

The Perception of the Impact of Training and Continuing Education on the Professional Performance of Biomedical Engineers.

تأثير التدريب والتعليم المستمر على الأداء المهني لمهندسي الطب الحيوي

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Abstract

The clinical engineering department is absolutely vital to the efficiency, productivity and safety of a hospital. Clinical engineering is designed to not only manage, but also effectively maintain the medical equipment and technology devices in a healthcare facility so it is representing a critical factor for successful healthcare management. It is important for the clinical engineering department to be efficient and timely in order to ensure that healthcare facilities provide the highest quality of patient care. The aim of this study is to assess the level of perception of biomedical engineers in the kingdom of Saudi Arabia toward the effectiveness of continues training in improving the performance, decrease accident and increasing outcomes. This study was based on cross sectional design, and was develop an integrated evaluation method for services introduce by clinical engineering departments (CED's). The research data were collected through an electronic survey or questionnaire from the clinical engineering department staff of three hospitals in Riyadh city, Kingdom of Saudi Arabia (KSA). The data was collected and analyzed using the statistical package for social science (SPSS version 23). Training and continuing education lead to well-educated, well trained biomedical engineer and provide them with the information of the latest technologies with regard to medical instrumentation and enhance their professional development. Also, the result of the current study revealed that there is significant correlation between the three independent factor scales (Biomedical Engineer's performance, decrease accidents, and increase outcome) ($P > 0.001$). lead the full life cycle of the technology and improve the quality of health services.

Keywords: *Biomedical engineering; Medical equipment; Training; Continuing education; Professional performance; patient safety.*

Introduction

Increasing demand for healthcare and therefore the expenditure required to provide efficient, equitable and effective healthcare systems, are the worldwide concerns. This leads to improvement and increasing the quality health care services, patient safety, and clinical effectiveness. Medical technology is the basis of all healthcare services, but increase complexity in technology also increase the difficulty in equipment management. As a biomedical engineer's professionals, we are a key member of the healthcare delivery system team by managing, installation, repairing, and utilizing health technology, working with clinicians and patients, ensure the highest standards and best practices in medical device safety, security, interoperability, and functionality. WHO recognizes the importance of medical devices management in contributing to the providing of high quality health care and state that trained and qualified biomedical engineering professionals are required to design, evaluate, regulate, maintain and manage medical devices and train on their safe use in health system around the world. (Organization WH. Global atlas of medical devices. 2017)

Responsibilities of biomedical engineering department: Education of biomedical engineering staff and health care facility staff, clinical research development, computing applications, facility planning, systems management and equipment management There are several branches of biomedical engineering that the engineer can specialize in, Where the continuous training of medical engineers opens up prospects for development and specialization in these fields, including: Biomedical Imaging, Biomechanics, Biomaterials Science, Tissue Engineering, Nanomedicine, Bioinformatics and Bioinstrumentations, In addition to other branches such as pharmacy engineering, neuro engineering and others. Biomedical engineers manage medical devices throughout the life cycle of a medical facility, managing not only medical devices but also implantable medical devices to protect the lives of patients. Biomedical engineers can also train clinicians, nurses, and other professionals working in healthcare facilities about how best and safest to use medical devices, A biomedical engineer's interactions describe at .Biomedical engineers work at various levels of healthcare facilities and should be involved in the planning of hospital areas or new units and the planning of healthcare facilities to support decisions about

medical technology requirements, depending on the clinical interventions undertaken in response to the needs of the patients.(Albadr ,2007:47).

As public health is the top priority, the Kingdom of Saudi Arabia has a considerable number of hospitals and is equipped with the latest and most advanced medical equipment. The selection, installation, maintenance and safe operation of these equipment all require additional care because of their high cost, precision and professionalism. The number of qualified personnel is needed, and they should be trained to perform the above-mentioned duties. Therefore, it is very important to work hard to develop standardized and lasting biomedical engineering continuing education and training in the country, considering its continuous professional development plan, which is part of the development of biomedical engineering training. (Organization WH. Human resources for medical devices,2017)

Regarding the local situation in Saudi Arabia, several post graduate courses were created to improve the training of biomedical engineers, one of these were King Abdul-Aziz University where new maser program was created , building on the already available undergraduate programs and providing research based solution to the local problems in the field. Providing well training for the local biomedical engineers will decrease the need for international engineers and decrease the overall cost of maintenance while increasing the income of the local engineers. this go well with the Saudi Arabia's Vision of 2030 regarding the efficiency of using health care resources.

Due to the urgent need for outstanding service in the hospitals and the urgent need to control their health services with the remarkable development in the level of international services, the Kingdom seeks to keep up with this progress through the continuous training of its employees, and believing in the importance of continuing education and training in the field of medical engineering. The aim of this study is to assess the level of perception of biomedical engineers in the kingdom of Saudi Arabia toward the effectiveness of continues training in improving the performance, decrease accident and increasing outcomes. Furthermore, Despite the availability of under and post graduate programs for biomedical engineers in Saudi Arabia, the perception of these engineers regarding the effectiveness of continues perception did not have the same amount

of attention, hence this study aims to analyze this level of perception in hope of designing better training programs that best suit the local biomedical engineer's needs and expectation.

(Aljamali,2021:154)

Problems Statement

The main aim of continuing education and training of biomedical engineers is to advance their use of biomedical technology and provide them with appropriate skills in order to reach the best clinical efficiency and safe management of technologies of healthcare facility. Furthermore, enriching the bioengineering paradigm with highly qualified, well-trained and solid basis engineers to enhance the profession of biomedical engineering and healthcare. Training and continuing education lead to well-educated, well trained clinical engineer and provide them with the information of the latest technologies with regard to medical instrumentation and enhance their professional development. Qualified professionals will safely guide the development and safely lead the full life cycle of the technology and improve the quality of health services. Training is a corner stone in providing efficient medical services by medical engineers however the perception of the local health engineers and specialist toward this aspect has not been well studied until now.

Justification / Rationale

The significant of the study stems from fact that medical equipment technologies have become main item in good health care system and medical equipment industry develop everyday as result their medical equipment specialist needs to keep update with medical equipment industry development so continuing education and training is essential to biomedical engineers. To our best knowledge few studies have been conducted concerning preoperative of continuing education and training of biomedical engineers in KSA. Within this perspective, this study may help in offering valuable trusted information for a variety of beneficiaries such the impact of continuing education and training on, performance, decrease accidents, and increase outcome for Biomedical Engineers. The study also provides date which might help in scientific research, improving health care system and health care education

Objectives

General Objective:

Assessing the level of perception of medical device specialist in Saudi Arabia toward the effectiveness of continues training in improving the performance.

Specific Objectives:

- Assessing the perception toward the effect on performance.
- Assessing the perception toward the effect on decrease accidents.
- Assessing the perception toward increasing the outcomes.

literature Review

The concept of continuing education in general is not a new concept. It was there at the beginning of civilizations. Education is also not a fixed process but an ongoing procedure that is not restricted to a certain stage of life, or a specific type of study. Continuing education can therefore be defined as any education or training after formal education directed at developing professional skills. In it is core it is designed to keep the skills at a continuous state of update and development. According to the Michel Armstrong, “Training is systematic development of the knowledge, skills and attitudes required by an individual to perform adequately a given task or job”. The term 'training' indicates the process involved in improving the aptitudes, skills and abilities of the employees to perform specific jobs. Training helps in updating old talents and developing. In order for training to be integrated, it must be characterized by a number of principles, it should have a specific applicable goal, sustained and inclusive, directed to employees at various levels and has a gradient status from easier to harder. Overall, the integrated training should improve the efficacy and performance of biomedical engineers. On the other hand the Impact of Training and Continuing Education for biomedical engineers include: Increased career promotion opportunities, increase the salary and Improvement of the CV leading to better carrier choices and eventually better life style. (Street,2011:87)

Clinical engineering is an integral part in the hospital system in Saudi Arabia. It helps in providing professional assistance to the different departments within the hospital, facilitating the smooth running these departments. Few studies were conducted to evaluate the perception of the impact of training and continuing education of biomedical engineering in the KSA. As we seen in the study done by Mohamed Ibrahim Waly who analyzed the management system of medical technology in the kingdom of Saudi Arabia (KSA) through two types of questionnaires, one for the medical practitioner and the other for the clinical engineering. the questioners in this study were checked and validated before use. A mix method of online and offline collection method was used. The result of the study indicates that the change in the size of the hospital does not affect the procedures, requirement for maintenance software or the interaction with local or international agencies done by the Ministry of Health (MOH). While in the same time, training skills of the

clinical engineers was affected by the size of the hospital and the number of patients with p value less than 0.05. Therefore, it was recommending that the MOH should design a central software to measure and supervise all maintenance activities taking places in these hospitals. Furthermore, an official regular training should take place in order to increase and maintain the effectiveness of clinical engineering. As mentioned in this paper serval evaluation attempts have been done before but no official measurement was done to the state of medical technology management in Saudi Arabia using standardized frame, this gab was tried to be filled by the author in the aforementioned. (Al Asif ,2018)

The study by Hamad Albadr from Riyadh Institute of Technology is titled "Technical Training in Biomedical Engineering in Saudi Arabia". This study determined the training programs and responsibilities of the biomedical department based on 23 questionnaires distributed in 23 hospitals in Saudi Arabia. The purpose of this study is to understand the state of the Saudi biomedical engineering department, support the involvement of the biomedical engineering department, and promote the repair and maintenance of medical equipment in medical facilities. Overall, this study is insufficient to achieve its goal of providing an overview of the biomedical engineering department in Saudi Arabia, as this information is not readily available. There is a lack of biomedical engineering industry organizations that are not authorized or authorized to issue licenses for such program information, especially in military hospitals, or give clear information. Finally, this study did not answer most research and survey questions. Finally, this study did not answer most research and survey questions. Several factors contributed to this result. Firstly, the number of surveys collected is very low due to the limited time, only three weeks, very slow, some hospital procedures and lack of understanding of certain issues and areas, as most managers are either not professionals in the field or do not have access to can access this information.

(Singh,2019)

Learning environment play an important role in the improvement of biomedical engineers. Based on his observation, a summit was held back a 2019 in Cleveland Ohio to discuss this manner. The summit consists of five workshops concentrating on different aspects of the learning environment. It involves subjects with a wide range of problem identification at different settings to team based learning and innovative platforms. The summit highlighted the importance of providing students with enough experience and training in order to make them read to solve complicated real world biomedical problems. Similar concepts could be applied to post graduate trainings with focusing on clinical and hospital based training in order to provide effective continues improvement of the biomedical engineer's performance. (Singh,2019)

In line with the previous research, a study was published in 2005 by Humphrey et al. supporting the concept of using real word scenarios in the training of biomedical engineers and validating the importance of team work in the training and education of biomedical engineers. It is worth noting as highlighted by the authors in this work, that research in the biomedical filed also have been shifting to the team work approach instead of the one-man endeavor which was prominent in the previous centuries. Furthermore, it was found that project base learning is a suitable way to introduce real word scenario to early life engineers. Moreover, it facilitates the involvement of students in interdisciplinary teams, hence It satisfy all the important skills needed for competent biomedical engineers. Out of these finding It can be argued that for post graduate biomedical engineers, project base learning could be a suitable approach for continues learning and training in order to maintain effectiveness as an engineer. (Humphrey,2005)

Clinical engineering has three main roles, training, maintenance and technological services providence. Moreover, the clinical engineering in the fact work mainly in the hospital with predominantly a management role with occasional interaction with external companies and agencies, and they play an essential role in insuring the wellbeing of patients in hospital. Their role is well studied in Arab countries despites several publications about it. Furthermore, the assessment of the how well the clinical engineer manages the medical equipment's in hospital is still under study issue despite the several attempt to tackle this problem. (Krishnan,2011)

One of the important articles in he filed was published recently in 2020, and it highlight the positive role of well-trained biomedical engineers on the outcome of the patients in the hospitals. This study analyzed data from over 400 case studies retrieved from different countries around the world. The pooled evidence from these studies confirms the notion that effective involvement of biomedical engineers will lead to better use of the available health technology tools, which translate to better service for the patients. This study among many other similar studies will justify the investment in continues training of biomedical engineers as it proves the positive association with improved patient's outcomes. Furthermore, the long duration (10 years) and heterogeneity of the sources of the collected data help in generalizing the result of the study to different part of the worlds. (Karagözoğlu,2011)

The level of perception toward any subject could be affected by many factors. One of them is the level of knowledge about the subject in hand. In a study done by Cruz e al. the level of perception of biomedical engineer's students were measured before and after attending an introductory course on bioengineering in George Mason University. The level of perceptions in this study improved from a mean of 4.01 before the course to a level of 4.21 after the course. Despite the study having no control group and the relatively small size of the study, the outcomes of this study shine a light about the association between the level of perception and he degree of knowledge in he filed of biomedical engineering. (Cruz,2016)

Several other studies and reviews suggestion about the effectiveness of quality improvement, training may have diverse and variable impacts. (25) A systematic review of 26 studies found that education had different effects on attitudes of students to quality improvement techniques and clinical practice guidelines. (26)Other studies have shown that many types of training can improve the knowledge and skills of professionals, and May have some influence on the care process. A few studies have shown that training is associated with improvements in clinical outcomes and the benefits of directly serving users or the care system, although these types of effects are rarely examined. (Abbas,2011:147)

It is important for the clinical engineering department to be efficient and timely in order to ensure that healthcare facilities provide the highest quality of patient care. All healthcare professionals are responsible for ensuring that all medical devices are used safely and efficiently, including awareness of the risks associated with the devices, education and training, and to develop and maintain their skills and achieve the highest quality standards, and with the provision of education and training on medical devices will make it easier for the staff to grow with confidence and provide health care at the highest levels, thereby increasing patient confidence in the services provided to them and to ensure high degree of patient safety. In medical practice all health care facilities must do routinely program of equipment users training to handle the equipment as per current methods of clinical engineering management.

As illustrated in the previous paragraphs, several aspects of medical devices management and important of regular education and training for biomedical engineers have been studied. Nevertheless, further studies remain necessary to assessing the level of the perception of the impact of training and continuing education on the professional performance of biomedical engineers, hopefully through this process the researcher could improve the safety and wellbeing of the patients. (Omair,2017)

Methodology

Population:

Medical device specialist working in three hospitals in Riyadh city, Kingdom of Saudi Arabia (KSA).

Study area:

Military, private and government hospitals in Riyadh

Study duration:

From November 2021 to Jun 2022.

Study type:

Cross sectional Survey.

Study instruments:

An online self-administered questionnaire was distributed to the selected samples through email and specific social websites. A pilot study was carried out on 10 participants to confirm the clarity of the questions. The questionnaire was covering general demographic information (age, gender, years of experience) and several questions assessing the level of perception of the participants toward the continues training effect with another set of question assessing the perceived effect on increase income and increase level of job satisfaction and decrease job accidents. Another question assessing the perceived possible mode of learning and probable barrier of effective training. All questions were close ended questions. An informed consent was taken from the participant before beginning the survey. Furthermore, an introduction about the aim of the survey was available at the beginning of the questionnaire.

Study sample:

The total number of medical device professional is 500, Sample size was 218, calculated using Raosoft online sample size calculator. The calculation was based on 50 % response

distribution, 5 % margin of error and 95 % confidence interval. The online software foundation is based on widely utilized descriptive studies sample size estimation formula proposed in Scott A. & Smith TM work.

Statically analysis:

That data was collected and analyzed using the statistical package for social science (SPSS version 23). The normality of the data measured. Then appropriate Tests were applied to test the significant association between the participant' perception and (age, gender, and years of experience) along with the overall degree of perception.

Discussion

Biomedical engineering is considered a profession responsible for innovation, All kinds of research and development, design, selection, management and safe use medical devices. Healthcare systems need trained and qualified BME professionals Design, evaluate, standardize, acquire, maintain, manage and train safes medical technology. Respond to desire, constantly Improve the quality of medical and healthcare services by using the latest medical technology, there are Increased demand for biomedical engineering Experts and providing proper plan for education and continues training for these experts who use up to date medical technologies. Biomedical engineering education is evolving technical, biological and medical knowledge integration for engineering science improve biomedical science and clinical practice human health. And training is biomedical engineering develop skills for the betterment of humanity Human health through the activities that done in the biomedical field project by the biomedical engineers. (Wang,2017:112) The main aim of continuing education and training of biomedical engineers is to advance their use of biomedical technology and provide them with appropriate skills in order to reach the best clinical efficiency and safe management of technologies of healthcare facility. Furthermore, enriching the bioengineering paradigm with highly qualified, well-trained and solid basis engineers to enhance the profession of biomedical engineering and healthcare. (Singh,2018)

The current study is cross sectional survey study investigating the perception of medical device specialist in Saudi Arabia toward the effectiveness of continues education and training in improving performance, the effect on decrease accidents and, their perception toward increasing the outcomes. The result revealed that biomedical engineering participants have good perception of the effect and importance of continuous training and education in their performance. The answers showed an aggregable response at Likert with arithmetic mean equal to 3.48, which means that most biomedical engineering participants feel the considerable effect and the importance of continuous training and education in their performance. (Nam JG,2019)

Regarding the effect of continuous training and education toward decreases accidents the descriptive statistics of the answers showed a strongly aggregable response at Likert with arithmetic mean equal to 4.33, which means that most of the biomedical engineering in the participants feel the importance of continuous training and education to decrease accidents and most of the biomedical engineering in the participants feel the importance of continuous training and education to decrease accidents. (Hochberg,2010:236)

This in same line with a study was conducted by *Cruz et al* who found out the perception of biomedical students at in George Mason University level of perceptions in this study improved from a mean of 4.01 before the course to a level of 4.21 after the course which emphasize the importance of continuous training and education in biomedical engineering. Moreover, the study found out that biomedical engineering participants strongly agreed with arithmetic mean equal to (4.33), that continuous training and education decreases accidents in same way the findings of the study showed that biomedical engineering participants agreed that continuous training and education in increasing the outcome. This in the same line with a study published in 2020 which justify that the investment in continues training of biomedical engineers as it proves the positive association with improved patient's outcomes. and also support the fact that Impact of Training and Continuing Education for biomedical engineers increased career promotion opportunities, increase the salary and Improvement of the CV leading to better carrier choices and eventually better life style.

The result of the study also showed that the continuous training and education helps in so solving a medical device problem the participant of the study strongly agreed on that with an arithmetic mean = (4.23). Also, the result of the current study revealed that there is significant correlation between the three independent factor scales (Biomedical Engineer's performance, decrease accidents, and increase outcome) ($P > 0.001$). on the other hand, there was a not-significant weak correlation between the three independent factor scales and the dependent factor, $P = 0.562$, 0.770, and 0.818, respectively. (Scott,1996)

There is some evidence that training biomedical engineer may improve knowledge, skills and attitudes. Care processes may also be improved in some instances. furthermore, this led to good impact on patient health outcomes, resource use and the overall quality of care. Training and continuing education lead to well-educated, well trained clinical engineer and provide them with the information of the latest technologies with regard to medical instrumentation and enhance their professional development. Qualified professionals will safely guide the development and safely lead the full life cycle of the technology and improve the quality of health services. (David,2020)

Artificial Neural networks (ANNs) model

ANNs is a nonparametric mathematical model comprising an interconnected set of processing units called (neuron) adaptive and trainable and contain experiential knowledge. Like the brain, ANNs consist of interconnected units of neurons capable of pattern recognition, prediction, classification, and learning. The network acquires knowledge in data and stores the knowledge in a system of neuron connection strength called synaptic weights. The parameter estimates of the ANNs model shown in table reported only has one hidden layer because models with more layers did not fit well. Hidden layers allow ANN to replicate accurately (model) nonlinear patterns in data; without them, ANN behaves like a linear regression model that is incapable of identifying nonlinearity. In the model used in this work, the hidden layer has four nodes; for example, H (1:1) denotes the first node from the first layer, while H (1:4) denotes the fourth node from the same layer. Moreover, the classification accuracy of the ANNs model for the training and testing stages, is 60.7% and 60.5%, respectively. Overall, strongly agree responses constitute 100% and 100% of the training and testing sets, respectively. Finally, the variable importance statistics of the independent variables, All the independent variables contribute to classifying the professional performance of biomedical engineering. Performance is the most important predictor (importance 0.434; normalized importance 100%) followed by decrease accident (importance0.290; normalized importance 66.9%), and increase outcome (importance 0.276; normalized importance 63.7%). (Alkhateeb,2019:5)

In summary, this study reports the impact of training and continuing education outcomes through a series of questions for a biomedical engineer in a different setting using an online self-administered questionnaire. The questionnaire was developed to covering general demographic information and several questions assessing the level of perception of the participants toward the continues training effect with another set of question assessing the perceived effect on increase income and increase level of job satisfaction and decrease job accidents. Another question assessing the perceived possible mode of learning and probable barrier of effective training. All questions were close ended questions. The study does offer some limitations. The current study is limited to 400 Medical device specialists working in three hospitals in Riyadh city, Kingdom of Saudi Arabia (KSA) Military, private and government hospitals in Riyadh during period from November 2021 to Jun 2022 assessing their perception toward the effectiveness of continues training in improving the performance. The population of the study wasn't categorized precisely but it doesn't affect the result since the study aim to assessing their perception toward the effectiveness of continues training in improving the performance.

Conclusion

The study conclude to that continuous training and education has great impact on biomedical Engineer's performance, decrease accidents, and increase outcome. And the biomedical engineers have good perception of the effect and importance of continuous training and education in their performance.

Recommendations

In the light of the findings discussed, the researcher came out with some recommendations which may be incorporated in the conclusion of the Study and assist in enhancing health care system in general and Biomedical Engineering in particular

1. More attention should be given to continuous training and education in Biomedical Engineering and Medical equipment specialist.
2. More study with wider population and different Method (qualitative) should be conducted on effect and importance of continuous training and education and Biomedical Engineering
3. Ministry of health should establish training centers for biomedical engineering and medical equipment specialist and support action research in this filed.

Reference:

1. Organization WH. Global atlas of medical devices. 2017;
2. Albadr H. (2007).Biomedical Engineering Technology Training In Saudi Arabia: Quality Training Challenges And Labor Market Needs. In: 2007 Annual Conference & Exposition. p. 12–315.
3. Organization WH. (2017) . Human resources for medical devices, the role of biomedical engineers. World Health Organization.
4. Aljamali NM, Almuhana WHY(2021). Review on Biomedical Engineering and Engineering Technology in Bio-Medical Devices. J Adv Electr Devices ;6(2):18–24.
5. Al Asif M, Roy S, Abdullah A, Raihan M, Akter R, Hossain M(2018) . Role and impact of biomedical engineering discipline for developing country perspective. Int J Innov Res Comput Sci Technol Vol Issue-4.
6. Yazdi Y.(2013) Developing innovative clinicians and biomedical engineers: a case study. Am J Prev Med. ;44(1):S48–50.
7. Pongpirul K, Sriratanaban J, Asavaroengchai S, Thammatach-Aree J, Laoitthi P.(2006) Comparison of health care professionals’ and surveyors’ opinions on problems and obstacles in implementing quality management system in Thailand: a national survey. Int J Qual Heal Care. 2006;18(5):346–51.
8. Peterson DR, Bronzino JD(2015). The biomedical engineering handbook. Crc Press.
9. Roberts VC.(1981) Education and training for biomedical engineering—A changing pattern. J Biomed Eng. ;3(3):180–2.
10. Brennan-Pierce EP, Stanton SG, Dunn JA (2021) . Clinical Immersion for Biomedical Engineers: Pivoting to a Virtual Format. Biomed Eng Educ. ;1(1):175–9.

11. Singh A, Ferry D, Balasubramanian S(2019). Efficacy of clinical simulation-based training in biomedical engineering education. J Biomech Eng.;141(12):121011.
12. Alkhateeb AF, AlAmri JM, Hussain MA.(2019). Healthcare facility variables important to biomedical staffing in line with 2030 Saudi Vision. In: 2019 Industrial & Systems Engineering Conference (ISEC). IEEE . p. 1–6.
13. Karagözoğlu B, Al-Othmany NS, Hussain MA, Al-Khateeb AF(2011). A novel graduate program in biomedical engineering at King Abdulaziz University to meet the local needs. In: 2011 1st Middle East Conference on Biomedical Engineering. IEEE . p. 363–6.
14. Alkhateeb AF, Sahhari FA, Hussain MA(2019). A Pilot Study of Biomedical Engineering Shared Service for Hospitals in Madinah Munawwarah. In: 2019 Industrial & Systems Engineering Conference (ISEC). IEEE. p. 1–6.
15. Armstrong M.(2006) A handbook of human resource management practice. Kogan Page Publishers.
16. Dehghan M, Heidari FG, Karzari Z, Shahrababaki PM(2020). Integrated training (practicing, peer clinical training and OSCE assessment): a ladder to promote learning and training. Int J Adolesc Med Health.;32(5).
17. Roh C-H, Kim D-S, Kim G-W, Won Y-H, Park S-H, Seo J-H, et al.(2021) Efficacy of an integrated training device in improving muscle strength, balance, and cognitive ability in older adults. Ann Rehabil Med. ;45(4):314.
18. Street LJ. (2011) Introduction to biomedical engineering technology. CRC press;
19. Waly M. (2020).Evaluation of Clinical Engineering Department Services in Riyadh City Hospitals;
20. Billiar K, Gaver DP, Barbee K, Singh A, DesJardins JD, Pruitt B, et al.(2022) Learning Environments and Evidence-Based Practices in Bioengineering and Biomedical Engineering. Biomed Eng Educ.;2(1):1–16.

21. Humphrey JD, Coté GL, Walton JR, Meininger GA, Laine GA.(2005) A new paradigm for graduate research and training in the biomedical sciences and engineering. Adv Physiol Educ.;
22. Scott A, Smith TMF.(1969) Estimation in multi-stage surveys. J Am Stat Assoc.;64(327):830–40.
23. Hwang EJ, Park S, Jin K-N, Im Kim J, Choi SY, Lee JH, et al.(2019). Development and validation of a deep learning–based automated detection algorithm for major thoracic diseases on chest radiographs. JAMA Netw open.;2(3):e191095–e191095.
24. Wang X, Peng Y, Lu L, Lu Z, Bagheri M, Summers RM.(2017) Chestx-ray8: Hospital-scale chest x-ray database and benchmarks on weakly-supervised classification and localization of common thorax diseases. In: Proceedings of the IEEE conference on computer vision and pattern recognition.. p. 2097–106.
25. Li Z, Wang C, Han M, Xue Y, Wei W, Li L-J, et al.(2018) Thoracic disease identification and localization with limited supervision. In: Proceedings of the IEEE conference on computer vision and pattern recognition.. p. 8290–9.
26. Singh R, Kalra MK, Nitiwarangkul C, Patti JA, Homayounieh F, Padole A, et al. Deep (2018).learning in chest radiography: detection of findings and presence of change. PLoS One.;13(10):e0204155.
27. Nam JG, Park S, Hwang EJ, Lee JH, Jin K-N, Lim KY, et al.(2019). Development and validation of deep learning–based automatic detection algorithm for malignant pulmonary nodules on chest radiographs. Radiology;290(1):218–28.
28. Suslick KS.(2001). Encyclopedia of physical science and technology. Sonoluminescence sonochemistry, 3rd edn Elsevier Sci Ltd, Massachusetts.;1–20.

Appendix

The Perception of the Impact of Training and Continuing Education on the Professional Performance of Biomedical Engineers

تأثير التدريب والتعليم المستمر على الأداء المهني لمهندسي الطب الحيوي

Questionnaire

NOTE: by filling this for you will provide us with useful information about the Impact of Training and Continuing Education on the Professional Performance of Biomedical Engineers. This would help in future improvement of Biomedical Engineers work environment. Any personal data obtained from this questionnaire will be kept confidential and under no circumstances will link back to you.

Part I: Demographic characteristics

Age:

Gender:

Male

Female

Nationality:

Saudi

Non-Saudi

Level of education:

Diploma

Bachelors

Masters

Doctorate

Other (specify) ____

Hospital:

Current position:

Work Experience:

<5 yrs.

5-10 yrs.

>10 yrs.

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- **Part II: Questions to assess the effect of continuous training and education in the Biomedical Engineer's performance.**

Question	Yes	No			
<p>1 Is there a continuous education and training programs for biomedical engineers at your hospital?</p> <p>هل هناك برامج تعليم وتدريب مستمرة لمهندسين الطب الحيوي في المستشفى الذي تعمل فيه؟</p>					
Question	Strongly disagree	disagree	neutral	Agree	Strongly agree
<p>2 If the answer is yes, Are the biomedical engineers satisfied with the continuous education and training programs they receive?</p> <p>إذا كان الجواب نعم ، هل مهندسو الطب الحيوي راضون عن برامج التعليم والتدريب المستمر التي يتلقونها؟</p>					
Question	Yes	No			
<p>4 Have you participated in a Training and continuing education program in the past 12 months?</p>					

هل شاركت في برنامج تدريب وتعليم مستمر خلال الـ 12 شهرًا الماضية؟						
Question	Strongly disagree	disagree	neutral	Agree	Strongly agree	
5	If the answer is yes, are you satisfied with the continuous education and training programs you received? إذا كانت الإجابة بنعم ، فهل أنت راض عن برامج التعليم والتدريب المستمر التي تلقيتها؟					
Question	Strongly disagree	disagree	neutral	Agree	Strongly agree	
6	Training and continuing education courses improves the level of functional and professional performance of the biomedical engineers تعمل دورات التدريب والتعليم المستمر على تحسين مستوى الأداء الوظيفي والمهني لمهندسي الطب الحيوي					
Question	Strongly disagree	Disagree	neutral	agree	Strongly agree	
7	Training and continuing education courses increase the productivity دورات التدريب والتعليم المستمر تزيد من الإنتاجية					
Question	Strongly disagree	disagree	neutral	agree	Strongly agree	

8	Do you think training and continuing education courses should be requested for relicensing? هل تعتقد أنه ينبغي طلب دورات التدريب والتعليم المستمر لإعادة الترخيص؟					
	Question	Strongly disagree	disagree	neutral	agree	Strongly agree
9	The current training system available in the country sufficient to provide effective service by the medical engineers نظام التدريب الحالي المتوفر في الدولة كافٍ لتقديم خدمة فعالة من قبل المهندسين الطبيين					
	Question	Strongly disagree	disagree	neutral	agree	Strongly agree
10	Research skills are important to be included in biomedical engineering training and continuing education courses المهارات البحثية مهمة ليتم تضمينها في التدريب على الهندسة الطبية الحيوية ودورات التعليم المستمر					
	Question	Strongly disagree	disagree	neutral	Agree	Strongly agree
11	Cost is barrier for continues education and training التكلفة تعتبر عائق أمام التعليم والتدريب المستمر					

	Question	Strongly disagree	disagree	neutral	Agree	Strongly agree
12	Time is barrier for continues education and training					

الوقت يعتبر عائق لمواصلة التعليم والتدريب المستمر					
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- **Part III: Questions to assess the effect of continuous training and education in the decrease accidents.**

	Question	Strongly disagree	disagree	neutral	agree	Strongly agree
13	<p>Do you agree or disagree that training and continuing education courses will decrease work error?</p> <p>هل توافق أو لا توافق على أن دورات التدريب والتعليم المستمر ستقلل من أخطاء العمل؟</p>					

	Question	Strongly disagree	disagree	neutral	agree	Strongly agree
14	<p>Training and continuing education courses increase work safety</p> <p>دورات التدريب والتعليم المستمر تزيد من السلامة في العمل</p>					

	Question	Strongly disagree	disagree	neutral	Agree	Strongly agree
15	<p>The training and continuing education programs increase problem solving skills</p> <p>تزيد برامج التدريب والتعليم المستمر من مهارات حل المشكلات</p>					

	Question	Strongly disagree	Disagree	neutral	agree	Strongly agree
16	<p>Training courses will translate to better devices maintenance</p> <p>تؤدي الدورات التدريبية إلى صيانة أفضل للأجهزة</p>					

17	Training and continuing education increases the experience of biomedical engineers يزيد التدريب والتعليم المستمر من خبرة مهندسي الطب الحيوي					
	Question	Strongly disagree	Disagree	neutral	agree	Strongly agree
18	Do you think Training and continuing education courses should be obligatory for biomedical engineers? هل تعتقد أن دورات التدريب والتعليم المستمر يجب أن تكون إلزامية لمهندسي الطب الحيوي؟					
	Question	Strongly disagree	Disagree	neutral	agree	Strongly agree
19	The training and continuing education programs are selected related to the specialization. يتم اختيار برامج التدريب والتعليم المستمر ذات الصلة بالتخصص					

- **Part IV: Questions to assess the effect of continuous training and education toward increasing the outcomes**

	Question	Strongly disagree	disagree	neutral	agree	Strongly agree
20	Continuous training will eventually lead to higher income for the biomedical engineer سيؤدي التدريب المستمر في النهاية إلى زيادة الدخل لمهندس الطب الحيوي					
	Question	Strongly disagree	Disagree	neutral	agree	Strongly agree

21	Continues training will translate to better job satisfaction سوف يؤدي التدريب المستمر إلى رضا وظيفي أفضل					
	Question	Strongly disagree	disagree	neutral	Agree	Strongly agree
22	The biomedical engineer is satisfied with the training courses he receives المهندس الطبي الحيوي راض عن الدورات التدريبية التي يتلقاها					
	Question	Strongly disagree	disagree	neutral	agree	Strongly agree
23	The training and continuing education programs enhance the healthcare and patient safety. تعزز برامج التدريب والتعليم المستمر من الرعاية الصحية وسلامة المرضى.					
24	Training and continuing education increases the successful professional collaborations يزيد التدريب والتعليم المستمر من التعاون المهني الناجح					
	Question	Strongly disagree	disagree	neutral	Agree	Strongly agree
25	The training and continuing education programs are necessary to better understand the healthcare settings and their needs. إن برامج التدريب والتعليم المستمر ضرورية لفهم إعدادات الرعاية الصحية واحتياجاتها بشكل أفضل.					

	Question	
26	<p>What are the most important skills that a biomedical engineer needs to be trained on?</p> <p>ما هي أهم المهارات التي يحتاج مهندس الطب الحيوي إلى التدريب عليها؟</p>	