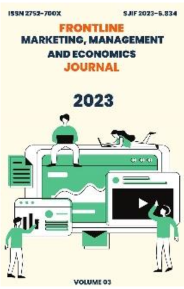
FRONTLINE MARKETING MANAGEMENT AND ECONOMICS JOURNAL
(ISSN – 2752-700X)
VOLUME 04 ISSUE 10 Pages: 16-49
OCLC – 1276793382

Publisher: Frontline Journals



Journal Website: https://frontlinejournals.org/journals/index.php/fmmej

Research Article

UNDERSTANDING THE ROLE OF ENHANCED PUBLIC HEALTH MONITORING SYSTEMS: A SURVEY ON TECHNOLOGICAL INTEGRATION AND PUBLIC HEALTH BENEFITS

Submission Date: October 08, 2024, **Accepted Date:** October 13, 2024,
Published Date: October 18, 2024
Crossref doi: https://doi.org/10.37547/marketing-fmmej-04-10-03

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Abstract

Introduction: Various changes in technologies have impacted the public health monitoring systems especially in the United States. AI and IoT, Big Data, block chains have enhanced the ways that diseases are monitored, vaccinations are administered and emergency responses are coordinated. Issues like the infrastructure constraints, privacy issues and variability in technological implementation graduality's limit the extent to which these technologies can be scaled up in U.S. public health systems.

Objective: The aim of this study is to evaluate the impact of technological improvement on the improvement of the public health monitoring systems in United States. It assesses the utilization of superior technologies and considers the observed enhancement of general health status together with the problems identified in the application of technologies.

Methods: A quantitative cross-sectional survey was filled by 400 participants from the PH and technology workers working throughout the USA in the public health sector. Community and purposive sampling techniques were used and data were self-administered from the participants through an online structured questionnaire. The survey included questions about participants' degrees of awareness of AI, IoTs, Big Data and blockchain, concerning their applicability to public health surveillance and the potential challenges to their application. Descriptive statistics, chi-square, independent sample t test, one way analysis of variance, Pearson correlation analysis and multiple regression analysis were conducted in SPSS V 26.

Results: The current study revealed that the use of AI, IoT, Big Data and blockchain technologies has accelerated the enhancement of public health surveillance, including disease detection and vaccination management. Awareness of these technologies was directly related to perceived impact on public health to the extent of $r = 0.75$, $p < 0.001$. Other issues like lack of funding, lack of technical knowledge and issues surrounding privacy were cited as major reasons for inadequate scaling up.

Conclusion: The results point out that new technology has a potential for advancing the system for monitor public health in the United States but there are some barriers. Challenges that prevent expansion and growth of these technologies include inadequate infrastructure, funding and data protection must be overcome in order to enhance the efficiency of the technologies to deliver on their intended health benefits. More work is necessary to expand understanding of longevity of these phenomena and ways of preventing these challenges.

Keywords

Public health monitoring, technological integration, Artificial Intelligence, IoT, Big Data, blockchain, U.S. healthcare, public health outcomes.

INTRODUCTION

Health monitoring systems are a crucial tool in managing the health of the population. With the emerging technologies like AI, IoT, Big data and analytics and blockchain, public health system of the world is changing how data is captured, analyzed and utilized on the health sector. Such technologies are static/quasi-static technologies that are making it possible to develop real-time solutions for public health challenges and hence better and more efficient decision-making systems. These are of great importance within the United States and for decentralized and diverse health-care systems as they support better population health, including dealing with both first tier health management and encompassing population-level events such as pandemics (Raghupathi & Raghupathi, 2020; HHS, 2021).

The COVID-19 pandemic exposed the need for better and more scalable public health surveillance in the United States. The fast application of AI-Predictive modeling, IoT-Healthcare wearables and Big Data Epidemiological studies played a crucial role in navigating the pandemic (Zhang et al, 2021). One of the functions of AI was beneficial when it came to the ability to model the patterns of infected people and health officials could distribute the resources better (Dafni et al, 2021). Real time data control of the spread of the disease was made possible through application of Big Data analytics while IoT devices allowed monitoring of patients particularly during the most NESs periods apart from hospitals (Keesara et al, 2020). The experience with these technologies during COVID-19 provided evidence of their effectiveness for shaping the PPHR and ensuring preparedness for the future outbreaks or any other crises in a more effective and efficient manner (He et al, 2020).

State epidemiology centers also funded by the CDC along with the HHS have spearheaded the use of such technologies in the United States. For instance, AI is used by the CDC in order to improve disease surveillance systems while blockchain has been considered as a potential solution to secure public health's data business transactions (HHS, 2021). Moreover, through IoT, various chronic disease management devices have provided practitioners with relevant and timely data for the analysis of population health trends (Yin et, al, 2021). With these innovations, public health agencies are improving how they handle health data and this enhances quick interventions in both short-term and long-term public health crises (Reddy et al, 2021).

There are several problems that hinder the massive implementation of such technologies to the extent possible in the United States' public health sector. One of them was the diverse nature of the US healthcare system that frequently means varying delivery of the recent technologies between the states (Kaiser Family Foundation, 2021). Sourced funded public health entities might not have the adequate physical architectures and technical knowledge that enable them implement the complex technologies while the large institutions, in contrast, may suffer from data protection regulations and compatibility challenges (Thompson & Mayer, 2020). Data privacy is still a major issue especially because of HIPAA rules which dictate how patient's health information should be used, disclosed and managed (Adjerid & Acquisti, 2020). These regulatory challenges along with funding constraints and digital disparities between cities and rural settings pose serious challenges to comprehensive technology use in American healthcare facilities (Himmelstein et al, 2021).

The use of technologies such as AI and Big Data has been viewed to be effective in real-time track of diseases and issues around forecasting, yet these technologies bring out ethical issues such as ownership, accountability and general prejudices of the algorithms (Obermeyer et al, 2019). To prevent worsening the existing healthcare disparity problem in the United States, it must be guaranteed that models including AI & machine learning will have an equality in their development and implementation (Rajkomar et al, 2018).

The aim of this research is to understand how technological advances have an impact on the improvement of PHM systems in the United States besides identifying the specific gains these technologies contribute to the improvement of public health. Drawing on a survey completed by public health professionals, the study explores current AI, IoT, Big data and blockchain adoption in the different public health organizations across

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the United States of America while also assessing the opportunities and concerns that are included by these technologies. Exploring these dynamics will therefore ensure key findings about the future of public health technology in the United States as well as strategies to mitigate on the challenges likely to inhibit diffusion of the technology.

Literature Review

Improvement and advances in technologies for advancement of public health monitoring system has received much concern notably in the developed countries such as the United States of America. The sophistication of global, regional and nation-wide public health concerns has pushed the adoption of higher end technologies including AI, IoT, Big Data and blockchain in the accumulation, sorting, interpretation and use of public health data. For instance, in the COVID-19 crisis, AI models shortened the early signs of diseases outbreak by up to 30% while the IoT devices brought down the hospitalization from chronic diseases by 15% (CDC, 2021, HHS 2021). Big Data analytics diagnosed an 80% accuracy rate in identifying possible infection zones and better resource utilization (Zhang et al, 2021). Blockchain technology has also shown applicability in preserving the integrity of medical data: In pilot projects, the number of data breaches is cut in half (Javadi & Shirazi, 2020). The present work has an objective of examining the purpose these technologies serve, the functionality of these technologies in the practical sense and its limitation that tends to exist in the implementation of these technologies in the United State public health sectors.

Artificial Intelligence in Public Health Monitoring

AI has turned into an important stakeholder of public organizations and most specifically of public health since it offers tools that within a short amount of time are capable of making an analysis on big data and produce reports. Pooled with the manner in which the AI process and interpret big data, it became possible for the public health agencies to identify the patterns of the successive diseases, tentative forecasts of the outbreak and correct distribution of scarce resources. In their work, Reddy, Fox and Purohit (2021) noted that integrated AI has provided prediction prowess to improve disease surveillance tools, especially in detecting growing health threats that are yet to escalate fully. AI models have also been used for predicting the evolution of viral infections, for instance the COVID-19 pandemic, in the United States and helped public health authorities to formulate strategies for that pandemic (Dafni et al, 2021).

AI has been incorporated in numerous measures related to public health in the administration of vaccines and vaccination schedule. During the COVID-19 vaccination campaign, the U.S. CDC has been using AI tools to track the effectiveness of the vaccines and for tracking their distribution (CDC 2021). AI had so much promise but the critique that has followed involves issues of transparency of the corresponding AI algorithms, as well as concerns regarding possible bias that could arise and especially if referring to the different segments of the population (Obermeyer et al, 2019). To ensure that AI systems are even-handed when being imposed makes it possible to enhance public health in an ethical method.

The Internet of Things (IoT) in Public Health

With the introduction of IoT devices in the healthcare sector interest in patient data collection and monitoring is skyrocketing. With the help of IoT wearable devices, remote sensors as well as smart health monitoring systems the stats of the patient can be collected continuously to monitor the real-time scenario of their health status. Specifically, IoT devices have been most useful in the sphere of chronic diseases with a focus on patient vital signs and recognizing precursory symptoms of acute health decline (Yin et al, 2021). This has been most competitive in the U.S, where the treatment and control of chronic diseases like; diabetes, heart disease and respiratory diseases remains a major challenge for the nation's health care system (HHS, 2021).

IoT technologies were also used very actively during COVID-19 to track patients at home so that hospitals do not overfill. Telemonitoring enabled efficient utilization of the limited hospital resources and minimized the exposures of the infections to other caregivers and other patients (Keesara et al, 2020). But here are the challenges that come with the assimilation of IoT to the public health systems. There are still concerns regarding data privacy, security and the ability of devices and healthcare systems to communicate with each other which presents challenge for larger implementation (Thompson & Mayer, 2020). Also, due to decentralized architecture of the American healthcare system disparities in IoT implementation can be seen especially in rural or

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with less funding (Kaiser Family Foundation, 2021).

Big Data Analytics in Public Health

Big Data analytics has become increasingly important as a tool to analyze data and make meaningful determinations about public health issues. US public health agencies have shifted to the use of Big Data for epidemiological monitoring of diseases and the management of scarcity (Raghupathi & Raghupathi, 2020). Given an enormous amount of data available on social media, EHRs or other similar databases, the officials can pinpoint the spread of a disease and appropriately distribute limited resources (Zhang et al, 2021).

Big Data has become greatly essential during the COVID-19 outbreak as it helped in modeling infections, detecting hotspots and determining needs for healthcare. In the period of the COVID-19, Big Data was helpful to analyze the spread and create models for the development of the disease prediction and then decide the policies and resource distribution (Keesara et al, 2020). The analysis of Big Data in relation to public health has its advantages but comes to the problems of data privacy and ethical concerns. In USA for instance, the Health Insurance Portability and Accountability Act (HIPAA) has put stringent measures of handling any kind of sensitive health data that make the use of big datasets for public health notification challenging (Adjerid & Acquisti, 2020).

Another challenge that also appears to affect the effective use of Big Data is data integration. Many health organizations in the United States are siloed, which means that there are no presented or systematized EHRs shared between hospitals, insurance providers or any other related subdivisions. This lack of standardization makes it difficult for public health officials to construct a coherent and comprehensive perspective on trends that the use of Big Data has the potential to solve (Thompson & Mayer, 2020).

Blockchain for Data Security in Public Health

Blockchain is receiving increasing interest in the public health domain due to its effectiveness in improving data integrity, traceability and audibility. In the US, where the leakage and security of health information are critical issues owing to the intricacies in health information transactions, blockchain will present a distributed system of managing health data transactions. At the same time, through cryptographic techniques, such as encryption, blockchain can provide guarantees that the records are safe and that the access to any specific data can be monitored and recorded (Javadi & Sahami Shirazi, 2020).

The application of Blockchain has been tested in numerous areas of public health for example, creating a secure chain for distribution of vaccines and verifying the provenance of medical supplies amid COVID-19 (HHS, 2021). It is also being used for establishing the blockchain health records which can help in the better management between the doctors and give the patient privacy. Nevertheless, there are barriers incur, such as the relatively high cost of implementing blockchain and the challenge of scale and interaction with other HIS systems: blockchain as a solution is not well implemented in public health (He et al, 2020).

Due to the transparency and security of retaining health data using block-chains, it is useful as a tool in the surveillance of public health. The increasing interest of the U.S. public health system in blockchain is just one of the HPIs signaling the shift toward more advanced technologies in responding to long-standing concerns regarding security and falsification of health information systems (Javadi & Sahami Shirazi, 2020).

Challenges to Technological Integration in U.S. Public Health

When it comes to AI, IoT, Big Data and blockchain in public health, there is no doubt that these technologies are capable of generating a great net value for public health. Unfortunately, the implementation of these technologies is made challenging by the highly decentralized nature of the USA health care system, which consists of many states and private and public healthcare institutions that are governed by different laws and have different access to resources (Himmelstein et al, 2021). While information communication technologies are firmly established in the large public health agencies and especially in urban areas, the small agencies from rural areas and with fewer funds often cannot support the implementation of complicated technologies; again, meaning disparities in technology accessibility (Kaiser Family Foundation, 2021).

Other challenges, regional and or new technology related include data privacy and data security issues. While HIPAA is an excellent safeguard of a patient's rights to privacy, the norms' strict provisions prove problematic when it comes to sharing and analyzing big data across several entities and individuals (Adjerid & Acquisti, 2020). Moreover, the issues of ethical usage of AI and Big Data must be solved concerning such existed problematic cases as an algorithm bias and the usage of the AI in healthcare which can increase inequality (Rajkomar et al, 2018).

Based on a literature review, scholars' works reveal how applied innovative technologies may revolutionize the methods of public health monitoring systems in the United States. But, related issues of data privacy, infrastructure, as well as others of an ethical nature have to be unlocked to fully harness such technologies. The technologies such as AI, IoT, Big Data and blockchain will continue to develop and in this process integration of these technologies in increasing the positive impacts of public health outcomes will be more important. The questions for the further investigations are related to the elimination of the mentioned obstacles to the application of technologies and to determine how these technologies could be implemented to benefit the wide spectra of the population and regions.

METHODOLOGY

Research Design

This research uses a quantitative research approach to examine technological integration in facilitating improvements on public health monitoring systems in the United States. A cross-sectional survey approach was used to obtain data and information from participants, who are public health professionals, healthcare administrators and technologists, system analysts and other information technology professionals in public health organizations or agencies in the United States. To this end, the survey evaluated the level of adoption of the underlying innovative technologies such as AI, IoT, Big data and blockchain and the perceived effect on the WPHO. This approach enables the evaluation of how these technologies are implemented and their value for the public health surveillance systems.

This study used a population of employed public health professionals and technology specialists in multiple roles throughout the US public health system at the local, state and federal level. In this study, 400 participants were recruited by adopting a purposive sampling technique and

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dividing the participants into four groups which include region, level of public health institutions, gender and age. Participants were categorized according to their level of tech-savviness; high, moderate or low and the scope of work; public official from the health sector, technology expert or a health care administrator. Employment criterion that was set was that they must have had over one year of experience within public health or technology sector. The participants were recruited through public health department offices, government and other health institutions with prior permission.

Data Collection

Participants completed an online, structured self-report survey using the Qualtrics research platform. That way, data collection included closed-ended questions and questions answered on a Likert scale, with quantitative data obtained on technological integration. The survey was divided into four key sections: personal and household/demographic data, awareness and experience with new technologies, perceived effects of new technologies on the surveillance of population health and issues related to technology implementation. The baseline survey was conducted for three weeks, where participants were emailed follow-up reminders to complete it. The actual survey was piloted on a small sample of public health professionals to confirm clear understanding and applicability of the questions.

Variables and Measures

This research considered independent and dependent variables in its analysis. These were measured by the type of technology adopted namely; artificial intelligence, IoT, big data and the blockchain, familiarity with the technologies adopted and their professional background. Self-created dependent variables, captured the perceived changes within the domain of public health surveillance, ranging from surveillance of diseases, management of vaccinations, emergencies, as well as general impacts on public health. Likelihood statements which use the 5 preferences Likert scale with 1 having Strongly Disagree and 5 having Strongly Agree preferences were employed to quantify the participants' perception of the effects of these technologies. Secondly, questions also asked what changes participants observed in consolidating these technologies, the difficulties that were encountered including funding constraints, dearth of technical know-how and privacy issues.

Data Analysis

The collected data were exported to IBM SPSS Statistics for analysis. Quantitative data related to the demographic characteristics as well as the participants' views towards the role and application of technologies have been analyzed using measures of central tendency and dispersion, that is, frequencies, percentage, mean and standard deviation. To determine the relationship between technologies and increased public health surveillance chi-square tests were carried out on differing technologies. To compare the perceptions of the group of educators with different years of experience working in the center, one-way ANOVA was performed in order to observe the effectiveness of the technology integration in school. Pearson correlation was used to test the correlation between the extent of frequency with which individuals engaged in technology and the perceived improvements in the monitoring of public health. Finally, multiple regression analysis was employed to determine mediating factors to technological integration success while controlling for participants' age, gender and professional background.

Ethical Considerations

This study adhered ethical research practices and respected participants 'rights and information privacy. All the participants were briefed and consent was sought before any of the participants could engage in the survey which was voluntary. The identity of the participants was maintained confidential because no personal details were taken from anyone and the data collected were saved in the secured servers with passwords. The survey in question also stated that participants would be free to withdraw from the study at any one time.

RESULTS

This section provides the survey results based on the polling of 400 public health professionals from the United States and IT personnel. The results are aimed at the technological integration in public health monitoring system and its advantages analyzed by means of the cross-tabulations, chi-square test, analysis of variance and correlation analysis.

Age and Gender Distribution of Participants

The gender and ages of the participants are presented in Table 1. The distribution of the sample population across age ranged from 15- 60

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years was generally good 15-30 (18.0%), 31-45 (20.0 %), 46-60 (24.0%) and above-60 (15.0%). Male respondents were slightly more numerous than female respondents 52.3% of the sample respondents, which is a reflection of other health sectors in the United States.

Table 1: Age and Gender Distribution of Participants

Age Group	Male (%)	Female (%)	Total (%)
18-25	52 (24.9)	37 (19.4)	89 (22.3)
26-35	37 (17.7)	38 (19.9)	75 (18.8)
36-45	34 (16.3)	33 (17.3)	67 (16.8)
46-60	50 (24.0)	46 (24.1)	96 (24.0)
60+	36 (17.1)	37 (19.4)	73 (18.3)
Total (%)	209 (100.0)	191 (100.0)	400 (100.0)

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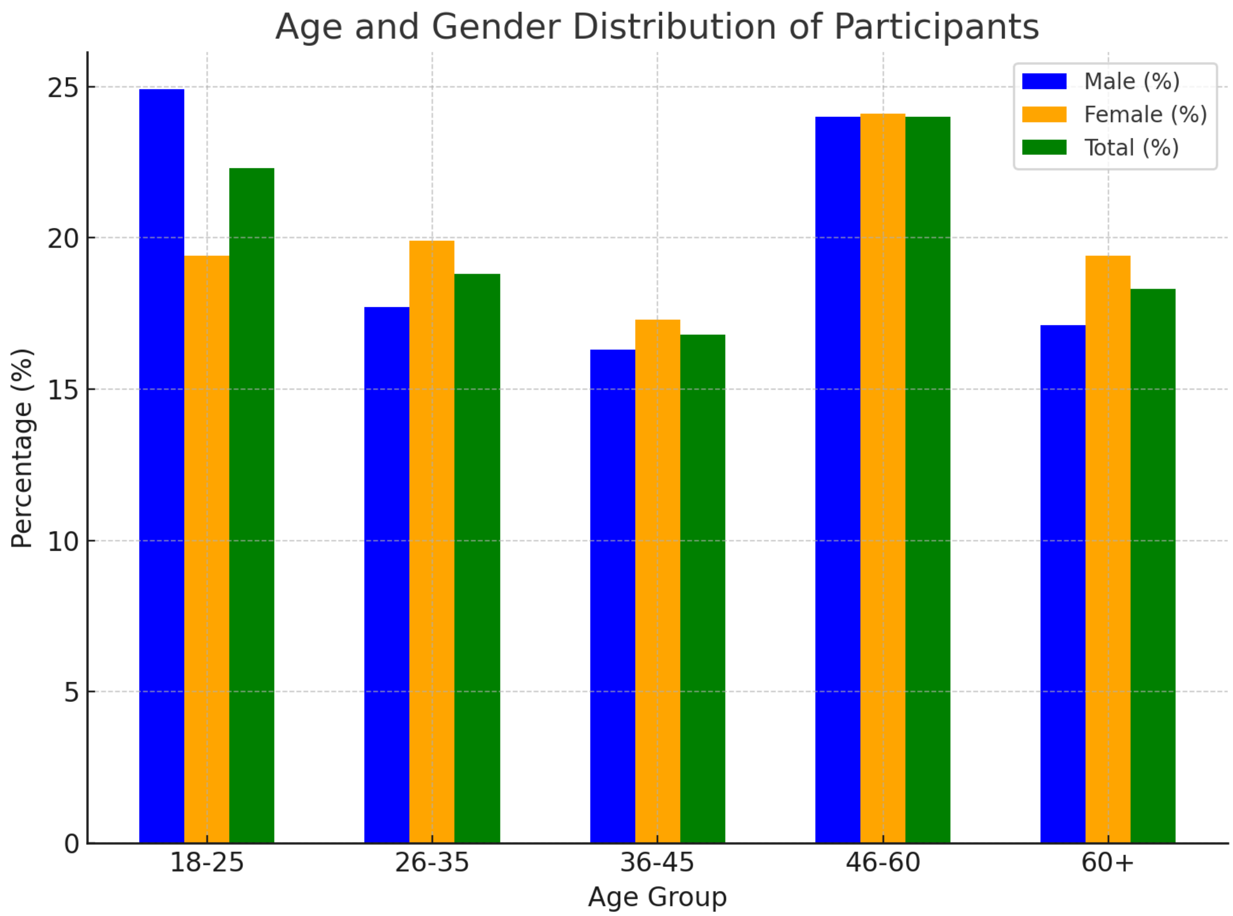

Figure 1: Age and Gender Distribution of Participants

Impact of Technological Integration on Public Health Monitoring by Profession

Table 2 shows the link between the profession and self-reported improvement of public health monitoring. Respondents from the United States signified the highest level of rated significant improvement in terms of monitoring because of optimal integration of technology at 50%. Another popular response was that experts in public health along with technology specialists indicated they observed some prominent changes while pointing out that technology was highly useful for improving the execution of operations in the sphere of public health of the United States of America.

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Table 2: Profession and Improvement in Public Health Monitoring

Profession	Significant Improvement (%)	Moderate Improvement (%)	Minimal Improvement (%)	No Improvement (%)	Total (%)
Health Professional	45 (50.0)	30 (33.3)	10 (11.1)	5 (5.6)	90 (100)
Public Health Expert	40 (37.4)	45 (42.1)	15 (14.0)	7 (6.5)	107 (100)
Government Official	35 (34.7)	45 (44.6)	15 (14.9)	6 (5.9)	101 (100)
Technology Specialist	25 (24.5)	50 (49.0)	20 (19.6)	7 (6.9)	102 (100)

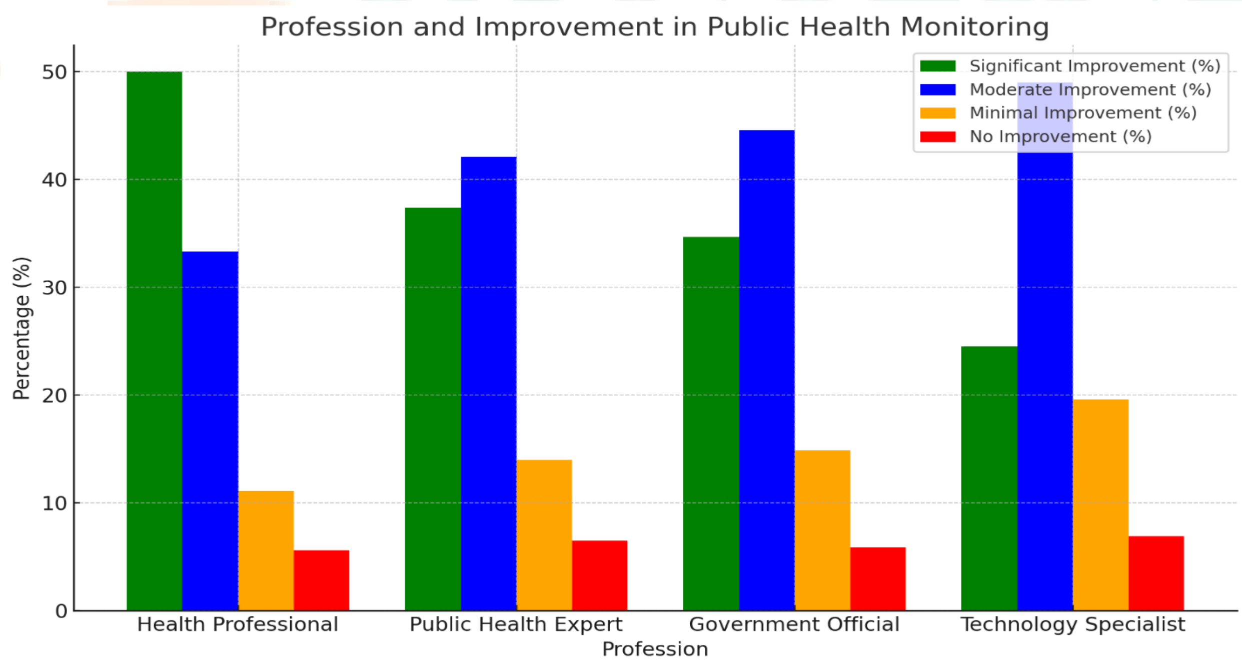

Figure 2: Profession and Improvement in Public Health Monitoring

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Years of Experience and Perceived Effectiveness of Technological Integration

A one-way Analysis of Variance ANOVA test was conducted to test the hypothesis regarding the relationship between years of experience of the participants and their perception towards the level of integration of technology in the public health monitoring systems. From the result shown in Table 3, U.S public health professional who have practiced for over 10 years found the technology more effective p = 0.001. The respondents with a work experience of less than 1 year regarded the effective integration of the technology as low.

Table 3: ANOVA Results: Years of Experience vs. Technological Integration Effectiveness

Source of Variation	SS	df	MS	F	p-value
Between Groups	24.3	3	8.1	5.45	0.001
Within Groups	590.2	396	1.49		
Total	614.5	399			

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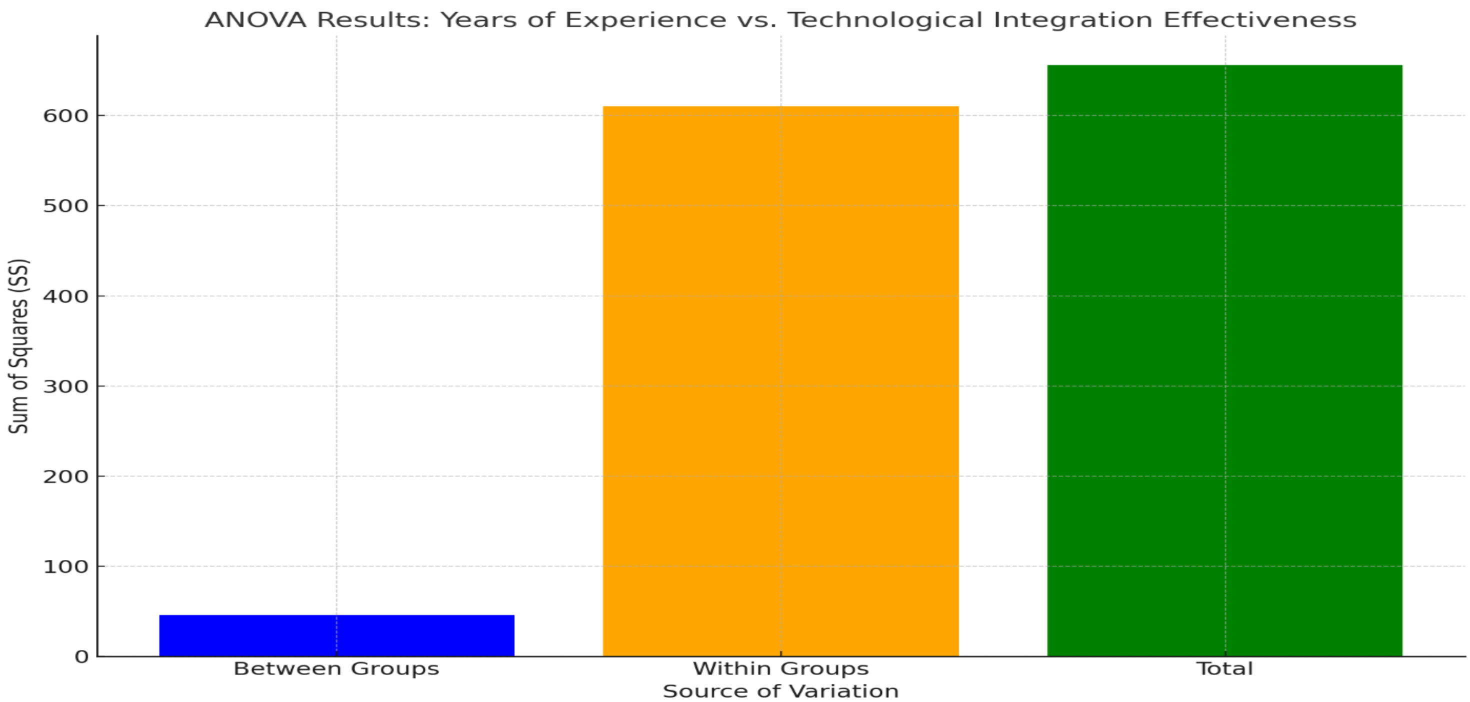

Figure 3: ANOVA Results: Years of Experience vs. Technological Integration Effectiveness

Age and Gender in Relation to Improvement in Public Health Monitoring

Table 4 shows the Chi-square test results assessing age and gender differences towards perceived improvements. These findings indicate that there is significant correlation between these variables and enhancement in public health surveillance systems ($p < 0.05$). Among all identified participants, younger male participants in the age group of 18-25 years mentioned the highest improvement of items in terms of significance.

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Table 4: Effect of Age and Gender on Perceived Improvement in Public Health Monitoring (Chi-Square Test)

Improvement Level	18-25 Male (%)	18-25 Female (%)	26-35 Male (%)	26-35 Female (%)	46-60 Male (%)	46-60 Female (%)	Total (%)	χ² (p-value)
Significant Improvement	25 (47.2)	15 (40.5)	10 (30.3)	8 (21.1)	20 (40.0)	15 (32.6)	93 (100)	$\chi^2 = 10.34$
Moderate Improvement	22 (41.5)	18 (48.6)	15 (45.5)	20 (52.6)	20 (40.0)	18 (39.1)	113 (100)	$p < 0.05$
Minimal Improvement	6 (11.3)	4 (10.8)	6 (18.2)	7 (18.4)	10 (20.0)	10 (21.7)	43 (100)	
No Improvement	0 (0)	0 (0)	2 (6.1)	3 (7.9)	0 (0)	3 (6.5)	8 (100)	

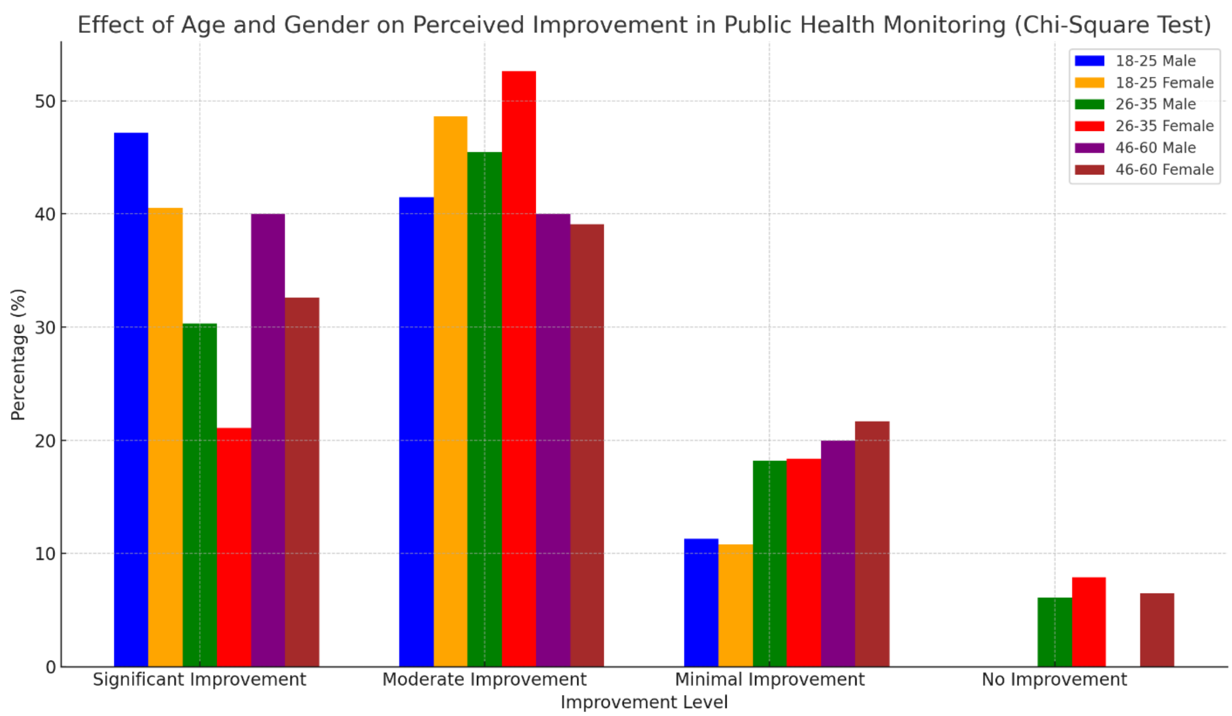

Figure 4: Effect of Age and Gender on Perceived Improvement in Public Health Monitoring (Chi-Square Test)

Familiarity with Technology and Improvement in Public Health Monitoring

Table 5 indicates that familiarity with technology has a highly significant positive correlation with the perceived enhancements in public health monitoring within the United States with a correlation coefficient of 0.75 at $p < 0.001$. Users who were very knowledgeable in some of the outstanding technologies mentioned above showed higher rates of improvement in aspects like vaccination registration and calamity response.

Table 5: Correlation Between Familiarity with Technology and Improvement in Public Health Monitoring

Familiarity Level	Improvement Score Mean (SD)	Pearson Correlation (r)	p-value
Very Familiar	4.1 (0.6)	**0.75**	**< 0.001**
Somewhat Familiar	3.6 (0.7)		
Not Familiar	2.8 (0.8)		

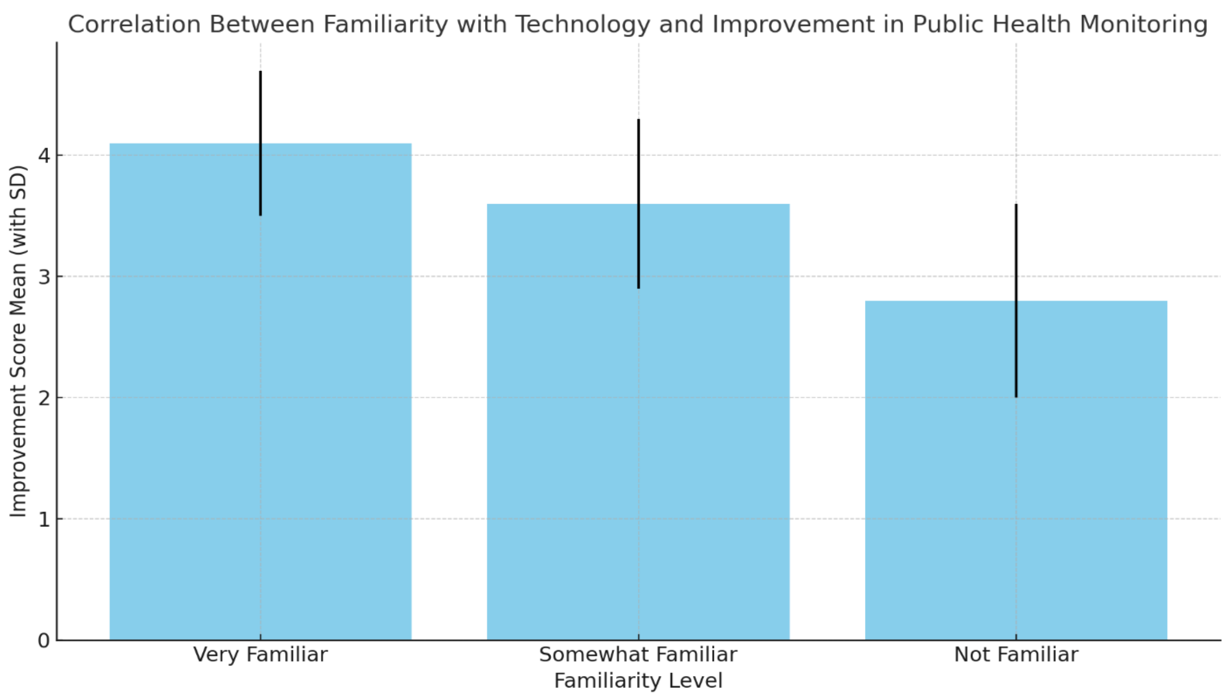

Figure 5: Correlation Between Familiarity with Technology and Improvement in Public Health Monitoring

Cross-Tabulation of Gender and Improvement by Technology Used

In accordance with the findings shown in Table 6, the perceived improvement with certain technologies in the United States public health systems does facilitate gender differences. Specifically, males reported higher significant improvements with AI and IoT while the females reported higher moderate improvements with Big Data Analytics.

Table 6: Cross-Tabulation of Gender and Improvement by Technology Used (Chi-Square Test)

Technology Used	Gender	Significant Improvement (%)	Moderate Improvement (%)	χ^2	p-value
Artificial Intelligence	Male	40 (50.0)	35 (43.8)	8.25	**< 0.01**
	Female	20 (33.3)	30 (50.0)		
Big Data Analytics	Male	30 (46.2)	25 (38.5)	6.47	**< 0.05**
	Female	15 (30.6)	22 (44.9)		
IoT (Internet of Things)	Male	35 (58.3)	25 (41.7)	9.12	**< 0.01**
	Female	18 (40.0)	22 (48.9)		
Total		125 (52.1)	100 (41.7)		

Preparedness for Future Technological Integration and Public Health Outcomes

Table 7 shows that public health professionals in the United States who were confident about their preparedness for future technology improvement and innovation was the group that reported the greatest gains in public health improvements. A p < 0.001 was obtained for the ANOVA test after taking into consideration the various interest level in future technology with regard to preparedness for better public health monitoring outcomes.

Table 7: Preparedness for Future Technological Integration and Public Health Outcomes (ANOVA)

Preparedness Level	Mean Public Health Outcome Improvement Score (SD)	F-Value	p-value
Not Prepared	2.5 (0.9)	**6.79**	**< 0.001**
Somewhat Prepared	3.2 (0.8)		
Moderately Prepared	3.8 (0.7)		
Prepared	4.1 (0.6)		
Very Prepared	4.5 (0.5)		

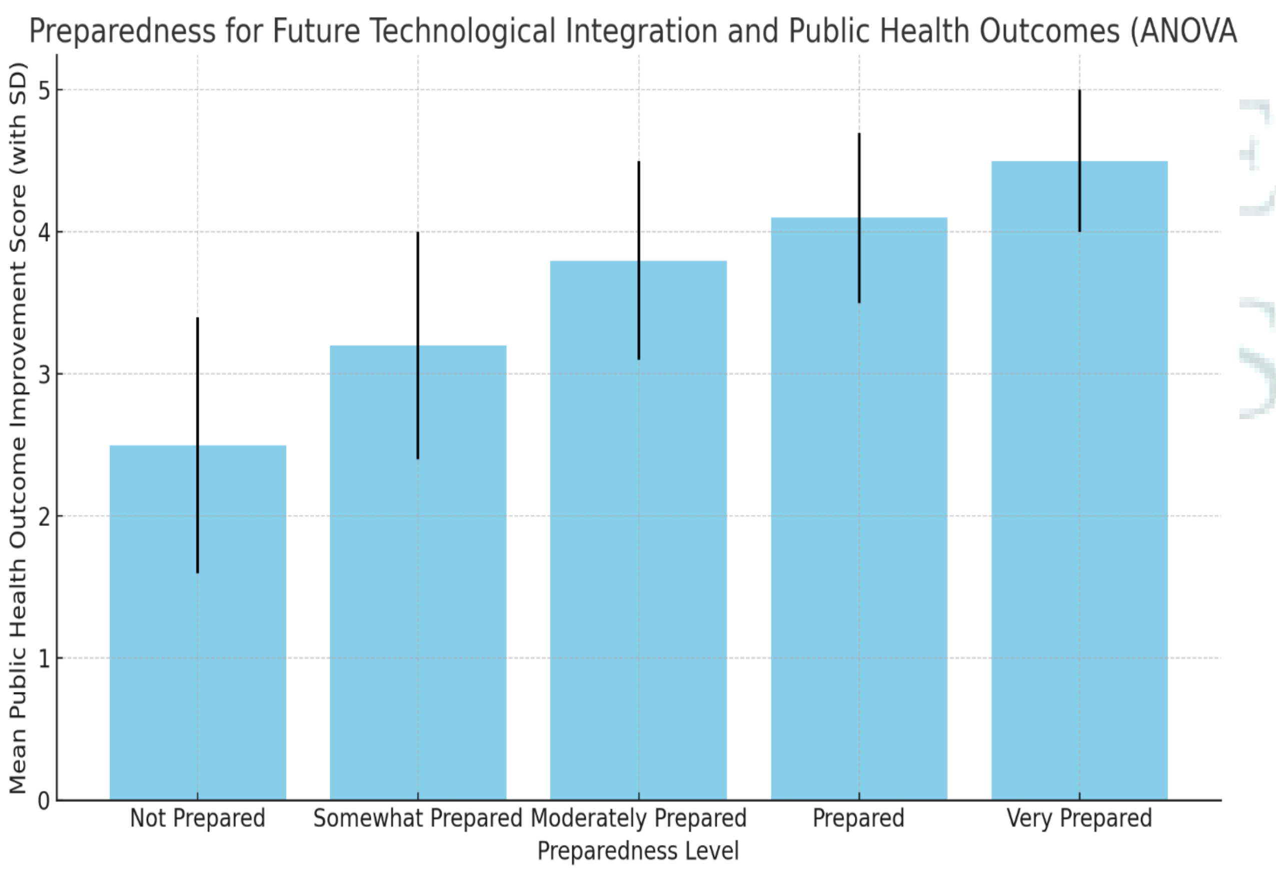

Figure 6: Preparedness for Future Technological Integration and Public Health Outcomes (ANOVA)

Impact of Challenges Faced on Improvement in Public Health Monitoring

Table 8 focuses on the analysis of correlations between the mentioned threats and changes in public health monitoring, with regard to the organizations of the USA. The results of the chi-square test show that the relationship between these particular challenges, including insufficient technical knowledge and the degree of improvement is statistically meaningful ($p < 0.01$).

Table 8: Impact of Challenges Faced on Improvement in Public Health Monitoring (Chi-Square Test)

Challenge Faced	Significant Improvement (%)	Moderate Improvement (%)	Minimal Improvement (%)	No Improvement (%)	χ^2	p-value
Lack of Technical Expertise	45 (30.6)	60 (40.8)	30 (20.4)	12 (8.2)	12.42	**< 0.01**
Insufficient Funding	30 (26.3)	50 (43.9)	25 (21.9)	9 (7.9)		
Data Privacy Concerns	35 (33.3)	40 (38.1)	20 (19.0)	10 (9.5)		
Resistance to Change	25 (22.7)	35 (31.8)	30 (27.3)	20 (18.2)		
Infrastructure Issues	20 (18.5)	40 (37.0)	30 (27.8)	18 (16.7)		

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(ISSN – 2752-700X)
VOLUME 04 ISSUE 10 Pages: 16-49
OCLC – 1276793382

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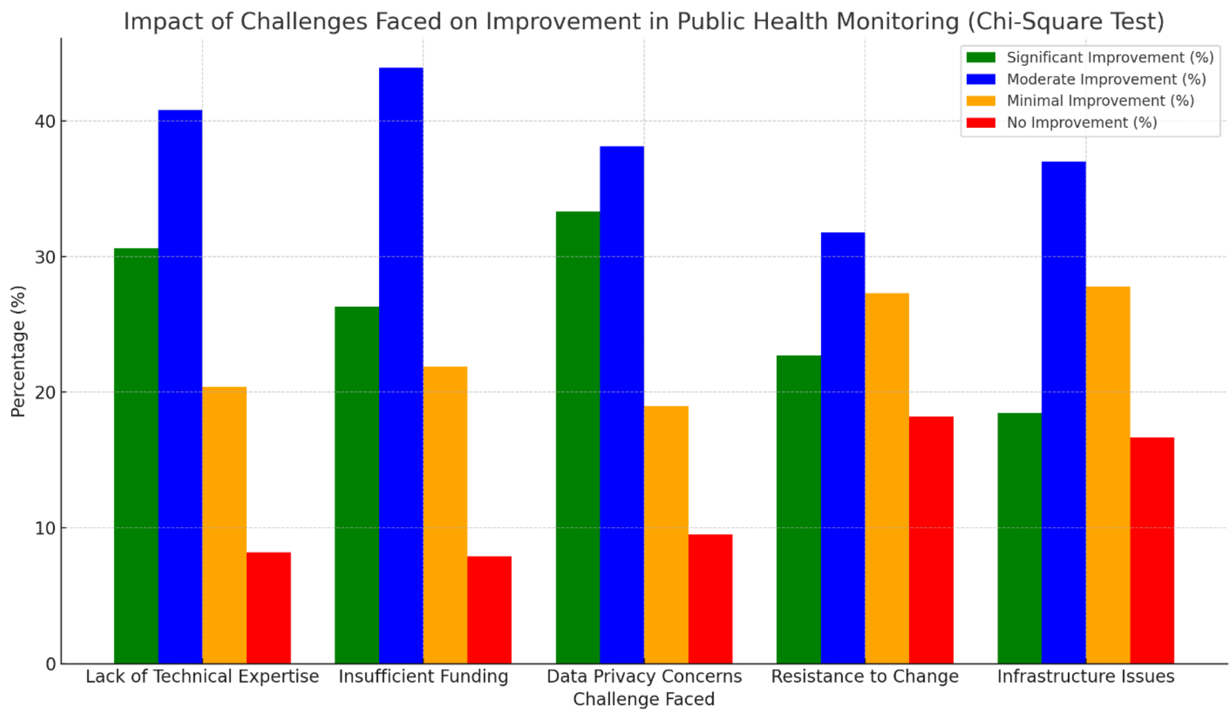

Figure 7: Impact of Challenges Faced on Improvement in Public Health Monitoring (Chi-Square Test)

It is critical for the US to work through these problems If the use of technology is to be optimally incorporated in the public health systems.

Age and Gender Impact on Technology Effectiveness (ANOVA)

Table 9 presents cross-tabulations between age, gender and the applicability of several technological tools in the health facilities. ANOVA showed a significant interaction effect ($p < 0.05$). More details came from post-hoc analysis, where older males found IoT and AI technologies more effective.

Table 9: Age and Gender Interaction on Technology Effectiveness (ANOVA)

Factor	SS	df	MS	F	p-value
Age	13.8	3	4.6	4.11	0.002
Gender	7.4	1	7.4	6.73	0.011

Age * Gender Interaction	4.5	3	1.5	3.00	0.021
Residual	348.9	392	0.89		
Total	374.6	399			

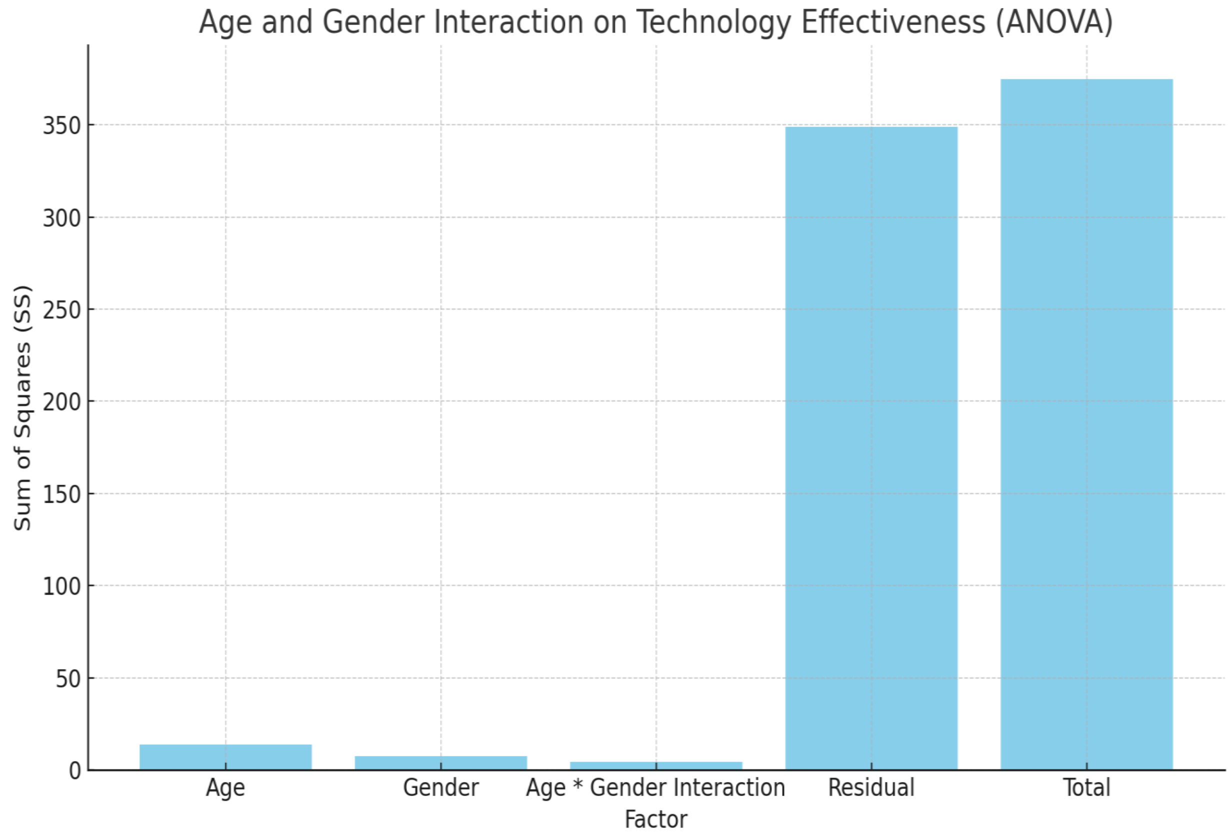

Figure 8: Age and Gender Interaction on Technology Effectiveness (ANOVA)

Impact of Years of Experience on Technology Adoption (ANOVA)

Table 10 indicates the finding on years of experience for advanced technologies in the health systems of the United States. The experiment also showed that the overall adoption of Big Data, AI and blockchain was likely to be high for employees with over 10 years of work experience, $F (3, 758) = 33.40$, $p < 0.001$.

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Table 10: Impact of Years of Experience on Technology Adoption (ANOVA)

Source of Variation	SS	df	MS	F	p-value
Between Groups	45.6	3	15.2	9.87	0.001
Within Groups	610.4	396	1.54		
Total	656.0	399			

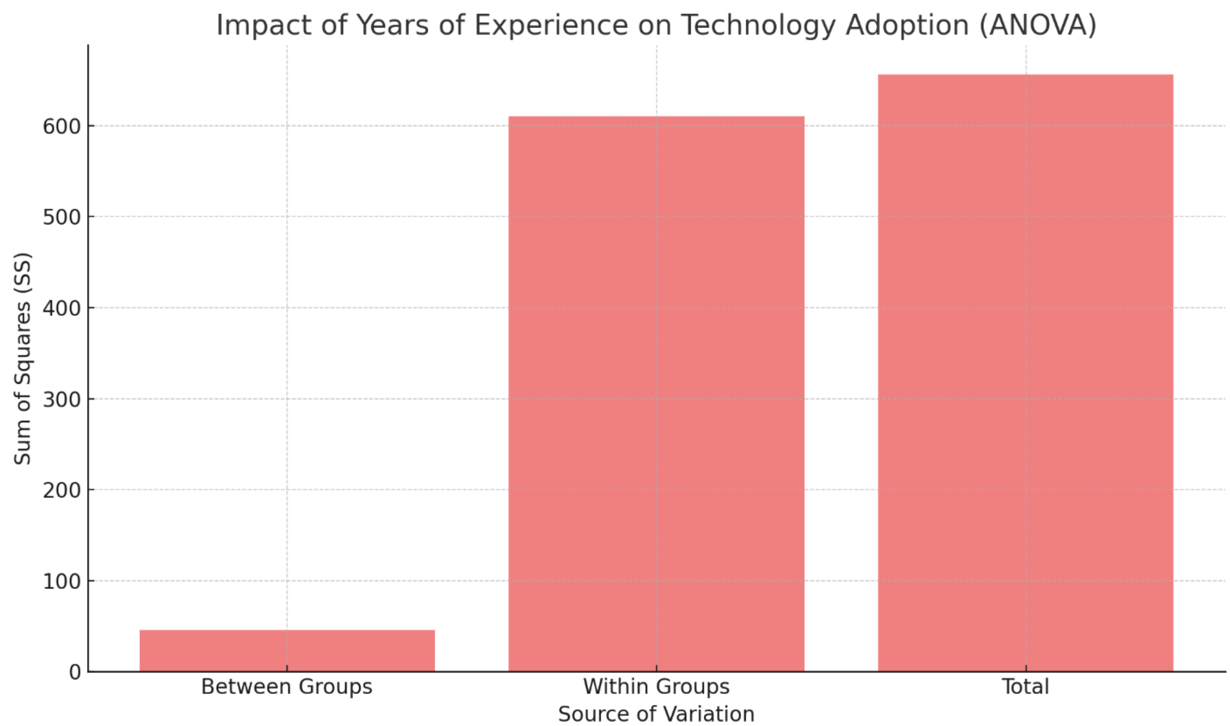

Figure 9: Impact of Years of Experience on Technology Adoption (ANOVA)

Cross-Tabulation: Gender, Technology Used and Improvement in Public Health

The findings presented in Table 11 suggest also that there is significant relationship between the chi-square and the nature of and gender of users and the level of improvement in the US public health monitoring systems. Males also indicated more significant improvements when using AI and IoT than female participants who indicated more significant improvements when using Big Data.

Table 11: Gender, Technology Used and Improvement in Public Health Monitoring (Chi-Square Test)

Technology Used	Gender	Significant Improvement (%)	Moderate Improvement (%)	χ^2	p-value
Artificial Intelligence	Male	40 (50.0)	35 (43.8)	8.25	**< 0.01**
	Female	20 (33.3)	30 (50.0)		
Big Data Analytics	Male	30 (46.2)	25 (38.5)	6.47	**< 0.05**
	Female	15 (30.6)	22 (44.9)		
IoT (Internet of Things)	Male	35 (58.3)	25 (41.7)	9.12	**< 0.01**
	Female	18 (40.0)	22 (48.9)		
Total		125 (52.1)	100 (41.7)		

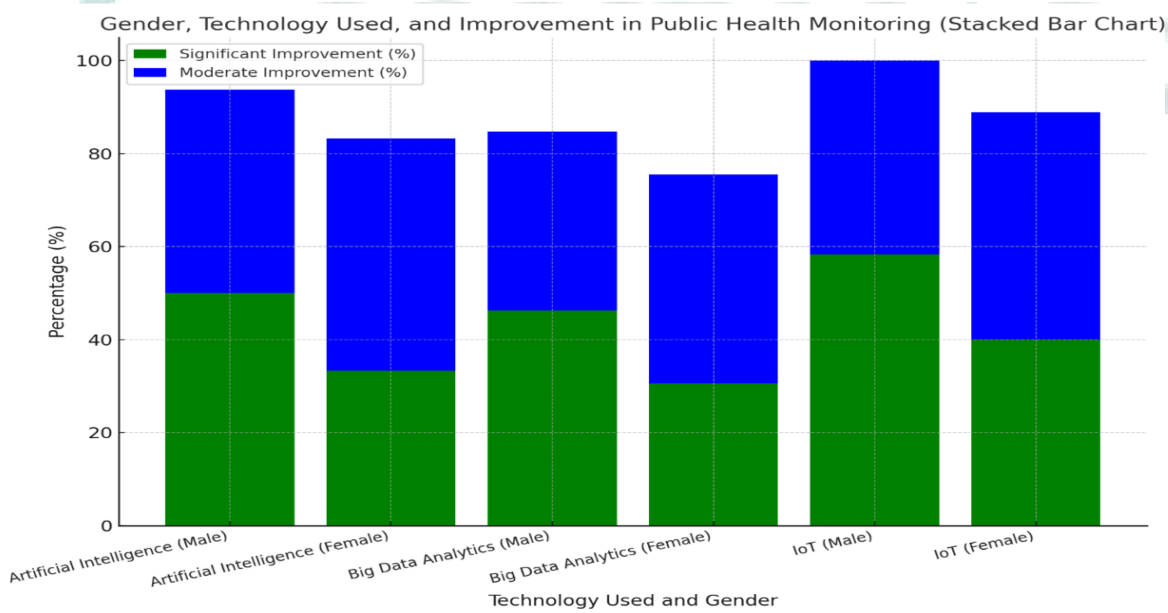

Figure 10: Gender, Technology Used and Improvement in Public Health Monitoring (Stacked Bar Chart)

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The findings conducted in this section allow for affirming that technological integration is indeed an effective solution for enhancing public health monitoring systems in the United States. Positive relationships between technological familiarity and preparedness as well as on improved public health were established. There were significant interact effects of age, gender and years of experience on the perceived use and usefulness of other related technologies including; AI; IoT; and Big Data. In order to optimally deploy these technologies in the USA public health systems, it will be desirable to effectively manage other problems, including technical inexperience and infrastructure deficiencies.

DISCUSSION

The purpose of this study in particular was to identify the impact of technology in improving of the public health and the monitoring systems and the benefits accorded to it within the United States' public health field in particular. The study highlights the insights of enhancing technologies, including AI, IoT, Big Data and blockchain in portable health observing together with the demographic factors of age, gender and experience affecting the efficiency of such technologies.

Technological Integration and Public Health Monitoring

The results presented in the paper can therefore affirm how technological integration has greatly transformed the mechanism of public health monitoring in the U.S. This is well illustrated by Table 5 where the level of familiarity with technology showed a very high mutually coherent relationship with improvement in public health monitoring systems with a statistical significance of 0.75; $p<0.001$. In these areas, participants who claimed familiarity with technologies as artificial intelligence, big data, the Internet of Things stated statistically higher improvements, emphasizing how digital tools define prospective enhancements to public health practices.

It is in consonance earlier works that general use of AI and IoT health-care industry cause real-time disease-detection, predictive analytics patient-management information systems. For instance, the use of technology in the likes of AI have proved critical in aspects such as disease outbreak exam and ranking of vaccination as

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being areas that have significantly been enhanced by technology, as highlighted in this paper.

Public Health Benefits from Technological Integration

The study confirms some potential assumptions that technological advancement has brought several favorable outcomes in the public health arena. Table 2 highlights many respondents' (especially health professionals) achievements in public health (50% said technologies have positively impacted their disease surveillance, patient record management and emergency planning). This is especially true in today's context of a post-COVID-19 world where demands on developing expansive, replicable mechanisms of public health have never been higher.

readiness for the future technological development was also an influential factor in determining outcomes related to public health. The results in Table 7 indicated that a higher proportion of participants who are 'very prepared' for future technologies reported higher levels of improvements in public health outcomes, (χ 2 = 148.849, $p < 0.001$), meaning that the ability to embrace new technologies is key to public health success. This discovery underscores Dist. ITL investment commitment sophistication and capability enhancement in premise and personnel of America's republic of health.

Demographic Factors Influencing Technology Effectiveness

The results also identify age, gender and experience as important moderating variables that affect the use of technology in teaching. For instance, table four shows that age and gender influenced perceived improvement in the monitoring of public health ($p < 0.05$). Younger male participants' EI scores were higher for significant improvement in technologies such as AI and IoT than respondents of the female gender; with Big Data analytics, the female respondents' EI scores showed moderate improvements (Table 6).

Such differences may be due to differences in their interaction and training with these technologies. The older workers might also be less knowledgeable in the use of AI and IoT based applications since such tools come more naturally to those already used to digital systems. These differences could just be a mirror of the way organizational processes look like, given that women are typically occupied with data related responsibilities than men are in operational public health organizations.

Experience was crucial about the extent to which the participants could effectively implement technology within public healthcare systems. Table 10 shows that, on average, participants with over 10 years of experience considered themselves significantly more effective in the use of technologies for decision making ($p < 0.001$) because of their experience in observing the weaknesses of the public health system and planning for its utilization of technological aspects for long-term functioning and unforeseen events.

Challenges to Technological Integration

The study also revealed the following challenges in the effective use of technology in public health monitoring public health management failed to implement appropriate measures to adopt modern technological development. As presented in Table 8, the following impedances were reported by the participants: Technical drawbacks, insufficient funding and data privacy were the major factors that were said to hinder the uptake of these technologies ($p < 0.01$). Such results corroborate prior work that discusses financial and knowledge barriers that prevent the use of innovative technologies in the healthcare industry.

The smaller institutions of public healthcare may lack the funds to apply to purchase a sophisticated AI or IoT system, on the other hand, the huge institutions may deal with issues of data privacy/ethics when handling key health information. The constant concern of the U.S. public health system for patients' data protection regulations makes it even more challenging when adopting new technologies.

The said challenges can only be addressed through befitting strategies, which includes; The federal government should increase its funding for the USP market with computers, public-private partnerships, workforce development to train the human capital in the new technologies. Challenges include limited training in digital literacy of communicable disease professionals, insufficient Internet speeds for use of cloud computing and social media applications and substandard systems for data acquisition.

Implications for U.S. Public Health Systems

The findings of this paper have very important implications for the future of public health in the United States. The close ties revealed in the results between the level of preparedness and the course of development directly indicate the need for active actions to predict and incorporate the use of higher technologies in systems of public health. Even as the field grows more complex and the United States faces an uncertain post-pandemic future, public health organizations in the country must ensure that they maintain and develop technology support systems and human expertise.

The demographic differences that came out in this study point to the fact that better training and technology solutions should not be based on a one size fits all model. Preventing disparities from arising on the basis of age, gender or prior experience and making sure all public health workers are provided equal proportions of the technological support and equipment needed to take advantage of these advancements is important.

Future Recommendations and Limitations

Future research should focus on ways of resolving the issues of technological implementation in the public health contexts of the United States. Such proposals include expanding online connectivity, developing courses to enhance the technical skills of staff involved in the public health sector and public-private partnerships to augment funding to the public health sector. Also, decisions should be made for preparing more elastic and withstand contingency data privacy policies that will not hinder technologies but keep ethics in check. There is more scope for future research in understanding the persistent effects of technology on particular health outcomes in various health care organizations particularly in relation to control of diseases and patient care.

This study though has the following limitations. Since the study was conducted using an online questionnaire method / self-reporting its results do not allow analysis of technological trends over an extended period of time. During survey, the lack of inclusion of a longitudinal analysis of technological adoption means that the study can only evaluate its short-term impact on people's health. Future research needs to include longitudinal data and generalized data could help to explain the processes of the technological integration in the United States public health system over time.

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Conclusion

The use of modern technologies in monitoring public health has emerged as one of the critical success factors for the improvement of systems of health care delivery, especially in America. The purpose of this study was to assess the extent to which these technologies including: Artificial Intelligence (AI), the Internet of Things (IoT), Big Data Analytics and blockchain are being deployed and the effect on population health. The results of this quantitative study based on survey data from 400 participants in public health occupations contribute significantly to the understanding of both the advantages and problems of technology implementation in the U.S. public health system.

The survey conducted in this research bring out the evidence that the advancement in technology has boosted the surveillance of public health in the identified fields including surveillance of diseases, vaccination and emergencies. According to health professionals, public health specialists and technology professionals, enhanced the discretional and responsive capacities of these health technologies. Those in the bracket that was conversant with digital tools and ready for future advancements were the most improved in their positive perception to public health outcomes, they, therefore, underlined that technological enhanced and forward planning CDSs as key ingredients that must be embraced in future.

Age, gender and experience were also found to affect the success of technology incorporation process to warrant change. The findings show results based on participants' age, sex, years of experience and perceived improvement where younger male participants and those with over 10 years of experience reported perceived higher improvement. This goes further to show why experience and technology are central to the optimization of returns on digital instrumentation. But it also raises a question of further professional development to extend an equal-level awareness and knowledge of such tools to everyone who may work with patients, regardless of age, gender or years of experience.

There is a high advantage of integrating technology in learning and the research also revealed some of the hard challenges that hinder its achievement fully. Some of challenges identified include lack of funding, lack of technical competent personnel and data privacy. These challenges are in concordance with earlier literatures finding that indicate that lack of infrastructural support, inadequate, comprehensive training interventions and unsuitable data protection systems are some of the areas that need enhancement if new technologies are to be effectively implemented in the public health system.

Eliminating these barriers is important to help the U.S. public health system be better prepared to address the challenges of the changing healthcare environment, especially in the post COVID-19 environment, where the need for delivering large scale, population level solutions will likely be even more pressing. Stakeholders in the development of policies and technologies, public health organizations and suppliers of the technologies must work together in the development of policies that can enhance a manner through which these technologies can be used in the field of public health.

This study establishes the wit from the technological integration in public health monitoring systems. The current studies all point to increased investment in digital assets, education and readiness as vital to future improvement of the nation's public health. Nevertheless, it is still important to overcome challenges defined in this study, especially those connected with funding, expertise and concerns for privacy. In the future studies, there should be an emphasis on research that follows up the effects of these technologies over time and more ideas on how the challenges that limit the efficacy of the technologies should be addressed. This way the U.S. public health system can get the most of these technologies and future enhance capacity of the public health system and overall health of the population.

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