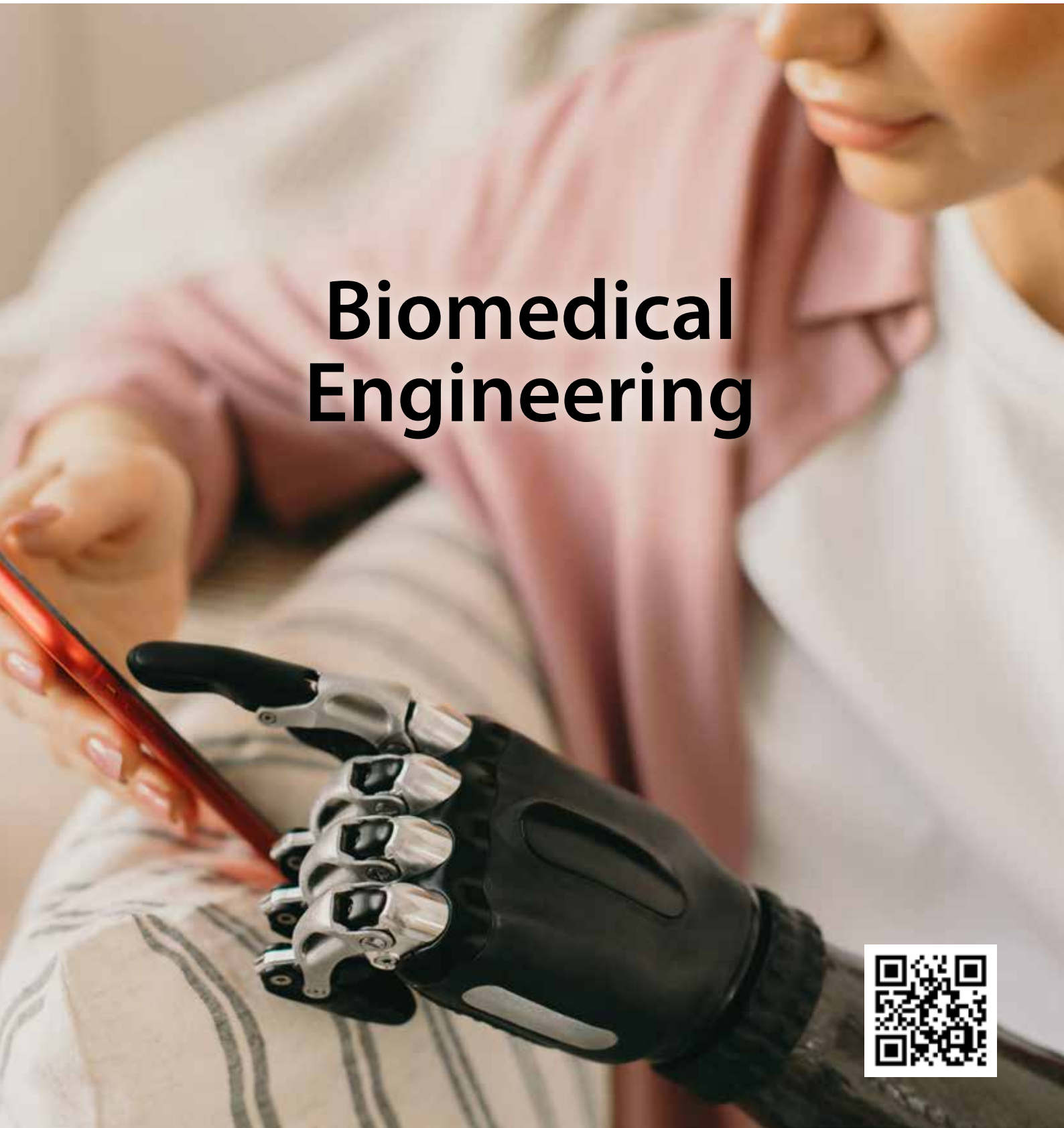
KDN PP 11720/4/2013 (032270)

LEMBAGA JURUTERA MALAYSIA
BOARD OF ENGINEERS MALAYSIA

THE INGENIEUR

VOL.95
JULY-SEPTEMBER 2023

MAGAZINE OF THE BOARD OF ENGINEERS MALAYSIA



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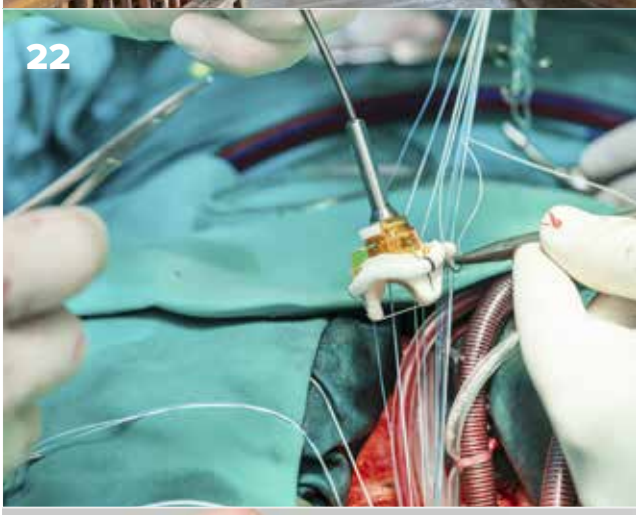

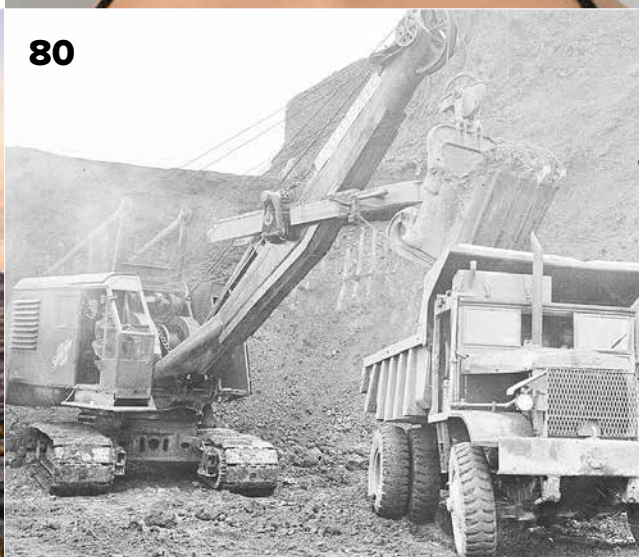

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LEMBAGA JURUTERA MALAYSIA
BOARD OF ENGINEERS MALAYSIA
2022-2023

The Ingenieur is published quarterly by the Board of Engineers Malaysia (Lembaga Jurutera Malaysia) and is distributed free to registered Professional Engineers. The statements and opinions expressed in this publication are those of the writers. BEM invites all engineers and readers to contribute relevant articles and views to the Publisher.

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Lembaga Jurutera Malaysia
Tingkat 17, Ibu Pejabat JKR, Jalan Sultan Salahuddin, 50580 Kuala Lumpur.
Tel: 03-2698 0590, 03-2691 2090 Fax 03-2692 5017
e-mail: publication@bem.org.my
website: www.bem.org.my

DESIGN AND PRODUCTION: Inforeach Communications Sdn Bhd
PRINTER: Percetakan Okid Sdn Bhd, 2 Jalan SS13/3C, Subang Jaya Industrial Estate, 47500 Subang Jaya, Selangor

Biomedical Engineering

When Institut Jantung Negara (IJN) announced recently that it made history as the first hospital in the ASEAN region to implant a Micra AV pacemaker for the treatment of slow heart rate, it spells the power of biomedical engineering in developing this state-of-the-art medical device. It is through biomedical engineering innovation that the Micra AV pacemaker was reduced to the size of a vitamin supplement capsule enabling the implant through a minimally invasive procedure, eliminating the need for extensive surgery.

Biomedical engineers work with medical professionals to design and develop advanced healthcare technology. Their early inventions such as mechanical ventilator, electrocardiograph, artificial heart, kidney dialysis have improved medical services to a large extent as life saving devices. Presently, there are expectations of greater access to affordable, safe and efficient medical devices as society is getting more affluent. In this context, more biomedical engineers will be expected to be involved in the integration of new medical devices and treatments into coherent health-care programmes that require comprehensive professional skills.

Biomedical engineering is a fast-growing field with emerging technologies such as gene editing, bioinformatives and neuroengineering leveraging on 4IR and digitalisation to break new frontiers in producing precision medical devices. To this end, I am happy to note that the are several local universities offering biomedical engineering programmes to supply sufficient talent to meet industry demand.

It is important that Malaysia possess sufficient competent Biomedical Technical Personnel (BTP) for the maintenance of medical equipment to ensure the safety of patients. The article on 'Competency of BTP' examines its role in relation to the standard of BTP as well as the prerequisite conditions of the medical device industry if Malaysia is to be recognised as a medical equipment producer.

The field of biomedical engineering is revolutionising the healthcare landscape by continually innovating more sophisticated medical equipment in treating complex health issues in a more efficient way. The article on 'Biomedical Engineering shapes healthcare and life' provides further insights on the advances made in X-ray, MRI, artificial organs, robotic surgery system and AI that are changing the landscape of modern medical treatment.

Health and safety remain the main concern of BEM for the engineering services provided by registered engineers. Biomedical engineers are gaining significance in tandem with the advancement in the medical field.

Datuk Ir. Ahmad Redza bin Ghulam Rasool
President, BEM

CALL FOR ARTICLES

The Ingenieur is published quarterly by the Board of Engineers Malaysia. The following are the themes for the coming issues.

- Vol. 96 October-December 2023
  Safety, Health & Environment
- Vol. 97 January-March 2024
  Environmental Social Governance (ESG)
- Vol. 98 April-June 2024
  Engineering & Law

Articles and other contributions relevant to the themes are welcomed, but the decision to publish rests with the Editorial Board.

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Biosensor Technologies In Sports: Advancements, Challenges, and Future Directions

By Ir. Dr Kasumawati Lias
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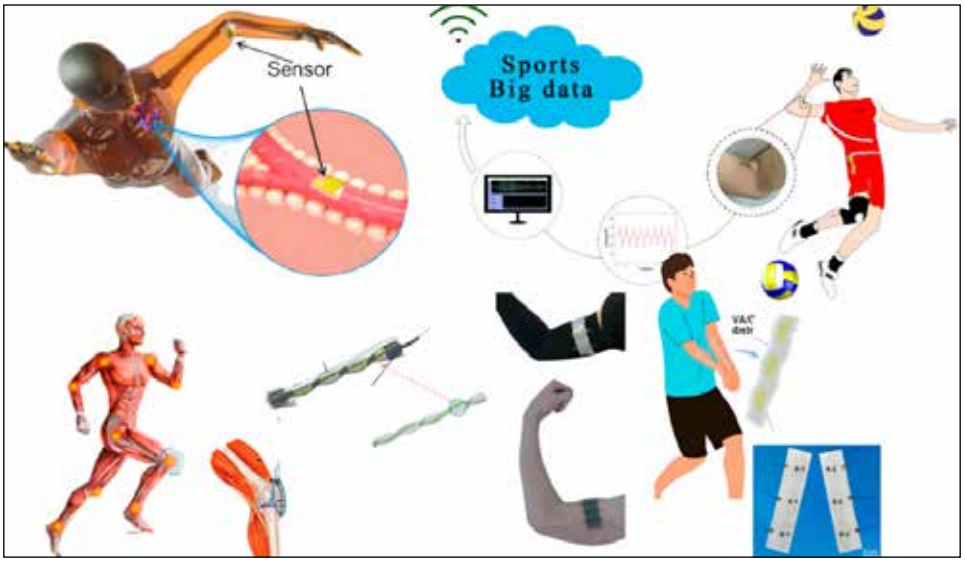

Figure 1: Examples of Biosensors for Sport

Biosensor technologies have revolutionised various domains, including sports applications. The use of biosensors for sports applications is aimed at enhancing athlete performance, monitoring health and fitness levels, and preventing injuries. In Malaysia, several research institutions, universities, and sports organisations have been involved in the development and implementation of biosensors for sports. These institutions work on various aspects, including sensor design, data analysis, and integration with wearable devices.

One example of biosensor research in Malaysia is the development of wearable sensors for athlete monitoring and performance optimisation. These sensors can measure physiological parameters such as heart rate, body temperature, oxygen saturation, and movement patterns. The collected data can be used to assess an athlete's physical condition, track training progress, and tailor training programmes to individual needs.

Furthermore, in Malaysia, biosensors are also being investigated for use in sports injury prevention and recovery. Biosensors can help

identify movement patterns that may result in injuries by monitoring biomechanical data such as joint angles, forces, and muscle activation patterns. They can also give athletes and coaches feedback to help them fix poor technique or posture.

The National Sports Institute of Malaysia (ISN) is one of the major sports organisations that implement sports science and technology programmes such as the use of biosensors. To incorporate biosensor technology into athlete training and monitoring programmes, the ISN works with researchers and sports professionals.

BIOSENSOR TECHNOLOGIES IN SPORTS

In the past, athlete monitoring was predominantly reliant on subjective observations and manual measurements, which inevitably curtailed the precision and immediacy of assessing an athlete's physiological and biomechanical parameters. The ascension of biosensor technologies has ushered in a new era in sports, imparting the capacity for objective and uninterrupted monitoring.

Biosensors are analytical devices that combine a biological sensing element (such as enzymes, antibodies, or cells) with a transducer to detect and quantify specific analytes or biomarkers. In sports, biosensors can measure various physiological and biomechanical parameters including heart rate, oxygen consumption, glucose levels, lactate concentration, muscle activity, joint movements, and more.

The significance of biosensor technologies in sports applications lies in their ability to provide real-time, accurate, and objective data for monitoring athlete performance, optimising training regimens, preventing injuries, and facilitating rehabilitation processes. These technologies have a number of benefits, including portability, non-intrusiveness, and the opportunity for individualised feedback and coaching support.

In recent years, biosensor technologies have advanced significantly for use in sports. Smartwatches, chest straps, and patches are a few examples of wearable biosensors that have grown in popularity because of how simple they are to use and how well they can gather data during workouts or contests. For additional research, these gadgets can wirelessly transfer data to mobile devices or cloud-based platforms.

In addition, biosensor technologies have been coupled with data analytics, machine learning, and artificial intelligence algorithms, extracting meaningful insights from the amassed data. This fusion empowers the creation of personalised training regimens, enables real-time performance appraisal, and facilitates the early identification of potential health hazards or instances of over exertion.

TYPES OF BIOSENSORS USED IN SPORTS

Biosensors used in sports applications employ various sensing mechanisms and detection platforms to monitor and analyse physiological and biomechanical parameters. The types of biosensors commonly used in sports include:

1. **Electrochemical Biosensors**: Electrochemical biosensors measure changes in electrical properties resulting from biochemical reactions. These biosensors typically consist of working and reference electrodes immersed in an electrolyte solution. The recognition element, such as an enzyme or antibody, is immobilised on the electrode surface, enabling selective detection of the target analyte. Examples of electrochemical biosensors used in sports include glucose sensors, lactate sensors, and pH sensors.
2. **Optical Biosensors:** Optical biosensors rely on the detection of light signals to measure analyte concentrations. These biosensors utilise principles such as absorbance, fluorescence, or surface plasmon resonance to quantify target analytes. In sports applications, optical biosensors are employed for measuring parameters such as oxygen saturation, glucose levels, and protein biomarkers. They are commonly integrated into wearable devices, such as smartwatches or patches, for real-time monitoring.
3. **Piezoelectric Biosensors**: Piezoelectric biosensors detect changes in mass or

Motion and position sensors, including accelerometers and gyroscopes, are widely used in sports to capture and analyse movement patterns, velocity, acceleration, and orientation of athletes.

viscoelastic properties by measuring the resonance frequency of a quartz crystal resonator. These biosensors are highly sensitive and can detect minute changes in analyte concentration. In sports, piezoelectric biosensors are used for monitoring parameters like hydration levels and detecting biomarkers related to fatigue or over exertion.

4. **Strain Gauges and Force Sensors**: Strain gauges and force sensors are examples of biosensors used for biomechanical measurements in sports. These sensors detect and measure physical forces, strains, and pressures applied to sports equipment or the human body. They are commonly integrated into wearable devices, sports equipment, or specialised insole systems to assess forces exerted during training, running, or impact events.
5. **Motion and Position Sensors**: Motion and position sensors, including accelerometers and gyroscopes, are widely used in sports to capture and analyse movement patterns, velocity, acceleration, and orientation of athletes. These sensors are commonly embedded in wearable devices, sports equipment, or clothing to provide insights into performance metrics, gait analysis, or injury prevention.
6. **Sweat-based Biosensors**: Sweat-based biosensors are gaining attention in sports applications due to their non-invasive and real-time monitoring capabilities. These biosensors collect sweat samples and analyse them for various analytes, including electrolytes, lactate, glucose, and hydration markers. Sweat-based biosensors offer valuable insights into an athlete's hydration status, electrolyte balance, and overall performance.

CHALLENGES IN SPORTS

Biosensor technology undoubtedly offers transformative possibilities for sports applications, but it is not without significant obstacles. Securing the correctness and dependability of the data obtained through biosensors is a significant obstacle. It is crucial to make sure that sensors can endure a variety of environmental factors.

Furthermore, the data interpretation algorithms must be sufficiently complex to take into consideration the complex dynamics of human physiology.

Another crucial issue pertains to wearability and comfort. Biosensors must fulfil certain criteria to be suitable for athletes: they need to be lightweight, inconspicuous, and robust enough to endure extreme levels of physical stress, all while neither impinging on performance nor inducing discomfort.

The issue of data security and privacy is also crucial. The proliferation of personal data transmission and gathering has raised serious concerns about security and privacy. It is crucial to put policies into place that ensure safe data collection, storage, and transfer while protecting the athlete's privacy.

The interpretation of data represents another major challenge. The sheer volume of data amassed by these sensors can be daunting and necessitates advanced data analytics for accurate interpretation. The utility of these devices could be limited if athletes or coaches lack the necessary skills to analyse and interpret such data.

Despite the growing affordability of biosensor technology, cost remains a prohibitive factor for many athletes, particularly at the amateur or youth level. Additionally, access to the high-tech analytics platforms required for data interpretation may be financially inaccessible for some.

Like all emerging technologies, biosensor technology faces the challenges of regulation and standardisation. This involves guaranteeing the safety and efficacy of these devices and developing standardised protocols for their application and interpretation.

The resolution of these challenges will undoubtedly be pivotal for the future evolution and widespread acceptance of biosensor technologies within the sports domain.

FUTURE DIRECTIONS

The future trajectory of biosensor technologies in sports applications involves several promising advancements, among which are the proliferation of emerging biosensor technologies and the incorporation of Artificial Intelligence (AI) and Machine Learning (ML).

1. Emerging Biosensor Technologies

Emerging biosensor technologies are constantly evolving and expanding, offering new possibilities for sports applications. Examples:

- **Flexible and Stretchable Biosensors**: These biosensors are designed to conform to the shape and movements of the body, allowing for comfortable and unobtrusive monitoring. They are often made from flexible materials, such as polymers or nanomaterials, and can be integrated into clothing, patches, or wearable devices.
- **Smart Textiles**: Smart textiles incorporate biosensors directly into fabrics, allowing for seamless integration with sports apparel. These biosensor-enabled textiles can monitor vital signs, movement, and other physiological parameters, providing real-time data without the need for additional wearable devices.
- **Implantable Biosensors**: Implantable biosensors are designed to be placed inside the body to monitor specific physiological parameters. These biosensors can provide highly accurate and continuous measurements of parameters such as glucose levels, oxygen saturation, or muscle activity. They are particularly useful for long-term monitoring or in specialised sports applications.
- **Lab-on-a-Chip Biosensors:** Lab-on-a-chip biosensors integrate multiple analytical functions, such as sample preparation, detection, and analysis, onto a small chip or microfluidic device. These biosensors offer portability and rapid analysis and can measure multiple parameters simultaneously, making them promising for on-field or point-of-care applications in sports.
- **Optical Biosensors:** Optical biosensors utilise light-based techniques, such as fluorescence, luminescence, or absorbance, to measure specific biomolecular interactions. These biosensors can be used to detect and quantify analytes or biomarkers in various bodily fluids, providing valuable information about an athlete's health and performance.

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The Board of Engineers Malaysia (BEM), formed in 1972, is a statutory body constituted under the Registration of Engineers Act 1967. BEM falls within the ambit of responsibility of the Minister of Works. Its primary role is to register and regulate engineering professionals, engineering technologists and inspectors of works in order to safeguard the safety and interest of the public.

To-date there are more than 16,000 Professional Engineers, 140,000 Graduate Engineers and 9,000 Engineering Technologists registered with BEM.

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- **Wireless and IoT-enabled Biosensors**: Wireless and Internet of Things (IoT)-enabled biosensors allow for seamless data transmission and remote monitoring. These biosensors can connect to smartphones, tablets, or cloud-based platforms, enabling real-time data visualisation, analysis, and sharing, facilitating remote coaching or medical supervision in sports.

While these emerging technologies hold great promise, their adoption must align with relevant regulations, ethical considerations, and privacy measures.

2. Integration with Artificial Intelligence and Machine Learning

Integration with artificial intelligence (AI) and machine learning (ML) techniques has the potential to greatly enhance the capabilities and performance of biosensors in sports applications. AI and ML can be integrated with biosensors in various ways, such as:

- **Data Analysis and Interpretation**: AI and ML algorithms can be employed to analyse the vast amounts of data generated by biosensors. These algorithms can identify patterns, correlations, and anomalies in the data, enabling more accurate and meaningful insights into an athlete's performance, health, and potential risks. ML algorithms can learn from historical data to make predictions or classify data into specific categories.
- **Real-time Monitoring and Feedback**: AI and ML algorithms can process biosensor data in real-time, providing instant feedback to athletes, coaches, or healthcare professionals. This real-time analysis can help optimise training programmes, identify fatigue or injury risks, and enable immediate adjustments or interventions to enhance performance or prevent potential issues.
- **Personalised Training Programmes**: AI and ML algorithms can utilise biosensor data to develop personalised training programmes for athletes. By analysing an individual's physiological parameters, performance metrics, and historical data, AI can tailor training plans to specific needs, optimising performance and reducing the risk of injuries.
- **Predictive Analytics**: AI and ML techniques can be used to develop predictive models based on biosensor data. By analysing historical data and patterns, these models can forecast an athlete's performance, predict injury risks, or provide early warnings for fatigue or over exertion. This information can be used to make informed decisions regarding training load, recovery, and injury prevention strategies.
- **Injury Detection and Rehabilitation**: AI and ML algorithms can aid in the early detection of injuries by analysing biosensor data for abnormal patterns or deviations from baseline. They can also assist in designing personalised rehabilitation programmes by considering an athlete's physiological data, movement patterns, and recovery progress.

Despite the benefits AI and ML bring, it is vital to ensure the diversity and representativeness of training data, compliance with ethical norms, and adequate data privacy and security measures to protect athlete information.

CONCLUSION

Biosensors are increasingly becoming indispensable tools within the sports sector, offering real-time surveillance and examination of physiological parameters, biomechanics, and performance metrics. These devices deliver vital insights to athletes, coaches, and healthcare professionals, aiding in optimising training regimens, forestalling injuries, and performance enhancement.

The utilisation of biosensors within sports reaps myriad benefits. Real-time tracking of physiological parameters enabled by these devices allows athletes to fine-tune their efforts during training or competitive events instantaneously. The ability to monitor biomechanical data offers an invaluable understanding of movement patterns, techniques, and efficacy.

Additionally, biosensors assist in the early detection of fatigue, over exertion, and injuries,

> Biosensors are increasingly becoming indispensable tools within the sports sector, offering real-time surveillance and examination of physiological parameters, biomechanics, and performance metrics.

enabling timely intervention and prevention. They play a crucial role in monitoring biomechanics to prevent injuries by analysing movement patterns and identifying potential risk factors. Biosensors also accelerate rehabilitation processes by providing data on progress, recovery, and injury healing.

The ability to design personalised training programmes based on biosensor data further elevates their utility, enabling the tailoring of workout regimens to meet individual needs and objectives. By monitoring training intensity and recovery, they assist in achieving a balance between exertion and rest, a crucial factor for peak performance and injury prevention. Furthermore, their ability to provide instantaneous insights and guidance to athletes and coaches affirms their value in providing feedback and coaching assistance.

Emerging technologies such as flexible, adaptable sensors and intelligent textiles are broadening the scope of biosensor applications in sports. Coupling these with artificial intelligence and machine learning techniques further amplifies the potential of biosensors, enabling sophisticated data analysis, predictive modelling, and personalised recommendations.

Despite the numerous advantages, using biosensors in sports comes with some difficulties. To ensure smooth data interchange and compatibility among various biosensor devices and platforms, there is a pressing need for standardisation and interoperability. In addition, concerns like informed consent, data security, and anti-doping rules compliance need to be addressed. Promoting the appropriate and efficient use of biosensors in sports will depend on addressing these issues.

In summary, biosensors offer immense potential in the world of sports, revolutionising performance monitoring, injury prevention, and athlete well-being. As technology advances and researchers continue to explore new frontiers, biosensors will continue to play a pivotal role in optimising athletic performance, improving training methodologies, and shaping the future of sports. ■

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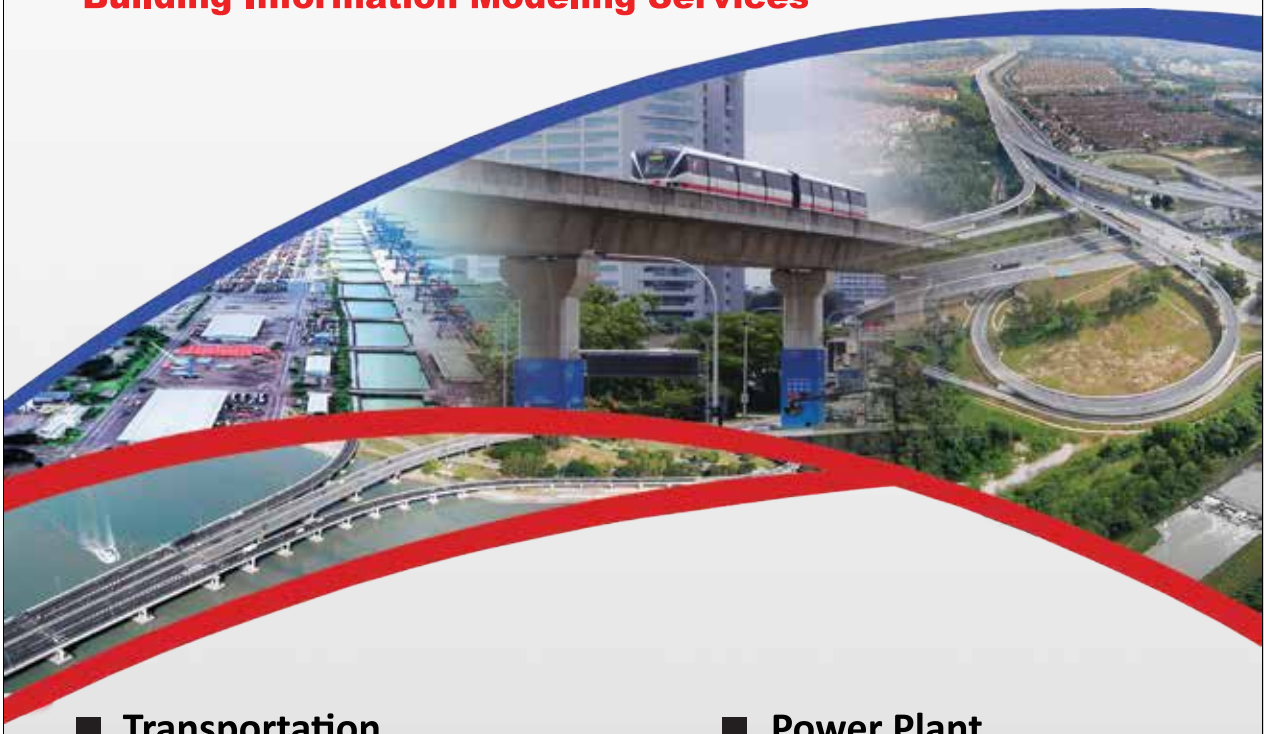

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