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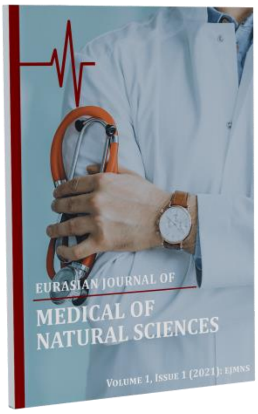

SPECIFIC ASPECTS OF BIOPHYSICS EDUCATION IN MEDICAL UNIVERSITIES

Shermanov Beknazar Ortikovich
Assistant teacher of the Alfraganus University
Email: Beknazarshermanov@mail.com
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ABSTRACT

The human body operates as a complex network of biophysical systems functioning in synchrony. Any disruption to this synchronization may lead to a breakdown of these systems, resulting in the cessation of bodily functions. Understanding the biophysical characteristics of the human body, along with utilizing diagnostic and therapeutic advancements facilitated by Medical Physics, can significantly enhance human well-being. This study aims to emphasize the significance of education in Medical and Biophysics, delineating various educational pathways. Two primary categories are addressed: traditional education, typically at the university level or beyond, where the requisites for educating Medical Physics professionals and users are outlined; and public education, which addresses societal concerns. Education in Medical Physics holds paramount importance for professionals and users alike. Investment in infrastructure enhancement and fostering collaboration among experts and educational institutions are pivotal for maximizing the benefits of advanced diagnostic and therapeutic modalities.

Introduction

The exploration of the Physics underlying the human body dates back to the 16th century when Leonardo da Vinci delved into the biomechanical intricacies of human anatomy. A century later, William Harvey's groundbreaking work showcased the mechanical pumping mechanism responsible for the circulation of blood throughout the body. Moving forward to the 18th century, Luigi Galvani's notable experiments with frogs in 1786 led to the discovery of 'animal electricity,' further illuminating physiological phenomena [1].

Medical and Biophysics delve into the extensive applications of Physics within the realm of medical sciences. Many of these applications can be attributed to two seminal discoveries made at the close of the 19th century. In 1895, Wilhelm Röentgen's revelation of X-rays revolutionized medical imaging, enabling the visualization of internal structures within the human body. Subsequently, in 1896, Henri Becquerel's discovery of radioactivity paved the way for innovative diagnostic and therapeutic techniques. X-rays became indispensable for diagnosing ailments and treating conditions like cancer, while radionuclides found utility in both imaging and therapy.

Furthermore, the identification of the electron by J.J. Thomson in 1897 ushered in a new era of electro-medical instrumentation, profoundly influencing medical practices. These breakthroughs collectively reshaped the landscape of medicine, offering novel tools and methodologies for understanding, diagnosing, and treating various aspects of human health and illness.

In the initial seventy years following these breakthroughs, there was a significant advancement in imaging technology, electronic amplification devices, and the introduction of scintillation cameras in 1958, ultrasonographic devices in 1962, along with the development of advanced high-capacity X-ray tubes and rapid film processing in 1956. However, the rapid evolution of computers further accelerated progress, facilitating the emergence of technologies such as Computed Tomography (1972), Magnetic Resonance Imaging (1980), and Interventional Fluoroscopy, which expanded the scope of technological utilization in routine medical practices. Additionally, therapeutic applications of radiation saw notable developments with the introduction of Cobalt-60 machines in 1951 and Linear Accelerators in 1952 [1,2,3].

Medical Physics education is now making significant strides in developing countries, with numerous Medical and Biophysics departments being established. However, certain questions arise in various scenarios: Are these universities adequately equipping the country with qualified Medical Physicists? A qualified Medical Physicist, as defined by the American Association of Physicists in Medicine (AAPM), is an individual competent to independently practice one or more sub-fields of Medical Physics, including Therapeutic Radiological Physics, Diagnostic Radiological Physics, Medical Nuclear Physics, and Medical Health Physics. Are these institutions providing sufficient education to medical students? Are they undertaking initiatives to educate society about various radiation hazards? Finally, how can these objectives be achieved considering the financial constraints prevalent in most developing countries?

MATERIALS AND METHODS

Below, we aim to address the aforementioned questions by categorizing the educational process into two main categories:

- Conventional Education: This category is further divided into two subcategories:

A. Education for Medical Physics Professionals, such as Medical and Health Physicists, and Biomedical Engineers.

B. Education for Medical Physics Users, including Medical doctors, radiopharmacists, radiographers, technicians, nurses in Medical Physics departments, physiotherapists, industrial workers, as well as other researchers who rely on Medical Physics as a fundamental tool.

- Public Education: This category primarily focuses on educating society about various significant aspects concerning health and well-being.

1-A. Conventional education of Medical Physics professionals: -

The process of becoming a Medical Physicist is now more structured compared to earlier times. Prior to the 1970s, individuals typically entered the field through on-the-job training, often with minimal specialized coursework following the completion of a graduate degree in Physics or a related physical science. However, starting from the 1970s and continuing into the 1980s, there was a gradual establishment of graduate Medical Physics programs. In the mid-1980s, the AAPM formed a commission to accredit these programs [3]. Today, many universities offer postgraduate courses in Medical, Health, and Biophysics, as well as Biomedical Engineering. The typical prerequisite for these programs is a B.Sc. in Physics or Engineering, with some universities also considering backgrounds in Chemistry or Computer studies. The primary objective of these postgraduate courses is to impart comprehensive knowledge of Physics as applied to Medicine, followed by intensive training in the specialized instrumentation requirements encountered in various hospital settings. The aim is to cultivate hospital physicists who possess both a strong scientific foundation and the ability to apply it to the diverse challenges encountered in their work, rather than merely accumulating factual knowledge through formal coursework [4]. A suggested curriculum for a postgraduate program in Medical and Biophysics, which typically spans 1-2 years, can be structured into three main phases:

Step 1: Core Courses During this phase, students are introduced to various disciplines within Medical and Biophysics. These include Nuclear and Radiation Physics, the Application of Radiation in diagnosis and therapy, Radiobiology, Radiation dosimetry and regulations, Medical Electronics and Instrumentation, Neurosciences, Optics and Laser, Audiology, Electromagnetism, Signal processing and Interpretation, Ultrasound, Magnetic Resonance Imaging, Image and Data processing, among others. Additionally, the core curriculum should encompass lectures on Biochemistry, Physiology, and Anatomy to provide students with a deeper understanding of the human body. This holistic understanding is essential for comprehending subjects like Radiobiology and Neurosciences. Moreover, the curriculum should incorporate statistical analysis and proficiency in at least one computational language. The inclusion of Biomechanics and Rehabilitation within the Medical Physics course is subject to debate. While some universities view these subjects as pertinent only to Biomedical Engineering specialization, others recognize the broad responsibilities of Medical Physicists, encompassing clinical support, teaching, and research. Therefore, a thorough understanding of the biomechanical properties of the human body, potential system failures, and maintenance procedures is deemed essential for Medical Physicists to effectively impart knowledge to both Medical students and Biomedical Engineers.

Step 2: In-depth Studies At this stage, students are required to select three or four topics for in-depth exploration. Increased emphasis is placed on laboratory work and practical training in hospital settings. Problem-based learning methodologies can also be implemented, allowing students to analyze and elaborate on various technical scenarios.

Step 3: Final Master's Project The culmination of the Master's course involves the completion of a small-scale project followed by the presentation of a final thesis. Subsequently, students undertake a hospital placement lasting one or two years, culminating in an examination for licensure to work in a hospital's Radiation department. Medical

Physicists intending to pursue careers in education may require additional courses in teaching skills and a brief introductory course in various medical terminologies to effectively instruct Medical Physics users.

The primary challenge faced by developing countries in establishing Medical Physics departments or educational programs lies in infrastructure limitations. This encompasses the availability of qualified teaching staff, well-equipped laboratories, and nearby teaching hospitals to facilitate necessary training. Significant investment is required to address these needs, including proper training for teaching staff abroad. Continuous education and training are essential to keep Medical Physicists abreast of advancements in medical technologies, thereby positively impacting education. Given the high cost of medical equipment, it is impractical for individual universities to procure all necessary equipment for a Medical Physics department. Proposed solutions include:

1. Establishment of national Medical and Biophysics societies to establish connections with regional and international societies and funding bodies.
2. Creation of centers of excellence specializing in one or two disciplines, capable of providing comprehensive facilities. Collaboration among these centers could involve staff exchange and student training.
3. Documentation of experimental work to overcome shortages in experimental tools. Video recordings and CDs detailing equipment installation, calibration, quality assurance and control tests, troubleshooting, maintenance, and handling of radioactive materials should be made available in audio-visual laboratories for practical sessions. Practical sessions could also incorporate computational simulations of diagnostic and therapeutic tools and their applications.

1-B. Conventional education of Medical Physics users: -

Physics plays a significant role as a fundamental medical science. The human body itself comprises systems governed by physical laws, encompassing mechanisms such as vision, hearing, olfaction, fluid and gas exchange, temperature regulation, electric field potentials, viscoelastic properties of muscles and tendons, and excretion, among others. Understanding these phenomena forms the basis for interpreting and addressing physiological abnormalities. Additionally, the origin of all living systems lies in physico-chemical principles, allowing for their explanation through physico-chemical laws [5].

The routine use of advanced diagnostic and therapeutic equipment by medical and paramedical professionals necessitates a solid understanding of the physics underlying such technology. Proposed Medical Physics topics for faculties of Medicine, Pharmacy, Physiotherapy, Nursing, and Radiography include the Physics of the human body, Radiobiology, and the applications and risks associated with non-ionizing and ionizing radiation. Various teaching methods should be employed, including lectures, laboratory work, visits to centers of excellence, hospitals, and clinics, as well as utilizing recorded videotapes and CDs, as mentioned earlier. At the postgraduate level, courses should be tailored towards specific specializations. For instance, individuals intending to work in Radiology, Oncology, Nuclear Medicine, or Radio-Pharmacy departments require extensive training in Radiobiology and Radiation protection, while those specializing in ophthalmology necessitate a deeper understanding of Optics and lasers.

Industrial workers may also encounter elevated radiation exposure while utilizing radiation in activities such as industrial radiography and sterilization. The recommended courses for these workers align with those suggested for various Medical schools.

Medical Physicists play a pivotal role in educating users of Medical Physics, facilitating the effective utilization of the subject by understanding the needs of this category. Involving experts from diverse fields in the educational process is highly advisable. Maximizing the utilization of centers of excellence across different institutes enhances the quality of educational programs.

2. Public Education:

Public education should aim to increase public awareness about significant issues while providing answers and solutions to highlighted risks to prevent unnecessary escalation of public anxiety. It is crucial to use simple terminology and understandable comparisons. For instance, illustrating the risk associated with a particular behavior as equivalent to smoking a certain number of cigarettes can effectively convey the message. The term "ionizing radiation" often evokes fear among the public, especially due to associations with disasters like the Chernobyl accident in 1986, which resulted from a flawed reactor design and inadequate training of personnel [6].

There is often resistance to the establishment of nuclear power plants despite their potential benefits. Under normal operating conditions, nuclear power plants can generate substantial electricity with lower pollution levels compared to coal or fuel power plants. For example, replacing a 1000 MW coal power plant with a nuclear power plant of equal capacity can prevent the release of millions of tonnes of carbon dioxide, sulphur dioxide, nitrogen dioxide, and dust into the atmosphere annually, thus contributing to environmental protection by reducing greenhouse gas emissions, global warming, and acid rain [7].

Regarding hazards associated with mobile phones and microwave ovens, individual perceptions of risk are influenced by the degree of personal choice involved. Despite known risks, activities like smoking and drinking may be perceived as lower risks due to a sense of control. Many individuals, including children, use mobile phones and microwave ovens, both of which emit radiofrequency radiation. While this radiation is below the ionizing frequency and cannot directly damage DNA molecules, it may still pose risks through indirect effects such as through intermediate chemicals or accumulated quantum effects. Research on the harmful effects of microwave radiation on the human body has yielded inconclusive results [9].

Several studies [10,11,12] have linked excessive mobile phone usage to an increased incidence of brain tumors and disruptions in brain regions responsible for memory and learning. According to these findings, prolonged mobile phone use can impair concentration, cognitive abilities, and mood stability. Additionally, it may interfere with the immune system by compromising the electromagnetic communication of white blood cells, thus reducing their ability to combat infectious diseases. Mobile phone use has also been associated with decreased efficacy of anti-asthmatic medications and delayed recovery from illnesses. The impact is particularly pronounced in children, as their developing nervous and immune systems are more susceptible to DNA alterations.

Mobile phones are no longer solely used for making calls; the incorporation of advanced features has expanded their utility for various purposes. They serve as alarm clocks, often placed in close proximity during sleep, and are utilized for activities like listening to the radio, with earpieces positioned near the brain for extended periods. The adverse effects of radiation exposure intensify with prolonged usage.

Public education initiatives should:

- Encourage individuals to curb these habits and minimize exposure durations.
- Discourage the use of mobile phones near infants, particularly in vehicles where the steel structure amplifies radiation.
- Advocate against the construction of mobile phone towers near residential areas and schools.

Breast Awareness Education:

Breast cancer is not a recent affliction; its existence dates back to ancient times, with evidence of its recognition by the Ancient Egyptians as early as 1600 BC [17]. Today, it stands as the leading cause of cancer-related deaths among women worldwide. In 2000 alone, breast cancer claimed approximately 189,000 lives in developed countries and 184,000 lives in developing nations, constituting 16% and 12% respectively of all cancer-related deaths in women [18]. While death rates from breast cancer have notably declined in developed countries, particularly among younger women, medical experts attribute this decline to advancements in early detection facilitated by breast screening programs and more effective treatments. However, the implementation of breast screening programs remains challenging in many developing countries, where the number of cancer cases is projected to double to 10 million new cases annually by 2015 [19].

In such settings, public education on Breast-Self Examination (BSE) holds significant value. It is imperative for medical professionals, including doctors, students, and Medical Physicists, as well as the press and mass media, to actively engage in educating women in rural areas about breast cancer and the importance and method of performing BSE. Teaching methods such as public lectures, posters, and role-plays are recommended for this public educational initiative, considering that many of these women may have limited education and difficulty understanding medical terminology. While this intensive program may not directly reduce the incidence rate, it is expected to positively impact the readiness of affected women to seek appropriate treatment. Additionally, it can serve to persuade donors to contribute mobile mammograms for future Breast Screening Programs (BSP).

Awareness of Medical Exposures: It has been estimated that more than 90% of the population's total radiation exposure stems from diagnostic X-ray procedures [20]. However, the situation is exacerbated in impoverished and rural areas where radiation protection regulations are not rigorously enforced. Inadequate monitoring of scattered radiation and the construction of hospitals using clay instead of concrete further elevate the radiation doses experienced by workers, patients, and accompanying individuals beyond recommended levels set by regulatory bodies. Shutting down these hospitals for non-compliance is impractical as it would deprive villagers of essential diagnostic services.

Educational initiatives, employing methods such as posters and role-plays, should focus on conveying the following key messages in simple terms:

- Maintain a safe distance from the X-ray room when other patients are undergoing irradiation.
- Inform the doctor or technician if there is a possibility of pregnancy.
- Refrain from undergoing X-ray examinations unless recommended by a physician. The absence of pain does not equate to harmlessness, etc.

Public education in Medical Physics holds significant importance in addressing these concerns. Medical Physicists, alongside medical professionals and students, supported by various organizations and mass media outlets, can spearhead campaigns to raise awareness about these hazards. It is hoped that such efforts will contribute to enhancing the quality of life for the general public.

RECOMMENDATIONS

- Incorporate Medical Physics into the curricula of various schools and institutions of higher education.
- Engage experts, both nationally and internationally, in the educational process, particularly in its initial stages.
- Establish centers of excellence dedicated to specific disciplines within Medical Physics, rather than relying solely on multidisciplinary departments. Collaboration among these centers for the training of both staff and students is strongly advised.
- Foster collaboration between Medical Physics lecturers and those from other natural and applied sciences to prevent information overlap.
- Strengthen national Medical Physics regulatory bodies with support from organizations such as the IAEA and the UNSCEAR.
- Ensure the performance of quality control tests on diagnostic and therapeutic machines, with exposures being justified and optimized.
- Prohibit the placement of mobile phone towers near residential areas and schools, aligning with recommendations outlined in the Stewards report [21].
- Mobilize Medical Physicists, medical professionals, educators, governmental and non-governmental organizations, and mass media to take a leading role in public education. Establish a council to oversee and review developments in the field, while delivering continuous public lectures to inform the community.
- Implement testing of cosmetics sold in the market, with non-compliant products being disposed of in accordance with regulations.

Increase investment in Medical Physics education to enhance its quality and effectiveness.

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