A Survey of Evolving Performance Analysis Technologies, Algorithms and Models for Sports

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***Abstract*—The emergence and extensive development and deployment of Industrial Revolution 4.0 have distinctly transformed the methodologies of sports performance monitoring. Consequently, there has been an increase in the emergence of new and adapted technologies in various areas of sports, such as competition analysis, player performance analysis and many others. There are rich and heterogeneous sports performance analysis technologies, algorithms and frameworks which provide constant basis for elevating new horizons of sports technologies. Thus, this paper aims to encompass significant findings that will provide a comprehensive survey in this area. Previous surveys have extensively focused on various methodologies of sports performance analysis, sport-specific analysis and other technology revolving around sports performance analysis. However, most of the focus is largely on training and competition performances and not off-field. The objective of this paper is to understand the current research trends, challenges and future directions of dynamically evolving technology embedded in the world of sports. This survey aims at contributing to this rich repository but with a new focus element of off-field that researches the connection between the athlete, the sports aspect of their life, the non-sport aspect and the methodologies of sports performance analysis. In addition, the exponential growth of Artificial Intelligence (AI) as a base for sports performance analysis systems and platforms is analysed extensively. This paper also presents a comprehensive classification of athlete performance analysis using algorithm tools and sports performance platforms and systems. Subsequently, the detailed analysis of this taxonomy has enabled the identification and detailed analysis of open issues and future directions.**

Keywords*—Sports performance analysis technology; on-field analysis; IoT; real-time monitoring; off-field analysis

I. Introduction

The Industry Revolution 4.0 (IR 4.0) has seen the extensive harnessing of multitudes of technologies in wide and rich spectrum of areas [1]. This encompasses the domain of sports and is a significant element in positioning itself as a national and global agenda. Since the inception of technological advances, the sporting world and its entities have been strengthened in multiple aspects [2], such as the usage of wearable Global Positioning System (GPS), sensor technology, virtual imaging, Hawk-Eye Line-Calling System, and time tracking systems. These contributions to sports have increased the accuracy of measuring equipment and instruments. Among the reference success cases of sportsmen partnering with technologist are like athletes Kell Brook have worked with Sheffield Hallam University in the lead-up to his International Boxing Federation (IBF) world welterweight title fight. The scientists collected Heart Rate (HR) and lactate data. Like Brook, multiple-time National Basketball Association Most Valuable Player (NBA MVP) Stephen Curry has overcome his physical shortcomings by incorporating technology into his training regime. The All-Star basketball player has used strobe goggles and on-court light discs that force a sensory overload and demand quick decisions. Team sports athletes constantly strive to improve their international and league rankings. Football athletes in the second division of England, Germany, and France have been monitored with over 11,000 team-matches observations to monitor the factors influencing the chance of promotion to the elite leagues [3]. The researchers executed a series of logistical regression analyses and made observations, proving that teams will do anything and everything to evolve and improve their status in the sporting world constantly. The athletes and coaching staff of the modern generation have resourced technology tremendously to enhance their athletic ability [1]. The cases presented above serves as a basis to justify the need to articulate the rich repository of sports technology to enable the trend analysis and determination of open issues especially with the rise of Artificial Intelligence (AI). The analysis of off-field and on-field correlations from a distinct perspective of existing work has high constraints. Thus, creating problem in identifying pertinent open issues in this domain of analysis. Thus, this survey paper is objectives are to address the solutions for this problem. The goal of this survey paper is to show the state-of-the-art sports performance analysis technologies. It encompasses a comprehensive review of papers. In the papers we reviewed, each algorithm, architecture or system is reviewed in detail from the implementation, their advantages and respective disadvantages. The developed taxonomy of comparison has provided a detail basis of the identification of the open issues.

This paper is organized as follows. Section I is the Introduction. Section II discusses in detail the various Surveys that have been published in this area and highlights the uniqueness of our Survey. Section III presents the Proposed Classification Model based on the research from three subsections: Competitive and Training Performance Monitoring or On-Field, Non-competitive Performance Monitoring or Off-Field, and Systems and Platform. Open

issues collectively analysed throughout this paper, recorded and arranged in relevance discussed in Section IV with six subsections: Relating the Monitored Research of Athletes on Competitive and Training and the Non-Competitive States, Adapting to Sports Performance Monitoring Systems, Combating Athletes' Stress, Rise of Extensive research in Machine Learning (ML) and AI Will Enable the Dominance of Demographics, Sport-Specific, and Data-Handling Ethics. Finally, the paper concluded in Section V.

II. Analysis of Related Surveys and Taxanomies

Reiterating the important fact that the recent acceleration in sports technology has motivated researchers towards the inclination to publish research based on sports performance analysis. This section discusses and reviews extensively the previous surveys conducted on sports performance analysis and the critical issues surrounding them. Research in [4] surveys elite and pre-elite athletes, evaluating unseen factors contributing to their success. 135 Australian Olympic, Paralympic, National, and state-level athletes from 25 Olympic sports were surveyed. Our research has also improved and elaborated that there are more factors than those included in athlete development programs such as lifestyle, social and support factors. In [4] it has been found that international athletes perceived psychological skills and attributes, along with strong interpersonal relationships, as vital to their success, and they also rated 'Recovery practices' as very important and made extensive use of available support services. However, the athletes have indicated the necessity for access to these services at the grassroots level. The study has concluded that athlete development systems need a complete environment that allows athletes to succeed, perform consistently, have longer careers, and gracefully transition into retired athletes.

In [5] the research done on analysis methods in sport for intelligent data has been reviewed in detail. More than 100 studies on intelligent data and its analysis methods use Smart Sport Training (SST). Some of the methods among others surveyed included Computational Intelligence (CI) methods like fuzzy systems and simulated annealing, data mining methods like Support Vector Machines (SVM), and Random Forests (RF), Deep Learning (DL) methods like Recurrent Neural Networks (RNN) and Conventional Neural Networks (CNN), and other methods like Naive Bayes (NB) and Bayesian Networks (BN). The research also classified the research surveyed by sport type; individual, mixed, and team. Researchers have focused their attention on soccer, running, and weight lifting. The relation to participation levels, over half of the research study focused on individual sports, with team and mixed sports accounting for a third of the total. The research elaborated on the study type done on a particular sport and the focus of the research and results. This research may improve by adding more validation-level research publicly available with the datasets for replicating research, which improves methods.

In team sports, numerous variables influence the outcome and performance of the teams. The research in [6] surveys team sports and the usage, challenges, and techniques of implementing AI and ML with computation, including forecasting match results, tactical decision making, player investments, fantasy sports, and injury prediction. The work evaluation on match outcome prediction found that, due to the unpredictability of sports, models still fail to forecast outcomes much better than bookmakers and appear to have hit a barrier, but there are several feasible solutions. This article also demonstrated the possibility of developing a one-of-a-kind real-world live testbed for AI and ML approaches to be validated in the future. According to a literature survey in the fantasy sports area, there are some AI approaches in the Fantasy Premier League (FPL) football competition to beat most human players dramatically. Overall, this study illustrates the impact of AI and ML approaches on the team sports domain, highlighting some processes with open areas and research issues. The survey focuses the research on six sports where only a finite amount of literature has been done. The narrow scope has allowed the team to be fortunate in finding research that contains the highest accuracy, cricket, with 75% in the prediction model. A broader scope would have seen sports with far more uncertainties and lower levels of accuracy in their research.

In [7] the role of ML in predicting and avoiding sports injuries has been discovered. The article uses Tree-based ensemble methods, SVM, and Artificial Neural Networks (ANN) ML methods. Pre-processing steps aided the classification algorithms, enhanced over and under sampling methods, hyper parameter tuning, feature selection, and dimensionality reduction. The comprehensive study found that ML technologies forecast sports injuries in 11 researches. The study closes by requiring ML to identify high injury risk athletes and essential injury risk indicators. AI offers a fascinating new viewpoint on injury risk and team sports performance prediction. Another literature study [8] covers AI in sports medicine, data processing, injury diagnosis, and prevention in competitive sports. Models and approaches in the literature study include fuzzy sets, ANN, Markov process, and other models such as Bayesian theory and multi-dimensional models groups. The review needs to be more systematic, a weakness of the research. In [9] the implementation of GPS units to collect data on a full-time basis has been done. The athletes, 52 players, enrolled into the Korean National Team, provided data to calculate the optimal ratio of Acute to Chronic Workloads (ACWR). The observational study reviewed other injury related research to deduce the calculation behind workload and the probability of an injury occurring to an athlete. Unlike the previous studies, which focused on pre-collected data, the research quantifies the workload of 52 athletes using GPS units collected during game-based training and matches. The research has filled the need for a standalone study, which has also conclusively suggested that hockey athletes and their ACWR should stay within the moderate low, especially for strikers and midfield playing positions, to manage non-contact and soft tissue injury.

In [10] the functional usage of ML and CI in sports prediction has been surveyed. ML, ANNs, BN and Logistic Regression Methods, SVM, and Fuzzy Logic and fuzzy systems are some models discussed in sports-related works. Many elements influence the outcome of a sporting event, including a teams' (or a players') morale, talents, and coaching plan. This review paper examines past research on data mining

methods for predicting sports outcomes and weighs the benefits and drawbacks of each approach. However, some sports, such as most track and field sports, are simply too easy to justify the complicated framework to the point where it is no longer necessary. There is a use of deep NN approaches in team sports analytics. Sports analytics using a DL approach is now possible thanks to tracking and visual data in sports and recent technological advancements. In [11] the use of modern DL techniques in team sports analytics has been reviewed. The survey researches two sports among the team sports that have benefitted from sports analytics, basketball, and football. The survey has tracked the advances in DL techniques in the two sports. The researchers aim to provide a study that provides insight to team sports analysts in sports and the ML aspect.

As discussed in the performance analysis subsection, [12] surveys the journal databases, reviewing the literature on Smart Wearables. The research classifies health, sports, daily activity, tracking and localization, and safety into four major clusters. However, data resolution of wearable sensors, power consumption, wearability, safety, security, regulation, and privacy became the primary obstacles of wearable Internet of Things (IoT) devices. In [13] the need for performance analysts within the coaching process within elite football coaches has been evaluated. The research dissects the differences in the necessity of PA's at the professional and football academy levels. The purpose of this study was to fill a gap in the literature on the function of match analysts in providing feedback via match and notational analysis techniques and systems. The exploratory study uses an online questionnaire based on information from current match analysts in elite football, academic practitioners in performance analysis, and current literature. 48 match analyst practitioners from significant football clubs completed the survey. The majority of 32 analysts worked in a professional team setting, while 16 worked in an educational setting. Educators and coaches can use the data gathered from training sessions and games analysis to understand better the challenges faced by a trainee, a player, or even an entire team and develop appropriate training and strategy plans. The research done by [14] has heavily influenced the structure and taxonomy due to emphasis on deliberating the finding of current surveys, current techniques, and trends of performance monitoring. This paper then proposes a classification scheme for these systems, separating them into invasive and non-intrusive categories. Researchers prefer nonintrusive systems since they do not interfere with the game. Each system's unique traits and strengths and weaknesses are listed. However, the system is still early and cannot extract high-level metrics such as game circumstances, team formations, or psychological characteristics.

The discussion in [15] is an in-depth understanding of content-aware systems for sports video analysis by examining the insight offered by research into the content structure under different scenarios. Themes relevant to the research on context-aware systems for broadcast sports were analysed. Analysis can benefit significantly from the use of ML. After evaluating coaches' responses, the study found that the system is valuable to daily work. The research summarizes the future trends and challenges for sports video analysis and sets the tone for the rest of this study in the section on video analysis. On the other hand, developing a unified framework that enables processing data from diverse sports is still challenging. The trade-off between commonality and robustness must prevail because the future goal of action recognition in sports is to develop a machine that can read, write, listen to, and speak a voice over to broadcast sports videos directly.

The uniqueness of creation is that no two human beings are the same. Similarly, the conditions of individuals are different based on their fitness level and training consistency [16]. The researcher must determine a standard or baseline for every athlete individually to evaluate the athlete's performance. This way, it is considered that all humans are unique and may react differently to the stimulus applied, thus increasing the accuracy of studies and making surveys more accurate for the reader's comprehension in mapping them to specific domains. In contrast, more requiring research on Tai Chi and Qigong effects has only a few studies. Future research could also use shorter time intervals between RHR measurements to understand the underlying processes, potentially contributing to RHR decreases. The research done by [17] gave an in-depth method of monitoring an athlete's sports performance or a team of athletes, and this includes looking at several potential moderator variables' effects, and the cohesion-performance relationship revealed in research utilizing the Group Environment Questionnaire (GEQ). Standard literature searches turned in 46 studies with 164 effect sizes in total. This analysis breaks down the cohesiveness and performance in the sport. The GEQ had a moderate effect in studies that employed it. Refereed publications (as opposed to unpublished sources) and female teams had a more substantial cohesion performance effect. The research further breaks down the methods of measuring splitting variables like gender, type of sport, level of skill or experience of the athlete, and data source.

Face video-based Photoplethysmographic (PPG) signals acquired with professional or consumer-level cameras to obtain HR remotely. In [18] the latest advances in video-based HR management were surveyed. The research focused on the technological updates that overcame the existing and overwhelming challenges caused by illumination variations and motion artifacts. The majority of available remote Photoplethysmographic (rPPG) methods currently work with uncompressed video data. Conversely, the uncompressed videos will take up a lot of disc space, making internet data exchange impossible. The background of imaging Photoplethysmographic (iPPG) and rPPG, which is an estimation method for HR, was discussed, and debating the prospects of this technique and potential research direction in [19]. PPG and noise reduction using wavelet transforms to measure people's HR, which proposed recreation of the method for obtaining HR from the rPPG. rPPG is a technology that uses current or previously recorded video from a simple web camera to estimate HR, oxygen saturation, and other parameters. The heartbeat is usually highly regular over a short time; these physiological characteristics estimate that arteries blood flow shows some periodic flow. As a result, slight fluctuations in the amount of light reflected from the face are visible in the arteries and blood vessels of the face, which can be caught by the camera and processed as a Blind Source Separation (BSS) problem. The research successfully created a

real-time system that detects an individual's face and facial tracking and displays the HR with maximum noise reduction. The work could be improved by incorporating the ML technique into the PPG signal identification and increasing face detection accuracy.

HRV is a promising and essential research technique for cardiovascular disease diagnosis. The Parasympathetic Nervous System (PNS) and Sympathetic Nervous System (SNS) of the Autonomic Modulate System (AMS) regulate and control the HRV. HRV analysis can evaluate a variety of cardiological and non-cardiological illnesses. The research done by [20] surveyed HRV and the linear methods involved in the methodological evaluation. The two linear domains are the time domain and frequency domain. The researchers also discussed nonlinear methods of HRV like Poincare Plot Analysis, Approximate Entropy (APEN), Sample Entropy (Sampentropy), Detrended Fluctuation Analysis, and Correlation Dimensions. The parasympathetic and sympathetic controls, on the other hand, may have an impact on the alpha value in the study and fail to discriminate between them ultimately. As a result, a separate examination of both the short-term and long-term scales is necessary to determine the actual range of the scale as it withdraws the reciprocal effect.

In [21] the focus is on football as the ML applications in sports analytics relate to player injury prediction and prevention, potential skill, or market value evaluation. CI has shown to be a valuable tool in various fields. This study looks into the possibility of predicting long-term team and player performance. By surveying 31 categories of study and deriving the methodologies, information, and applications, large amounts of data turn into meaningful knowledge through data mining. Historical data and advanced statistics offer a reliable projection of the final league table and whether a team will have a more robust season. The findings taken from different leagues show a significant disparity. As a result, essential differences across leagues should apply universally. Player exhaustion and severe long–term injuries are problems that can harm players or teams, but if addressing the intricacy of the situation, such data could be valuable study tools. Many sports organizations have begun to understand that the data previously retrieved has a treasure of undiscovered knowledge, as data mining techniques capture the attention of the information industry and society due to a significant volume of data and the impending need to turn it into valuable knowledge. The research in [22] classified the 31 articles into nine thematic types with a systematic review of sports data mining from 2010 to 2018. The researchers also located possible areas to be explored, such as swimming, athletics, hockey, boxing, fencing, and tennis. The review concluded the survey by encouraging new research in this field.

The work in [23] surveyed multiple online databases for articles using AI techniques applied to the team sports athletes. The team applies AI to predict injury risk and team sports performance possibly. The most used methods surveyed are ANN, decision tree classifier, SVM, and Markov process, including good performance metrics. Soccer or football, basketball, handball, and volleyball were researched as the traditional team sports. The research concluded with the assurance of a promising AI and team sports future. There are some differences in sample sizes in the manuscripts, with some samples being lesser than others.

The review done by [24] analyzed the literature on sports predictions that have utilized the application of ML. The research categorizes the method of ML into unsupervised learning and reinforced learning. Location, player health, player performance, weather, and ground conditions are all factors that influence whether a game is won or lost. Plenty of data is available for long-seasoned and high-scoring games like basketball, making prediction considerably more manageable, but guessing the outcome for games that are only played once a year and are low-scoring becomes a problematic endeavor. The team then attempts to show the comparison using a table, displaying the approach, game, technique, and review of the research surveyed. The research concludes by highlighting the study's limitations and prospects.

In [25] the microsensors usage and the monitoring approach implemented in basketball and did an online survey, and applied multiple responses, Likert-scale level of agreement, and open-ended questions on basketball practitioners were researched. Questions for the basketball practitioners included how player monitoring was performed, highlighting the barriers and facilitators with microsensors. Nearly two-thirds of respondents implement player monitoring, and almost one-third of basketball practitioners use microsensors. The survey concludes that basketball has low uptake of microsensors in sports performance monitoring. Because of this study's small sample size, it was impossible to analyse results based on criteria such as the playing skill of respondents.

The study in [26] did a survey on recovery strategies among basketball practitioners. The majority agreed that recovery strategies are very vital in their routine. The best strategies were active recovery, massage, foam rolling and stretching. The biggest challenges for the basketball athletes surveyed would be the lack of devices and facilities, high cost and lack of time. The research does find that there is a disassociation between scientific evidence and perceived evidence. The survey also noticed the inclination of athletes to prefer easily implemented strategies rather than evidence-supported strategies.

The work in [27] has given a comprehensive explanation about wearable monitoring systems. There are highlights of the usage of sensors, specifically commercial wearable systems for sports applications. The book overviews the psychological parameters measured by wearable systems. The HR and oxygen consumption parameters are analyzed in the respective sections. The following sections discuss the practitioners and the sports utilizing these wearable systems. The book concludes by evaluating the immense value of wearable systems to multiple sectors, including sports. The authors express their opinion on the current business expansion of wearables, which is currently small, and market forecasting has yet to produce an accurate and generally disseminated insight. Wearables technology can collect rich contextual data from the device itself and use it to provide a truly tailored experience.

In [28] the work surveys wearable technology, the progression in the development of wearable devices, and the

latest advances in the wearable devices market. They also classified the wearable devices based on factors and analysed in-depth information on the technology, highlighting the adverse challenges and prospects of wearable devices. Due to the lack of good practices in interoperability and proper standardization in the new Internet of Wearable Things (IoWT) niche, the close connection of various systems provided by different suppliers remains one of the most critical issues of wearables. AI in Sports Performance, ML and Sports monitoring, and RTM are the primary demographics and focus searched for throughout the research.

III. Proposed Classification Models

In this paper, we proposed two classification models as a basis to address the importance of the term "off-field" performance analysis tool. This proposed classification being given a distinction is based on the extensive survey conducted in the previous section and the analysis has inspired that there is a need to give the analysis of athletes beyond the training and competition venue. Thus, creating the need to empirically analyse their off-field activities and their impact on the on-field. In this section we will review pertinent research done in off-field and subsequently the next section will present the open issues we have identified based on our extensive survey.

The ecosystem of an athlete consists of a broad spectrum of activities with multiple interactions with varying groups of people. This research surveyed 50 athletes, from national to state, and added the most common results.

Different athletes may have different timetables or schedules. Top-tier athletes train at least one or more times a day. Before stepping on the pitch, many athletes have Pregame Rituals (PGR) to complete [29]. In Ghana and other Sub-Saharan African countries, unorthodox PGR is common in sports, mainly soccer. Based on scientific descriptions, empirical investigations, and specific field observations, the paper also underlines the conceptual contrasts between PGR and pre-performance routines. The study in [30] put these superstitions to the test among track and field athletes, where there is more to the athlete's preparation than mere superstition. The positive correlation between athletic identity and superstitious behaviour shows that student-athletes with strong athletic identities used more superstition in sports events. Individuals with a high athletic identity utilize superstition as a coping mechanism to minimize anxiety during the competition [31] and protect their egos. Precompetitive Mood States (POMS) have been reviewed by [32] and give us the ideology behind the Mental Health Model of the athlete before a competition as well as the more suitable Hanin Individual Zone of Optimal Function (IZOF) model. An athlete must consider all facets of the preparation time allocated before the tournaments. Whether on the pitch or off the pitch, every move imprints the athletes. There are multiple studies targeted at the effects of the actions carried out by athletes when the athletes are in a non-competitive state. The research surveys the studies devoted to uncovering the truth behind the effects of non-competitive actions on the athlete's performance.

The proposed patent Prest and Hoellwarth is looking to monitor the vital signs of an athlete using headphones, earbuds, or headsets. While managing the electronic device, the monitoring system monitors user activity during exercise or sporting activities. Other user characteristics such as biometric data, temperature, sweat, and HR are attributable to the monitoring system's placement. The usage of headphones or earphones is rising during training sessions, despite having multiple side effects such as perforated eardrums [33]. There has been a study relating the effects of music on exercise [34]. It is also viable for a non-competitive approach. The athlete might want to calm his nerves before and after the game, and during that period, a reading of the HR, perspiration level, and steps taken should be recorded. Music can have a considerable positive impact on exercisers and athletes, especially in terms of increased effective reactions and physical performance, reduced perceived exertion, and more efficient oxygen consumption. The duration an athlete takes to reach a state of physical readiness for the next activity allows coaches to plan out substitutions of athletes for the games. Other alternatives like monitoring the step counter through the shoes have lost some avenues to monitor vital signs like HR and perspiration levels as effectively as this patent. The research in [35] measures an athlete's performance without measuring their physical performance, but instead taking a psychological measurement, Sports Performance Inventory (SPI). A principal components' analysis with Varimax Rotation performed on the original survey items resulted in an 83-item survey with six interpretable factors: competitiveness, team orientation, mental toughness, emotional control, positive attitude, and safety consciousness. Compared to novice athletes, college athletes had a higher SPI composite, a more positive attitude, and were more competitive. Females were more team-oriented than men, and novice males were more competitive than novice females, with college females outperforming college males. However, there is no direct proof that the SPI's dimensions will predict an athlete's performance, and sex differences discovered between athletes may be premature due to the small sample size.

The health industry has a huge responsibility. Discharged patients are still under the monitoring eye of the hospitals. The common issues for missing monthly check-ups are distance and transportation. The analysis in [36] has multiple uses and currently monitors the patients' vital signs. The developed VJ is a microelectronics and textiles based vital signs monitoring system. The VJ has multiple readings for the usual ECG, respiration, perspiration, and oxygen saturation percentage. One unique feature that a clothing-based sensor can detect is posture. The VJ can detect the posture reading of the test subject. The posture reading can be beneficial in a sports-based environment because sports require posture perfection, which could be one of the solutions for these sports. Moreover, games that find an external wearable sensor disrupt the gameplay's efficiency. Not to mention the question of safety, some sensors are waist-mounted, and even watch-based can quickly disrupt a play of games like rugby, whereas a shirt or vest used under the players' uniform will form minimal resistance for the gameplay.

Other studies have touched on the negative behaviours among athletes and how that affects training to gather evidence that no matter to what extent the athlete puts the body through gruelling training sessions, the effects from non-competitive

activities leave a lasting impression on the performance. Drugs are categorized by [37] into usage and abuse [38]. The usage of allowed substances for an athlete's recovery has long been a part of the life and diet of performance athletes, but there is a fine line between usage and abuse. The overall harm of drug misuse comprised the substance's direct physical harm to the individual user, the drug's ability to create dependence, and the impact of drug abuse on families, communities, and society [39] [40]. Marijuana addicts are more likely to develop a persistent cough, bronchitis, and lung and upper airway cancers. Regular marijuana usage has sadness, anxiety, and schizophreniform illness in some people with a pre-existing predisposition [41]. Many drugs are outside the Health Ministry and International Sports governing bodies such as the World Anti-Doping Agency (WADA) [42]. The study in [43] highlights drugs like cocaine, meth/amphetamine, ketamine, and other drugs among "full-time" athletes and discusses the effects on the population of "full-time" athletes. The monitoring happens on a self-reporting basis and drug tests. The survey has also clarified that drugs harm current performing athletes and affect them when they stop competing and retire. It is common knowledge to note that drugs are harmful to any class of humans, but as the study has thematically targeted athletes, the survey discovers that athletes are no exception.

The athlete must recognize the body's biological signs and capabilities and sense what the body is going through. The research in [44] monitors the point at which the subject has reached the level of fatigue. This analysis documents a self-reporting, and the athlete notes the point at which he or she reaches fatigue while playing a sport of the choice. The test subjects needed to complete three surveys daily, and some relied solely on these surveys to covey what the test subjects were experiencing. The test subject saw that as the weeks progressed, there was more and more load that test subjects could handle, and this showed that progressively overloading the body meant that the body was less likely to feel fatigued at an earlier stage. The body muscles get accustomed to the athletes' load, and as the documentation proved, the athletes can withstand more the next time the test subjects are under the tests.

In [45] the manner in which an athlete's training affects their competitive performance is examined. The researchers analyze the link between competitive disc throwing performance and maximum lifting weights in female disc throwers. Maximum lift weights were recorded for the bench press, full squat, deadlift, high clean, and snatch. They use Pearson's R Accumulated Correlation Coefficient to determine the relationship between competition performance and 1-RM. Weights show a substantial positive link between female discus throwers' performance and their maximal lifting weight in the bench press, high clean, and snatch as female discus throwers weigh less than male discus throwers; hence they need to throw faster to convey the same amount of force. The high clean and snatch actions may contribute to power output during the delivery phase.

The COVID-19 pandemic is an example of an extended period forcing the athlete to be away from training. Almost all nations enforced nationwide lockdowns. The research in [46] observes the usage of Virtual Reality (VR), which has already proven to be a step forward compared to video playback training. VR was used to separate the visual data of player movements from the visual data of the ball trajectory. The three conditions described are the player's throwing action, ball trajectory, and final location. The immersive environment emulates the field of play, the players, and the game methodologies, allowing for a comprehensive game mode to be tapped and trained in the athlete.

IV. Open Issues

The extensive discussion and review of the wide spectrum of research conducted in off-field and on-field has distinctly and empirically illustrated the depth and spectrum of research in sports performance analysis. Our analysis has derived the following open issues which will further enhance the spectrum of harnessing resources *to elevate sports.*

A. Relating the Monitored Research of Athletes on Competitive and Training and Non-Competitive States

In summary, when writing this survey, there is no predefined research between the stress applied to the athletes from the non-competitive daily routines and the performance displayed during competitive and training states. Studies performed on monitoring an athlete in competitive and training states, creating baseline readings, and through training and practice comparing the athlete's current state and performance over a while. Despite having studies done to relate pre-competition state using POMS, and the athlete's performance during competition, no specific correlation has been derived between what happens when the athlete leaves training or competition. An athlete spends an average of 20 to 30 hours a week in training and doing on-field activities, and there is an average of 140 hours that an athlete is away from the field. Therefore, 80% of the athlete's schedule is bound to affect the 20% spent on the field.

B. Adapting to Sport Performance Monitoring Systems

As sporting fraternities continue to evolve, all avenues must ensure excellence. An avenue like a stress monitoring system to access the athlete's current state will be extremely valuable and open to being tapped. There has been a void in this sector that has limitless potential in the case of pursuit. The sports world must accept the digitalization of performance analysis. Newer and more advanced systems than video monitoring have emerged in the sports fraternity. A recent survey researched the perception of rink-hockey head coaches and the usage of performance analysis as a tool to assist training, match preparation, observation, and interventions. The research has further cemented the importance of performance analysis by including seven experienced First Division Portuguese rink-hockey head coaches and conducting semi-structured questions, and the data analyses through inductive and deductive content analyses. Rink-hockey head coaches prefer to analyse the opponents themselves to plan training, assist with tactical preparation, and implement within-match strategies. They considered video analysis a vital tool to analyse opponents' strengths and weaknesses, focusing on the opponent's goalkeeper. Rink hockey has adopted performance analysis to prepare for tournaments and world sporting events in their armoury, like many other sports. Like rink hockey,

many other sports and coaching staff must be open to working with researchers, providing data on their athletes, and taking part in performance analysis of the individual athlete or team. The grassroots federations have less to worry about introducing new technology because the severity of the contracts and agreements, if present, is less than that of the professional leagues. The athletes are younger and will be more open to accepting and working with new technology introduced by the researchers. Also, wearable devices in grassroots level training sessions and games will not hinder high-profile games, unlike the professional games played by star athletes.

C. Combating Athletes' Stress

An athlete is the face of the country in international multi-sport events, and there should be no unnecessary stimuli that bother the athlete. Research on the lifestyle of an athlete analysis the action that may induce stress recorded through HRV and isolates the athletes from such actions. An athlete should be able to allow competing without stress, which in turn is known to cause performance anxiety. Research that proves the importance of athletes' surroundings and the effects on performance will encourage national sports bodies to shape the surroundings of athletes according to their needs and remove stress triggers to ensure more potential tapped out of the athlete and more glory brought to the nation.

D. Rise of Extensive Research in ML and AI will Enable the Dominance of Demographics

The modern sport of hockey boasts a fast-paced, physically grueling sporting event. One such sport is field hockey; with over two billion viewers annually and the top five most watched sports globally, minimal documented studies have been done on the sport or its athletes. Athletes of the top calibre require very high levels of stamina. Elite athletes need to maintain a high fitness level and constantly train their skills. The skills of hockey are displayed in the accuracy of shots and passes, the ability to run with the ball, and take power shots. The athletes in the sport need to monitor their performance during the competition and training and non-competitive states if the aim is to reach the top level of hockey play. The National Level hockey players could benefit from the study and the knowledge that many activities knowingly or unknowingly cause the dip in sports performance during athletes' competition and training. It will be another tool in the arsenal for the coaches and athletes to exploit and further improve.

E. Sport-specific

The study has surveyed an array of different sports and the method of monitoring athletes and monitoring the performance of the athletes. The difference from one sport to the other changes drastically the more profound the research goes into the details and skills of a sport. Every sport has a unique skill set and abilities that the athletes must complete, and sports monitoring has been very sports-specific. Some sports have a huge reception globally, but very little documented research. Sport-specific research proposed directing towards that is focused on the uniqueness of the sports and the respective demographics. The research should cover an existential issue of the effects of the athletes' non-competitive practices and how top-level athletes are affected by it. The study should cover the area of wearable sensors as their go-to research method. Using the current systems in the market, like Suunto, boast a repertoire of precision and accuracy in measuring the physiological changes in the body. Unfortunately, mega-corporations like Suunto do not divulge the readings and information recorded on their watches to the public or is search team. They expect users to use their hardware and readings taken at face value. Another option is the Samsung Watch due to their operating system running on Tizen. Tizen allows developers and researchers to develop their applications to be tested in the Samsung Watch hardware, applying using the sensors optimally. The Tizen software also allows for the readings to be taken, recorded, and analysed by researchers.

F. Data-Handling Ethics

Bio-metric data has been a repeating element in most of the research discussed in the survey. The power and accessibility of the technology behind bio-metrics have made it very susceptible to monetization or the user's identity being stolen. In the professional sporting sector, some laws involve data sharing policies. The agreements and contracts for athletes allow their documents and data to be protected from being misused, which is not the case for lower levels of the sport. There is a gray area in the confidentiality of athlete data collected by researchers. There has to be a standard protocol for all athletes and researchers, allowing for more ethical practice in sports research. The current trend leaves a gap that hackers can exploit.

V. Conclusions and Future Work

This paper presents a survey on the sports performance analysis of athletes' competitive and training states in various sports. We also surveyed the athletes and monitored their non-competitive activities or away from training. Then taxonomy of comparison was done on the research based on metrics like using the wearable sensors. The most common method in the modern age is to use mobile wearable sensors on the athletes while monitored during competition and training. However, there is also an avenue to use the same concept of wearable sensors to monitor athletes that leave the pitch. As mentioned above, an athlete's job is continuous and not only during competition and training. Therefore, we have presented the option of a bridge where non-competitive monitoring is the void many researchers may need to exploit in the open issues. On the topic of open issues, we have also found that:

- Stress monitoring among athletes is done extensively during competitive and training activities, but not once the athlete leaves training. The stress subjected to the athletes could be why the player's progress and performance are stunted.
- The national sporting bodies in nations need to pay heed to the lifestyle of athletes and foster an environment conducive to the athlete, besides the vigorous and state-of-the-art training facilities.

Sports with a fan following and stadium ambience creation by these fans need more research on their players and the sporting environment. The future direction of this research will be to encourage more researchers to create holistic and complete performance monitoring systems. The performance monitoring system or architecture must contain a registration

module for the national-level database of athletes, which acts as a recommend system for national-level athlete selection. The athlete selection must be based on collective performance data and not only a single qualifying event win. Single event qualifying win has been the method of qualifying for state to national level athletes. The lack of a complete database of athletes requires sports federations to select athletes through events, not merit or potential performance. Thus, performance analysis tools will constantly need to be enhanced and to be designed to furnish the specific and demographics in precise.

The future work will be focused on the analysis of sports performance analysis based on sports specifications. The harnessing of intelligence in its wide spectrum will be further covered. The detailed review and analysis of hardware development such as biomedical sensors is also being pursued.

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