A Perspective on the Potential of Utilizing AI Models for Predicting Athletic Injuries

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Abstract

The goal of this research paper is to investigate the potential of utilizing artificial intelligence in order to predict athletic injuries. Predicting injuries is paramount to preventing them in athletes. If athletic injuries can be predicted, they can be prevented. This paper examines injury categorization across multiple kinds of injuries and then explores AI methods, specifically machine learning, and how it has the possibility of predicting injuries. I discuss the positives, along with the negatives, of using AI with this specific domain. I also discuss risk factors, along with risk prediction, and show an example pipeline model for a mechanism that can be used to predict injuries for anyone, and especially athletes.

I. Introduction

Subsection 1.1 Research Question

The purpose of my study is to answer this question: Is it possible for AI to predict injuries before they even occur? In other words, is it possible for a machine to use different artificial intelligence methods in order to spot an injury before it occurs, in order to prevent it from occurring or worsening. This can be a significant advancement in the medical field because it can possibly lead to a notable decrease in the number of athletic injuries per year.

For athletes, injuries occur frequently. This means that the athlete cannot partake in a given sport or really any contact activities for an extended period of time. For many athletes, this can significantly harm their athletic performance in their given sport. If AI was able to predict these injuries before they occur, based on data such as imaging and medical history, it could prevent many athletes from injuries causing them to be forced to take a break.

Subsection 1.2 Why This Problem is Challenging and Unsolved

Predicting if an injury is going to happen is challenging because injury occurrence depends on multiple different factors. These factors depend on a patient's medical history, their family health history, training workload, and other. A patient's medical history, along with their family's medical history is important in making a diagnosis. If a person has broken their ankle once in their past, for example, if it did not fully recover, they are likely to break it again. If another person in their family has Channelopathy and passes it down to them, the individual is more likely to get injured as well. Channelopathy is a disease which causes people an excessive amount of pain and a higher likelihood of breaking a bone. A patient's workload is important to their diagnosis because it gives the doctors information of the extensive training that the patient is doing, which can be a common factor in many injuries.

Another factor that makes injury prediction difficult is that not all athletes are the same. A minor injury may bother one athlete more than it bothers another. Pain in a specific spot can be chronic for one athlete or just a one time, small, painless injury for another.

Subsection 1.3 Approach Overview

In this paper I approach this problem by discussing the use of machine learning in predicting injuries. The goal of machine learning is to train the model on preexisting data instead of having to program all of the details manually. Data that can be input is images such as x-rays, MRIs, and CT scans. This data can also be things such as background about the athlete such as age, weight, and medical history, along with risk factors. The data that is input is trained, validated, and tested before it is output.

Athletes should be scanned frequently, rather than only when they are in pain. If they are scanned before they are in pain, it is more likely that they are able to prevent the injury from occurring.

II. Related Work

Lots of research has been done that can be related to this topic. In one article I read that tree-based machine learning models, specifically models such as random forest and XGBoost, were found to have the highest predictive performance compared to other machine learning algorithms [1]. This paper suggests that nonlinear, ensemble-based approaches are most likely to be better suited than simple linear models, such as logistic regression models, for showing how different risk factors work together to cause injuries. However, the author also observed that in a couple of cases, logistic regression outperformed other complex machine learning models. This proved that the best model really depends on context and data quality [1].

I have also researched how specific risk factors play a large role in injury prediction. While it isn't always the same risk factors that play a role, some important, and commonly encountered ones, are history of prior injury, training load and workload metrics, biomechanical and kinematic variables, fatigue and recovery, flexibility, range of motion, etc [2]. Most of the time, these risk factors are crucial for athletic injury prediction.

In an article regarding knee injury detection using deep learning, discusses custom made deep learning networks. One study evaluated three customized CNN (convolutional neural network) models with variations in the input fields of view, as well as dimensionality for the detection of complete ACL tears. It was proved to be important to limit the field of view for high algorithm performance. For ACL injuries specifically, field of view had to be limited to the intercondylar region for the best performance. Another study created a DL model that combined meniscus segmentation (the process of digitally outlining and separating the meniscus from surrounding tissues in medical images) and a 3D CNN for accomplishing the detection and the severity of meniscus lesions. The model produced a lesion detection accuracy dataset of 80.74%, 78.02%, and 75.00% for determining severe, mild-moderate, and no lesions [3].

A systematic review of PubMed was performed in order to identify studies investigating machine learning methods in injury prediction and prevention. This article claims that of the eleven considered papers, nine papers used tree-based models, four papers used Support Vector Machines, and 2 papers used Artificial Neural Networks.The training, validation, and test strategy used for the machine learning approaches varied largely between the different studies.

Seven papers used cross-validation and four papers used a single data-splitting approach [4]. This paper also analysed the most important injury predictors, one of these being risk factors. Risk factors included both modifiable factors such as training load, psychological and neuromuscular assessment, stress level, etc; and non-modifiable factors such as demographics, genetic markers, previous injury, and more. It was noted that the most important factors were previous injury, higher training load, and higher body size in youth players [4].

My research builds upon the aforementioned studies by combining topics and ideas that are all associated with the idea of injury prediction. My research is comprehensive and encompasses multiple aspects of the topic, making the information more accessible and a more definitive guide.

III. Background

Subsection 3.1 Categories

Injuries can be classified into many different categories. Classification of an injury refers to the process in which an injury is described or categorized.

One way that injuries can be classified is by relationship of injury to sports activity. Injuries may directly result from participation in a sport, such as collision between players or overuse from repetitive training, or indirectly from participation in a sport, such as an athlete slipping and sustaining an injury when on a basketball court. Injuries can also be not sport-related, such as an athlete being involved in a car crash [5].

Injuries may also be classified through the mode of onset. Usually, injuries are classified as injuries with a sudden onset or a gradual onset. Episodes such as acute and overuse are specific modes of onset. An acute episode is a sudden injury occurrence due to an exchange of large amounts of kinetic energy, For instance, collision between athletes. An overuse episode comes from a gradual accumulation of low energy transfer over time. This can result in tendinopathy, which is induced by repetitive movement or stress fracture. An acute episode due to overuse can also be a classification of mode of onset. This is a combination of both an acute episode and an overuse episode. This comes from repetition, but presents suddenly [5].

Mechanisms of injury are another way to classify injuries. These can be grouped as non-contact, contact indirect (through an object or with another athlete), or contact direct (with another athlete or object). Body regions and areas for injuries are also considered as injury classifications. Head and neck, upper limb, trunk, and lower limb are the different categories that an injury can be classified as. Upper limb includes injuries to the shoulder, upper arm, elbow, wrist, or others. Lower limb includes injuries to the hip, thigh, knee, or others. Trunk includes injury to the chest, abdomen, lumbosacral, or others [5].

Further classification can be to the specific tissue type and pathology involved such as muscle/tendon, nervous, bone, cartilage/synovial/bursa, and internal organs. Muscle injuries can be classified through grades one through three. Grade one showing no appreciable tissue tearing and no loss of function or strength. Grade two shows tissue damage and reduced musculotendinous unit strength. Finally, grade three shows a complete tear of musculotendinous junction and a complete loss of function [5].

Subsection 3.2 AI Methods

Artificial intelligence (AI) is the broadest concept of all and gives a machine the ability to imitate human behavior. Machine learning (ML) is the application of AI into a system or machine, which helps it to self-learn and improve continually. Deep learning (DL) uses complex algorithms and deep neural networks to repetitively train a specific model or pattern.

According to the National Library of Medicine, AI enables sports professionals to make more informed decisions, reducing the risk of injury and improving athlete performance [6]. ML, on the other hand, allows systems to learn from historical data and make predictions without being explicitly programmed. Finally, DL is particularly useful in sports injury prediction when working with data from wearables, video analysis, or sequential performance metrics. DL methods such as convolutional neural networks (CNNs), artificial neural networks (ANNs), and recurrent neural networks (RNNs) provide powerful tools for identifying subtle injury risk factors and predicting potential injuries based on an athlete’s historical and real-time data [6].

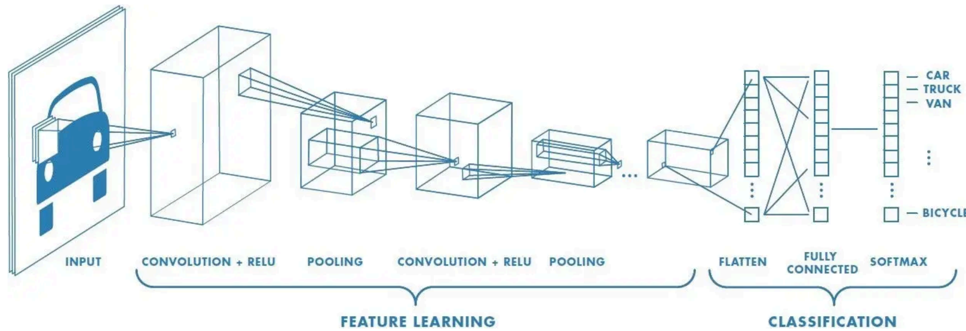

Figure 1. Convolutional neural network diagram [7]

In Figure 1, we see a convolutional neural network diagram that is designed to train or "supervise" algorithms into classifying data or predicting outcomes accurately [7]. Examples of data sets that could be used may be x-rays and MRIs.

Subsection 3.3 Risk Factors

Injury risk factors can be described as any condition, characteristic, or factor that may increase the likelihood of someone experiencing an injury. Anyone can suffer from sports injuries, but several factors can increase the risk of sustaining an injury. Some risk factors for sports injuries include not using the correct techniques for exercises, overtraining, increasing physical intensity too quickly, running or jumping on hard surfaces, having had a prior injury, and much more. The type of injury that one is most vulnerable to can depend on the type of activity they partake in, their age, and their sex [8].

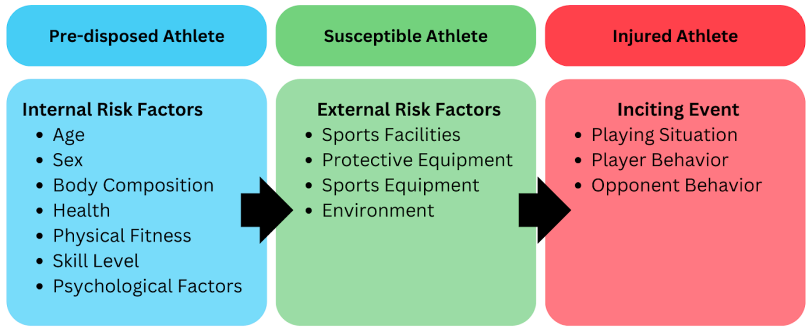

Figure 2. Injury Risk Factors in Sports [9]

Figure 2. shows how sports injuries happen step by step, beginning with internal risk factors. Some athletes have certain risk factors that make them more susceptible to injury. This diagram shows risk factors such as an athlete's age, sex, health, past injuries, fitness level, skill level, and mindset. External risk factors shown in the diagram such as facilities, protective gear, sports equipment, and the environment are factors around an athlete that can either increase or decrease their chances of getting injured. Finally, the inciting incident is the event that can trigger the injury. The diagram shows examples of inciting events such as the playing situation, the player’s behavior, and the opponent’s behavior.

IV. AI In Predicting Injuries

Subsection 4.1 Sports Injury Definition

Injuries are common in both individual and team sports and can have significant physical, psychosocial, and financial consequences to the athletes. Sports injuries are a consequence of complex interactions of multiple risk factors and inciting events making a comprehensive model necessary. It has to account for the events leading to the injury situation, as well as to include a description of body and joint biomechanics at the time of injury [4].

Subsection 4.2 Data Sets For Machine Learning in Injury Prediction

In order for an algorithm to work, data must be input. This data can be specific to the sport that the athlete plays. Figure 4 shows different examples of data that can be input in an algorithm in order for it to come up with an outcome. These examples are things such as exposure, jumps, duration, total efforts, heart rate, sleep quality, and physical exhaustion, as shown in the chart below. These data inputs can result in multiple different outputs.

External load	[33]	[35]	[36, 37] *	[39]	[41]	[42]	[43]	[44]
Exposure							X	
Jumps		X					X	
Distance	X	X				X		X
Accelerations and decelerations	X	X				X		X
DSL (Total weighted impacts above 2 g)	X							
Duration		X				X		
Player load		X				X		X
Speed and velocity		X				X		X
Meterage per minute		X						
Total efforts		X						
High inertial movement analysis		X						
Average metabolic power								X
Dynamic stress load								X
Impacts								X
Energy expenditure								X
Step Balance								X
Dribbling				X				
Sprint				X				
Jumping, moving and balancing				X				
Internal load —physical data								
Body mass index	X		X	X	X	X	X	
Fat percentage				X			X	
Step yo-yo test				X			X	
Heart rate		X						
Ratings of perceived exertion (RPE)						X		
Internal load—psychological data								
Sleep quality			X			X		
Physical exhaustion			X					
Reduced sense of exhaustion			X					

Figure 3. Training load features from specific papers [11]

Subsection 4.3 An Example Injury Prediction Pipeline

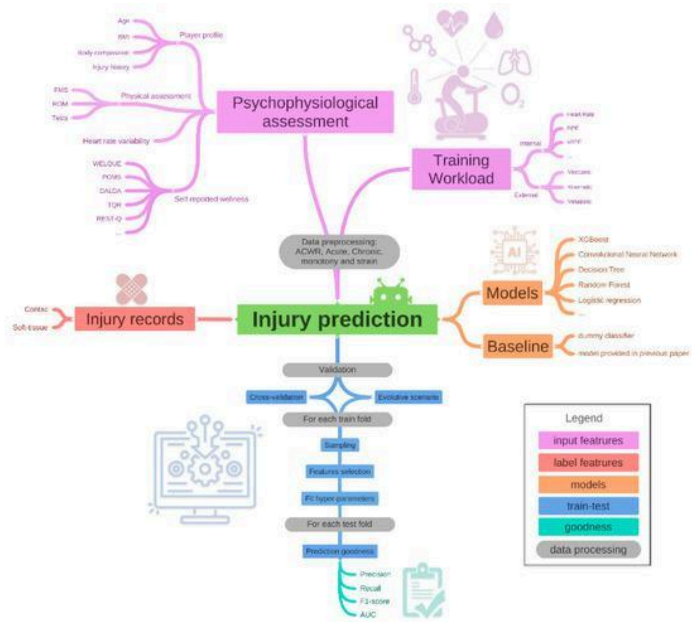

Figure 4. Diagram of the injury prediction validation [12]

In this subsection, we take a look at an example model machine learning pipeline for injury prediction. Figure 4. Shows the pipeline for injury prediction when machine learning is used. The input features, the pink and purple, show psychophysiological assessment. This can be the age of a player, their profile, their physical assessment, their heart rate, and other factors. The label features, the red, show injury records. Models such as decision tree, random forest, and logistic regression are shown by the orange. Train, test, and validation are shown by the blue, meaning that data is split, selected, fit to a model, and comes out with a prediction.

Step one of the example injury prediction pipeline is what goes in, the pink and purple. The psychophysiological assessment, training workload, and injury records are all input. Step two of the pipeline is preparing the dates, the grey bubble. This means computing the workload features and summaries that relate to risk. Aligning all of the inputs also happens in this stage. Step three is when a model is chosen. This is the orange. Several machine learning models are tried such as logistic regression, decision tree, random forest, and more. Step four is the train and test procedure, the blue. This is when a sample of predictions are tested. Step five, the teal, is a checklist where all of the information is precisely evaluated and the models are determined as "injury soon" or "no injury". Finally, step six, the green center, is the output. The final model produces an injury prediction for an athlete using all of the features from the workload and psychophysiological data [12].

Subsection 4.4 Supervised Learning and Classification for Sports Injuries

In this section, we discuss the different types of algorithms that can be used in this model. The specific approach that can be used to predict injuries is supervised learning. Supervised machine learning models can learn a function that maps an input (e.g., external workloads, internal workloads, and self-reported wellness) to an output (e.g., injury label). In past reviews about injury forecasting by machine learning models, it has been asserted that the results detected are promising in the sense that these models may be able to help coaches, physical trainers, and medical practitioners in the decision-making process for injury prevention and prediction. The most common supervised machine learning models used for injury forecasting are decision trees, binary logistic regression, random forests, and supporting vector machines.A decision tree model is a machine learning technique that is tree-structured and is used for regression and classification tasks. The four main nodes that are in a decision tree model are roots, branches, internal, and lead nodes. Internal nodes, also known as decision nodes, receive outgoing branches from the root nodes, which do not have any incoming branches. The two types of nodes perform assessments to create homogeneous subsets, which are represented by leaf nodes, also known as terminal nodes.

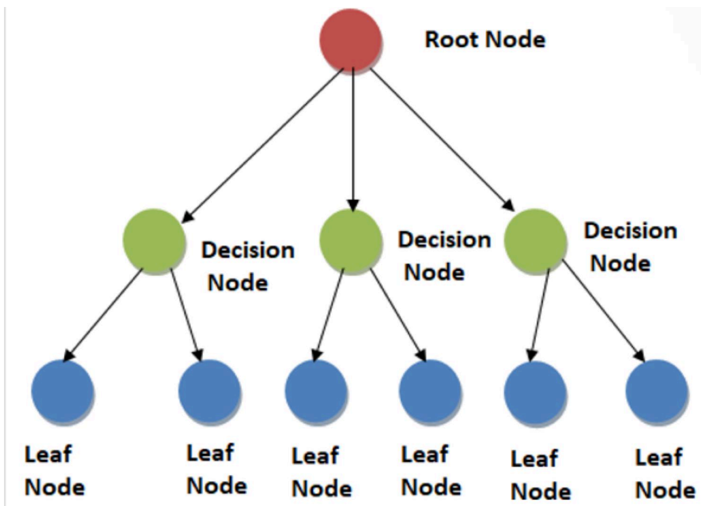

Figure 5. Decision Tree Model [13]

Classification, regression, and clustering are specific mechanisms used in machine learning. For injury prediction, the specific mechanism that could be used is classification. Classification is all about putting things into categories. For example, classification is used when sorting emails into “important” and “spam” folders automatically[14][15]. In order to predict injuries, body scans can be placed and labeled into sections with scans showing a large amount of inflammation in a specific body part and scans that are completely healthy. The scans that have inflammation in a specific body part are most likely prone to injury. The scans that are prone to injury, can be separated into multiple groups based on the body part that has inflammation, such as elbow, knee, ankle, shoulder, etc.

Figure 6. shows various machine learning methods and evaluates their applicability for utilization in athletic injury prediction. Some of the algorithms that are identified as reliable are random forest, bootstrap methods, topic modeling techniques, and more. Additional methods can be characterized in terms of qualities such as autonomous, fair, transparent, explainable, trustworthy, and private.

Characteristics References	Accountable	Autonomous	Fairness	Transparent	Explainable	Trustworthy	Privacy	Algorithm/ Techniques
[52]	✓							Random Forest
[9]	✓		✓	✓	✓			Bootstrap Methods
[68]						✓	✓	Convolutional Neural Network, Pattern Refinement Algorithm
[63]					✓			Brain Imaging technique
[64]					✓			Genetic Algorithm, Regression Algorithms
[12]				✓	✓			Genetic Algorithm, Logistic Regression, Support Vector machine
[65]					✓			Reinforcement Learning Algorithms, Convolutional Neural Network, Artificial Neural Network
[53]	✓							Topic Modeling Technique
[54]	✓		✓			✓	✓	Differential Privacy, Multi-party computation, Blockchain-based Accountability.
[70]							✓	Deep Learning Models
[14]							✓	Cryptographic Approaches, Homomorphic Encryption Techniques, etc.
[60]			✓					Risk Assessment Technique
[61]			✓					Adversarial bias framework
[57]		✓						Optimization based Algorithm
[58]		✓						Signal Temporal Logic
[59]		✓						Deep Neural Networks
[69]					✓	✓		Blockchain-Based Framework

Figure 6. Characteristics of Machine Learning and Algorithms/Techniques [16]

V. Traditional Approach vs AI

Subsection 5.1 Injury Diagnosis

Sports injuries can happen suddenly, or they can develop slowly over time. Typically, these injuries are diagnosed by a healthcare provider with a physical exam and looking at medical history. They will ask about what happened at the time of the injury and then they will go over your symptoms with you. They may check how the injured body part moves and where it hurts. Depending on what the injury is, they may take pictures through imaging tests such as x-rays, CT scans, or MRIs [17].

AI continues to advance across various fields, especially health care. AI can be used for imaging analysis. AI algorithms can quickly analyze images such as CT scans and MRIs and identify fractures, internal bleeding, and other abnormalities. AI can also highlight areas of concern and help doctors form more accurate decisions quicker [18].

Subsection 5.2 Risk Prediction

Before AI, risk prediction was done by studying risk factors such as workload ratio, weighted moving average, and monotony and strain of athletes. Doctors would compare these risk factors with other athletes, allowing them to predict if an athlete is more likely to obtain an injury than another [19].

Risk prediction can be used to help with the final diagnosis of an injury. Injury risk prediction and prevention algorithms identify athletes with elevated injury risks and highlights situations where injury risks are low [20]. AI can predict potential issues or risk factors based on the data of a specific patient. Once patterns in medical history and vital signs are analyzed, AI can flag patients who are at risk for different conditions and prompt doctors to take actions that can prevent these conditions from occurring before they do.

The use of AI can make injury risk prediction more accessible. This will cut down on doctor visits for athletes, which will lead to cost savings for both the athlete and insurance companies. This is because injury prediction and prevention will lead to less doctor visits. Medical professionals currently focus on treatment as opposed to prevention. AI may have the capability of predicting injuries before they occur, allowing athletes to prevent them.

Subsection 5.3 After Injury Treatment

Sports injuries are treated in many different ways depending on the injury. An athlete should never work through the pain regardless of how small an injury may feel. For serious injuries, surgery may be necessary to repair torn ligaments or to realign fractured bones, but most musculoskeletal sports injuries do not require surgery. Other serious injuries require immediate immobilization, which can be done right away by an athletic trainer or paramedic. Immobilization limits movement near the area of injury, which reduces pain, swelling, and muscle spasms. This allows the healing process to begin [17].

Minor injuries, on the other hand, can be treated at home. Many injuries are treated by using the R-I-C-E method. This stands for rest, ice, compression, and elevation. Resting means limiting activities that involve using the injured body part for at least a couple of days. This also means avoiding putting weight on or using the injured part too much. Icing means to simply apply ice to the injured area for 20 minutes at a time between four and eight times a day. Compression means keeping pressure on the injured area in order to reduce swelling. Elastic bandages work well as long as they are not wrapped too tightly. Elevation means keeping the injured body part above the level of the heart in order to reduce swelling. Other treatments can include medication over the counter such as anti-inflammatory or pain relief medication [17].

AI can come in and help with this by creating images, videos, and text that can be used in patient education. These images, videos, and text can be used to show patients exercises that can help them to speed up their healing time. AI can also give patients some sort of instructions on what is necessary to heal faster [21].

VI. Concerns, Impacts, & Limitations

Subsection 6.1 Concerns of AI in Medicine

In order to train a model to predict an injury, a surplus of data is necessary. Many images from x-rays, MRIs, and CT scans, along with medical history must be used. It is very difficult to obtain enough data for this because many medical records and imaging are private and confidential to only the doctor and the patient, therefore, it would be a violation of privacy.

Subsection 6.2 Risks of AI in Medicine

Privacy is a large concern with AI, especially in the medical field. AI systems use specific algorithms that need large datasets to improve their accuracy. This process poses significant risk to patient security, privacy, and confidentiality. Today, the danger of hackers is increased due to the interest in pharmaceutical and insurance companies. Hacking in the medical field can also be used as a cyber attack against the government. Another issue is data bias, in which specific minorities may be misrepresented. This bias in the algorithms can affect the outcomes of clinical trials and insurance claims [22].

Subsection 6.3 Impacts of AI in Medicine

AI in medicine can positively impact the future and the present in many ways. One example of this is the introduction of the consultation program Causal-Associational Network (CASNET) in the late 70s. This program used disease data and applied it to an individual, giving advice to the doctor on how to help the patient manage the disease. Since then, there have been many advancements in the medical field such as other programs like that one. The use of these advancements has had a positive impact on the quality of medicine improving accuracy and consistency in many aspects. AI continues to evolve as it impacts the future of medicine [23].

While there are many upsides to the use of AI in medicine, there are also many downsides. The use of AI may cause doctors to be less accurate due to the fact that many AI platforms do not reference medical articles. The major ethical concern with AI in medical fields comes from the common use of electronic health records and their data breaches. Those health records that are breached may contain sensitive information about a patient, causing a major privacy violation. In addition, another concern is clinical implementation. Humans fear that AI and robots may eliminate some of their jobs. This may get rid of many human office jobs in terms of efficiency and there will be fewer errors made as there is no room for human error. While this may not necessarily be true, it is still a stigma that can cause an uproar in many workplaces [22].

VII. Conclusion

This research paper has explored the possibilities of utilizing machine learning in athletic injury prediction. By examining methods of classification of injuries, injury risk factors, and injury predicting modeling approaches, this analysis demonstrates that the use of artificial intelligence is promising in the field of predicting athletic injuries before they even occur. However, my findings also show limitations such as limited data and questions of generalizability across different sports and different populations.

These data are important and can inform sports medicine and athlete management. It can revolutionize the field of sports medicine. Predictive models can change the approach to injury prevention, rather than rehabilitative treatment. This change can not only improve an athlete’s performance, but can greatly affect an athlete's long-term health. Athletes will not have to be sidelined as often and their careers can potentially be expanded.

Future research should focus on combining larger and more diverse datasets, developing more explainable pipeline models, and obtaining collaboration from scientists, clinicians, and coaches. By addressing this, injury prediction can become more accurate, safer, and more sustainable athletic practices.

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