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A COMPARATIVE STUDY ON MICROCHIP IMPLANTS IN HUMANS AND WEARABLE DEVICES

Ltifa Mohammed Almansoori

جامعة الإمارات العربية المتحدة
United Arab Emirates University

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Cover: An x-ray showing an RFID chip injected into a person's hand after a local anesthetic.

(Photo: from https://bigthink.com/culture-religion/human-or-machine-some-people-are-getting-microchipped/)

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Declaration of Original Work

I, Ltifa Mohammed Khalifa Salmeen Almansoori, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled "*A Comparative Study on Microchip Implants in Humans and Wearable Devices*", hereby, solemnly declare that this is the original research work done by me under the supervision of Dr. Fady Alnajjar, in the College of Information Technology at UAEU. This work has not previously formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and/or publication of this thesis.

Student's Signature: 

Date: 2/5/2023

Approval of the Master Thesis

This Master Thesis is approved by the following Examining Committee Members:

1) Advisor: Dr. Fady Alnajjar
   Title: Associate Professor
   Department of Information Systems and Security
   College of Information Technology

   Signature Fady Alnajjar Date 5/2/2023

2) Member: Dr. Munkhjargal Gochoo
   Title: Assistant Professor
   Department of Information Systems and Security
   College of Information Technology

   Signature Adel Al-Jumaily Date 5/3/2023

3) Member (External Examiner): Dr. Adel Al Jumaily
   Title: Associate Professor
   University of Technology Brunei, Faculty of Engineering, Brunei

   Signature  Date 5/3/2023

This Master Thesis is accepted by:

Acting Dean, of the College of Information Technology: Dr. Fekri Kharbash

Signature 

Date 25/01/2024

Dean of the College of Graduate Studies: Professor Ali Al-Marzouqi

Signature 

Date 26/01/2024

Abstract

After the tragic covid pandemic in 2020, many things changed in the world, from learning physically all the way to e-learning, as the whole world was forced to switch digitally. It is expected that a lot of people will be more willing to invest in new technologies that aid in human development and among them are human microchip implants. The emerging technology of human microchip implants is slowly catching the attention of various countries around the world after the sudden surge of adoption in Europe. With the introduction of Biohax microchip implants in the UAE by Etisalat it is most likely that there will be more technological advancements and plans of adoption. Moreover, not so long-ago wearable devices also started as an emerging technology that is nowadays being used by a lot of people and that is why both wearable devices and microchip implants are worth comparing and exploring. Furthermore, this research aims to provide a preliminary study on the general perception of UAE citizens towards human microchip implants and wearable devices. The research will shed light on the perceived barriers amongst the population as well as investigate impediments to the adoption of human microchip implants and wearable devices in the future of the UAE. The outcome should provide the people of the UAE with a clear foundation of what is expected in case of adoption and provide initial recommendations and strategies.

Keywords*:* Human Microchip Implants, RFID Tracking, Human Microchips, Human Tagging, Wearable Devices.

Title and Abstract (in Arabic)

دراسة مقارنة بين زرع الرقاقات الإلكترونية للبشر والأجهزة القابلة للارتداء

الملخص

باتت ظاهرة زرع الرقاقات الإلكترونية للبشر تلفت انتباه العديد من الدول حول العالم، لا سيما بعد اندفاع الكثير من الدول الأوروبية إلى تطبيق هذه التكنولوجيا حاليا. مع التغيرات الجذرية التي حصلت جراء جائحة فيروس كورونا في 2020, وأهمها القفزة الإلكترونية من التعليم الحضوري في المدارس إلى التعليم عن بعد من خلال الإنترنت فإنه من المرجح أن يكون البشر أكثر تقبلا وتسابقا إلى تطبيق أي تكنولوجيا حديثة تستخدم لخدمة البشر. نظرا إلى أنه تم الإعلان عن شريحة "بايوهاكس" مسبقا من قبل شركة اتصالات في الإمارات فإنه من المؤكد أن تكون هناك نظرة مستقبلية إلى طرح وتطبيق هذه الظاهرة في الدولة. الأجهزة القابلة للارتداء أيضا بدأت كظاهرة منذ وهلة وعليه تمت المقارنة والاستكشاف بين كل من تكنولوجيا زرع الرقاقات الإلكترونية والأجهزة القابلة للارتداء. وعليه يهدف هذا البحث إلى توفير دراسة أولية حول النظرة العامة والآراء المختلفة لشعب الإمارات حول ظاهرة زرع الرقاقات الإلكترونية والأجهزة القابلة للارتداء. كما أن البحث يسلط الضوء على العقبات والحواجز التي قد تعيق تطبيق زرع الرقاقات والأجهزة القابلة للارتداء من منظور الشعب. حصيلة هذا البحث العلمي هو توفير شعب الإمارات بأساس واضح وتوقعات دقيقة حول ظاهرة تطبيق زرع البشر برقاقات إلكترونية وتكنولوجيا الأجهزة القابلة للارتداء بالإضافة إلى العقبات المتوقعة إذا ما تم تطبيقها محليا، كما يوفر البحث مقترحات وإستراتيجيات.

مفاهيم البحث الرئيسية: شرائح الكترونية للبشر، شريحة RFID للتعقب، زرع شريحة إلكترونية للبشر، الأجهزة القابلة للارتداء.

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Special thanks go to my parents, family, and friends for their patience with me, their words of encouragement, and their faith in me to finish my thesis even when I did not have it in myself. Throughout the process of writing my thesis, I learned the following important lessons that in my opinion, are worth sharing. Firstly, Complex problems sometimes require a simplistic approach. Secondly, Life is constantly evolving and changing and so should you. lastly, it does not matter if you are slow, what matters is your steadiness as you go.

Dedication

To my beloved parents, family, friends, and my country

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List of Abbreviations

BMI	Body Mass Index
EXPO	Exposition
GPS	Global Positioning System
ICT	Information and Communications Technology
IMD	Implantable Medical Devices
IoMT	Internet of Medical Things
IT	Information Technology
MI	Microchip implants
NFC	Near-Field Communication
NO.	Number
RFID	Radio Frequency Identification Device
SM	Subcutaneous Microchip
SWOT	Strengths – Weaknesses – Opportunities – Threats
UAE	United Arab Emirates
WD	Wearable Devices

Chapter 1: Introduction

1.1 Overview

In the peak of 2021, various headlines from multiple news outlets in Europe stated that a sudden rise in human microchip implants started to emerge. The headlines specifically mention that thousands of Swedes are getting microchips implanted in them in order to conduct their mundane day-to-day activities such as paying for their food, entering and unlocking their offices, sharing their LinkedIn profiles with other individuals and even getting their Covid-19 vaccines passports stored within the microchips [1–3].

1.2 Statement of the Problem

Although microchip implants were first introduced back in 1989, yet to this day not a lot of adoptions were implemented on humans outside of Europe. Moreover, most of the known adoptions of microchip implants are mainly on animals and especially in pet/animal tracking [4]. Whereas wearable devices in comparison to an emerging technology were and still are used to this day regionally and locally. Moreover, no publications published in the UAE measure out or present the general perspective of the population on human microchip implant technology nor its usage (if used), as opposed to wearable devices where it has been published numerously on its usage and utilization in the UAE on both private and public sectors and it will be discussed thoroughly in the thesis motivation section. Apart from the general perception locally, the perceived barrier to adoption is also a vital topic to study prior to introducing microchip implant technology as a lot of barriers to adoption can be attributed to the reason why this technology may not necessarily work well in the UAE especially if people would rather use wearable devices instead.

Furthermore, even if the general population seems accepting of the adoption of the microchip implant and does not mind using it just like wearable devices still, not a lot of options are available in the market for use. Even with the introduction of Biohax implants, still there is a lot to be understood from the implant and what to expect to both gather from and utilize. The problem that will be faced in the future if human microchip implants will be adopted is the decision on what to do with the accumulated amounts of data to be gathered from the microchips and how can it help and aid humans.

1.3 Thesis Motivation

This thesis motivation section will tackle and discuss the main aim and motivation behind the thesis specifically on the comparisons between human microchip implants and wearable devices.

The United Arab Emirates has always taken initiative in new IT ventures and technologies. Around 2019 one of the leading firms in telecommunication in UAE Etisalat took notice of the emerging trend of microchip implants (MI) and unveiled the Biohax microchip and introduced their partnership with the Swedish leading company in human embeddable technology Biohax [5]. Towards the end of the same year, the department of health-Abu Dhabi in UAE introduced the world's most comprehensive genome program that combines genomics and artificial intelligence to enrich health management with genomic data to provide physicians and healthcare practitioners with high quality and precise information that will aid in the process of medical diagnosis in addition to scientific discovery and with that taking an ambitious step towards the usage of technological advancements in the health sector [6]. In 2020, Dubai introduced the worker's wellness program in preparation for its largest event of the year which is the Dubai Expo 2020. The program uses wearable devices, specifically the Whoop devices to ensure the safety and health of their construction workers by monitoring the vital signs of all workers on site along with increasing the awareness level of each worker's health condition [7], [8]. Emirates Global Aluminum also took a similar approach to protect and ensure the well-being of their workers, as they provided their workers that operate in an outdoor setting and as a result are facing direct heat, with a wearable device that detects whether a worker is exposed to heat stress and are unaware of it and ensure that they immediately go to a cooling room or a hydration station as a counter measure [9].

From the above, it is quite evident that the UAE consistently endeavors to adopt and finance cutting-edge technology solutions and forward-looking IT projects.

1.4 Research Objectives

The main objective of the research is to be able to shed light on the perception levels of microchip implants by comparing them with wearable devices. The main grounds why

both microchip implants and wearable devices are being compared and contrasted will be listed in the following section.

1.4.1 Grounds for Comparison

The main reason for the comparison between microchip implants in humans and wearable devices is that both technologies are used to collect and transmit information about the human's physical activities, health, well-being, and even location. Both wearable devices (WD) and microchip implants (MI) utilize a similar technology in gathering data about the wearer of the device or the person with the microchip implants. Furthermore, it is worth mentioning that the main difference between both technologies rests in the method by which they are used such as wearable devices which as the name suggests its “worn” externally and can be removed at any time by simply taking off the device from the body to which it is attached to. Microchip implants on the other hand are “implanted” meaning they are usually injected or inserted subdermally underneath the skin of the person’s arms or hands semi-permanently. To summarize, below are the most crucial elements and grounds for comparison between wearable devices (WD) and microchips implants (MI) in humans:

1. Invasiveness: WDs are external and non-invasive, while MIs require a surgical procedure for implantation and involve a more invasive approach.
2. Removability: WDs can be easily removed, replaced, or upgraded as needed, whereas MIs might require another surgical procedure for removal or replacement.
3. Functionality: WDs and MIs may serve different functions, ranging from health monitoring and fitness tracking to identification and payment. Comparing their specific features and capabilities is essential in determining their suitability for various purposes.
4. Privacy and Security: Both WDs and MIs can potentially gather and store sensitive personal data. Examining the privacy and security protocols for each technology is crucial to protect users' information and preventing unauthorized access.
5. User Acceptance: The willingness of individuals to use and accept these technologies may differ, as some might be more comfortable with wearable devices while others may prefer the integration and convenience of microchip implants.

6. Regulatory and Ethical Considerations: The use of WDs and MIs may raise ethical and regulatory concerns, especially when it comes to consent, data protection, and potential misuse. Comparing the regulatory frameworks and ethical implications of both technologies is vital.
7. Maintenance and Durability: The lifespan, durability, and maintenance requirements of WDs and MIs can differ significantly. Wearable devices may require more frequent charging, updates, and maintenance, while microchips might offer longer-lasting functionality with fewer maintenance needs.
8. Cost and Accessibility: The financial investment and accessibility of WDs and MIs can vary, with factors like production, implementation, and maintenance costs playing a role in determining their affordability and widespread adoption.

1.5 Hypothesis and Research Questions

The main thesis hypothesis is that just like wearable devices started as an emerging technology, that nowadays is very much known and used, it is predicted that Microchip implants in humans will take a similar path in the foreseeable future.

Listed below are the research questions pertaining to the thesis's core essence:

1. What are the expected adoption barriers and benefits of Microchip implants in humans in the UAE?
2. What are the commonalities and differences between microchip implants and wearable devices?
3. Are UAE citizens more likely to adopt wearable devices over microchip implants?
4. What is the most suitable strategy for tackling this emerging trend?

Chapter 2: Related Literature

This section is part of the extensive literature review that was conducted and specifically focuses on and tackles all previously conducted research and questionnaire that is relatively similar to the proposed thesis approach that will be taken for this study. This section shall also list surveys that were conducted regarding wearable device perception and attitudes towards it along with Microchip implants in humans and the perceived barriers to their adoption.

2.1 Survey on Microchip Implants

An international cross-sectional survey conducted in 2016 and 2017 on the perception level towards human microchip implants depicts that the major predictors of intention towards using microchip implants in humans rely upon three critical components, beginning with trust in technology along with its usefulness and ease of use [10]. Although the survey was conducted in four countries which are the Czech Republic, Croatia, Slovenia, and Poland yet it was noticed that almost all countries had similar concerns and barriers concerning Microchip Implants. The common concerns were the trust that the Microchip Implant is private and safe technologically along with other concerns such as painful procedures and other health concerns. The paper finally proposed an acceptance model for specific behavioral intention towards the use of microchip implants for every participant country in the survey. The model consists of nine elements that heavily influence the intentions of use and they are:

1. Privacy threats.
2. Privacy rights.
3. Perceived trust.
4. Perceived usefulness.
5. Safety of the technology.
6. Health concerns.
7. Age factors.
8. Perceived ease of use.
9. Painfulness level of the procedure.

An international cross-sectional survey was conducted in 2021 and 2022 on the concerns and expectations of the MI acceptance rate in the general population [11]. Two qualitative questions that have been subjected to analysis were answered by 179 adults from the ages of 18 to 83 that are residing in the United States. To create themes for both concerns and expectations, identified codes were first categorized and then clustered. Each theme's prevalence was calculated using a variety of demographic variables. Expectations included the rejection of microchips, technological advancements, human development, restrictions, and accessibility. The frequency of issues and advantages varied according to legal status and health issues. One of the research questions on the survey covered the main concerns about microchip implants including:

1. Data Protection: This subject brings to light participants' worries about the security of the information recorded or stored in microchip implants. Participants were worried that hackers could steal or even misuse the data contained in the microchip implants, subjecting the user to more serious issues like increased insurance rates and identity fraud. Another worry was that powerful organizations, like employers or governments, might use this tool to access people's private information, subjecting them to unwanted surveillance and damage. Particularly a few participants stated that their freedom would be in danger from the GPS tracking ability of the Subcutaneous Microchips (SMs).
2. Health Risks: Participants expressed their worry about the health risks associated with SM in three distinct manners. Firstly, participants worried that using a chip would affect the user's mental and physical wellness. As an explanation, microchips could cause allergies, obstruct thinking, and damage the body's normal internal systems. Secondly, Participants were worried about how long such health issues would last. Finally, Concerns about the character of health issues were expressed by participants. They argued that because microchips are artificial and foreign to the body, they will cause unnatural and irreversible health problems.
3. Lack of Knowledge: Participants believed that it is challenging for the public sector to accept or reject microchips because of the lack of information about microchip implants. Users were interested in learning about the advantages and drawbacks of SMs as well as upcoming technological developments. Overall, participants felt that

more studies were necessary to confirm the advertised promises and that the benefits of microchips today were not sufficiently supported by science.

4. Negative Affects: Numerous comments showed disapproval of microchips. The notion of undergoing implantation and removal surgeries was disliked by the participants. The majority of them did not like the thought of having an uncontrollable foreign substance inside their bodies.
5. Ease of Use: In general, participants did not anticipate any difficulties with using a microchip, but they thought that the activities for which they were being used would be impacted by microchips. Participants were concerned that microchips would make it difficult for them to use medical tools like MRI or would interfere with airport security checkpoints.
6. Metaphysical dilemmas: Additionally, they disagreed that a microchip gives users adequate authority over its functions. Since SMs were embedded within the body, they did not believe they would facilitate error and mistake repair.
7. Negative Social Impact: Participants primarily stated that they had ethical concerns about some potential benefits of microchips, such as providing them unfair advantages over others by improving their mental capabilities. Additionally, some individuals viewed microchips from a religious perspective. Because they believed that using microchips for enhancement would go against the initial intent of creation, they saw microchip implants as being directly at odds with their religious principles. They believed that microchips restricted people's ability to think independently and exercise their free will [11].

A transnational Study was conducted on the perceived barriers to implanting microchips in humans in 2014 [12]. This quantified, descriptive research examined potential obstacles to implanting radio frequency identification signal boosters in individuals for staff ID and the nationalities of small company owners in four nations including Australia, the USA, India, and the UK. The survey's researchers concluded that there were significant correlations between the participants in these nations and how institutional microchips perceived barriers. Participants were questioned about the biggest obstacles to implementing microchip implants specifically for network access in companies. Participants could choose all applicable options from a list of six, and they

could also designate additional barriers [12]. To summarize, Table 1 lists the six perceived barriers and their details.

Table 1: The Six Perceived Barriers and Concerns on RFID

No.	Barrier	Concern
1	Technological problems	RFID is an essentially unsafe technology.
2	Social problems	A split between both workers who have implants for identity and those who use old electronic identification will exist. Eventually, it will cause a divide digitally and will create a "distinguishment" factor amongst people.
3	Cultural problems	Skin incisions are not favorable and in some cultures considered "taboo".
4	Religious problems	Labeled as the "Mark of the Beast", which is a biblical reference to the followers of the Antichrist.
5	Philosophical problems	The freedom to bodily autonomy.
6	Health problems	Microchip Implants that have been inside the body for a long time may have dangers that are not fully understood as of yet.

A comprehensive survey was conducted on the security and privacy issues in implantable medical devices in 2015 [13]. The area of bioengineering is growing, and technological advances are emerging to treat illnesses and biological defects more effectively. One such example is implantable medical devices (IMDs), which have severe threats to privacy and security that could jeopardize the implant as well as the person's health, according to multiple research studies in the area of cybersecurity.

The article examines the primary security objectives for the upcoming implantable medical device generation and evaluates the most pertinent defense system. The security plans should incorporate the obvious limitations of these tiny and implantable devices, such as computing capacity and energy storage. Implantable medical devices are placed

inside a patient's body to handle a condition, track their health, enhance a body part's functionality, or simply give them a new capability. Recent examples of IMDs include pacemakers, Defibrillators, and systems for delivering drugs in the shape of infusion pumps. These have made it possible for plans to have a higher level of intelligence and tolerance as well as greater autonomy, as hospital staff can obtain that information and change the implant. In addition to the substantial cost savings, Telemetry, and processing capability, IMDs also enable healthcare professionals to observe the patient's symptoms and to build innovative diagnostic methods relying on an interpersonal system of medical implants [13]. Table 2, lists the Four types of Implantable medical devices(IMDs) and their uses in treating cardiac issues.

Table 2: Four types of Implantable Medical Devices (IMDs) and their Uses

Implanted Cardiac Gadget	Spinal cord Stimulator	Medicine Delivery Method	A hearing aid or "Cochlear Device"
Cardiovascular arrhythmia	Impact on neurons	Unsuitable scheduling	Hearing Loss.
Cardiovascular bradycardia	Seizures and convulsions	Insufficient dose	Noisy Background.
Cardiovascular failure	Improper stimulation	Injuries	Ear Ringing.
Cardiovascular tachycardia	Inability to provoke stimulation	Pain-Relief loss	Confusion or Diversion

IMDs hold confidential information like vitals, symptoms, illnesses, treatments, and a diversity of private information, which could lead to a serious violation of privacy. Additionally, it makes it easier for spy agencies to access data transmission by listening to the frequency. A bad communication connection also makes it simpler to target the implant using techniques used to attack more widely utilized competitive devices, like fabricating, modifying, or responding to previously recorded data. Without obviously being near the victim, a cybercriminal could keep an eye on and alter the implant. Richard Cheney is a prime illustration. Due to his position as a former US president, his implantable cardiac defibrillator was replaced by one that lacked Wi-Fi to avoid any remote cyberattacks. The

patient may experience harmful medical consequences if an attacker takes advantage of an IMD vulnerability. “Adverse Events” are the term used to describe such consequences. The negative effects that can result from an attack are very diverse because each type of implant is designed to address a specific medical condition [13].

2.2 Wearable Devices Acceptance Surveys

A growing body of literature examines the perceptions and concerns towards wearable devices. A literature survey of wearable devices in education was conducted [14]. The summaries of the existing research in this field were organized into a framework of three layers. The first layer addressed data acquisition; that is, the method of obtaining the learner’s data, such as electroencephalogram, heart rate, eye movement, and position. The second layer was the analysis layer, which performs data preprocessing, feature extraction, data analysis, and other processes. The last layer consists of the application layer, which supports users in the education setting. Diverse types of wearable devices were examined, including head-worn, eye-worn, wrist-worn, and body-worn styles [14]. The key characteristics of these devices were examined, such as the key features, acquisition mode, data type, sample frequency, energy efficiency, and cost. The data collected via wearable devices were categorized as either behavioral or physiological. The preprocessing and analysis techniques of the data were discussed based on the characteristics of the data and six scenarios of wearable device applications in education were presented. Lastly, the challenges and future research directions of wearable devices were examined. Three categories of issues were identified: security and privacy, safety and comfort, and cost-related issues [14]. It was suggested that future research should focus on equipment innovation, novel applications, and feedback methods to promote the widespread application in education.

Security and privacy are major concerns in the use of wearable devices because they store privacy-sensitive data. The perceptions, concerns, and acceptability of wearable and mobile sensors were examined [15]. Purposive sampling of non-patient adults and cancer survivors was used to recruit 22 and 17 study participants, respectively. Face-to-face and virtual small-group interviews were used to collect data from the participants. The data was analyzed using reflective thematic analysis to identify privacy concerns. The

consensus was that privacy is not a concern for sensor adoption in the context of physical activity health monitoring. However, privacy was an issue in contexts that require user data access by a health insurer. It was concluded that there is a need for more transparency between potential adopters and users of wearable and mobile devices and caregivers. In addition, there is a need for transparency in privacy policies for health insurers [15]. A comparison of the responses from the non-patient population and the cancer survivors established that age is not as influential as an individual's lived health experience in the adoption of mHealth technologies.

The security and privacy issues of Internet of Medical Things (IoMT) health systems were examined in a bottom-up approach starting with a review of data challenges and requirements and the potential security applications for safeguarding IoMT [16]. Three levels of IoMT-based healthcare systems were identified: (1) sensor level, which consists of inertial sensors, ECG sensors, and motion sensors, (2) personal server level, which encompasses on-body coordinator and off-body coordinator, and (3) medical server level, which consists of medical professionals and medical and telemedicine servers [16]. Postural body movements, temperature control, energy inefficiency, quality of service, and short transmission range were the key network and protocol design challenges identified. The major security and privacy requirements at the data level were confidentiality, integrity, and availability. At the sensor level, the key requirements were tamper-proof hardware, sensor localization, self-healing, compatibility, and over-the-air programming. At the personal server level, the issues were device and user authentication. Access control, trust management, resistance to DoS attacks, and key management were the most critical requirements for the medical server. Five characteristics were identified for biometric authentication systems: (a) universal – use by all potential users (b) unique – ability to differentiate each user, (c) measurable – the ability to measure biometrics, (d) acceptable – user-friendly sampling method, and (e) circumvention – prevent attackers from circumventing authentication[16]. Future research should focus on emerging security techniques using blockchain methods and Artificial Intelligence (AI) technology to improve the security and privacy of IoM healthcare systems.

User authentication is one of the crucial security techniques used in wearable devices. However, traditional authentication techniques have security weaknesses.

Several novel authentication methods have been presented to mitigate the weaknesses of traditional user authentication techniques. A review of user authentication methods and techniques for wearable devices was recently performed [17]. Two categories of biometrics were identified, and the respective signal-processing methods were underpinned: physiological biometrics and behavioral biometrics. Biometric signal pre-processing methods included wavelet denoising, band-pass Butterworth filtering, and adaptive filtering. Signal processing techniques for feature extraction were based on direct-domain signal processing. The extracted features could be used to design a novel user authentication scheme for wearable devices using improved classification methods. A performance evaluation of the proposed classification models should examine the accuracy, precision, F1, and recall metrics.

Wearable devices have the potential to offer biometric recognition. The recent advances in the application of wearable devices to record physiological traits have been reviewed [18]. All the biometric traits that can be recorded using a wearable device were examined. It was noted that measurements taken using consumer wearable devices are not as accurate as those taken with medical devices. A critical evaluation of the current wearable biometrics was also presented, with a focus on technology readiness. The maturity of wearable devices is evaluated based on the universality and uniqueness of biometric traits, acceptability of biometric approaches, performance, throughput, data processing, interoperability, recognition modality, and multi-modality. It is recommended that the development of wearable devices requires continuous monitoring to identify solutions to existing and emerging concerns.

The perceptions and perspectives of employers and employees toward the ethical use of biosensors were examined [19]. A survey based on key questions and previous research studies was distributed to various industries in British Columbia, Canada, including construction, health, education, government, and service sectors. Data was collected from both employers as potential implementers and employees as potential end-users. There was a convergence of opinions across industries, workplaces, and genders on perceived benefits and concerns between employers and employees on the motivation to use biosensors in the workplace. Both employers and employees agreed on issues of safety, privacy, risks, data ownership, data sharing, and transfer between workplaces. The

only aspect where employers and employees did not agree, as potential users and implementers respectively, was the issue of data ownership. It was concluded that a shared interest, motivation, and responsibility exists between the potential users and implementers of wearable biosensors in the workplace. Yet, clear policies are required to ensure transparency and ethics in employee monitoring using sensor technology.

A new research model was presented for studying the intentions of employees to use wearable devices [20]. The proposed model was based on the Technological Acceptance Model (TAM) with four antecedents that reflect the intention of employees to use wearable devices: organizational trust, perceived usefulness, hedonic motivations, and privacy. In addition, the proposed TAM model recognized rewards as a mediator variable as it mediates the relationship between organizational trust and employees' intention to use wearable devices. A 46-item survey questionnaire was used to collect data from 523 temporary employees. The responses were analyzed using multiple regression analysis, which showed a strong relationship between the intention to use wearable devices and the perceived benefits of using these devices [20]. However, regression analysis also showed a negative relationship between perceived risks, like privacy, and the intention to use wearable devices. It was determined that rewards positively mediate the link between organizational trust and the intention to use wearable devices.

A wellness program was implemented using wearable devices to monitor the activity levels and sleep patterns of employees in the hospitality industry to study the effects on work attitude and health improvements [21]. Convenience sampling was used to recruit study participants in Florida, U.S., involving a wide range of hotels, such as budget hotels, holiday resorts, and international hotel chains. Employee work attitude was measured based on employee engagement, organizational commitment, turnover intention, and job satisfaction. Two categories of metrics were adopted to assess health improvements: objective measures like step count and sleep duration, and subjective measures like awareness of health issues. wearable devices had positive health effects, including the ability to reduce sedentary lifestyles, increase intake of a healthy diet, and reduced consumption of foods with calories [21]. In addition, wearable devices led to improvements in employees' level of job satisfaction, engagement, and commitment.

However, it is not clear whether the study findings could be replicated in other sectors because wellness challenges are idiosyncratic to each industry or sector.

Wearable devices can also have indirect effects on users. The potential impact of wearable health-tracking devices on psychological distress and the design implications were examined [22]. A cross-sectional probability survey known as HINTS was administered to U.S. public data. Six variables from the survey data were used in the analysis: use of wearable devices, health perception, self-care, psychological distress, body mass index, and workout duration. The relationships among the variables were analyzed using Pearson correlations. In addition, linear regression was used to assess the impact of the predictors on psychological distress. A total of 9303 survey responses were obtained. Pearson correlation analysis showed significant relationships of all variables examined, except for the connection between self-care and health perception. There was a negative correlation between psychological distress and the use of wearables, health perception, self-care, and workout duration. A weak positive correlation was observed between all the predictors apart from BMI. However, it was noted that the use of wearables was not a direct predictor of psychological distress.

Concerns abound about the accuracy and trustworthiness of wearable devices, with implications for the relationships between patients and caregivers. The potential impact of wearable devices on the relationship between patients and cardiologists was examined with the view of underpinning the adoption opportunities and barriers. Three major concerns were identified among cardiologists: concerns over the quality of data captured, concerns over the implications for future research and development, and concerns over compliance among patients [23]. The stakeholder implications were examined as follows. First, for consumers, it is noted that most patients are young females who are concerned with matters of health. Secondly, it is noted that consumers are willing to share device data with doctors and implement biometric tracking of cardiovascular parameters. Thirdly, big technology companies need financial incentives to continue developing these devices. The major future issues for big technology companies are to collaborate with cardiologists and other professional bodies on hot design digital workflow, partner with consumers, and provide users with affordable options. On the other hand, there are disparities over the role of insurers and the protection of user privacy and socioeconomic limitations of wearable

devices. However, the regulation of medical devices has been slow. Regulators need to develop robust oversight frameworks.

The application of mental devices to evaluate workload was examined by monitoring heart rate and motion data [24]. A laboratory experiment was performed with a sample of 24 university students aged between 18 and 38 years who were recruited through an email list. The students were asked to compute arithmetic tasks and count numbers. The difficulty of the arithmetic task varied based on three levels: easy, medium, and hard. In each experimental condition, the heart rate was measured with the smartwatch and the chest strap. The arm motion was also recorded. The findings showed that the heart rate measurement was accurate when the participant was in a sitting condition. However, heart rate measurements were less congruent when the measurements were taken during stepping.

Wearable devices can be used to assess human user performance, especially in mission-critical areas. The performance of consumer wearable devices was examined regarding their ability to determine mental states [25]. Various signals were obtained from a sample of 17 volunteers who participated in an experiment that simulated different working conditions to induce different levels of workload, stress, and emotions. Three tasks were included in the experimental protocol: N-back task (NB), Doctor Game task (DG), and Webcall task. The performance of participants was assessed for both NB and DG tasks. Two subjective survey questionaries were administered after each experimental condition to quantify perceptions of mental demand and measure emotional reactions, respectively. The findings demonstrated a positive correlation between the parameters computed using the wearable device and those computed using experimental sensors, with similar performance in terms of discriminating mental states. It was concluded that wearables could replace experimental methods in monitoring user performance.

A criterion was developed for reviewing wearable device application areas [26]. The evaluation criteria consisted of five parameters: accuracy, sensitivity, precision, true positive, and false positive. The methods, models, and evaluation metrics for wearable IoT devices were examined and the challenges and open issues were elucidated. The open issues identified were integrity, interoperability, cost, and comfort for patients.

The social acceptability of wearable devices has been a topic of interest. Studies on the social acceptability of wearable devices seek to understand why people accept or reject these devices and the situations that may increase adoption. The impact and body location of a mobile device and the activity for which the device was being used were investigated [27]. A two-factorial research design was conducted with two independent variables: body location and shape. A survey questionnaire was used to assess the perceptions of users with different device shapes strapped on their bodies. The findings showed not in all cases can a device influence stereotypical rating. These findings demonstrate that users of wearable devices can differentiate the context within which they are using these devices.

The adoption of IoT wearable devices was investigated focusing on factors like trust, security and privacy issues, and social standards [28]. A survey was conducted with 200 respondents. The findings revealed that the proposed model was valid for the current study. It was noted that privacy risks and awareness affect the intention to adopt wearable devices. However, social norms negatively affect privacy and security.

2.3 History and Existing Applications of Microchip Implants in Humans

Technology is increasingly getting closer to human bodies, from the smartwatches on many wrists to the smartphones in pockets. In the modern world, technology is getting under people's skin. The human implant, a technology embraced in various fields, including health care, entertainment, and human resource management, demonstrates that the human population embraces the RFID and other human implant technologies to enhance the day-to-day experience and ensure seamless functioning. Generally, Humans Implants are defined as any parts that are artificial, organs that are alive, or devices that are essentially implanted in a human body [29].

Today, innovation in the form of microchips is being inserted under people's skin. The technology used is Radio-Frequency Identification, an integrated circuit device implanted into a human being's body and encased using silicate glass [30]. The device contains a unique identifier linked to data in a database positioned outside the individual's body. The stored data may include their medical, contact information, personal identification, allergies, and law enforcement record. The RFID system comprises a radio transmitter, receiver, and radio transponder. The RFID chip is placed under an individual's

skin and contains information on several aspects. A unique code is used with the passive RFID microchip absorbing energy and emitting RFID signal [31]. The technology can also be used to store emergency data. It represents the Internet of Things concept extension. The Near Field Communication represents another frequently used technology. The RFID-type technology is a contactless communication technology operating on 13.56 MHz. the identification information can be sent to the receiver wirelessly [30]. The technology used has been key in enhancing the use of microchips in the human body.

A. History of Microchips Implanted in Humans

Kevin Warwick became the first individual to have a surgically implanted silicon chip in his body in 1998, increasing the chances of having a man-machine cyborg. The cybernetics professor and a British scientist underwent the operation, which placed a chip on his forearm with the study intending to understand computer run, intelligent building control [32]. An electronic device, the human microchip plant, was implanted subcutaneously through an injection. Warwick's implant enabled verbal output, opened doors, and switched on the lights. The implant was left under the skin for nine days before being extracted [32]. The technology has only been commercially availed in the last ten years. The medical procedure on Warwick lasted for twenty minutes and has enhanced the debate on whether a human body should or is fit to have a microchip. This concept means a similar computing power, usually found in an entire building, can be inserted in an individual's left arm. The operations to insert the microchip on Monday, 1998, were led by Dr. George Boulos. The microchip is smaller compared to a pearl and holds several microprocessors. The British Broadcasting Corp documented the historic event with Warwick stating that he was able in theory to see and understand the process or what was going on. Boulos likens Warwick to Edward Jenner, famously known for injecting himself with cowpox while researching the vaccine for the condition in 1776 [33]. According to Warwick, the doctors punched and lifted the skin, placing the chip inside just above his elbow, in his left arm [33]. Warwick did not name the chip's manufacturer but stated that it would be used commercially. For over 20 years, Warwick engaged in intelligent building research with the surgically implanted silicon chip expected to be used in real-world applications. However, many experts and organizations have been instrumental in developing and improving the technology.

B. Available Human Microchip Implants in the Market

Various types of microchips are now available in the market with different functionalities. The microchip can record everything, helping speed up the normal or daily routine of the global population and enhancing human lives [34]. A famous example of human microchip utilization in the transport sector is the SJ Railways Microchip. The largest train company in Sweden has a commuter-designed and customized microchip allowing them to embrace HMI as tickets [35]. Each member is provided with a membership number stored using the microchip, and proper monitoring is performed by an app found on the commuter smartphone. Near-Field-Communication technology is used utilizing similar transfer technology usually embraced by Amiibo, Android Pay, and Apple Pay [35]. In the past, the primary cutting edge was the e-ticket system but using a microchip implanted in the commuter's hand instead of a paper train ticket. The Swedish Company is the first globally to let commuters utilize such an innovative method, with many comparing the approach to a scene borrowed from a sci-fi film. The technology is currently being used by more than 3,000 commuters in Sweden [35]. Such a trend is expected to revolutionize the transport sector.

Biohax Micro Implant represents another popular microchip making waves in Europe and globally. The Bio-compatible NFC implant supports smooth digital association and functioning with various encounters daily, including access cards and money, loyalty tokens, and doing away with keys. Many players, including Mindshare, TUI Nordics, and Epicenter Stockholm, have adopted the company's microchip and customized it to fit seamlessly into their digital eco-system, and needs [36]. Jowan Osterland started the organization in 2013 with the human microchip project requiring two years to complete. Currently, the company is developing training materials for medical professionals, including nurses and doctors, to ensure that some of the workloads are transferred to other players [37]. The human microchip ensures that the hyperconnected surroundings that human beings live in the modern world are streamlined.

Three Square Market, an organization based in Wisconsin, the United States, offers its human resources an implant with various functionalities, including logging into the company devices such as computers, opening doors, and making purchases in the canteen. More than 50 employees have already accepted and signed up for the program since its

inception in 2017. Two popular microchips in the healthcare industry are the baby LO-Jack and Verichip [37]. The United States Food and Drugs Administration was one of the pioneer authorities encouraging the technology by approving an RFID named VeriChip. The microchip was approved in 2004 with VeriChip developing and introducing the health-care-oriented device, with research showing that 90 percent of the population in the United States had concerns with such a technology. However, the company folded after just three financial periods mainly because studies showed a relationship between the transponders found in RFID and cancer [37]. Further research has shown that cancer risks as a result of implants in virtually nonexistent concerning animals. It is also negligible for animals.

A Seattle-based organization, Dangerous Things introduced small RFID and NFC chips that can be injected into a human being's body using a syringe. The company also provides larger programmable chips [38]. An individual can install the chip by slicing the hand and placing the device beneath the skin. LED lights ensure that one can see the device through the skin. However, the company cautions users to utilize the device at their risk since regulatory agencies have not certified or tested the product. Such a device can help communicate with various other devices and technologies with a product, such as the xNT tags having the Near Field Communication technology [38]. Such device functionality, including the price point, demonstrates the significant uptake of the technology. However, ethical and health concerns, including failure by some companies to seek regulatory approval and authorization, must be considered.

C. Existing Applications of Human Microchip Implants

In the modern world, such technology is being embraced in various sectors, including health care, human resource management, and transportation.

1. Entertainment Industry

Human Implants are becoming common and attractive aspects of the entertainment industry, with parties and events embracing them. A popular example is the Baja Beach Club, which has roots in Rotterdam in 1994. One of the club's owners and managers was interested in gaining a sustained competitive advantage by designing and introducing a program that would go beyond normal technologies that the rivals had embraced [39].

While perusing through an information system and technologies magazine, the owner found a VeriChip device, a technology that uses radio waves to change, store and read data. The device functionality of ensuring the use of the VeriPay system made it an interesting proposition for the club [39]. Linking the identification code to a financial institution meant that the device would be valuable, helping the club differentiate itself and enhancing payment and other functionalities conveniently. The club found purses and wallets more annoying, with the customers expected to welcome the new concept since most of them already had silicones, piercings, and tattoos. In 2004, the club introduced the possibility to the customers and ensured that a confirmation stating that the club was not responsible for medical issues was required. The chip ensured that customers could enter the club and make payments. The Barcelona venue introduced the concept in 2004, with people with the device enhancing their status and becoming local celebrities, a newfound fame that encouraged others. Only a few minutes are required to get the implant, and the club has ensured that a doctor is on-site for the procedure.

2. Law Enforcement

The law enforcement field is also increasingly embracing technology. For instance, the attorney general of Mexico and 160 individuals in his office implanted the microchips to ensure they could gain security access [40]. The was dubbed as one of the high-profile use of the technology yet, with a 16-digit code used for the VeriChip device. Security has, over the years, become a cause of concern globally, with security agencies and employees seeking technology that will guarantee confidentiality and privacy helping fight against crime and unwanted events. In Mexico, the top federal investigators and prosecutors embraced the technology helping gain access to areas of places considered restricted with an organization named Solusat, distributing the devices in the country. A single rice grain-sized device caused the taxpayer in Mexico $150 [40]. Such technology may help enhance security effectiveness and service delivery for security agencies.

3. Human Resource Management

Microchip implants have also become popular in the employment world, with some organizations across the globe embracing technology for their human resources. Organizations, including start-ups, are implanting microchips in their human resources,

with some having a similar size to a grain of rice [41]. Such microchips serve as swipe cards helping functions such as printer operations and opening doors. However, many questions concerning the medical effects and safety raise ethical issues [29]. The technology being used cannot be termed as new since it has previously been used as virtual collar plates for animals such as pets and tracking of deliveries. However, there is a concern that hackers may obtain significant and critical information as more employees globally embrace the use of microchips.

4. Healthcare Sector

Another critical area where microchip use has been significantly embraced is the health sector. Experts have predicted that the technology has the potential to transform health care and the industry, especially in the modern world, where drug therapies have become increasingly effective and complex in addressing healthcare challenges and treating diseases [29]. Medical devices, including pacemakers and defibrillators, have been used to restore a human being heart rhythm enhancing public health and the well-being of the population. Technological advances ensure that implantable controlled-release systems will help the delivery of drugs and monitor individual health. According to healthcare experts, the future represents having minimal trips to medical professionals and the increased use of microchip implants [41]. For instance, at a healthcare conference in Dubai, many experts argued that the industry will be entirely digital in less than three decades. An average human being life has been equated to the science fiction scenes found in Sci-fi movies as a result of embracing technologies such as the microchip in humans. One of the health experts argued that in a few decades, people would have an MRI scan while taking a shower [42]. Such an approach can ensure that an individual can record his vitals at home, eliminating the need to access a doctor physically.

The technological developments, including the increasing popularity of human implants, demonstrate the importance of innovation and technology in enhancing the global population's quality of life and solving day-to-day challenges. From Sweden's popular human implant in the railway station to Baja Beach Club's use of implants for venue access and payment, the technology using RFID and NFC technologies has demonstrated that they can enhance the quality of life and ensure a seamless and secure,

and secure way to addressing day-to-day challenges. Therefore, despite the moral and ethical challenges raised by embracing such technologies in the modern world, proper and positive tapping of human implant devices will help enhance human lives.

2.4 History and Existing Applications of Wearable Devices

wearable technological devices are increasingly being used to monitor various metrics such as heat rate, distance, acceleration, and others. The popularity of wearable devices is driven by advances in technology as well as the development of appropriate materials. Wearable devices can collect and share data, which can be used to improve the quality of life. Due to their functionality, wearable devices have been applied in multiple areas. In this section, a summary of the history of wearable devices and existing applications is provided.

A. Description of Wearable Devices

Wearable technology refers to electronic devices, which are worn on the body of a user. Wearable devices can be in form of accessories, smart glasses, electronic garments, smart tattoos, smart watches, skin patches, or smart jewelry [43]. Wearable devices can be made from different materials including flexible materials, organic materials, and paper-based materials. Each of these materials has unique features, which make them appropriate for specific applications. For instance, paper-based materials are used in respiratory monitoring because of their ability to absorb moisture [44]. In addition to materials, wearable devices use different sensors to capture the required data. The most common sensors include chemical sensors (convert chemical signal to electrical or optic signal), optical sensors (use light scattering or absorption to directly display information), and electromagnetic sensors (rely on resistance, conductivity, or capacitance). The choice of the sensor depends on the specific metric targeted by a device.

Wearable devices can be divided into two categories: contact wearable devices and implantable devices. Contact wearable devices are designed to be fixed on the skin surface through adsorption or adhesive forces [44], [45]. For instance, a contact wearable device based on a microfluidic chip can be used to monitor glucose levels. Unlike contact wearable devices, implanted wearable devices penetrate the skin [45]. The purpose of

implantable wearable devices is to collect data from the body and then send it to an external system for analysis. An example of an implantable wearable device is a microneedle, which is an important source of biomarkers. Microneedles can penetrate the human skin without causing pain or discomfort [46]. A key point to note is that implantable wearable devices are mostly used in medical applications. As such, the popularity of wearable technology has been driven by contact wearable devices.

B. History of Wearable Devices

Wearable devices can be traced back to the 13th century with the invention of spectacles with corrective lenses. The possibility of walking around with spectacles was the pioneering work towards the development of smart glasses. In the 16th century, the concept of the pocket watch was developed by Pomander in German. This development led to significant interest in the development of wearable watches with multiple models being developed. However, the development of watches with straps was achieved in the 19th century due to the successful miniaturization of the prototypes. During the first and second world wars, wristwatches became important in military operations, which led to their global adoption. In this era, the wristwatch also became a fashion device, which could be purchased by all people.

After the end of the war, the next notable development was the Stereophonic Television Head-Mounted Display in 1960 by Morton Heiling. This device could be considered the pioneer of virtual and augmented reality. A year later, researchers from MIT developed a shoe device, which could be used to predict the landing point of a ball on the roulette table. This invention was considered the first computerized wearable device. In 1963, Hugo Gernsback used battery-powered cathode-ray tubes to develop television glasses to enhance the stereoscopic experience. Ivan Sutherland also invented a virtual reality headset in 1968. A key development regarding watches was the invention of the Pulsar Calculator watch in 1975. similarly, Hewlett Packard (HP) invented an algebraic calculator watch with a miniature and smart design in 1977 [47]. Most of the developments during this time focused on the development of wearable devices for specific tasks, which limited their commercial viability.

In the 1980s and following years, rapid advances in technology increased the development pace of wearable devices. For instance, Steve Mann developed an eye-mounted camera, which could transfer data to a computer for processing. Similarly, Reflection technology developed an eye head-mounted display. In 1998, a mobile bracelet (mBracelet) was developed to support financial transactions in automated teller machines (ATMs). The era of smart wearable devices commenced at the turn of the 21st century when Donald Brewer worked with Microsoft engineers to develop smart personal objects technology (SPOT) watches. In 2006, Nike developed a device to monitor various personal metrics such as acceleration and distance. Fitbit also developed a wireless activity tracker, which could be connected to the internet. Samsung also joined the race with the development of the S9110 smartwatch, which was essentially a General Packet Radio Service (GPRS) phone with email support. In 2014, Google developed the Android Wear operating system to accelerate the development of wearable applications [47]. Since then, wearable devices have become mainstream products, which can be used in multiple applications.

C. Applications of Wearable Devices

Today, wearable devices are used in a variety of applications in sports, personal fitness and leisure, entertainment and gaming, healthcare, and others. Wearable fitness trackers are some of the most popular wearables today. The trackers are used to track and monitor fitness metrics such as heart rate, sleep time, distance covered, and calories consumed [48], [49]. The information is captured and displayed on a screen or smartphone. There are various fitness trackers in the market including Fitbit Flex, Withings Pulse, Misfit Shine, Jawbone, and others. These trackers can be used to motivate users to stick to exercise targets, which is critical in sports and personal fitness. For instance, trackers can be used by obese individuals to ensure that they burn enough calories each day. Regarding usage, these trackers can be wristwatches, clothing accessories, or pocket devices. A key point to note is that most of the trackers are contact wearable devices. As such, the devices do not pose any safety risks to the users.

Wearable devices are also increasingly being implemented in the healthcare sector. The goal of healthcare wearable devices is to continually monitor physiological

parameters so that the health of an individual can be managed through personalized care [50]. For instance, the devices can be used to monitor heart rate, body temperature, respiration rate, and other biomarkers. The devices are beneficial in this area because they reduce the cost of detecting or monitoring physiological parameters. Furthermore, the devices minimize safety risks because they are not invasive. A key feature of healthcare wearable devices is the use of bio-potentials such as electroencephalograms (EEG), electrocardiograms (ECG), and electrooculograms (EOG) [51]. Most general-purpose wearable devices such as Apple Watch, Samsung Galaxy Watch, Fitbit Versa 2, and Mi and 4 can be used to monitor various healthcare parameters. However, some conditions require novel devices [52]. For instance, measuring the intraocular pressure of the eye requires a novel wearable health device because general devices do not support such functionality.

The entertainment and gaming industry is another area where wearable technology is increasingly being used. The goal of wearable devices in the entertainment and gaming industry is to improve the experience of users. For instance, the Oculus Rift offers users an opportunity to get a 3-Dimensional (3D) experience in a virtual world. Research has shown that the platform can improve the gaming experience of users and enhance their engagement with gaming elements [53]. It is important to note that a virtual reality system is not complete without offering the ability to interact with real and virtual objects. In this case, wearable devices can be used to improve the experience of controlling virtual reality devices. The goal of the wearable device is to improve the experiences of users with head-mounted virtual reality devices [54]. In addition to virtual reality, wearable devices can be used to improve the experience of listening to music. For instance, a mood glove hepatic wearable device has been proposed to enhance the experience of movie viewers through hepatic sensations [55]. Overall, both general-purpose and specialized wearable devices can be used in the entertainment and gaming industry.

Finally, wearable devices have been applied in industries for various purposes. For instance, wearable devices have been used in the construction industry for safety monitoring [56]. The devices provide real-time information, which can be used to monitor safety performance. Furthermore, the devices can be used to track workers in the work environment including their movements, work rate, and rest time. In this case, the devices

can improve work efficiency, reduce injuries, and improve the physical well-being of workers. Similarly, wearable devices are useful in enhancing human-machine interaction in industrial automation [57]. Google Glass is one of the applications, which can enable users to receive real-time data on industrial processes (such as production data, transactions, and machine status) so that they can initiate commands without using their hands. Such devices can enhance the engagement, productivity, and experience of users.

Wearable devices have evolved to become a popular technology in society. Initially, the devices were mainly used for simple tasks such as tracking time. Today, technological advances have led to the application of wearable devices in multiple applications in healthcare, entertainment and gaming, sports, and personal fitness. With the development of new materials and technological advances, wearable devices are likely to be applied in all aspects of society.

Chapter 3: Method and Results

The following chapter will cover the main methods and basis on which this thesis was constructed on. The main two sections will be about the methodology and the results of the conducted survey.

3.1 Method

The most suitable method to gain valuable insights into people's views, opinions, and thoughts even is through surveys and questionnaires. A survey also acts as a direct method of receiving information directly from its source effectively and efficiently. Questionnaires also serve as an efficient tool to assess and evaluate responses and hypotheses.

For this particular study, a survey was constructed to be distributed and circulated publicly, especially towards academics such as students and faculty members in an academic institution. Based on the gathered responses a detailed analysis was presented in SWOT form. The SWOT analysis stands for the strengths perceived as well as weaknesses, and opportunities that overlay along with the noticed threats based on the responses. The main aim of the analysis is to give an objective idea of the general perception of human microchip implants and wearable devices. Being able to draw an objective idea of the perception of the population towards human microchip implants, helps in deriving and identifying future barriers to the adoption of human microchip implants in the future. The survey was tailored in a way to both gather information as well as spread knowledge and awareness without it being excessively long. The total number of questions in the survey is 13 and the questions were divided into three main sections with each section roughly containing three to four questions. The first section consists of demographic multiple-choice questions followed by the second section which includes questions set to test out the basic knowledge level in both microchip implants in humans and wearable devices. The last section consists of questions that directly pertain to barriers perceived by people toward human microchip implants. The majority of the survey was filled with close-ended questions, especially the last section to measure precisely the perceptions and barriers to adoption for the participants. Some questions also contain a brief description and introductory part before answering questions and that was added on purpose for some of

the questions to spread awareness and educate the participants while they are answering the survey. Giving respondents an educational introduction before each question ensures that participants are somewhat knowledgeable concerning the topic that they will be asked about thus increasing the credibility of the gathered answers.

3.1.1 Methodology

The survey contains a variety of questions that aims to gather the optimal answers possible from the participants. A questionnaire was created to both educate and learn from participants on the general perceptions and knowledge levels of both wearable devices and microchip implants. The questions were designed and constructed in a way that can spread awareness and gather insights into microchip implants and wearable device technologies but also to better comprehend whether one technology is preferred over the other. The following are the main characteristics of this study's methodology:

1. To spread awareness throughout the process of filling out the survey regarding the emerging trend of human microchip implants if participants happen to lack knowledge on the subject matter.
2. To efficiently comprehend the different perceptions, viewpoints, and barriers of adoption towards both wearable devices and microchip implants.
3. The survey for this study uses a quantitative strategy approach that aims to gather as much data as possible, whilst also including a qualitative approach that will be demonstrated in the results and analysis section of the survey's statistics.
4. Construction of the survey was made to maintain a random sample approach.

3.1.2 Survey Details

Using a survey or questionnaire to comprehend perception or even predict the knowledge level is almost the optimal way to tackle any emerging trend or technology in IT. Microchip implants in humans are not yet adopted in the UAE hence, it is extremely difficult to understand the impact it will have on the population without directly asking them whilst keeping in mind multiple factors such as knowledge level, perception, and even potential barriers to adoption.

The study is heavily based and derived from the gathered data from a survey titled "A Comparative Study on Microchip Implants in Humans and Wearable Devices Survey" which was distributed and circulated online by the United Arab Emirates University surveys office to all the staff in the university including students and faculty members. The dates in which the surveys were circulated are from July 2022 up to October 2022. The Survey was constructed in a way to gather information as well as spread awareness. The main survey is sectioned into three major categories that set out to measure multiple aspects of microchip implants and wearable devices' adoption and acceptability. The first section consists of the Demographic details of the respondents. Moreover, the second section tests the knowledge level of participants on both WD and MI. The last section measures the willingness level to use either technology or even derived from the participant's preferences.

3.1.3 Population and Sampling

The Surveys sample included various participants from the academic fields and individuals in the UAEU community. The background of participants came from all regions around the country in order to be inclusive of all populations of the country and have a diverse selection of survey responses. A random sampling strategy was adopted to ensure that the sample accurately reflected a decent amount of the target audience. All in all, a total of 296 responders answered the survey and all of the responses were captured and analyzed in order to for them to be utilized in the SWOT analysis section later on.

The survey was circulated and distributed to the entire community of UAEU only. The community included faculty members, students, and even employees. The main purpose behind circulating the survey to almost everyone in the academic community is to gather as much mature responses as possible for analytical purposes later on in the study. Moreover, to dissect and analyze the participants accordingly, the sample selection was categorized based on education level as follows: 148 (50%) postgraduate and undergraduate level, 112 (37.8%) representative of the graduate level and above, 28 (9.5%) high school education level, 5 with elementary education and lastly 3 only are illiterate or without a specific education level.

3.1.4 Factors Affecting the Results

Certain factors of this research must be addressed prior to diving into the results section and the main aspects that must be addressed pertain to the factors that affect the results and must be validated and taken under consideration. Furthermore, the main impediment faced in the data gathering and literature review process was the lack of resources and research conducted on human microchip implants, that is due to the fact that this technology, in particular, is rather recent and just started to emerge hence why not a lot of papers were published and found on this topic. Limited resources, Validity, and generalizability are some of the factors that are meant to be addressed methodologically in this study:

A. Limited resources: perhaps one of the most prominent limitations found in this research is the lack or rather limited quantity of resources found on the technology of human microchip implants. One of the main reasons that there are limited resources on this topic is that human microchip implants are considered a fairly recent emerging technology, even with enough resources it is still difficult to find ones conducted or applicable in the UAE. As of yet, there are no scientific publications nor resources found on both microchip implants and wearable devices technology that is conducted or published in the UAE that give clear indications of the perceived barriers and barriers to adoption.
B. Validity: a limitation found was the possibility that the study's results might yield inaccurate measured insights or perceptions and that is due to the sample population being narrow and not diverse enough to cover the majority of people. The suggested approach to tackle these limitations is to try as much as possible to broaden and diversify the sample selection and take into consideration that the sample gathered reflects only one institution which in this case the UAEU community. Another possible limitation would be the credibility of the gathered answers and whether respondents and participants of the survey answered with truth and honesty which are unfortunately something that cannot be controlled and it is always a possibility in any conducted survey or questionnaire.

C. Generalizability: As discussed previously, no studies or research were conducted in the UAE that can be utilized to understand the impact of human microchip implants and general perception and any of the studies that were conducted in other countries are unfortunately non-applicable to the UAE. The information found in this study faces the risk of being non-applicable to other countries as people's perceptions towards technologies tend to differ from region to region and different from one country to another.

All regulations and ethical rules that are imposed by the Research Ethics Committee of the United Arab Emirates University were followed, and on the 2nd of June 2022, ethics approval was obtained from the committee. Every participant and respondent was aware and informed of their rights and no personal data was gathered or leaked. At the beginning of every section of the survey, a brief introduction and information were added to inform the participants a little bit about the technologies of wearable devices and human microchip implants.

3.2 Results

The following section is dedicated entirely to the results retrieved from the circulated survey in UAEU. The results section will display responses captured from participants as is without any alterations or analyses. The in-depth analysis and discussion will be presented in the next chapter thoroughly. The results indicate the perception levels of barriers to the adoption of each wearable device and microchip implant. Furthermore, the results also shed light on the general awareness level of UAE citizens toward both technologies.it is worth mentioning that only the significant answers and tables are mentioned in this section and not the entirety of the results are presented.

The results and responses gathered can be divided into three major sections beginning with the demographic section followed by the awareness level section and lastly the perceived barriers to adoption. The question pertaining to the residence place in the UAE was divided into 6 regions within the country. 296 responses were gathered from the UAEU community, 81 were males whilst females were 215. Out of the 296 participants, 8 respondents did not want to participate in the survey. As mentioned before only the significant parts will be added in the coming section.

A. Microchips implants and wearable devices knowledge level.

1. The question “What is your awareness level towards wearable devices?”

Figure 1: Awareness Level Towards Wearable Devices

As depicted in figure 1, about 37.8% stated that they have an intermediate level which means that about 109 respondents acknowledge that they know well enough about wearable devices whereas, about 30.9% stated that they have a basic level which means they know a little bit about wearable devices. 24.7% claim to be highly knowledgeable and know a lot about wearable devices whereas about 12% responded with an expert knowledge level meaning they know everything they need to know about wearable devices. Finally, 7% responded with “None” meaning they do not know anything about wearable devices.

2. The question “What is your awareness level towards microchip implants?”

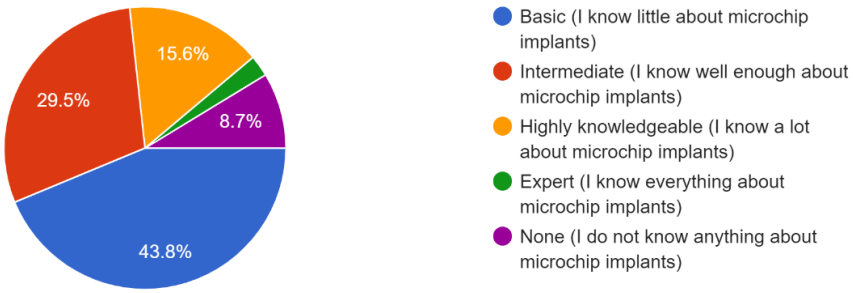

Figure 2: Awareness Level Towards Microchip Implants

Figure 2 shows that about 43.8% of respondents have a basic knowledge level of MI, meaning they know little about human microchip implants. 29.5% of respondents stated that they have intermediate-level knowledge meaning they know well enough about microchip implants. Surprisingly, 15.6% answered that they ate highly knowledgeable which means they know everything they need to know about MI. About 8.7% answered that they do not know anything about MI and lastly 2.4% of participants answered that they know everything about MI, making them experts.

3. The question" Do you use any of those wearable devices? (Choose as many applicable)"

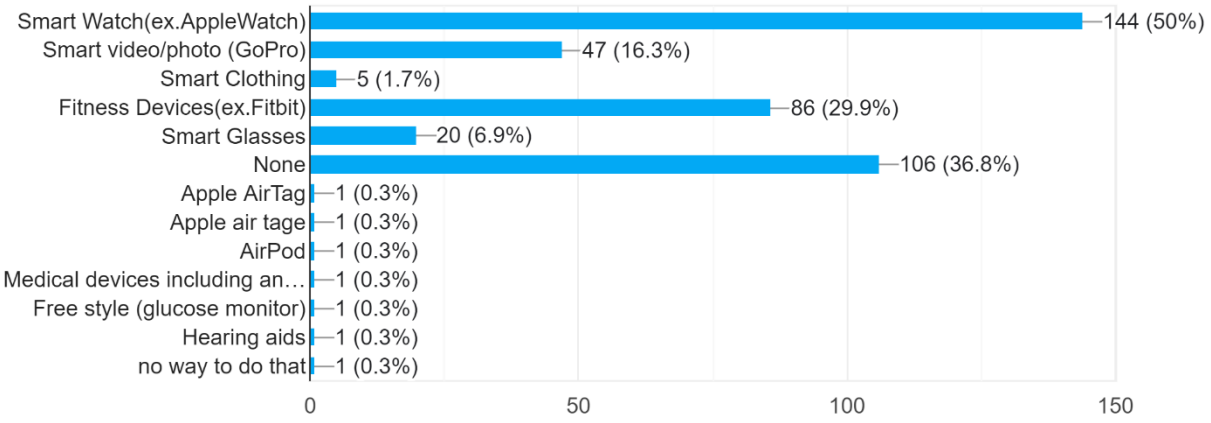

Figure 3: Types of Used Wearable Devices

From the six multiple choices offered in figure3, almost the majority of picked answers were related to apple products, as even the other options included other types of apple wearable devices such as apple air tag. Around 50% of respondents picked the apple watch out of the six choices of which wearable devices the participants use. Secondly, around 36.8% answered that they do not use any type of wearable device. Out of the six multiple choices, about 29.9% answered that they use fitness devices such as the health tracker Fitbit. 16.3% answered that they use the attached smart videos and photo-taking wearable devices such as the GoPro. Furthermore, about 6.9% of participants picked the smart glasses option of used wearable devices whereas, about 1.7% picked the smart

clothing option of used wearable devices. In the other option, a participant added hearing aids whilst another participant also added medical devices in general as a type of used wearable device. A very intriguing answer was added to the other options which is “no way to do that”, most probably this could be about lacking the means whether monetary or physical to purchase or use wearable devices, to begin with.

4. The question “In your opinion, what is the most suitable field to utilize microchip implants in humans? (Choose as many applicable)”

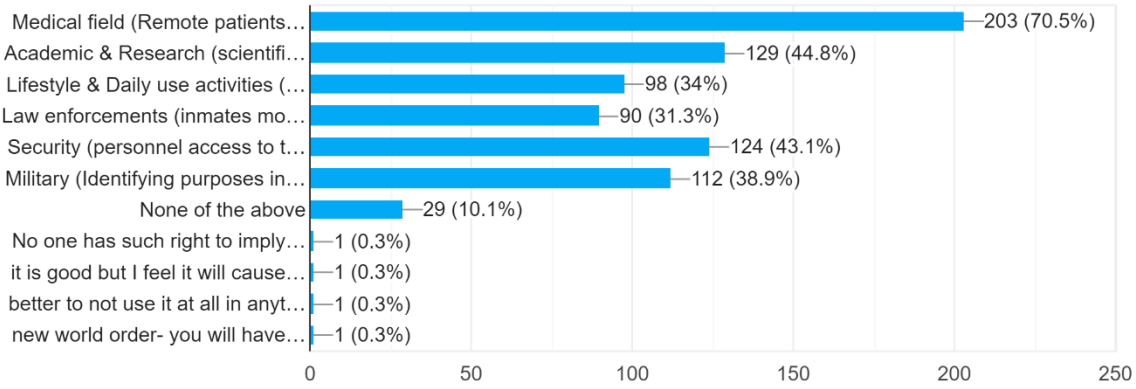

Figure 4: Perception of the Most Suitable Fields for MI

Figure 4 explains the most suitable field to be utilized for microchip implants in humans based on the survey’s participants' perceptions. The questions consist of 8 options and out of them the most picked choice with 70.5% is the medical field with the example of Remote patient care, biometrics scans /instant blood tests. Secondly, around 44.8% of participants chose the best field to utilize microchip implants in humans is in the academic & Research field (scientific expeditions, experiments. Etc….) whereas, about 43.1% of respondents answered that in their opinion the field of Security (personnel access to top secret areas, identity theft prevention Etc...) is the best to use in MI. Meanwhile, 38.9% of participants chose the best field to be the Military (Identifying purposes in conflict zones, Reconnaissance Etc...) while 34% picked the Lifestyle & Daily use activities (Transportation, entertainment, payments, and permits) field to be the most suitable in

their opinion for microchip implants adoption. Lastly, out of the 8 options about 31.3% chose the Law enforcement field (inmates monitoring, identification tags for officers) for microchip implants while 10.1% chose None of the above options, meaning none of the above seems suitable for microchip implants.

What is worthy to mention, is that in the "other" option, it was noticed that people wrote the concerns perceived from their point of view concerning wearable devices even though there is a specific question for their perceived barriers to adoption. Some of the additional answers in the "other" options were "No one has such right to imply such thing in other people", "it is good, but I feel it will cause a great disturbance maybe", "better to not use it at all in anything" and "new world order- you will have nothing and you will be happy WEF".

5. The question "What do you think limits the use of wearable devices in the UAE? (Choose as many applicable)"

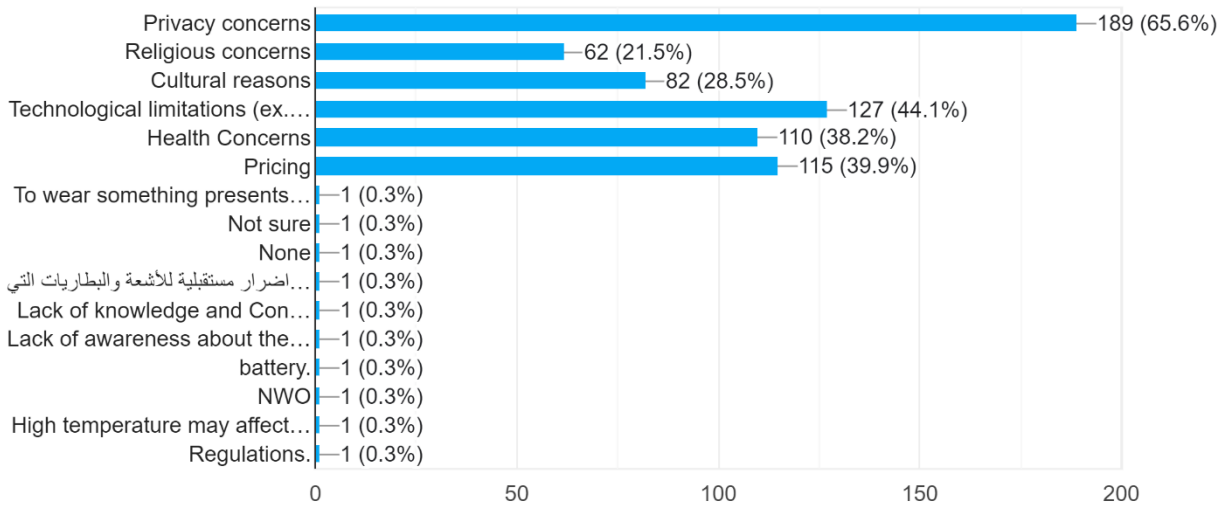

Figure 5: Wearable Devices Perceived Barriers to Adoption.

Figure 5 shows that almost 65.6% percent of participants expectantly chose the privacy concerns out of the 7 choices, followed by Technological limitations (Recent technology), where almost 44.1% chose it as a limitation for wearable device adoption in

the UAE. 39.9% of respondents chose the “price” answer as the perceived limitation of wearable device usage or adoption followed immediately by Health Concerns where 38.2% picked it as a limitation for wearable devices. What is interesting is that almost 28.5% chose cultural reasons as a limitation for wearable devices. Lastly, around 21.5% chose religious concerns and around 0.3% chose none of the above as a concern that would limit the use of wearable devices.

On the “other” additional option, two of the answers were on the lack of awareness concept “Lack of awareness about the capabilities and benefits of such devices” and “Lack of knowledge and Conspiracy theories” which can be considered a valid limitation. whereas the rest of the written answers can be categorized in any of the already provided options such as “High temperature may affect the battery life” which can be categorized under technological limitations.

6. The question” What do you think would limit the use of microchip human implants in the UAE? (Choose as many applicable)”

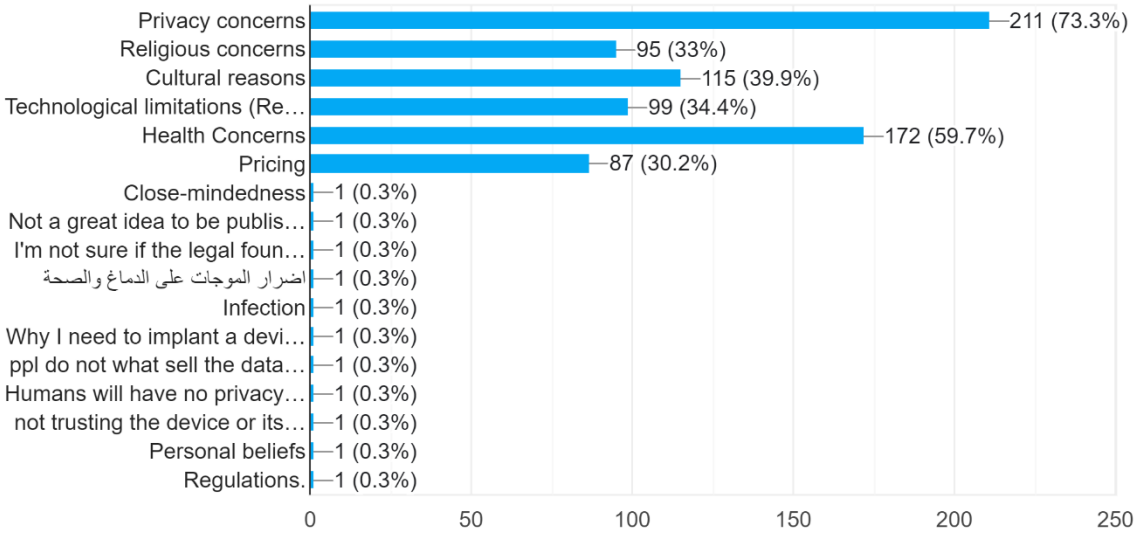

Figure 6: Microchip Human Implants Perceived Barriers to Adoption.

Just like in figure 5, figure 6 also shows the limitations of microchip implants as opposed to wearable devices. Just like the previous question, out of the 7 choices almost 73.3% chose privacy concerns as the limitation for human microchip implant usage. About

59.7% of participants picked the health concerns option whereas, about 39.9% picked the cultural reasons as a possible limitation for human MI in the UAE. 34.4% chose the “Technological limitations (Recent technology)” option followed by 33% who answered the “religious concerns” option. Lastly, 30.2% answered that pricing is a limitation for human MI. Surprisingly, no captured answer was on “None of the above”.

In the additional responses options, some of the answers can easily be sorted in the already given choices such as “Infection” which can be sorted in health concerns, the same applies to the given answer “Humans will have no privacy and will be tracked with everything they do and wherever they go, it might be dangerous if these facilities and microchips were hacked, someone could find you easily. Plus, I don’t think having a microchip planted inside a human body is healthy, just like putting anything with Bluetooth inside your body, can cause a magnetic field against the human body and interactive with other technological devices you own and can lead to headaches and many other health problems. The human body is designed to work by itself with all the blood clots and veins, why add a microchip in the middle of a well creation? Wear a wristband with a microchip if necessary.” where it can be sorted under privacy concerns. the following are some of the additional received responses:” I'm not sure if the legal foundations for implantable microchips are available. If not, this will be a major limiting factor. I need also to comment on the question below which does not allow space to provide a written answer. No one will be willing to use wearable or implant devices unless he/she must. Therefore, the question could be "if you have to use...."”, “Not a great idea to be published in our country because of several reasons and no one will accept to do that in his body, but that would be a great idea in country that have some very serious problem”, “Why I need to implant a device if I can wear it” and “not trusting the device or its uses.”

7. The question “If given the option, are you willing to use Wearable devices or Microchip implants?”

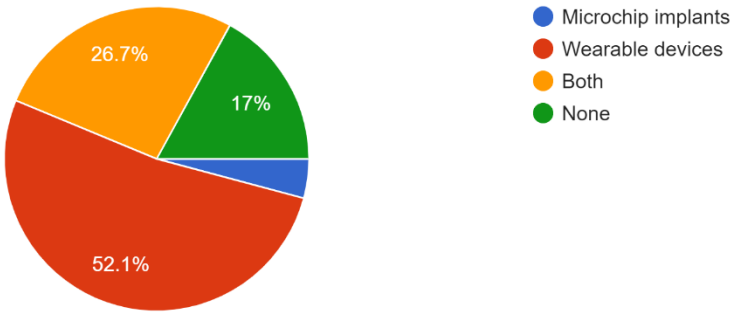

Figure 7: Willingness to Adoption for both Technologies

As Shown in Figure 7, about 52.1% chose to adopt wearable devices only. Meanwhile, about 26.7% expressed that they are willing to use both wearable devices and microchip implants. 17% chose that they are not willing to use either wearable devices or microchip implants. Surprisingly, the lowest percentage was 4.2% and it was for the willingness to use microchip implants.

Chapter 4: Analysis and Discussion

Analysis of both the conducted survey along with the proposed recommendations and strategies to approach these emerging technologies will be discussed in detail in this chapter. The main aim is to showcase an overview of the top main findings of the comparative survey, which includes the overall description and statistics of the respondents as well as Results and analysis of the answers of the respondents. This section also depicts strategies and guidelines techniques for wearable devices and microchip implants.

4.1 Overview of the Main Findings

This section will discuss the overview of the main findings derived from the survey's results. It is worth mentioning that only the questions and answers of significance were used in the analysis section. The main reason behind selecting the following questions for comparison and contrasting purposes is to help draw insights into the noticed patterns that were detected upon analysis.

1. Awareness level

A. The question" What is your awareness level towards wearable devices?" and the question" What is your awareness level towards microchip implants?".

Table 3: Awareness Level Comparison of Both WD and MI

Awareness Level	Wearable Devices (%)	Human Microchip Implants (%)
Basic	89 (30.9)	126 (43.8)
Intermediate	109 (37.8)	85 (29.5)
Highly knowledgeable	71 (24.7)	45 (15.6)
Expert	12 (4.2)	7 (2.4)
None	7 (2.4)	25 (8.7)

Table 3 compares and contrasts the awareness level of both technologies based on participants' responses. It is quite evident based on Table 3 that around 43.8% of participants claim to have basic knowledge of human microchip implants whereas around 37.8% claim to have an intermediate level of wearable devices which is considered higher

than the knowledge level of microchip implants as only 29.5% participants chose an intermediate level knowledge on Microchip implants. One possible reason behind having a higher level of awareness of wearable devices could be attributed to the fact that wearable devices are fairly common in the UAE and sold almost everywhere, whereas human microchip implants are a fairly recent and emerging technology that is only common in Europe. Furthermore, the lowest response in terms of awareness level was 2.4% and it was at the expert level in terms of knowledge of human microchip implants, on the other hand, the lowest level of answers was 2.4% on the "None" level in wearable devices. Understanding and establishing the awareness level of the survey participants for each technology is crucial as it influences the adoption level later on as well as determines the credibility level of participants in understanding the technologies and their potential.

2. Willingness to adopt technologies.

A. The question" If given the option, are you willing to use Wearable devices or Microchip implants?" and the "Gender" question.

Table 4: Willingness to Adopt Based on Gender

Willingness to Adopt	**Genders**	
Question:" If given the option, are you willing to use Wearable devices or Microchip implants?"	Female (%)	Male (%)
Both	53 (26)	24 (30)
Microchip implants	9 (4)	3 (4)
None	38 (18)	11 (14)
Wearable devices	107 (52)	41 (52)
Total participants per gender	207	79

As shown in Table 4, there is a slight difference between both genders and the willingness to adopt amongst them, it is quite evident that about 26% of females are willing to use both wearable devices and microchip implants. surprisingly, about 30% of males chose to adopt both wearable devices and microchip implants which is slightly higher than

that of females. Males on the other hand prefer to use wearable devices more than both technologies combined. What is worth mentioning is that about 18% of females prefer not to use either technology whereas, around 14% of males only, also prefer not to use wearable devices and microchip implants. Both genders showed lower numbers of willingness to adopt microchip implants as both 4% of females and 4% of Males chose to adopt Microchip implants only.

B. The question "If given the option, are you willing to use Wearable devices or Microchip implants?" and the question "What is your education level?

Table 5: Willingness to Adopt Based on the Education Level

Education Level	Willingness to Adopt				
	Both (%)	Microchip Implants (%)	None (%)	Wearable Devices (%)	Total Participants per Education Level
Uneducated/illiterate	1(50)	-	1(50)	-	2
Elementary education level	1(20)	2(40)	1(20)	1(20)	5
High School education level	9(38)	-	6(25)	9(38)	24
Postgraduate/Undergraduate level	49(33)	4(3)	20(14)	74(50)	147
Graduate level & above	17(16)	6(6)	21(19)	64(59)	108

As shown in Table 5, the vast majority of responses gathered were from Postgraduate, Undergraduate level, Graduate level, and above and it is quite expected since the survey was only circulated within the community of a United Arab Emirates University. What is also interesting is the fact that many Postgraduate and Undergraduate levels were accepting of adopting wearable devices as almost 50% answered that they are willing to adopt this particular technology over microchip implants. Furthermore, microchip implants seem to have the lowest rate of willingness to adopt as almost all

education levels had an extremely low number to no number of responses to Microchip implants. What is quite interesting is that 16% of graduate levels and above chose willingness to adopt both technologies same apply to 33% of postgraduate/undergraduate levels and 38% of high school education levels. Lastly almost 50% of uneducated or illiterate chose to implement both along with 20% of elementary education level.

The possible explanation behind the microchip implants in humans having the lowest rate of responses might potentially be because of the lack of awareness as expressed previously. It is expected that the lowest rate of awareness and knowledge, in general, might be the root cause behind people's doubt and hesitance regarding any new and emerging technology.

4.2 Profile and Statistics of Respondents

The section below reflects a statistical analysis of the demographic section.

1. Demographic section

A. Age participation breakdown, The question "What is your age group?" along with statistical analysis and more insights including average, variance, and standard deviation.

Table 6: Age Participation Analysis

Age Group	**Participation Percentage %**	**Categorization**
19 and under	18.2432	Young Adult
20-29	47.973	
30-39	18.9189	Adult
40-49	9.12162	
50-59	3.37838	Older adults
60 and above	2.36486	
Average		27.897
Variance		68.7259
Standard Deviation		8.29011

Table 6, depicts the age breakdown percentages of all the participants in the survey. The age groups were categorized into three main categories to better distribute the age groups and analyze them better. the first category is the Young adult category which consists of the age group from 19 years old up to 29 years old. The second category is the adult category which consists of 30 years old up to 49 years old. The last category is the elderly category and it is from 50 to 60 and above.

Prior to categorization, the percentage of age group participation was calculated and presented in percentages. The top percentage of participation age groups was in the young adult category specifically 47.97% from the ages of 20 to 29 years old. The second-highest participation percentage was equally distributed amongst the age group of 19 and under with 18.2432% and 30-39 years old with also 18.9189% which makes it only slightly higher than the 19 and under age group. The last age group with the lowest participation rate is the 60 and above age group with 2.36486%.

The average or mean number of all age groups is 27.897, which indicates that the majority of age groups were typically between the age of 27 and 28 years old. Overall the standard deviation or dispersion of participants in the surveys is 8.29011.

B. The question "Would you like to participate in this survey?" and "Where do you reside(region)?" questions.

Table 7: Survey Participation Inclination Based on UAE Regions

Regions in the UAE	**Survey Participation Inclination**	
	No	Yes
Abu Dhabi	4	96
Abu Dhabi;Eastern region /Al Ain region (Al-Ain-Sweihan, Nahel, Al Hayer and Remah)	2	6
Dubai	-	20
Dubai;Eastern region /Al Ain region (Al-Ain-Sweihan, Nahel, Al Hayer and Remah)	-	2
Eastern region /Al Ain region (Al-Ain-Sweihan, Nahel, Al Hayer, and Remah)	1	127
Fujairah- Ras Al Khaimah	1	15
Sharjah-Ajman- Umm Al-Quwain	-	17
Sharjah-Ajman- Umm Al-Quwain;Eastern region /Al Ain region (Al-Ain-Sweihan, Nahel, Al Hayer and Remah)	-	1
Western region /Al Dhafra region (AL Dhafra- Liwa- Madinat Zayed, Mirfa, Liwa, Sila, Ghayathi, and Delma)	-	2

As demonstrated in Table 6, Most of the responses based in the UAE regions were from the Eastern region / Alain region and Abu Dhabi, which is expected since most of the participants were around the university's region. However, out of 94 participants, only 4 people rejected the participation and that's the highest value presented in the whole table in terms of rejecting the survey participation inclination. A few participants were under 4 regions including Abu Dhabi's Easter Region, Dubai's Eastern Region, Sharjah-Ajman - Umm Al-Quwain: Eastern Region, and the Western Region. The regions with a few participants and no rejections were Dubai, Dubai's Eastern Region, Sharjah - Ajman-Umm Al-Quwain, and their easter regions as well as, the Western region.

A possible explanation surrounding the significantly low rejection rates to participate in Dubai region may involve the idea of the city's technological advancements leading to participants depending more on technology in their daily routines. Another region with a high participation rate includes the Eastern region / Alain region as well as, Abu Dhabi. An explanation could be that those regions specifically have universities with IT programs and are surrounded by technology (smart boards, smart gates) in their daily routine, these participants also possibly use technological gadgets including laptops, tablets, and smartwatches around the campus or in classes. These factors affect their answers in the survey, which is possibly why most of these regions accept the survey participation inclination.

C. The question" What is your nationality?".

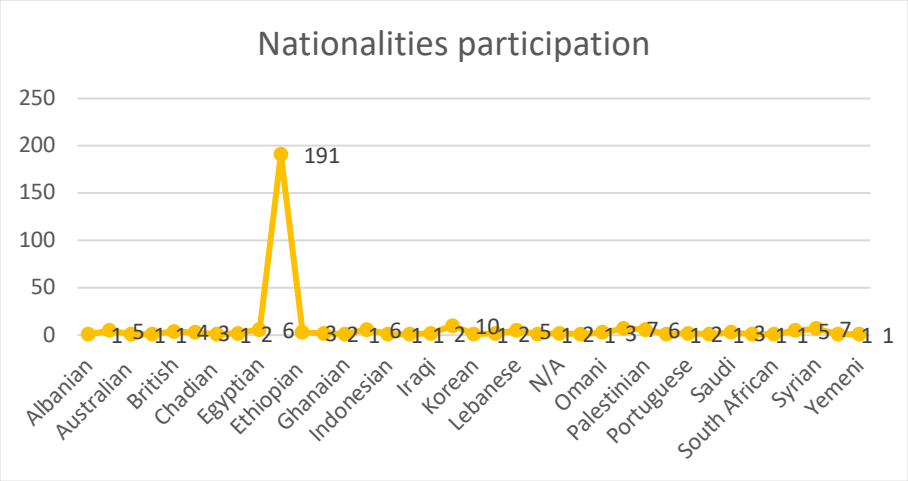

Figure 8: Nationalities Participation Distribution

As displayed in Figure 8, according to the nationality's participation distribution the highest number was for Emirati participants. A possible explanation would be that the survey was conducted amongst citizens residing in the UAE. However, other nationalities show a small percentage of participation, yet the numbers are still significant. Koreans rank the second highest with 10 and a possible justification would be that they could be exchange students from universities as students tend to help other students with surveys and participation for scientific purposes.

Another possible explanation for the increased number of participants in the survey being “Emiratis” is due to the number of Emirati students enrolled in most universities around the UAE as proven in the education level question where the majority of answers were attributed to under and postgraduate students. Most likely, if the survey was circulated within the community of UAE university, it would target students more than faculty members and possibly increase the percentage of Emirati students participating in such a survey.

4.3 SWOT Analysis

After the literature review and the survey results and analysis was taken under consideration the following SWOT Analysis was conducted to showcase the general perception of microchip implants and wearable devices in case of adoption.

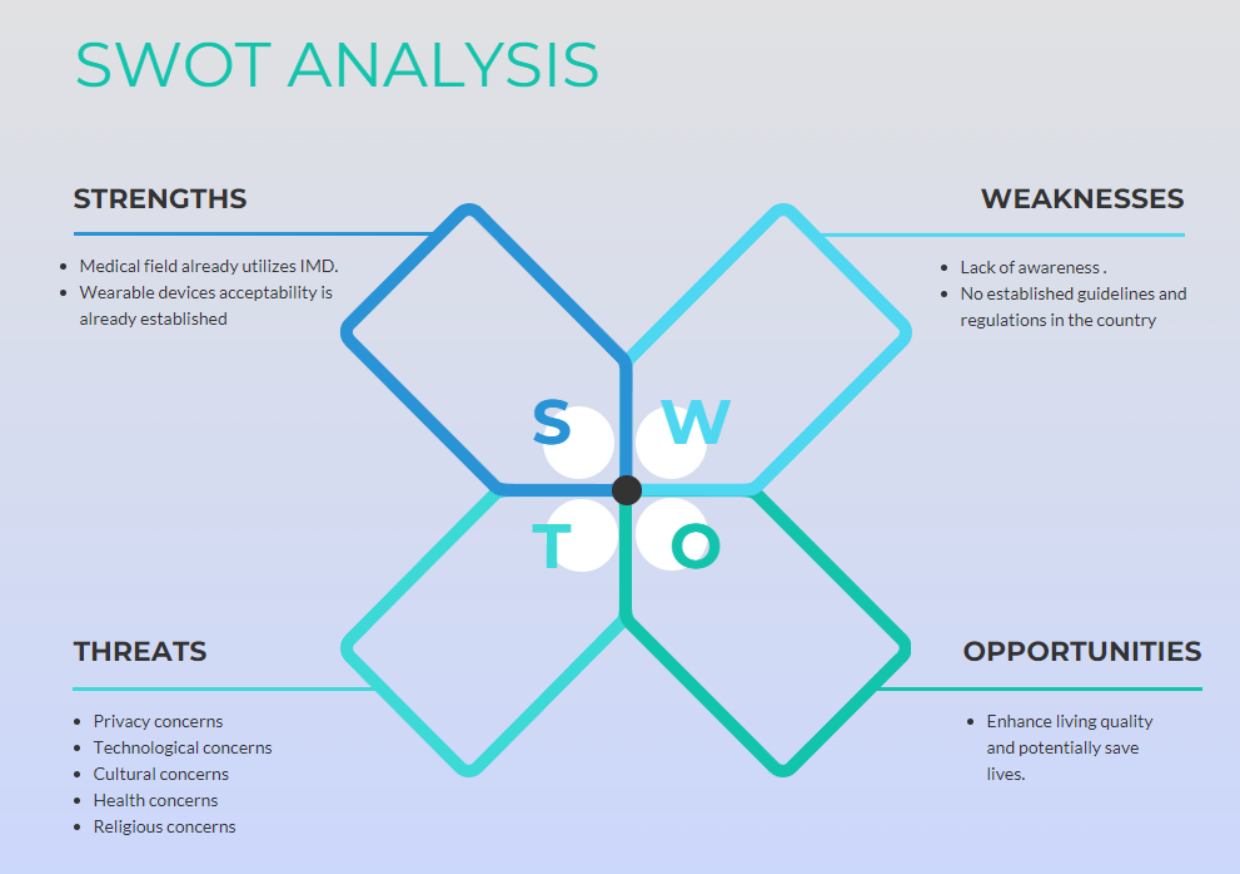

Figure 9: SWOT Analysis of the Perception in the Case of MI and WD Adoption

As mentioned previously, multiple variables directly influence the perceptions surrounding the adoption of wearable devices and microchip implants in humans.

1. Strengths

Perhaps one of the strongest arguments in favor of the adoption of both wearable devices and microchip implants is that the notion of implanting devices (IMDs) underneath the skin, has been in use in the medical field as previously mentioned in the literature review.

Based on the gathered responses, it was noted that there is a slightly increased response towards the implementation of wearable devices, as it seems participants are more accepting of it. It is advisable to keep in mind that the survey still does not reflect

the entirety of the UAE population yet even the sample gathered of academics shows that still there is a slight inclination towards trying to adopt wearable devices.

2. Weaknesses

Based on the analyzed results, one of the main weaknesses of both technologies, and especially human microchip implants is the lack of awareness as expressed by some of the participants as well. Moreover, another weakness is the lack of established guidelines and regulations concerning the technologies. Lacking an established foundation of rules and guidelines creates further ambiguity regarding these emerging technologies which furthers the reluctance to use them. The proposed strategies and guidelines to tackle this weakness will be discussed in the upcoming section.

3. Opportunities

Such is the case with all emerging technologies, there are a lot of opportunities that can be harnessed for the better good, such is the case with the microchip implants and wearable devices as some were adopted in some fields and proved to have a good potential to enhance living quality and potentially save lives.

4. Threats

Based on the analysis of the survey along with the conducted literature review, it is quite evident that the major threats are to be considered before adopting any of the emerging technologies. Some of the expected concerns to be faced upon adopting microchip implants or wearable devices are Privacy concerns, Technological concerns Cultural concerns, Health concerns, and religious concerns.

4.4 Proposed Strategies and Guidelines

The following are a few tactics for handling the emerging technology of human microchip implants as well as wearable devices. First, staying up to date with the most recent trends and advancements in the technological world of microchip implants and wearable devices. Regular research and keeping current on new developments and potential applications are required for this. carrying out comprehensive risk analyses to find possible threats and weaknesses, both internally and externally, and based on it

organizations can use this to create suitable prevention measures and backup plans. Moreover, creating an environment that values experimenting and originality in order to promote innovation with the technology and also creating and executing technological innovations by working with other entities and industry professionals. This can encourage creativity and knowledge exchange while also distributing the risk and expenses associated with creating technological advances in the field of wearable and embedded technologies. It was quite evident from the analysis of the survey that people tend to choose not to explore any new technology in the case of no or low awareness level, and that is why it is crucial to clearly define how the two technologies of Microchip Implants and Werablde Devices are going to be utilized, which individuals will have the information at their disposal, and also know how security and confidentiality will be maintained in these rules and guidelines.

Offer regular reports on quality standards and possible risks as well as instructions for workers on how to use new technologies. This can guarantee that all individuals are aware of their obligations and can support the development of an atmosphere of stakeholders. Monitor and evaluate the use of both technologies to ensure that they are being used effectively and ethically, and to identify and address any issues that arise. Overall, being active, educated, and careful when dealing with emerging technology, in general, is the best course of action. Organizations could perhaps keep up with the most current revelations and be ready to move to reduce risks and take advantage of the opportunities as they appear.

It is important to give the use of individual microchip implants proper consideration and to comply with all applicable legal, ethical, and confidentiality regulations. Several of the finest recommendations for human microchip implants adoption are listed below:

Table 8: Microchip Implants Adoption Recommendations

No.	Recommendations	Breakdown of Recommendation
1.	Informed permission	prior to such a microchip implant being made, people must be thoroughly informed about its origin and intended use and provide evident permission and consent.
2.	Confidentiality	It is important to take steps to protect the privacy and security of the confidential data the microchip implant collects. Personal data should be under the authority of the person and only be accessible to those who have been given permission.
3.	Voluntary involvement	Each plan incorporating microchip implants should always allow free enrollment; neither coercion nor incentive should be used.
4.	Disclosure	People should be notified of the specifics of the implanting process, any risks, or advantages, as well as the types of information that are gathered and how they are used.
5.	Principles of Ethics	Any application of microchip implants in people should adhere to ethical principles, such as respecting human rights, avoiding discrimination, and acting without hostility.
6.	Conduct evaluations regularly	To make sure that the implementation of microchip implants remains essential, efficient, and morally correct, they should be routinely examined and assessed.
7.	Regulatory adherence	Any application of microchip implants must abide by all applicable laws, including all those pertaining to data security and privacy.

In the end, the ideal strategies for human microchip implants and wearable devices must place a priority on the person's liberty, confidentiality, and well-being while also taking into account the technology's possible advantages and risks. It's crucial to handle this matter with forethought and give thoughtful consideration to the points of view of all parties involved.

Human microchip implants are a controversial and complicated topic that needs cautious thought and preparation and wearable devices also but to a lesser degree. The following are some strategies that businesses or any entities can employ to deal with human microchip implants and wearable devices use:

1. Conduct extensive research:

Organizations must thoroughly investigate the topic before actually pondering the use of microchip implants and wearable devices in order to comprehend the technology, its possible advantages and disadvantages, as well as the ethical and legal ramifications.

2. Create clear rules and guidelines:

Companies ought to develop specific rules and regulations regarding the utilization of microchip implants along with wearable devices, such as the manner in which they will be used, who has the information at their disposal, and also how confidentiality and safety will be protected.

3. Inform all involved parties (ex. stakeholders):

It's critical to dispel any misunderstandings or worries by educating stakeholders, such as staff members and clients, about the advantages and risks of both technologies.

4. Give people the option of choosing to participate:

Organizations must give people the option to choose to have microchip implants or wearable devices, as well as make sure that the choice is optional and educated. Having autonomy and choice is extremely advisable with this particular technology.

5. Guarantee the confidentiality and safety of data:

Organizations should implement secure encryption and permissions to guarantee the confidentiality and safety of data gathered by the technologies.

6. Constant assessing:

To ensure that microchip implants and wearable devices are utilized efficiently and with integrity, as well as to recognize and deal with any potential problems that may arise, organizations should constantly assess their use and ensure their operative functionality.

4.5 Summary of Findings

This section consists mainly of the findings summary of the thesis and specifically of the research questions answers and additional insights gathered from the survey.

1. What are the expected adoption barriers and benefits of Microchip implants in humans in the UAE?

The expected adoption barriers of microchip implants in humans in the UAE are mainly related to the concerns and issues that are perceived by the public. Furthermore, the major barriers that were found are mainly related to privacy concerns and technological concerns. Other potential barriers stem from cultural concerns, health concerns, and religious concerns. When asked about the most suitable field to be utilized for microchip implants in humans based on the survey's participants' perceptions. The most picked choice with 70.5% is the medical field with the example of Remote patient care, biometrics scans /instant blood tests. This indicates that according to the public's perception, the main benefit of microchip implants is their utilization in the medical field.

2. What are the commonalities and differences between microchip implants and wearable devices?

The comparison between microchip implants and wearable devices can be briefly summarized into the following criteria, beginning with Invasiveness as WDs are external and non-invasive, while MIs require a surgical procedure for implantation and involve a more invasive approach. Secondly, Removability can be used as a comparison metric between the two technologies as WDs can be easily removed, replaced, or upgraded as

needed, whereas MIs might require another surgical procedure for removal or replacement. Moreover, the functionality of WDs and MIs may serve different functions, ranging from health monitoring and fitness tracking to identification and payment. Comparing their specific features and capabilities is essential in determining their suitability for various purposes. Lastly, User Acceptance for Both WDs and MIs differs as the willingness of individuals to use and accept these technologies may differ, as some might be more comfortable with wearable devices while others may prefer the integration and convenience of microchip implants. Moreover, the lifespan, durability, and maintenance requirements of WDs and MIs can differ significantly. Wearable devices may require more frequent charging, updates, and maintenance, while microchips might offer longer-lasting functionality with fewer maintenance needs.

3. Are UAE citizens more likely to adopt wearable devices over microchip implants?

Based on the analyzed survey question when asked about the willingness to adopt either, both, or none technologies of wearable devices and microchip implants almost a large portion of 52.1% of participants chose to use wearable devices alone rather than use microchip implants on their own.

4. What is the most suitable strategy for tackling this emerging trend?

The best strategy to tackle the emerging trend of human microchip implants if adoption is considered will be first to establish Informed permission meaning people must be thoroughly informed about its origin and intended use and provide evident permission and consent. Secondly, Confidentiality is followed by Voluntary involvement which means that adoption must not be mandatory. Lastly, Disclosure, Principles of Ethics, Regulatory adherence, and the conducting of Evaluations Regularly must be applied.

Chapter 5: Conclusion

New technology offers organizations, companies, and even governments many fascinating possibilities, yet they also carry a lot of dangers and ambiguities. It is extremely vital to first and foremost set a clear understanding and awareness of the technology and then try to establish guidelines, recommendations, and strategies to tackle this technology and put it to good use. Not so long ago, the technology of human microchip implants started to emerge in Europe and thousands of Swedes were getting microchips implanted in their hands. It is expected that soon enough the same technology will be spread around the world. Even with the introduction of the UAE's telecommunication company Etisalat of their partnership with the microchip implanting company "biohax", it is still unclear whether the microchip will ever be sold in the UAE market for human use. However, what is clear is that it is imperative to first understand the technology itself and understand the general perception towards it, and what better way to do that than to take another similar technology like wearable devices that also started a long time ago as an emerging technology and compare it with microchip implants in humans.

As a result, this thesis explores and compares human microchip implants with wearable devices to shed light on the expected perceptions and barriers to the adoption of both technologies. Moreover, the main aim of the study is to provide clear recommendations and guidelines in case of adoption, and by doing so this should allow any policymakers, organizations, and even governments to be better equipped and prepared if adoption is even considered. There are a lot of factors to be considered and the first being that the survey's results and analysis will most likely not reflect the entirety of the UAE population but instead reflect only a small portion of the UAE sample and specifically the academic sector. Findings after conducting the literature review and analyzing the results of the survey reveal that there were a lot of barriers to be expected upon adoption of either technology (wearable devices or microchip implants) and they are Privacy concerns, Technological concerns Cultural concerns, Health concerns, and religious concerns. Those multiple concerns must be tackled and understood before adoption such as the fear of the technologies being unsafe, unethical, and ambiguous in a sense of how it works. It was perceived also that wearable devices seem to have a higher

acceptability rate than microchip implants in general, this outcome could be attributed to multiple reasons however, one of the reasons might be that participants seemed to have a higher knowledge level on wearable devices as opposed to microchip implants amongst other things. Therefore, it is expected that a lot of citizens might prefer using wearable devices and have reluctance towards microchip implants in the future. Lastly, the key to both technologies is to make sure that the population is well knowledgeable and aware of anything regarding this technology. In conclusion, handling human microchip implants requires being open, moral, and considerate of people's rights and privacy, and the same applies to wearable devices. To make sure that both technologies are utilized appropriately and for suitable purposes, organizations should proceed with prudence and cautiously consider the possible advantages as well as the hazards.

Finally, it is essential to mention the major complications faced upon preparing this thesis and one being the lack of publications available and the limited resources on microchip implants in humans, even with limited studies conducted elsewhere in the world it is still not applicable in the UAE.

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List of Publications

L. M. Al Mansouri and F. Alnajjar, “A survey on the emerging trend of human microchip implants and their potential,” *2023 Advances in Science and Engineering Technology International Conferences (ASET)*, 2023. doi:10.1109/aset56582.2023.10180565

Appendix

A Comparative study on Microchip implants in humans & Wearable devices Survey

I am a graduate student at UAE University, conducting a comparative study on microchip Implants and wearable devices. We invite you to participate in a research survey about the general perception of microchip implants in humans and wearable devices. This research aims to study the awareness level of microchip implants and wearable devices, the perceived barriers to adopting the mentioned technologies, and the adoption willingness level.

Section I: Demographic Study

1) Gender

○ Male

○ Female

2) What is your nationality?

3) What is your age group?

○ 19 and under

○ 20-29

○ 30-39

○ 40-49

○ 50-59

4) Where do you reside(region)?

☐Dubai

☐Abu Dhabi

☐Sharjah-Ajman- Umm Al-Quwain

☐Eastern region /Al Ain region (Al-Ain-Sweihan, Nahel, Al Hayer and Remah)

☐Western region /Al Dhafra region (AL Dhafra- Liwa- Madinat Zayed, Mirfa, Liwa, Sila, Ghayathi and Delma)

☐ Fujairah- Ras Al Khaimah

5) What is your education level?

○ Uneducated/illiterate

○ Elementary education

○ High School education

○ Postgraduate/ Undergraduate level

○ Graduate level &

6) Would you like to participate in this survey?

◉ Yes

○ No

Section 2: Microchips implants and wearable devices knowledge level

Wearable technology is defined as any electronic device made and designed to be worn on the user's body. Wearable devices can take many different forms, including jewelry, accessories, medical devices, and clothing (or clothing elements). Fitness trackers, often in the form of wristbands or straps, monitor things like physical activity and vital signs such as Fitbit.

1. What is your awareness level towards wearable devices?
   - ○ Basic (I know little about Wearable devices)
   - ○ Intermediate (I know well enough about Wearable devices)
   - ○ Highly knowledgeable (I know a lot about Wearable devices)
   - ○ Expert (I know everything about Wearable devices)
   - ○ None (I do not know anything about Wearable devices)

Microchips were used heavily in supply chain management, specifically in inventory management and control, shipping, manufacturing and asset tracking, and equipment tracking. Microchips are also used for many other things, such as livestock tracking and pet tracking.

2. What is your awareness level towards microchip implants?
   - ○ Basic (I know little about microchip implants)
   - ○ Intermediate (I know well enough about microchip implants)
   - ○ Highly knowledgeable (I know a lot about microchip implants)
   - ○ Expert (I know everything about microchip implants)
   - ○ None (I do not know anything about microchip implants)

3. Do you use any of those wearable devices? (Choose as many applicable)

   - ☐ Smart Watch(ex.AppleWatch)
   - ☐ Smart video/photo (GoPro)
   - ☐ Smart Clothing
   - ☐ Fitness Devices(ex.Fitbit)
   - ☐ Smart Glasses
   - ☐ None
   - ☐ Other (please specify)

The emerging technology of human **microchip implants** is slowly catching the attention of various countries worldwide after the sudden surge of adoption in Europe (Sweden). In 2021, it was announced that a Swedish company is implanting microchips under the skin and is promoting its devices as a COVID-19 health pass. Click here if you are interested to learn more about it: https://youtu.be/EpFRcv7_fbk

4. In your opinion, what is the most suitable field to utilise microchip implants in humans? (Choose as many applicable)

☐Medical field (Remote patients care, biometrics scans /instant blood tests. Etc…)

☐Academic & Research (scientific expeditions, experiments. Etc….)

☐Lifestyle & Daily use activities (Transportation, entertainment, payments and permits)

☐Law enforcements (inmates monitoring, identification tags for officers)

☐Security (personnel access to top secret areas, identity theft prevention Etc...)

☐Military (Identifying purposes in conflict zones, Reconnaissance Etc...)

☐None of the above

☐Others (please specify)

Section 3: Barriers perceived by people towards human microchip implants.

5. What do you think limits the use of wearable devices in the UAE? (Choose as many applicable)
   ☐Privacy concerns
   ☐Religious concerns
   ☐Cultural reasons
   ☐Technological limitations (ex. Battery life)
   ☐Health Concerns
   ☐Pricing

6. What do you think would limit the use of microchip human implants in the UAE? (Choose as many applicable)
   ☐Privacy concerns
   ☐Religious concerns
   ☐Cultural reasons
   ☐Technological limitations (recent technology)
   ☐Health Concerns
   ☐Pricing

7. If given the option, are you willing to use wearable devices or microchip implants?

   - ○ Microchip implants
   - ○ Wearable devices
   - ○ both
   - ○ None

End

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This research aims to provide a preliminary study on the general perception of UAE citizens towards human microchip implants and wearable devices. The research will shed light on the perceived barriers amongst the population as well as investigate impediments to the adoption of human microchip implants and wearable devices in the future for the UAE. The outcome should provide the people of the UAE with a clear foundation of what is expected in case of adoption and provide preliminary recommendations and strategies.

Ltifa Al Mansoori received her MSc in Information Technology Management from the Department of Information Systems and Security, College of Information Technology at UAE University, UAE. She received her BSc in MIS from the College of Business and Economics, UAE University, UAE.