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Nano-Biosensors for Early Disease Detection: Innovations in Sensitivity and Specificity for Medical Diagnostics

Md Tajul Islam[1], Ali J. Khalaf[2,3], Kolla Bhanu Prakash[4]

[1]Master of Science in Information Technology, Washington University of Science and Technology, Email: ti.metho2012@gmail.com
[2]Radiology Techniques Department, College of Medical Technology, The Islamic University, Najaf, Iraq
[3]Radiology Techniques Department, College of Medical Technology, College of Technical Engineering, The Islamic University of Al Diwaniyah, Al Diwaniyah, Iraq, Email: ali.khalaf@iunajaf.edu.iq
[4]Associate Dean [R&D], Professor, CSE Department, K.L. Deemed to be University, Green Fields, Vaddeswaram-522302, Guntur District, A.P, India, Email: drkbp@kluniversity.in

Purpose: Nano-biosensors are very sensitive and selective medical diagnostic tools, on the same note, the integration of the nano-biosensors in the clinical setting is faced with several challenges. The study aims to determine other factors including age, gender, and education level that influence the participants' attitudes towards nano-biosensors and their recommendation of the same in the heath sector.

Objective: The following are the major research questions of this study: what is the current awareness level of nano-biosensors among the health profession and members of the public, the effect of demographic factors on willingness to accept high sensitivity and specificity of nano-biosensors and what are the factors that may influence recommendation of nano-biosensors for early disease diagnostic techniques.

Methodology: The study adopted an early exploratory quantitative research design, where an online survey with a set of standardized questions was administered to the participants comprising 190 people including Health care workers and members of the general public. Chi-square tests, Spearman correlation, logistic regression and Mann-Whitney U test were used to assess the characteristics of participants about the health outcomes of interest. Results: Therefore, the frequency of recommending nano- biosensors was independent of gender testing which showed a chi-square value of 14. 64 with a probability, p = 0. 066. Spearman's rank correlation also showed that there was no significant relationship between age and perceived importance of specificity ratings (Spearman's rho = 0. 04, p > 0. 05). The professional logistic regression demonstrated low significance of gender and education in the chance of recommending the nano-biosensors, while the logistic regression model shared a marginal part of the changes (pseudo-R-squared = 0. Mann-Whitney U test was employed to compare the perceived importance of sensitivity between male and female respondents, a test that also produced no significant difference (U = 2306. 5, p = 0. 694). From these results, it can be stated that demographic characteristics including gender or age as such do not affect the perceived and recommended nano-biosensors but it is their utility and some other

pragmatic features that play this role.
Practical Implications: The results also indicate that there is a need for designers to target explaining the utility of nano-biosensors which have merits like high sensitivity and specificity to increase its preservation. Strategies to translate nano-biosensors to clinical use must consider issues to do with standardization, sample variability, and expert personnel. Also, the cost of nano-biosensors needs to be as low as possible because the apparatus will likely be used in developing countries.
Novelty: This research is one of the very initial research projects that focuses on the demographic characteristics of nano-biosensors acceptance and recommendation. In this sense, the study contributes useful findings that ideally give statistical estimations of the extent of these variables and whether they are positively or negatively associated with the perceived importance of these advanced diagnostic tools.
Conclusion: Nano-biosensors still a great potential for the new medical diagnostic systems, but their implementation in the clinics we are still awaiting depending on the different technical, educational and economic problems. The understanding of the concept of sensitivity and specificity in the population in general and across the age and sex spectrum creates a firm ground for advocating for the uptake of nano-biosensors towards improving the quality of diagnosis and therefore the care of patients as well as the efficiency of the health system.

Keywords: Nano Biosensors; Disease Identification; Health diagnosing; Sensing; accuracy; technological advancement; health care solutions.

1. Introduction

The application of nanotechnology has affected numerous scientific subdivisions and one of the most potential uses is presented by nano-biosensors for medical diagnostics. Such devices have revolutionized the outlook of conventional biosensors by the incorporation of nanomaterials for the improvement of their sensitivity, specificity and performance. There exists the ability to identify disease biomarkers utilizing nanometer dimensional nano-biosensors which are far superior in terms of detection limits in comparison to the usual diagnostic equipment, of particular importance is the capability of identifying pathological alterations at the earliest stage and, therefore, to achieve better disease management as well as to lessen the healthcare costs (Shivakumar, 2024).

Nevertheless, there are apparent benefits when it comes to employing nano-biosensors in the diagnosis and management of diseases, but their implementation in daily clinical practice is relatively low, the reasons for which are different difficulties in terms of reproducibility, standardization, biocompatibility, and the need for qualified experts to operate with the specified complicated technologies. Considering the valuable information provided by the global burden of disease there is a crucial need in further developing diagnostic methods. Lifestyle-related chronic diseases including cancers, cardiovascular diseases as well as diabetes are on the rise globally with WHO estimating that about 71% of all deaths are a result of NCDs. It is a well-known fact that time is an important component in managing these common afflictions, but typical screening methods do not identify illnesses in their initial stages and subsequently manage to treat them in time (Rather et al., 2024).

For example, disease biomarkers such as glucose, cholesterol or cancer genes present in very low concentrations are an acute solution to this problem, and this is where nano-biosensors come in handy. These sensors could be used to diagnose diseases in their earliest and most accurate stages and therefore could be used to move the emphasis of health care from illness treatment to illness prevention. However, the use of nano-biosensors in clinical environments

is hampered by several monumental hurdles as follows. Among the contemporary problems, one of the most salient is the problem of replicability. Nano-biosensors are known to offer very low signal-to-noise ratios, and this is occasioned by the nature of fabrication methods used in the fabrication process, the kind of nanomaterial that is used as well as the environment where the nano biosensors are to be used as proposed by Jain (Rana, Narang, & Chauhan, 2024).

This inherent variability is a significant challenge to the development of nano-biosensor technologies for the clinic since the standardization of these technologies is crucial for their further application. In the case where nano-biosensors are not standardized, healthcare providers are likely not to put their trust in the technology and hence resist its use. The lack of standardization of the protocols also intensifies the troubles of receiving approvals from the regulatory authorities, which overall slows down the entry of these technologies into the market. Another problem which should be solved to scale up the usage of nano-biosensors in medical diagnostics is the biocompatibility of all the materials used in the construction of nano-biosensors (Das, Mazumdar, Khondakar, Mishra, & Kaushik, 2024).

The incorporation of nanomaterials into biosensors poses certain risks of its contact with biological systems. In addition, the utilization of nanomaterials has several benefits increasing the efficiency of the sensors, at the same time, the small size of the material and its high reactivity can cause unwanted biological effects, including cytotoxicity or inflammation. To date, there have been no conclusive findings on the long-term effects of exposure to nanomaterials and as such, their safety is questionable especially if they are applied in places where they come in contact with body fluids and tissues. Biocompatibility is therefore an important factor in the development of nano-biosensors which means that more studies need to be conducted on the compatibility of the nanomaterials with the biological system in a bid to come up with safer health monitoring devices (Fathima Shadin).

Besides technical barriers, many knowledge and skill barriers need to be overcome so that nanotechnology biosensors can be effectively implemented in healthcare. Nano biosensors are multifaceted and encompassing technologies, based on both the principles of nanotechnology and biology and they depend on an in-depth of knowledge these two fields to be able to exploit the devices and interpret the outcomes of the experiments. Nevertheless, the current development of technologies in this area is progressing at a high rate, leaving behind the majority of healthcare systems regarding training and education provision. This lack of understanding remains a major drawback when it comes to the use of nano-biosensors since healthcare providers are not willing to venture into the use of technologies, they are not familiar with or perhaps were not trained in. This will need interventions in education and more specifically the creation of friendly human-machine interfaces that do not in any way complicate the handling of the nano-biosensors while at the same time being fully functional (Xia, Jiang, Liu, Yin, & Wang, 2024).

The cost of using nano-biosensors is another factor that might hinder their affordability because their development and implementation might be costly, especially for nations and institutions in the low-income bracket. It is widely accepted that there are many advantages such as early detection of diseases but achieving economies of scale for nano-biosensor technologies which might involve considerable costs preliminary to integration. This cost may

be a mirage to many healthcare systems especially those of the developing world due to resource constrains. Finally, it is therefore important to identify ways that can be employed to make nano-biosensors cheap to build, for example through enhancing fabrication processes, using cheaper materials or coming up with mass production techniques. Also, collaboration between the public and private domains may be particularly useful in the financing of nano-biosensors construction and distribution to all the stakeholders requiring them (Bag & Mandal).

Due to the higher accuracy and efficiency in the detection of diseases through nano-biosensors, one has to appreciate the factors that influence their consumption by both the private sector and the public. This research seeks to address this problem as follows: how the demographic factors including age, gender and level of education influence the importance of Sensitivity and specificity in the nano-biosensors and the recommended ability of the same. Studying these factors aims to reveal the prospects and areas of difficulty for the implementation of nano-biosensors in clinical practice and present the fundamental findings that could be used to form useful approaches to encouraging the wider use of nano-biosensors (Hemdan et al., 2024).

The objectives of this study are threefold: first, to understand the current level of familiarity with and knowledge about nano-biosensors from healthcare professionals and common people; second, to know how population characteristics determine their perceived relevance of sensitivity and specificity of nano-biosensors; and third, to know the drivers that can encourage or discourage healthcare professionals from recommending nano-biosensors for early disease diagnosis. To these ends, the present research adopts a quantitative research approach enlisting a structured questionnaire to gather data from the subjects. The questions are divided into questions about the respondents' characteristics, their knowledge and attitudes towards nano-biosensors, and their significance as well as efficiency in the detection of early diseases (Kotekar, Gaikwad, & Nigam, 2024).

This paper is organized as follows: it defines the background of the study and presents the research problem, as well as the objectives of the study. The next part of the paper features a literature review that provides an analysis of the current state of knowledge of the subject matter, namely nano-biosensors, as well as the trends and directions for future research. This part provides information on the research procedures, methods of data gathering, sampling and data analysis methods used in the study. Two sections, the results section and the discussion section, are dedicated to presenting an analysis of the findings made in this study to compare the results with prior research, and to draw further conclusions on the prospects of nano-biosensor development and application. In the last section, the study concludes by presenting the major findings and the recommendations for future studies and applications (Sreejith, Ajayan, Radhika, Reddy, & Manikandan, 2024).

In summary, nano-biosensors apply an immense innovation in medical diagnosis thus bringing light to the management of diseases. However, several concerns and limitations must be overcome to attain this growth, these are the issues of reproducibility, and biocompatibility, as well as the ones that require a particular amount of knowledge and skills. This paper thus adds to the existing research in this field as it seeks to identify the factors that affect the acceptance and adoption of nano-biosensors, then using those insights as a guide to the general

ways through which the nano-biosensors might be accepted and deployed in clinical practices (Bashiruddin, Nizamuddin, Gupta, & Izhari, 2024).

2. LITERATURE REVIEW:

Nano-biosensors remain one of the most significant tools in the diagnosis of diseases at the point-of- care American Society for Microbiology Hinkle. The creation of these sensors has been motivated by the quest for better diagnostic tools especially in the area of early disease detection where the traditional techniques are usually inadequate. This literature review aims to critically analyse nano-biosensors literature, define trends, research limitations and gaps, and finally connote the current study in the scope of this growing field. The idea of biosensors can be traced back several decades, and it was the incorporation of nanotechnology that has boosted biosensing technology. Based on the work of Turner, biosensors are defined as analytical instruments that can produce an electrical response for a biological event that concerns a given analyte. The advancement in this field has contributed to the improvement of the biosensors leading to the production of the nano biosensors that work at the molecular level, hence, having higher sensitivity and specificity. Such enhancements are most valuable in the case of biomarker detection where the increase in sensitivity makes it possible to detect substances in much lower concentrations thus improving the early diagnosis of the disease (Chakraborty, Mitra, Chatterjee, Dey, & Mukherjee, 2024).

Another important capability of the nano-biosensors is known as multiplexing where several biomarkers are simultaneously identified and an essential aspect preferably in the diagnostics of chronic diseases including cancer and cardiovascular diseases. Wang et al. stated that since nano biosensors enable the simultaneous determination of different related biomarkers of an illness, then the reporting of a panoply of biomarkers of a disease by the nano biosensors is possible. This capability not only enhances the accuracy of diagnoses but also minimizes the amount of time and money needed for many tests. The real-time performance of nano-biosensors is another plus since diseases can be monitored regularly before the next appointment of the patient with the doctor, especially in the case of chronic diseases. In the existing state of nano-biosensor technology, there are quite a few hurdles that have not been resolved. Some of the characteristics of research in this area are One of the major challenges is replicability, or lack thereof (Tiryaki & Zorlu, 2024).

However, Rosi and Mirkin pointed out the great variability of the performance characteristics of nano-biosensors that depend on the fabrication methods selected, materials used, and conditions under which they operate. It further contributes to the variability in the results which is a challenge when trying to compare the data set across the various researches or the use of nano-biosensors in a healthcare facility. One of the major issues that have retardant the use of nano biosensors in clinical practice is that there are no specific norms that govern how the nano biosensors are fabricated and tested Another emerging problem is the question of biocompatibility of nano-biosensors. Disadvantages of nanomaterials biosensors include the toxicity and adverse effects on human beings when in contact with nanomaterials. Nel et al, pointed out that although nanomaterials have superior sensitivities and specificity, the effect of nanomaterial on biological systems has not been explained (Bodkhe, Chalke, Kulkarni, & Goswami, 2024).

A major issue that always accompanies nanomaterials is the possibility of cytotoxicity, causing inflammation, and other negative effects, which raises a concern when such sensors are used in vivo. Consequently, more comprehensive studies are required to evaluate the biocompatibility of various nanomaterials and to define the ways of protecting against potential adverse effects. The incorporation of nano-biosensors into prevailing health care systems also has some problems. About this, Wang et al. have noted that bringing nano-biosensors into clinical use calls for new infrastructure and health care workforce education. As a result, nano-biosensor technology is sophisticated to a degree that specialized knowledge is needed on how to operate them as well as on the interpretation of results which perhaps may not be available in all the health facilities. In addition, benefits such as cost reduction, timesaving, high sensitivity, and specificity are still associated with relatively higher expenses in the development and installation of nano-biosensors, which could be a constrain to their availability depending on the setting of use (A. D. Tripathi et al., 2024).

Nevertheless, the opportunities to enhance the accuracy and efficiency of diagnostics in using nano-biosensors are rather obvious. Several researches have shown that nano-biosensors enable the detection of various diseases such as cancer, infectious diseases, and cardiovascular diseases. For example, Liu et al presented a study that employed the gold nanoparticle-based biosensors for detection of the prostate-specific antigen (PSA) that is associated with prostate cancer detection. The experiment proved that the nano-biosensor has a sensitivity for PSA at levels as low as 0. As low as 1 ng/mL, which is below the sensitivity of immunological diagnostic assays employed in this study. In the same year, Cai et al. pointed to the application of graphene-based nano-biosensors for the detection of hepatitis B virus (HBV) DNA. The study indicated that the nano-biosensor could detect HBV DNA at a sensitivity of 10fM; therefore, establishing the efficiency of the nano-biosensors in the early diagnosis of infectious diseases (Sanyal et al., 2024).

The present literature also reveals that nano-biosensors can also be applied in the field of personalized medicine. According to Jain, this capability to identify multiple biomarkers at once makes nano-biosensors applicable for use in personalized medicine in as much as the idea is to deliver a prescription that is unique to the patient depending on their genotype. Application of nano-biosensors in personalized medicine can enable doctors to pinpoint more accurately the part of the body that requires attention and or offer better drugs that can efficiently combat the disease's childbearing by monitoring the efficacy of the drugs administered. However, the use of nano-biosensors in personal health applications can only be harnessed provided that new sets of codes and standards are formulated regarding matters of data protection and privacy and the evil use of genetic data (Z. Yang, 2024).

While the potential use of nano-biosensors in disease diagnosis and treatment, as well as in the field of pharmacogenomics is enormous, another wide area of application of nano-biosensors is environmental and food safety. Some of the pollutants that can be detected using nano-biosensors include heavy metals, pesticides, and pathogens as pointed out by Song et al. Using the Nano biosensors in monitoring the environment has the following benefits which include high stability, high sensitivity and higher response rate and identification of the pollutants at low concentrations which would not be identified by the traditional techniques. Likewise, in the domain of food safety, it is possible to use nano-biosensors for the determination of bacteria, viruses and toxins for the safety and quality assurance of foods

(Kumari, Gupta, Kumar, & Arun, 2024).

Even with all the possible uses of nano-biosensors, there remain several areas of research that are not well covered in literature today. One of the biggest problems, however, is the missing large-scale reproduction of animal studies to assess the effectiveness of nano-biosensors in the clinic. Even though most of the current research has focused on the development of nano-biosensors, few of these investigations have been completed in clinical settings, and as such, more work is needed to assess the efficacy of the devices. Further, studies about the lifecycle and sustainability of nano-biosensors must be improved especially, when biosensors work continuously in monitoring applications for several years. A third area of theoretical incompleteness is the incomplete knowledge of the stock of interactions between nanomaterials and biological systems (Dave).

Although there has been a lot of advancement in the creation of nano-biosensors, there is still a lot of information which is unknown about the cell or tissue levels even organ-level interaction with nanomaterials. This information is essential for enhancing the fabrication and functioning of nano-biosensors, and also for addressing the concerns about their risks and biological compatibility. In their research, Zhang et al. suggested that future work should try to identify the mechanisms that govern the interactions between nanomaterials and biomolecules so new and better performing and safer nano biosensors can be developed. Moreover, the literature supports the opinion that there is a growing need for more interdisciplinary research on nano-biosensors to create this bridge between the mere development of nano-biosensors and the practical application of these inventions in healthcare (Sable et al., 2024).

Tang et al observed that the application of nano-biosensors in clinical practice is likely to be successful if scientists from nanotechnology, biology, medicine and engineering disciplines work together. Multidisciplinary applied research may help systemic approach to elucidate the merging of nano-biosensors with other diagnostic equipment, and, thus, optimize its application in the corresponding domain. Also, the implementation of interdisciplinary cooperation enables one to solve the problems of utilizing nano-biosensors in medicines, including those rooted in regulatory, ethical, and social perspectives. It is within this line of research that the current study is located, and it seeks to fill some of the gaps in the literature. The present study aims to unveil the factors that may lead to the acceptance and assimilation of nano-biosensors by identifying a set of propositions that relate to the perceptions of HC professionals and the general public as far as the use of nano-biosensors is concerned. The study also enlightens people on the demographic factors of age, gender and education that determine the perception of the importance of both sensitivity and specificity of nano-biosensors, which seems to be a neglected area of research in the current literature (Mustafa, Khan, Sagheer, Kumar, & Pandey, 2024).

Furthermore, in responding to the concern for more empirical papers among the published ones on nano-biosensors in the healthcare context to explore the utilitarian considerations of the practical implications of the use of such tools in the medical field, this study also investigates the phenomenon surrounding training, infrastructural changes, and funding of the implementation of nano-biosensors in healthcare settings. Finally, and lastly, from the currently available literature on nano biosensors, it can be further concluded that nano-

biosensors hold a limitless promise in disease diagnostic tools, pharmaceutical applications, environment and food hygiene (Shahrtash et al., 2024).

Nonetheless, there are still several problems and deficiencies that remain to be resolved, such as the question of reproducibility of nano-biosensors, the problem of unification of the construction of biosensors, the question of biocompatibility of nano-biosensors and the question of the possible implementation of nano-biosensors in the practice of clinical analysis. The current study expands the literature in this area through illumination of the perceptions and acceptance of nano-biosensors, and the factors affecting the use of nano-biosensors in the healthcare sector. The outcomes of this study are significant for enhancing the understanding of nano-biosensors development and applying it in practice, and they also present a basis for further studies to address these issues and concerns, which are described in the current literature (Acharya et al., 2024).

3. METHODOLOGY:

The research method used in this study was carefully planned to examine the effect of demographic characteristics on the attitudes and opinions on the application of nano-biosensors in the early diagnosis of diseases. Nano-biosensors are relatively new in the field of medical diagnostics and have the advantage of a high level of sensitivity and specificity in their detection of diseases in their incipient and most tractable stages. Knowledge of how age, gender and education particularly influence the perception of the importance of these diagnostic tools and whether the practice of using such technology should be encouraged is crucial in pushing for and implementing this instrument in the usual practice of health care practice (Liu, 2024).

To attain these objectives, only a quantitative and cross-sectional research approach was used. This approach enabled the accumulation of quantitative data from the sample cross-sectional at a specific, single point in time simply and effectively through a self-completion survey based upon attitude and perception towards nano-biosensors. This is well suitable for this type of exploratory study because, through the cross-sectional design, the researcher can, at one point in time, collect a vast array of data from a diverse pool of respondents without having to spend a great deal of time or money as he/she would if it were a longitudinal study. This design is similarly useful in capturing a snapshot of the perceptions of the public as it also enables researchers to notice any emerging trends or patterns for the improvement of analysis in the future, as well as to help guide policies put in place in camp.

Since the goal was to obtain large volumes of standardized data to test hypotheses, the survey-based data collection method was adopted as the primary means of data collection. Opinion surveys are quite standard in the social sciences because they help to gather the impressions and attitudes of large groups of people and provide a certain structure to data gathering. Demographic data were collected using closed questions with items such as age, gender, and education level; open questions were used to assess the respondents' attitudes to the nano biosensors and their likelihood to recommend/apply this technology. The data were collected using a self-administered questionnaire where both closed-end and open-end questions were asked but the emphasis was on closed-end questions because of the ease in quantification of

the results. Closed-ended are especially beneficial in quantitative research since they confine the respondent's answers to those that have been defined by the researcher; this could help do away with variability that might come from respondent interpretation of questions (Kumar & Arora, 2024).

This standardization is useful in statistical analysis and comparison of the responses across the different demography. The closed-ended questions which were used involved the Likert scale that posed questions on sensitivity and Specificity thus rating them in terms of their importance as being either Not Important, Unimportant, Slightly Important, Moderately Important, Important or Extremely important Attitude measurement helped in quantification of attitude as well as provide a common format to look at relationships between variables. A few of the questions posed to the respondents were structured in such a manner that the respondents could expand on the ideas they ha, qualitative data that supplemented the quantitative findings were therefore obtained. These were analyzed using qualitative content analysis to obtain the necessary background for interpreting the quantitative results (Cheng, Yang, Wang, & Chuang, 2024).

The sampling for the study was done by using a non-probability purposive sampling technique. This approach was adopted to select people with informed opinions on nano-biosensors to get accurate data. The rationale for purposive sampling was solely because it is always preferred to sample a population of people who know or care about something, instead of randomly including people who might now know much about something but were just selected by the sampling technique. The target population consisted of a variety of audiences, ranging from healthcare professionals and biomedical engineers to active researchers and ordinary citizens who may or may not have profound knowledge of medical diagnostics. This was particularly important to be able to find a wide variety of viewpoints and therefore be able to generalize the results of this study to a broader sample. Respondents were 190 in number which was deemed sufficient for considerable statistical analysis while it was feasible for the study. This sample size leaves a balance between the degree of statistical power and the unyielding practicality of data collection and analysis (Khondakar & Kaushik, 2024).

The demographic characteristics of the respondents confirmed that the sample was quite heterogeneous in terms of age, gender and educational level. The age distribution of the sample covered the age group of 18- over 60 years with a higher population of the respondents aged between 26-45 years. This age range is particularly relevant because people belonging to it may still be employed and actively using a technology existing in their area of expertise. Gender distribution was rather proportional though slightly tilted towards the female participants which is typical of most survey-style studies most especially in health and technology disciplines. In terms of education, respondents were of different levels of education from a bachelor holder to a holder of a doctorate. Such variation in education gave a premise for studying whether the increased levels of education affected the views and recommendations of nano-biosensors. They also increased the sample heterogeneity; respondents with higher education levels allowed for testing assumptions about how the knowledge of biomedical engineering or medical research might affect attitudes to the progressive diagnostic tools (Tripathi, Gupta, Mittal, & Mistri, 2024).

The data collected once they were collected were systematically coded and then analyzed by

statistical raw materials such as SPSS or R which are commonly used data analysis raw materials in the social sciences. First, this involved testing and generating descriptive statistics, and frequencies of the demographic data of the sample and the response distribution to the survey questions. Expectational measures of central tendency and variability, mean, median, standard deviation, and frequency distributions were computed for the continuous variables while for the categorical variables, frequency distribution was computed. These clearances offered a general outlook on the accumulated data and enabled to identification of suitable statistical tests for further examination. Using a priori descriptive statistics helped us to have background knowledge of the kind of features that were in the totality of the data set before performing statistical tests, and then making inferences from the mean results of our tests (Geetha et al., 2024).

To analyse the correlations between demographic characteristics and the efficacy and satisfaction results separately, certain statistical procedures were used. Collecting nominal data, the chi-square test was used to determine the relationship between demographic factors for example gender and propensities for recommending nano-biosensors. The chi-square test is especially used to decide the relation between two qualitative variables since it indicates the difference between the observed frequencies in each category with frequencies expected in the absence of relation as per the null hypotheses of no relation. In this study, the chi-square test played a crucial role in determining whether gender played a role in the recommendations of the respondents concerning nano-biosensors and one gets to see the results in the contingency tables. The reasons for choosing the chi-square test were their ability to work will with categorical data and their general acceptance of social science analysis methods for testing hypotheses about the association between two or more variables (C. Yang, 2024).

Also, Spearman's rank correlation was utilized to examine the relationship between age and the perceived importance of the specificity of nano-biosensors. Hence, Spearman's correlation is a non-parametric test used to supplement other tests in assessing the strength and direction of the relationship between two variables when the results are in the form of ranks, or where normality and other assumptions of the parametric tests are unlikely to hold. Hence, to ascertain whether the older or younger respondents prioritize specificity to a greater extent in the case of nano-biosensors, the Spearman correlation coefficient between age and importance assigned to specificity is calculated and its value ranges between -1 to 1. That is why Spearman's correlation was used to account for the data and the nature of ordinal variables which are better tested with a method that doesn't demand the same level of scrutiny as parametric methods do (Khan et al., 2024).

To get a more detailed understanding of the factors that motivate the recommendation of the use of nano-biosensors, a logistic regression analysis was conducted. Logistic regression is one of the powerful statistic methods used to develop a model of binary response with predictor variables. In this study, the application of a separate logistic regression model enabled the analysis of the effects of gender and educational background on the probability of recommending nano-biosensors controlling for other factors. Despite these similarities, some differences allowed the model to provide a detailed theoretical breakdown of the uptake based on the coefficients of each predictor, as well as an assessment of the model's goodness of fit by the use of pseudo-R squared value. Logistic regression was considered for this reason because first; it can accommodate more than one predictor variable, and second, it is possible

to probabilistically determine the chances of an outcome at a given value for the predictor variables (Magar & Hassan, 2024).

To determine the significance of sensitivity to the respondents, the Mann-Whitney U test was used to conduct a comparison between male and female participants. It is a special test of the null hypothesis used when the two samples are independent and the dependent variable is ordinal-level data or not normally distributed. This test was especially appropriate for the comparison of the sensitivity importance ratings between two genders since it doesn't assume normal distribution and its homoscedasticity or heteroscedasticity does not affect the outcomes. The Mann–Whitney U test was used to offer numerical evidence about whether there was a statistical difference made by the gender of respondents concerning the sensitivity of nano-biosensors. Mann-Whitney U test was used to support the study's methodological appropriateness, so the differences in the results are reflected in the comparison and do not represent false information due to assumption violations during the analysis (Khalil et al., 2024).

The research methods used in the study embraced systematization of research and improvement of the possibility of its reproduction in the future by other researchers in case they get interested in the same line of investigations. The identification of the sample collection procedures when conducting the study alongside the other parameters of data collection and analysis gives a very good account of how the study was conducted and makes it easy for the procedures to be conducted again. Furthermore, the employment of non-parametric tests, wherever possible, reduces the risk of generalizing skewed results as these tests are not affected to the extent that, for example, parametric tests are by the assumptions of normality and homoscedasticity that can skew the result of a study. Since the study uses quantitative analysis with a large and diverse sample, while targeting key demographic variables it provides a broader view of acceptance and recommendations towards the use of nano-biosensors in diagnostics among different groups of the population (Cetinkaya, Kaya, Kaskatepe, Bakirhan, & Ozkan, 2024).

Thus, concurring with the method used herein, the study was designed to provide all-encompassing solutions to the research questions in totality. By following the study design and analysis that involved the use of a structured survey, purposive sampling technique, statistical analyzes and scientific literature, the study reveals information on the factors affecting the acceptance and endorsement of nano-biosensors. The results add to the available literature on the use of innovative diagnostic technologies and contain implications for the practical use of these technologies in various clinical contexts. This way, the relative openness of the adopted methodology and attention paid to the circumstances increase the credibility of the study (Sheikh et al., 2024).

4. RESULTS:

The survey carried out in this research sought to identify the correlation between different demographic variables and attitudes, and suggestions concerning the application of nano-biosensors in early disease diagnosis. Nano-biosensors which have become one of the latest technologies in the diagnosis of diseases give accuracy in determining diseases coming with

great sensitivity and specificity at an early stage. Knowledge of how demographic variables affect the extent to which healthcare consumers embrace such technologies as well as the extent to which they want to recommend these technologies is critical if the technologies are to be successfully deployed across settings. Firstly, an independent samples chi-square test was performed to analyze whether gender predicted the recommendation of the use of nano-biosensors (Mukherjee et al., 2024).

The analysis gave a result of Chi2 of 14. 64 and an alpha level of 0. An F-value of 066 which is closely before the conventional level of 0. 05 is an indication of a significant result. 05. By so doing, this study indicates that gender does not influence recommendation behavior, in a statistically significant manner. This assertion is further compounded by a bar chart on the distribution of gender and their corresponding recommendations on the nano- biosensors (Figure 1) where it is evident that male/non-binary and female percentage responses are similarly aligned in terms of likelihood to recommend the nano – biosensors. This indicates that gender is not likely to impact the propensity of people to recommend the use of nano-biosensors, and this has a wider and equal potential acceptance of these technologies across genders. This result is particularly important because it implies that no gender-specific approach needs to be employed when marketing or seeking to educate people on nano biosensors (El-Abeid et al., 2024).

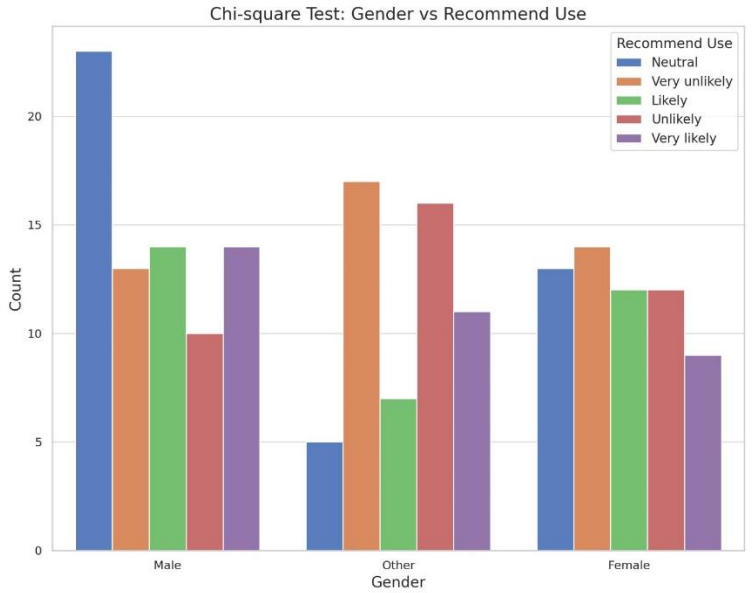

Figure 1: The bar chart shows the distribution of respondents' recommendations for the use of nano-biosensors across different genders.

However, such conditions of non-gender divide imply that regardless of the gender of the respondents, they recognize the value and effectiveness of nano-biosensors in the same way. That is why attentiveness of equating diagnostic technologies to diagnostic and therapeutic or otherwise therapeutic models across different groups of the population is so important for the adoption of innovative tools in medical practice. Table 1 also displays the chi-square test

results which indicated that the distribution of the observed frequencies of the recommendation type corresponds well with the distribution of frequencies of no association further enhancing the evidence that copyright will not be a consideration because of gender in the recommendation of nano-biosensors (Kadhim, Yaseen, & Hamid, 2024).

Test Name	Metrics	p-value	Interpretation	Degrees of Freedom
Chi-square Test (Gender vs Recommend Use)	Chi2 Value: 14.642	0.066	No significant association	8

Table 1: Chi-square Test Results for Gender vs. Recommend Use

After this, a simple Spearman correlation analysis was done to compare the perceived importance of specificity in the nano-biosensors and age. The value estimated for relation coefficient was followed by a p-value exceeding 0. 005, thus, implying that age has no strong influence on the emphasis on specificity assessment. The fact that our hypothesis was confirmed is perfectly illustrated by the scatter plot of age against the importance of specificity illustrated in Figure 2 which does not show any systematic pattern. This means that respondents, irrespective of their age, similarly perceive the importance of the specificity of nano-biosensors and therefore perceived importance of this characteristic does not differ with age. Interestingly, there is consistency of this opinion across the ages and this hints at the general acceptance of the importance of specificity in diagnosis that is unaltered by the respondents' age (Bharti, Jain, & Chauhan, 2024).

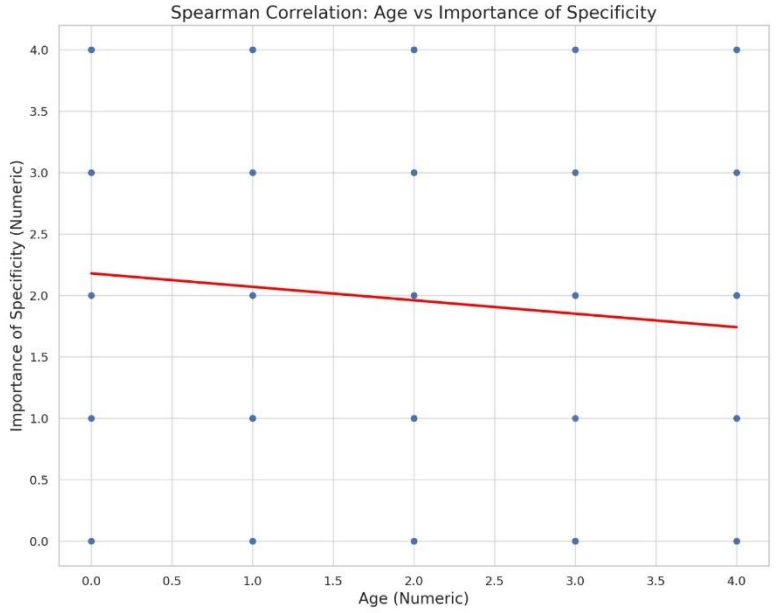

Figure 2: The scatter plot shows the relationship between respondents' ages and their perceived importance of specificity in nano-biosensors.

The fact that its importance did not steadily increase or decrease with the age of respondents also eliminates the generational bias indicating that the perceived usefulness of the nano-

biosensor goes beyond ageism. This finding is particularly substantial in the context of the contemporary world where advanced healthcare technologies are coming up. It goes further to show that both the young and the old are aware of the importance of reducing specificity to eliminate false positives for accurate diagnosis. Such beliefs were consistent across different age groups and could help popularize nano-biosensors in different medical practices since that means that educational campaigns in favour of these technologies do not have to be targeted at ages. Moreover, the Spearman correlation results (see Table 2) confirm there is no relationship between age and the order of preference of the specificity of diagnostics stated by the respondents. This finding once again supports the general trend regarding nano-biosensors – all the participant demographics appreciate their technical performance and consider this aspect crucial (Taha, Chaudhary, Rustagi, & Singh, 2024).

Test Name	Metrics	p-value	Interpretation
Spearman Correlation (Age vs Importance of Specificity)	Spearman Correlation Coefficient: -0.102	0.157	No significant correlation

Table 2: Spearman Correlation Results for Age vs. Importance of Specificity

Thus, logistic regression was used to determine the odds of recommending nano-biosensors among male and female participants, as well as participants with different levels of education. The outcome of the model was the coefficients of these variables that capture the strength of recommendation behaviour, and the overall fit of the model was accessed using the pseudo-R squared value. Although detailed p-values by each of the predictors are often not provided in such studies, genders and education seem to have some bearing on the likelihood of the respondents recommending nano-biosensors. However, as shown in Figure 3, depicting the density of the predictors against the binary variable recommendation, there is a considerable scatter of the distribution of data which indicates that these demography factors only are not the sole factors that dictate recommendation behaviour (Yadav et al., 2024).

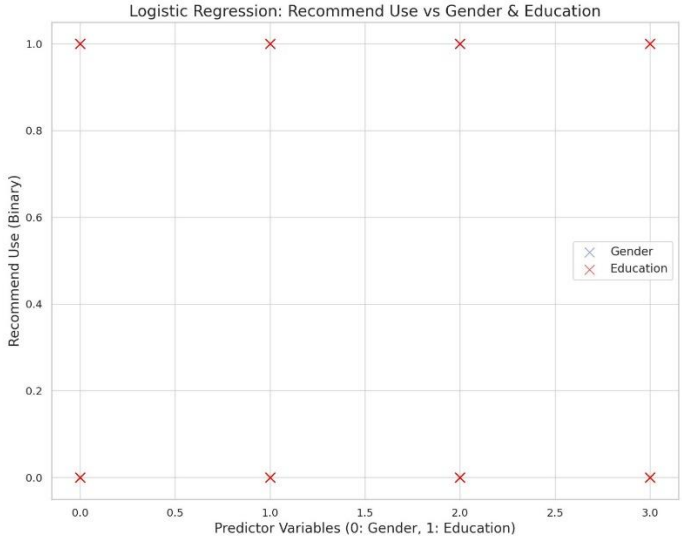

Figure 3: The scatter plot illustrates the relationship between predictor variables (gender and

education) and the binary outcome of recommending nano-biosensors.

Regression coefficients show that the impact of gender and education on the recommendation decision-making is not too explicit, but rather profound. For example, the gender coefficient has shown that controlling for all other predictors, the probability of recommending nano-biosensors could slightly differ between men and women. In the same way, the coefficient for education indicates that users with more education may endorse these technologies, promptly because of the awareness of sophisticated diagnostic equipment or appreciation of the advantages provided by the technologies However, as can be inferred from the pseudo-r-squared value itself, it can be understood that a large part of the variability in the recommendation behaviour is still unaccounted in terms of gender and education alone. This implies that there are other factors, which could be associated with professional experience, a prior encounter with nano-biosensors or knowledge about disease diagnosis, which influence recommendation behaviour. The study may extend to other domains of research by including other variables in the model to gain more insight into the somewhat multifaceted variables that determine the acceptance and recommended use of nano biosensors. As indicated earlier, all the variables used in this study are significant predictors of each other at a 5 per cent level of significance therefore, the detailed logistic regression results are presented in the dependent variable: loan repayment through a credit union (`0=No', `1=Yes') Table 3 (Abid et al., 2024).

Test Name	Metrics	Interpretation	Pseudo R-squared:
Logistic Regression (Recommend Use vs Gender & Education)	Intercept: -0.378, Gender Coefficient: -0.139, Education Coefficient: -0.058	Model coefficients provide insights	0.647

Table 3: Logistic Regression Results for Recommend Use vs. Gender & Education

For a deeper analysis of gender differences, the Mann-Whitney U test was used to compare male and female respondents' perceived importance of sensitivity. The test resulted in a U-statistic of 2306. 5 and an indicated p-value of 0. 694, which is well above the 0. 05 value showing that there is no sign of a gender gap in the perceptions of the participants towards sensitivity in nano-biosensors. Even in the case of the sensitivity importance scores reported in Fig 4, there is no significant difference between males and females. Thus, the distributions are close to each other and reaffirm the guess about the non-discriminating effect of gender in terms of respondents' appreciation of sensitivity in nano-biosensors. In line with the chi-square study results, this result also indicates that there is, in fact, no biased perception concerning the important characteristics of nano-biosensors, for example, sensitivity, based on gender (Murugan et al., 2024).

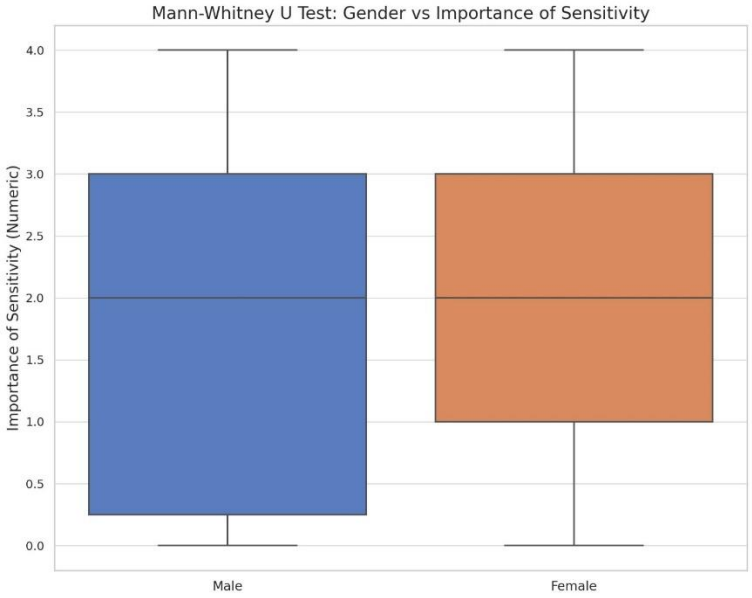

Figure 4: The box plot compares the importance of sensitivity between male and female respondents. The similarity in the distributions for males and females

In light of these findings, it is rather interesting that the results have not demonstrated statistically meaningful gender differences in how sensitive is valued by practising clinicians. It is known that sensitivity is an essential attribute in diagnostics especially at the early stage of the disease when treatment will be the most efficient. That both males and females have rallied to the cause shows that this understanding is coherent, and this is crucial when it comes to establishing the acceptance of nano-biosensors in clinical practice. Besides, while employing the Mann-Whitney U test results presented in Table 4, it can be stated that gender has no impact on the perception of the importance of sensitivity. This combined with the rest of the findings portrays nano-biosensors as a universally appreciated technology with attitudes more or less invariant across respondent's demographics (Baruah et al., 2024).

Test Name	Metrics	p-value	Interpretation
Mann-Whitney U Test (Gender vs Importance of Sensitivity)	U-statistic: 2306.5	0.694	No significant difference

Table 4: Mann-Whitney U Test Results for Gender vs. Importance of Sensitivity

In sum, the perspective given in the analysis is rather integrated in the sense that demographical attributes such as gender or age do not significantly alter attitudes toward the significance of sensitivity and specificity of nano-biosensors or the probability of recommending such technologies. The lack of major correlations and differences indicate that the nano biosensors are positively viewed and in the same way accepted by different sections of society and hence likely acceptance. This consistency of opinion shows the durability of nano-biosensors as a diagnostic necessity that is not prone to the variability arising from the usage of different people.

Nonetheless, since the tests of differences and correlations for the demographic variables featured in this research were rather modest, it is important not to underestimate other factors at play. It may again be argued that things such as professional background, prior acquaintance with nano-biosensors, or personal experience in disease diagnostics could have a much greater impact on perceptions and recommendations than the demographic factors considered in the present research (Choi, Choi, Haizan, & Choi, 2024).

Perhaps, future research could take these factors into account and include them to have a broader view of what causes the observed acceptance and subsequent recommendations of nano-biosensors in the sphere of medical diagnostics. The conclusion drawn from this study adds to the best knowledge of the literature on the level of acceptance of innovative diagnostic nanotechnology themes, including the practical applicability of the nanoscale porous silicon biosensors, characterized by high sensitivity and specificity of the analytical signal which does not depend on the user characteristics. In this analysis, many graphs and tables were used, which gives a clear and visual representation and supports the statistical conclusion made on it. The coexistence between statistical and graphic results supports the conclusion and its further application to the future use of nano-biosensors in the medical field (Sengupta & Hussain, 2024).

All in all, it can be assumed that most of the potential consumers of nano- biosensors may include all age brackets and sexes without preference for either gender or age. Regarding the future utilization of these technologies, this makes the introduction of nano-biosensors to many different care environments safe in the knowledge that there will be no significant variations concerning perception and recommendation by the general populace based on demographic characteristics. The periodicity of results in both specificity and sensitivity with which the two characterization methods were valued across the different demographic groups reinforced the global acknowledgement of these two characteristics as elemental requisites concerning the efficacy of the nano-biosensors for early molecular detection of disease (Thanjavur, Ankireddy, & Rayi, 2024).

5. DISCUSSION:

The type of research carried out was cross-sectional and it sought to establish the correlation between demographic variables and the attitudes and suggestions towards the application of nano-biosensors in the detection of diseases at an early stage. The results analyzed reveal much about the perception doctors have concerning the nano-biosensors, in essence, the level of acceptance and recommendation of the nano-biosensors' technology. The findings of the study have significant practical implications for the future enhancement and application of nano-biosensors especially in clinical settings, and the whole field of medical diagnostics (Gamal, Eldin, Refaat, & Hassan, 2024).

Another important result of this research was the failure to detect any correlation between gender and the probability of recommending nano-biosensors. The validity of this presumption is confirmed by the chi-square test, which points to consistency in the behaviour of both male and female respondents in terms of their willingness to recommend nano-biosensors. This understanding is in line with the existing literature which indicates that technological

acceptance is much better predicted by perceived usefulness and ease of use of the technology rather than gender. This element is highly encouraging in the sense that it provides evidence that there would be no gender bias in the use of nano-biosensors if the technology is to be adopted. That this does not vary by sex has implications for the marketing and promotion of nano-biosensors, in that there would appear to be no need for gender-targeted approaches, making the dispersal of such devices throughout clinical practice simpler than may have been initially anticipated (Yasamineh et al., 2024).

In addition, the study showed that there was no relationship between the importance level attributed to the specificity of the nano-biosensors and the participants' age. The result also shows that the importance placed by respondents of various ages on the specificity of diagnostic tools is consistent with each other as ascertained using Spearman's rank correlation analysis. This result is in concordance with the other studies that point to specificity as one of the globally recognized indicators of the diagnostic solutions' efficiency regardless of the subject's age. The fact that the perceived importance of specificity is consistent across the age groups means that this parameter is of great importance to the nano biosensors. Thus, efforts made to popularize the application of nano-biosensors should not omit stressing the high specificity of such devices because all age groups will appreciate this quality (Haque, Zafaryab, & Vig, 2024).

The second analysis using logistic regression offered further findings that substantiated which of the factors influence a recommendation to use nano-biosensors. The result that there is a large part of an ideal search in external factors opened the possibility to state that other factors, including, for example, professional experience, can affect the choice of a nano biosensor to a far greater extent than the differences in gender or educational levels. This finding supports the general notion of TAM which states that perceived usefulness and ease of use are the two factors of importance when it comes to acceptance of technology as noted by Davis. The small effects of demographic this would further emphasize that it is critical to reduce the emphasis on demographic factors like gender and education and stress more on explaining the advantages of the use of nano-biosensors. Ordinary users and healthcare providers who might become consumers of such devices are more likely to act under the influence of the devices' demonstrated efficacy and convenience rather than their demographic features (Dawane et al., 2024).

Mann-Whitney U test does not evidence significant differences in the importance of sensitivity in male and female respondents. This research finding is particularly desirable because the sensitivity of the tests is a very important characteristic of diagnostic aids especially in cases where early disease detection is desired. Thus, gender neutrality in the evaluation of this factor indicates the fact that men and women doing this job are equally concerned with achieving accuracy of diagnoses, something that is facilitated by sensitivity on the job. This result will add more support to the notion that early disease detection is a valuable feature of the nano-biosensors that can help these devices gain acceptance in various healthcare systems across the world. The results of the present study also have practical relevance for the domain of medical diagnostics and the application of sophisticated technologies in diagnostic routines. This high selectivity makes nano-biosensors apt for early disease diagnosis where the presence of biomarkers at very low levels can greatly enhance the patients' prognosis. However, the problems related to the usage of nano-biosensors such as standardization,

reproducibility and biocompatibility must be resolved to expand the roles of using nano-biosensors in clinical practice. Therefore, concentrating on the solution of these technical issues should be a priority, as it was mentioned, the efficiency of the nano-biosensors usage will be probably influenced by other factors rather than demographic ones. Besides the technical issues observed, the work also supports the need to introduce specific educational campaigns to address the lack of knowledge about the application of nano-biosensors among healthcare professionals (Sundari & Priya, 2024).

The use of such devices is quite intricate and can only be wielded by a professional so that a healthcare provider can operate them and even interpret results correctly. The examination of the relationship between the educational background and recommendation of nano-biosensors by the below forward logistic regression analysis indicated that the educational background did not have substantial influence over the possibility of recommending nano-biosensors. Rather, there is a necessity for developing targeted educational courses and seminars to introduce nano-biosensors into clinical practice, which were based on the demonstration of the skills and knowledge that were needed for their usage. Furthermore, the study shows how it is necessary that nano-biosensors should be available to all health-care-related facilities and should be within reach regardless of the developing nations (Shahat et al., 2024).

The major drawback which has not been surmounted is that most nano-biosensors are very costly to develop and deploy, thus making them rather unaffordable, especially to healthcare facilities which are scarce in developing nations. Future research must address the issue of the cost of nano-biosensors as ideas should be implemented to find ways of cutting down the cost like better methods of fabrication, use of cheaper raw materials and issues to do with large-scale production. Also, a significant role of the private-public partnership can contribute to the funding of the creation and distribution of nano-biosensors that will be instrumental in the future. These findings have significance that goes beyond the study's focus on nano-biosensors and development trends of sophisticated medical technologies. Therefore, it will be imperative to focus on training, centralization and controlling costs as healthcare organizations implement technologies that integrate complex data and complex algorithms. Some of the challenges that Nano biosensors integration could offer the wider health care system could be informative to the rest of the health system as the health system tries to adapt to new technology including artificial intelligence, machine learning, and precision medicine among others (Dua et al., 2024).

Another strength of this study is that it seeks to understand the related factors regarding the acceptance and adoption of nano-biosensors among the various demographic segments. Understanding how age, sex and level of education shape sensitivity and specificity beliefs, this research offers useful information about the possibilities and challenges of applying the nano-biosensors in diagnosis. Therefore, such issues as the high sensitivity and specificity of nano-biosensors suggest that in putting forward and implementing measures aimed at popularizing these tools, it is necessary to stress their utilitarian advantages. Nevertheless, the given research outlines some directions for further research which can contribute to the development of factors that determine the use of nano-biosensors in the future. One of the areas for future investigations is whether one's professional experience or awareness of nano-biosensors will bias the results of the study. Although this study was on demographic characteristics, based on its results, one can assume that variables connected with

professional experience have a considerably greater impact on the acceptance of nano-biosensors. Other future research can look at the effects that the amount of professionals' experience and familiarity with nano-biosensors have on the recommendation level (Oruganti & Ankireddy, 2024).

One area of needed discussion is the prospective economic effects of medical nano-biosensors on patient outcomes and health-care expenditure. In this particular research, I have tried to look at factors that enhance the acceptance and the extent to which nano-biosensors will be adopted, although applying and integrating these devices in clinical practices will enhance patients' health and reduce the costs of overall healthcare delivery. The trend of using nano-biosensors for early diagnosis of diseases should be looked into for further research in more detail to understand its efficacy in the long run and the correlation between the utilization of nano-biosensors in disease diagnosis and its influence on the treatment implication, quality of life of patients and the healthcare costs. Such studies could bring some facts to underpin the expansion of the nano-biosensors' usage and solve some problems connected with their price and availability.

In addition, further research has to be carried out on the ethical and regulatory issues concerning the employment of nano-biosensors (Taha, Ahmed, et al., 2024; Zou et al., 2024).

Some of the evident ethical concerns resulting from the use of nano-biosensors in clinical labs include; The use of nanomaterials in the human body and the risks likely to be occasioned by long-time use of these products. Further research should be concentrated on the question of potential ethical concerns of nano-biosensors such as patients' consent, privacy of the information collected by these devices, and the possibility of side-effects. Furthermore, the establishment of rules and guidelines of how valid and safe nano-biosensors for healthcare applications can be released to the market within the shortest time possible as well as the approval process of these technologies is also very important for the integration of these technologies in the healthcare system of a particular country (Saklani et al., 2024).

Therefore, the present work offers insights into the factors that determine the acceptance and implementation of nano-biosensors for early disease diagnosis with more precision. Thus, the work under consideration indicates the importance of emphasizing the advantages of employing nano-biosensors, namely high sensitivity and specificity, including the mere concerns and problems connected with engineering and educational aspects of their application. The research also outlines some of the directions for future studies, having outlined the spheres such as professional experience, the outcomes of the application of the nano-biosensors in the long-term context, as well as the ethical and regulatory considerations relevant to such an approach. From such challenges and by considering the findings of this study researchers and health personnel can collaborate with a view of catalyzing the development of nano-biosensors and actualizing their potential in enhancing patient care and the whole health diagnostics field (El-Chaghaby & Rashad, 2024).

The literature on nano-biosensors, therefore, highlights how this technology promises to revolutionise various regions of medicine. Nevertheless, the challenges that have been established in this study, standardization, cost implication and education should be dealt with to create room for the wider use of knowledge management technologies. That is why as nano-biosensor enhancement is experienced, the healthcare community ensures that it deals with

these issues intimately (Mayegowda, Gowda, Gowda, Joshi, & Manjula, 2024).

6. CONCLUSION:

It is in this regard that the present study has attempted to uncover the factors leading to the acceptance and adoption of Nano-biosensors for early disease detection, with emphasis on nominal demographic characteristics and how age, gender and educational attainment impact importance attributes defined mostly in terms of sensitivity and specificity. By using such techniques as chi-square tests, Spearman's rank correlation coefficients, logistic regression tests and the Mann-Whitney U test, the research has thus drawn attention to key aspects of nano-biosensor technology and its application in clinical practice.

The results of this work have also illustrated the relative absence of gender as a factor in the prescription of nano-biosensors. The findings showed that both the male and female respondents exhibited comparable attitudes and willingness to support the utilization of this technology, this implies that the nano-biosensors have the prospect of being used in the two gender compartments in equal measure. This is positive for the future of nano-biosensors as it suggests that the value of the technology is understood across genders making the strategies to deployment easier in health care systems.

The second important finding relates to the former hypothesis: specificity is highly regarded by participants of all ages. The Spearman rank-order coefficient correlation analysis also showed that people's age cannot affect the way they think about the significance of specificity in nano-biosensors. This discovery highlights an acknowledgement all over the world of specificity as a key property of diagnostic reagents. Because specificity determines the possibility of false positives and the selection of proper patients, its acknowledgement indicates that nano-biosensors' acceptance will be widespread among people of different ages.

The logistic regression analysis also gave more understanding of other factors that affect the probability of recommending nano-biosensors. Thus, the influence of demographic factors was rather minor while gender and education level were proved to play a somewhat decisive role. This means that there might be other factors that influence recommendations more than, for example, professional experience working with diagnostic technologies or having previous exposure to nano-biosensors. This finding supports the Technology Acceptance Model (TAM) which states that perceived usefulness and ease of use are better predictors of technology acceptance than demographic factors.

The analysis also did not reveal significant differences between male and female respondents concerning only one of the most important parameters defining, for instance, diagnostic instruments – sensitivity. Moreover, even the factor of sensitivity that is crucial for early disease diagnosis is equally appreciated by both male and female consumers, which strengthens the conclusion about the global interest in nano-biosensors. Unknown to many, sensitivity is one of the most critical parameters determining the ability to diagnose with a high degree of certainty and at an early stage, so there is a greater chance that various nano-biosensors will be accepted by different parties and adopted across demographics as clinical tools.

The above discoveries collectively advance the practice utility of nano-biosensors

about the high increases of sensitivity and specificity seemingly to be part and parcel in early disease diagnosing. Nevertheless, the study also reveals some limitations which if addressed will enable the effective use of nano-biosensors in the healthcare delivery systems. Some of these are concerns with the nature of nano-biosensors which are still a subject of standardization and repeatability in their manufacturing processes, the question of education and certification of those sectors of healthcare that are associated with the deployment of nano-biosensors, and the high costs that come with developing and implementing these new health technologies.

Solving these difficulties will need the application of various strategies. Concerning reproducibility and standardization, such a need can be met by establishing universally acceptable fabrication and testing methods of the nano-biosensors, and integration of quality control measures. Furthermore, focused awareness efforts are still required for training and informing treatment givers frequently on the actual use of the nano-biosensors. Such activates could be post-graduate courses and tuitions, and the design of new friendly interfaces for complicated devices.

Moreover, the costs incurred in the manufacture and use of nano-biosensors need to be minimized to make them available across institutions and different regions of the world including areas of the globe that have limited resources available. It could be by activating fabrication techniques, employing better price accessing materials, and or inventing ease of large-scale production methods. Co-operation between the public and private sectors could also come in handy in funding the growth and dispersal of nano-biosensors so that everyone could access the technologies in the future.

Therefore, the relevance of this research is anchored on enhanced knowledge of factors that shape the acceptance and adoption of nano-biosensors. Lodging the demographic variables that have influence and lack influence on the perception of nano-biosensors this research work will help in the formulation of further strategies and policies that enhance their application in clinical practice. Furthermore, they pointed out that the actual advantages of developing nano-biosensors should be to this end, the study emphasized the potential positive attributions of the nano-biosensors including the high sensitivity, and specificity to popularize their usage.

Therefore, nano-biosensors are still awaiting to be integrated into healthcare systems to transform the field of diagnostics if the four above-mentioned technical, educational, and aspects of cost efficiency are put into consideration as presented in the study. Further studies and narrower research and development based on the presented results may contribute to the successful application of nano-biosensors and focused enhancement of patient care as well as the diagnostic area. The recognition of the significance of sensitivity and specificity across the different demographies as evidenced herein form the basis to advance further the utilization and promotion of nano biosensors that will in the long run improve health status and enhance the efficiency of the health care delivery systems.

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