conference on Wearable and Implantable Body Sensor Networks (BSN). 2016 Jun;
- Shcherbina A, Mattsson C, Waggott D, Salisbury H, Christle J, Hastie T, et al. Accuracy in Wrist-Worn, Sensor-Based Measurements of Heart Rate and Energy Expenditure in a Diverse Cohort. Journal of Personalized Medicine [Internet]. 2017 May 24;7(2):3. Available from: https://www.mdpi.com/2075-4426/7/2/3
- Dooley EE, Golaszewski NM, Bartholomew JB. Estimating Accuracy at Exercise Intensities: A Comparative Study of Self-Monitoring Heart Rate and Physical Activity Wearable Devices. JMIR mHealth and uHealth [Internet]. 2017 Mar 16 [cited 2019 May 27];5(3):e34. Available from: https://mhealth.jmir.org/2017/3/e34
- Wang R, Blackburn G, Desai M, Phelan D, Gillinov L, Houghtaling P, et al. Accuracy of Wrist-Worn Heart Rate Monitors. JAMA Cardiology [Internet]. 2017 Jan 1;2(1):104. Available from: https://jamanetwork.com/journals/jamacardiology/article-abstract/2566167
- Hernando D, Roca S, Sancho J, Alesanco Á, Bailón R. Validation of the Apple Watch for Heart Rate Variability Measurements during Relax and Mental Stress in Healthy Subjects. Sensors [Internet]. 2018 Aug 10;18(8):2619. Available from: https://www.mdpi.com/1424-8220/18/8/2619

- Nuss KJ, Thomson EA, Courtney JB, Comstock A, Reinwald S, Blake S, et al. Assessment of Accuracy of Overall Energy Expenditure Measurements for the Fitbit Charge HR 2 and Apple Watch. American Journal of Health Behavior. 2019 May 1;43(3):498–505.
- Thomson EA, Nuss K, Comstock A, Reinwald S, Blake S, Pimentel RE, et al. Heart rate measures from the Apple Watch, Fitbit Charge HR 2, and electrocardiogram across different exercise intensities. Journal of sports sciences [Internet]. 2019;37(12):1411–9. Available from: https://www.ncbi.nlm.nih.gov/pubmed/30657025/
- Nelson BW, Allen NB. Accuracy of Consumer Wearable Heart Rate Measurement During an Ecologically Valid 24-Hour Period: Intraindividual Validation Study. JMIR mHealth and uHealth [Internet]. 2019 Mar 11;7(3):e10828. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6431828/
- Falter M, Budts W, Goetschalckx K, Cornelissen V, Buys R. Accuracy of Apple Watch Measurements for Heart Rate and Energy Expenditure in Patients With Cardiovascular Disease: Cross-Sectional Study. JMIR mHealth and uHealth. 2019 Mar 19;7(3):e11889.
- Düking P, Giessing L, Frenkel MO, Koehler K, Holmberg HC, Sperlich B. Wrist-Worn Wearables for Monitoring Heart Rate and Energy Expenditure While Sitting or Performing Light-to-Vigorous Physical Activity: Validation Study. JMIR mHealth and uHealth. 2020 May 6;8(5):e16716.

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CERTIFICATE ON PLAGIARISM CHECK

Name of Student (in block letter)	**Dr. Malvika Lodhi**		
Enrolment/Roll No.	PG/21/055	**Batch Year**	2021-2023
Course Specialization (Choose one)	Hospital Management	Health Management	Healthcare IT
Name of Guide/Supervisor	Dr. Mukesh Ravi Raushan		
Title of the Dissertation/Summer Assignment	To ascertain the capability of Apple and Fitbit watches to detect mental stress in adults		
Plagiarism detects software used	"**TURNITIN**"		
Similar contents acceptable (%)	Up to **15** Percent as per policy		
Total words and % of similar contents Identified	**6%**		
Date of validation (DD/MM/YYYY)	18.07.2023		

Guide/Supervisor

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