FOR THE LOVE OF MEDICAL PHYSICS AND FOOTBALL

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Abstract—**Engaging and exposing students to various applications of physics for the improvement of health, can be fun and productive. This study was done to broaden students' view of medical physics, showing its applications beyond traditional healthcare settings and encouraging them to consider it as a career, using the sports they love as a tool.**

Keywords—**Football, Medical Physics, Physiological Measurements.**

I. INTRODUCTION

How do you explain the applications of physics in medicine to a group of undergraduate students who are new to the idea and have a 'not so interesting time' understanding its relevance? What happens when both the students and their supervisor love and play football? A good approach is to leverage their interests as an opportunity to introduce and clarify the less familiar aspects of medical physics.

Medical Physics is an interesting field of study that intercepts physics and medicine. It applies the theoretical and experimental principles of physics in medicine for the diagnosis and treatment of diseases. It has existed for as long as the discovery of X-rays and radioactivity by Wilhelm Roentgen and Marie Curie respectively while the applications of physics in medicine dates to the very beginning of life. However, the profession started to become popular when the complexity of physics applications in medicine required high level of specialised scientists, the physicists themselves [1,2]. Internationally, Medical Physics as a profession is promoted and overseen by the International Organisation for Medical Physics (IOMP), established in 1963 and it is recognised by the International Labour Organisation (ILO) formally as a health profession [3]. Over the years, the specialties of medical physics in health care have expanded from the applications of ionizing and non-ionizing radiation to physiological measurements, rehabilitation, orthopaedics, audiology, and the list goes on.

Football, also known as soccer mainly in North America, is undoubtedly the most popular and most watched sport in the world [4]. Though widely seen as an art of teamwork and instinct, it is fundamentally a science of motion, force, and energy. Physics governs every action on the pitch, from the curved trajectory of a free kick to the impact force of a tackle and the acceleration of a sprint. It is a wholesome sport that combines various other 'mini' sports like athletics, running, throwing, and kicking. These activities are all governed by the principles of physics. Physics principles like Newton's laws, gravitational force, projectile motion, kinetic energy, potential energy, impulse, friction, momentum, torque, and angular velocity.

One branch of medical physics that has applications in football is physiological measurements. Physiological measurements involve taking measurements of how the body functions and these can be very simple measurements from taking the temperature of the body with a clinical thermometer to much more complicated measurements like ECG and brain functions [5,6]. These measurements are used for diagnosis and monitoring using various methods and tools.

The advancement of technology especially in the areas of development of wearable devices for measurement of players health and performance has greatly improved performance monitoring [7]. These devices help to check metrics like heart rates, temperature, player speed, velocity, distance covered, and so on. Concepts all grounded in the principles of physics. Data collected with the help of these devices connected to a phone app or computer, help to track health status players in real time to evaluate performance, prevent injuries or other health complications.

Teaching and learning medical physics need not be boring and so the objective of this study was to highlight and demonstrate practically, the intersection of medical physics and football amongst a group of undergraduate students, to help their understanding of the field with the hope that they will consider taking up medical physics as a career. Common physiological factors affecting player' performance were collected and analysed during which there were teaching moments explaining the 'limitless' opportunities physics has beyond the hospital.

II. MATERIALS AND METHODS

Football teams of university students competing at the 2025 annual freshmen vs seniors' competition at the University of Ibadan, Nigeria were used for the study. Two different designs of four smart watches (Fig. 1) were used: the M4 Smart Bracelet (watch A) and the Kingnote Smart watch (watch B). The M4 Smart Bracelet features a 0.96-inch color touch screen, and it includes basic health monitoring capabilities such as heart rate and sleep tracking. The Kingnote Smart watch provides functions such as heart rate, blood pressure, sleep, and blood oxygen monitoring. Prior to use, both devices were calibrated by downloading their respective applications from the application store on four android phones. The watches were paired with corresponding phones. Each team comprised of the standard 11 team members (10 players, 1 goalkeeper). Due to the simplicity and lightweight of watch A, it was assigned to the players, one per opposing team, per match. Watch B was assigned to two linesmen per match. The players who were assigned the watches were selected based on their activity level in a match e.g. striker or midfielder. This configuration enabled simultaneous collection of physiological and activity data from both teams and the match official under similar environmental and game play conditions. Eight matches in total were observed.

The match comprised two halves of 30 minutes each, with a short interval between halves. During gameplay, the players engaged in regular football activities, including running, passing, tackling, and shooting. The linesman performed normal officiating duties, running along the sidelines to monitor offside positions.

Before the commencement of the match, screenshots of the readings on the smart watch applications were taken and stored for reference. During the game, all physical activities were observed, and key events were recorded in the order they occurred to create a clear timeline of actions. After the match, all data recorded from the players and the linesmen were gathered and saved. The parameters included Blood pressure(mmHg), Heart rate(bpm), Distance covered (km), Blood oxygen (%), and time(min).

Once data collection was completed, the students, who are also the co-authors of this study, participated in an interactive session where they examined physiological measurements gathered during football matches. The supervisor (lead author) discussed the results, connecting the physical challenges of football with the physiological responses recorded by the smart devices. By linking these practical observations to key physics concepts such as energy use, cardiovascular activity, and biomechanics, the session sparked engaging conversations. The students and interested players, were invited to pose questions, discuss their perspectives, and explore how similar measurement methods are used in medical and sports environments to track health and enhance performance.

Fig. 1 Smart Watches - M4 Smart Bracelet (left) and the Kingnote Smart watch (right).

III. RESULTS AND DISCUSSION

Table 1 presents physiological data for 16 linesmen, with each row representing an individual and the columns detailing the following metrics: serial number (S/N), distance covered (Km), heart rate (beats per minute, BPM), time (min), blood pressure (mmHg), and blood oxygen saturation (%).

The distance covered by the linesmen varied widely, ranging from as little as 0.53 km (linesman 14) and 0.56 km (linesman 16), up to 3.74 km (linesman 12). Most of them covered between 1.44 km and 3.74 km, suggesting variations in either patrol time or activity level. Linesmen who covered longer distances (3 and 12) generally had longer patrol times and maintained heart rates within the lower end of the observed range. The lowest distances covered corresponded to the shortest patrol times (linesmen 14 and 16), which may be due to the time used to manage substitutions, reduced activity, or different tracking roles.

Table 1 Physiological Data from the Linesmen

S/N	Distance Covered (Km)	Heart rate (BPM)	Time (min)	Blood Pressure (mmHg)	Blood Oxygen (%)
1	3.08	84	33	126/76	97
2	2.22	88	58	100/71	97
3	3.63	83	76	100/71	97
4	2.41	83	69	126/76	97
5	2.91	83	68	100//71	97
6	1.93	89	76	110/79	97
7	1.94	83	69	121/76	95
8	3.23	83	78	113/77	97
9	2.12	88	61	113/77	97
10	1.73	83	68	121/76	95
11	1.44	88	77	115/70	96
12	3.74	87	95	115/70	97
13	1.65	83	60	121/76	95
14	0.53	83	48	121/76	95
15	2.24	88	91	126/76	96
16	0.56	88	36	126/76	96
Mean (SD)	2.21 (0.95)	85.25 (2.54)	66.44 (17.11)	116/75 (9/3)	96 (0.85)

Heart rates were generally clustered between 83 and 89 BPM, with several linesmen (2, 9, 11, 15, 16) recording 88 BPM. The highest heart rate was 89 BPM (linesman 6), and the lowest was 83 BPM, which was the most common value. There was significant variation in patrol time, with the lowest being 36 mins (linesman 16) and the highest being 95 mins (linesman 12). Most linesmen had times between 48 and 95 mins, indicating differences in patrolling or tracking offsides. The blood pressure readings fluctuated across board, with common values being 121/76 mmHg, 126/76 mmHg, 100/71 mmHg, 113/77 mmHg, 115/70 mmHg, and 110/79 mmHg.

Most readings fell within the normal adult range, with no values indicating hypertension or hypotension. Oxygen saturation levels were consistently high, ranging from 95% to 97%, which is within the normal healthy range. Most linesmen had readings of 97%, indicating good oxygenation during activity. Blood pressure and oxygen saturation remained stable across all players, suggesting that the physical exertion did not cause significant physiological stress or compromise cardiovascular/respiratory function. Heart rate did not show a strong direct correlation with distance covered or playing time, remaining relatively stable across the dataset.

Overall, the data in table 1 showed that the linesmen maintained healthy physiological profiles during the game. Most of them had normal blood pressure and high oxygen saturation, regardless of the distance covered or playing time. This suggests good cardiovascular and respiratory fitness among the group, with individual variations likely reflecting differences in intensity of participation.

Table 2 Physiological Data from the Players

S/N	Distance Covered (Km)	Heart rate (BPM)	Time (min)	Blood Pressure (mmHg)	Blood Oxygen (%)
1	4.50	79	34	109/75	97
2	7.30	93	72	127/96	97
3	6.50	90	85	106/79	98
4	8.60	73	73	123/76	97
5	7.24	74	73	111/72	97
6	6.90	90	71	106/79	98
7	6.50	74	88	118/84	97
8	5.80	74	74	118/84	97
9	7.60	93	75	115/70	97
10	5.80	79	70	108/64	97
11	5.00	81	70	110/76	97
12	3.25	78	50	108/75	96
13	3.42	85	30	111/80	99
14	5.10	73	103	117/68	98
15	5.12	87	90	107/78	98
16	4.56	89	103	101/76	98
Mean (SD)	5.82 (1.47)	82 (7)	72.56 (20)	112/77 (7/7)	97.37 (0.72)

Table 2 presents data for 16 players, documenting the distance covered (Km), heart rate (BPM), time (mins), blood pressure (mmHg), and blood oxygen saturation (%) for each entry. The distances covered by the players ranged from 3.25 km to 8.6 km, showing a broad variation in the performance of players and indicating moderate to high activity levels among most of them. Players with higher distances generally had higher heart rates and spent more time, as expected. There were a few players for example players 14 and 16 with only 5.10 km and 4.56 Km respectively, in 103 mins, who covered relatively shorter distances in long times, possibly indicating lower fitness, a walking pace, or breaks during the match.

The heart rates ranged from 73 to 93 BPM. Higher heart rates were generally seen in players who covered greater distances or spent more time, as expected due to increased cardiovascular demand. However, some outliers exist, such as player 4 (8.6 km, 73 BPM) indicating good cardiovascular fitness or pacing strategy. The time spent varied significantly (from 30 to 103 mins). Those covering longer distances generally took more time, but some players (e.g. player 4, 8.6 km in 73 minutes) were able to cover more ground in less time, suggesting higher speed or intensity. The blood pressure readings were within normal range, with systolic values between 101mmHg and 127 mmHg and diastolic values between 64 mmHg and 96 mmHg. There was no clear trend correlating higher activity with significantly higher blood pressure, which is typical in healthy and physically fit individuals. The blood oxygen levels were consistently high, mostly between 96% and 99%, indicating efficient oxygen uptake and delivery during physical activity. All players maintained healthy oxygen levels, indicating adequate aerobic response.

This data demonstrates a positive relationship between distance covered and heart rate/time, as would be expected during physical exertion. The physiological parameters (blood pressure and oxygen saturation) remain within healthy ranges for all players, indicating no adverse responses to the activity with individual variations likely reflecting differences in playing position, duration, and intensity of participation.

To further inspire students about the discipline, the supervisor showcased the wide range of careers available in medical physics. The description of how skills like data analysis, utilising wearable technology, and interpreting physiological data are directly relevant to work in hospitals, research, sports science, and medical device development was done. Real-world examples included medical physicists collaborating with athletes, creating diagnostic tools, and improving patient care. This strategy allowed students to view medical physics not only as a subject of study, but as a vibrant career that connects their interest in sports with a meaningful opportunity to advance health outcomes. Additional questions were raised by the students and even some of the players. Some of the questions and responses are presented below:

1. How do the principles of physics, apply to the actions performed during a football match?
   Response: *Physics governs every action on the pitch. For example, Newton's laws explain how a player accelerates, kicks, or collides with another player. The curved trajectory of a free kick is a result of projectile motion and angular velocity, while the impact force of a tackle involves momentum and impulse. These principles help analyse and optimise player movements and strategies.*

2. How can data collected from wearable technology during football matches be used to prevent injuries or optimise player performance
Response: *The data allows coaches and medical staff to monitor players' cardiovascular and respiratory responses. For example, consistently high heart rates or abnormal blood pressure readings can indicate fatigue or risk of overexertion, prompting timely substitutions or adjustments in training. Stable oxygen saturation and blood pressure, as observed in the study, indicate healthy responses to exertion.*
3. In what ways does medical physics contribute to the design and improvement of sports equipment and wearable devices used in football?
Response: *Medical physics principles are used to develop and calibrate sensors in wearable devices, ensuring accurate measurement of physiological parameters.*
4. What career opportunities exist for medical physicists in the field of sports, particularly football?
Response: *Medical physicists can work in sports science, rehabilitation, and medical device development. Their expertise in physiological measurement and data analysis is valuable for monitoring athlete health, optimising performance, and designing new technologies. medical physics offers diverse career paths beyond traditional clinical settings.*
5. How can the study of biomechanics, a branch of medical physics, improve training techniques and reduce the risk of injury in football?
Response: *Biomechanics analyses movement patterns, force application, and joint stress. By studying these aspects, coaches and medical physicists can optimize running and kicking techniques, reducing injury risk and improving efficiency. Football activities like running, kicking, and tackling are governed by physics principles, making biomechanics essential for performance enhancement and injury prevention*

After the interactive session, the students were asked if they would strongly consider careers in medical physics after being exposed to its applications both in the hospital and in sports. They all responded in the affirmative. Two of them who are acive football players were particularly pleased and relieved to know that their physics degrees, and interest in medicine, could be directly linked to what they already love doing making medical physics more relatable.

IV. CONCLUSIONS

Integrating football into the study of medical physics provides a relatable approach for undergraduate students who love the sport to appreciate the practical applications of physics in medicine. Medical physicists possess a solid a foundation in physics, which enables them to clearly explain and analyses the principles underlying sports. Their expertise allows them to contribute meaningfully to both the performance outcomes of games and the health and well-being of athletes. By utilising wearable technology and analysing physiological data during real matches, students gain hands-on experience that bridges theoretical concepts with real-world scenarios. This method not only enhances their understanding and engagement but also broadens their perspective on the scope of medical physics, encouraging them to explore diverse career opportunities within the field. The data supports the use of these variables as effective markers for monitoring exercise intensity and players' health.

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