ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG462

The Impact of Machine Learning in Sport Injury Rehabilitation: A Specialist Perspective

Mohamed Ahmed Kamel
REPS UAE Academy, No REPS15420

Rasha Ragheb Atallah
Department of Computer Science, Faculty of Computer Science and Information Technology, Al Aqsa University, https://orcid.org/0000-0002-1433-8964

Abstract:- One specific component of the athletic performance management paradigm is sports injuries and their rehabilitation. It plays a major role in a competitor's good recuperation and long-term physical well-being. This study looks at athletes' histories of sports recovery and develops several machine learning models based on these findings. This paper aims to assess the current state of machine learning applications for sports injuries and determine how each injury element—extrinsic, intrinsic, and triggering events—should be analyzed. The current dearth of models and open-source data sets, as well as the effectiveness of ML in sports injury prediction, are the conclusions drawn.

Keywords:- *Sports Training, Rehabilitation. Reconditioning, Participation, Psychological, Injury.*

I. INTRODUCTION

Artificial intelligence (AI) is increasingly widely used across various industries as the digital era advances. Deep learning, flexibility, and sensory perception are essential AI components crucial to this digital transformation(Rao, Gaddam, Kurni, & Saritha, 2022). The role of AI in improving decision-making and problem-solving processes cannot be overstated. Its sophisticated data analytics, pattern recognition, and experience-based learning are revolutionizing the way we approach sports injury rehabilitation (Komasawa & Yokohira, 2023). AI is not just about technology; it's about enhancing the human-computer connection(Shneiderman, 2020). This connection is crucial in sports injury rehabilitation, as it reassures us that the human element, represented by the specialists, is not lost during technological advancements(Qazi & Iqbal, 2024). We can create a more interactive and engaging experience in sports injury rehabilitation by utilizing natural language processing and creative engagement techniques.

When an injury occurs, that athlete must be rehabilitated in the most efficient way, effective way, and supportive manner possible way. When specialists are developing rehabilitation programs, decision-support systems must be implemented(Hess, Gnacinski, & Meyer, 2019). Machine learning-based systems, previously identified as providing tools to support less complex rehabilitation objectives in sports settings, can generate such solutions(Amorim et al., 2021).

Fundamentally, the goal of a healthcare system is to develop and utilize such machine learning-based rehabilitation decision support systems(Antoniadi et al., 2021), in which various athletic stakeholders may assist injured athletes in their return to play at a desirable and previously achieved performance level.

II. DEFINITION AND SCOPE

In the context of sports, the rehab of injuries has been the most explored by optimizing machine learning models that help rehabilitate the injuries.

So, the purpose is to find the most effective treatment for injuries. However, the field of injuries has already shown increasing gains in image processing and deep learning models(Salehi et al., 2023).

Some contributions in feature engineering highlighted the importance of physiological evolution to prevent morbidity, mortality, and, ultimately, the end of a career (Nesse, 2023).

Similarly, Smith et al. stress the relationship between muscle mass, strength, and anterior cruciate ligament injury(Thomas, Wojtys, Brandon, & Palmieri-Smith, 2016). Also demonstrated the relevance of joint instability and proprioception impairment in preventing new injuries(Jerosch & Prymka, 1996).It is already possible to see real operations without human intervention for the detection of ACL injuries(Štajduhar, Mamula, Miletić, & Uenal, 2017). Silva et al. used various variables for this prediction, but the stylized predictive model that could have translational potential in musculoskeletal injuries effective in tensor fasciae latae (TFL) injuries identified only quadriceps function and reduced trunk motion(Mengarelli et al., 2024). We, in turn, identified difficulties in predictive modeling in numerous biomarkers.

- *Importance of Effective Rehabilitation*

To ensure that competitive athletes can return from their injuries as soon as possible is paramount in any sport. As high-performance mentors, it is important to provide a reliable and meaningful understanding to our athletes during their treatment time. Established in the demographic of athletes, especially professional athletes, this seeks to make a quick return to play a central feature of the treatment procedure.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG462

This concern can lead to athletes neglecting helpful recovery periods. More efficient and comprehensive recovery procedures allow us to improve each athlete's overall long-term and short-term physical and psychological health. It's recognized that the treatment time of professional elite athletes will reduce their professional income. Working efficiently can also have long-term health results besides preventing any earnings difficulties. During the recovery phase, the risk of later chronic pain incidents can be minimized by using the most accurate, strengthened, and specific physical rehabilitation plan.

The goal of the therapy and rehabilitation processes is to keep athletes from putting their health in danger so they may continue competing in sports for a longer period. Since the goal is to return an ill or injured individual to self-sufficiency or meaningful work at his maximum level of attainable skill, the method is the same as that of non-athletes. Athletes who sustain injuries require a different kind of rehabilitation because they need to recover completely and reach the same level of performance and fitness as they had before to the injury(Hanson, 2019).

The injured athlete's rehabilitation program of activities is presented. The kind of treatment that is given will depend on the nature of the damage. When the afflicted portions can move through their complete range of motion without experiencing pain, strengthening exercises with weights and springs can be introduced. When the athlete is able to complete fitness exercises, he turns himself over to the coach and is permitted to begin light training. From there, he advances to medium training, heavy training, and finally graded training, which is required to avoid a relapse(Sharma, Salibi, & Tzenios, 2023).

III. MACHINE LEARNING IN HEALTHCARE

The era of personalized healthcare is here, with machine learning leading that revolution(Chakraborty, Bhattacharya, Pal, & Lee, 2023). The recent digitization of healthcare data draws the interest of many machine learning algorithms that can provide advanced analysis and support clinical decision-making. Many healthcare systems are developing models to predict patients' statistics and the outcome of diseases. In clinical research, machine learning is being used to improve patient care by finding solutions to disparate problems of varying complexity(Jiang et al., 2023). The popularization and exponential growth of data storage and the large number of diverse algorithms combined with the rapid evolution of the machine learning domain have facilitated its widespread application.

Another aspect of healthcare is the rehabilitation of injuries or pathologies. In physical therapy, rehabilitation treatment aims to increase mobility and function for a specific region or throughout the body. Usually, the area that requires rehabilitation therapy is linked to previous injuries or surgical interventions(Piedade, Arruda, de Vasconcelos, Parker, & Maffulli, 2023). Although humans are managing to personalize treatment plans based on the therapy evolution of specific patients, patients' outcomes are hard to predict using static metrics. Frequently present criteria, such as gender, age, initial range of motion or physical capacity, the initial status or the pathology in question, are also insufficient to guarantee rehabilitation therapy success for the patient. Therefore, the decision process of developing patient-specific rehabilitation treatment can be enhanced by creating machine learning models that predict physical therapy outcomes.

The goal of a personalized outcome prediction model is to provide the physical therapist with alternative treatment plans or rehabilitation duration. Additionally, these personalized models can help better identify the number of patients who would benefit from and be admitted into physical therapy clinics.

- *Overview of Machine Learning*

Machine learning (ML) is a subfield of artificial intelligence (AI) that involves the development of adaptive systems that can learn from data and can improve their performance through learning. In recent years, AI and ML have become popular across various disciplines (Lampropoulos, 2023). AI is the quest to simulate human capabilities such as reasoning, learning, and perception with a computer program. ML involves different methods of teaching software and the ability to improve and develop from experience. These methods are used to process multitudes of information and data and subsequently identify patterns in the data that lead to increased precision, which has led to medical-related ML.

The rapid development of AI and ML can be attributed to noticeable advances in large-scale database creation and collection, increased computer power, and improvements in algorithm design. This rapid growth has led to the integration of AI into several clinical specialties, such as surgery. concluded that AI had begun to be used to help surgeons improve surgical processes and to support decisions. There are also various examples of specialists in the medical field using AI to improve patient care. Adaptive systems are also being developed in rehabilitation, and their use can play a role in patient awareness and positive recovery support. However, the infrastructure of ML has yet to be integrated into multidisciplinary clinical practice, although several directions of this practice are actively progressing. The involvement of AI in personalized patient management has the potential to contribute effectively to the process of injury recovery.

- *Applications in Healthcare*

Machine learning has started to show potential in chronic disease management, clinical decision support, and other healthcare areas. Three broad types of machine learning are applied in healthcare: supervised learning, unsupervised learning, and reinforcement learning.

Supervised learning is used for classification and prediction. Unsupervised learning is used for tasks such as clustering and density estimation. Reinforcement learning is used to optimize control and sequential decision processes(Azevedo, Rocha, & Pereira, 2024).

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG462

Each subsection will present methods from these paradigms with representative machine-learning tasks in healthcare applications. We will also present real applications and discuss the challenges and potential solutions.

Healthcare is one important application in which machine learning techniques are being applied. Digital health's emergence and extensive digitalization have led to a proliferation of health-related data.

The healthcare system requires personalized and digital health tools that leverage significant technological and scientific advances. These tools are essential for facing the new challenges of the digital age and providing an effective solution to offer scalable and efficient healthcare and social inclusion solutions, especially for those needing the most care.

The early discovery of diseases, the understanding of the complex machinery that underlies them, and the development of precise treatments are indeed great opportunities to rely on those models.

IV. INTEGRATION OF MACHINE LEARNING IN SPORT INJURY REHABILITATION

Machine learning can revolutionize various stages of patient care models, including prevention, biotechnology, diagnosis, and treatment. When applied to musculoskeletal radiographs, machine learning-based models have demonstrated significant progress in identifying a range of pathologies, such as fractures, osteoarthritis, degenerative joint disease, joint erosions, and knee injuries. A machine learning model for concussion identification is currently under investigation and can be up to 100% accurate(Nascimben, 2024). Incorporating items like biosensors, telemedicine, and other digital data sources using machine learning provides rehabilitation with a greater understanding of every patient's injury and recovery status. The most successful models include both physiologic, biomechanical, and medical data, as well as psychosocial characteristics, which the systems have been able to use to predict prognosis.

A deep sequence model for predicting new musculoskeletal disorders using patient demographics and previous diagnosis codes learned from different Asian sites and widely used administrative data(Yoon, 2023). The implemented machine learning model showed the feasibility of transferring knowledge across diverse healthcare systems and provided accurate patient prognoses to help specialists tailor preventative care. The rehabilitation domain is still unexplored in developing and validating new machine-learning models to support patient assessment. Machine learning integrated into rehabilitation would strengthen treatment plans and significantly shorten downtime, saving time, cost, and labor. People have a strong relationship with technology, so greater physician access to smart integrated tools would enable more precise rehabilitation. The revolutionary impact of machine learning in developed regulatory expertise for specialist consideration and approval is rapidly consumed by commercial devices.

- *Current Practices and Limitations*

In orthopedic injury rehabilitation, there has been an increasing integration of available sports-specific data, such as load counseling, strength profiling, joint-specific injury prevention strategies, daily recovery strategies, and in some cases, rehabilitation timeframes(Ehioghae et al., 2024).

Data acquisition is often objective, through such equipment as GPS units, force plates, and isokinetic dynamometers, as well as other sports devices like inertial sensors, wearables, and other at-home recovery supports that are attached to the body(Ehioghae et al., 2024). Return-to-play assessments reproducibly measure many human performance elements, sometimes using mobile markerless motion capture systems, as well as more advanced systems. Furthermore, such advanced systems can act as very effective educational tools. Physical support during orthopedic injury rehabilitation has changed with the easier adoption of a remote physical conditioning coach for home-bound function improvement, and telerehabilitation is now a valid and reliable method of delivering rehabilitation services whilst increasing access to such services.

A new algorithm sports injury prediction algorithm using convolutional neural network (CNN) based on visual analysis technology. The experiment consisted of 30 volunteers between the ages of 19 and 4(Chen & Yuan, 2021).

Another study was obtained to build and validate a Support vector machine predictive model that keeps the ability to make an early and accurate detection of a player's injury using athletic load data. The model was evaluated using a data set consisting of 21 soccer players' athletic. The dataset information was collected from different sources including internal load data such as heart rate, external load data as the duration of workout and number of jumps(Naglah et al., 2018).

Also, another model based on the Logistic Regression Model focused on ankle injuries was built; this ground-breaking study uses cutting-edge analytical methods like artificial intelligence (AI) and machine learning (ML) to address the common problem of sports injuries. The study has a sample of 400 athletes who participated. Using a logistic regression model, the study provides a strong prediction tool for detecting and categorizing athletes with injuries, with an astounding 90.0% accuracy rate(Hu, Raza, Patel, Wasif, & Chomiak, 2024).

Moreover, To enhance athletes' rehabilitation outcomes and lower the likelihood of recurrent injuries, this project will investigate a sports injury prevention and rehabilitation monitoring technique based on fiber optic sensors and machine learning algorithms. A machine learning-based sports injury prediction algorithm that lowers the chance of recurrent injuries in athletes. Another approach used to sports rehabilitation and outcome prediction using RNN-LSTM , is

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG462

the performance of sketched model different performance metrics is considered. It shows an accuracy of 85.2%(Cui, 2024).

Although these sports-specific advancements have benefited athletes during orthopedic injury rehabilitation, limitations do exist. Despite known weakness being a common predisposing factor in a range of leg injuries, these profiles are not always assessed by the strength and conditioning coach or other rehabilitation specialists in order to adopt strength-focused programs.

When adaptations are made, guidelines or percentage reductions in activities or movements that should not be undertaken or should be moderated to stay within safe zones are often only provided by healthcare professionals, meaning that athletes frequently experience non-specific reductions. Data relations are otherwise inconsistently notified. Existing healthcare specialist input is often received in response to progress, rather than input being an integrated part of recovery. Such information tends to occur less frequently over a longer episode of care, occurs on an as-required or call-to-arms basis, and is currently not part of generalized sports-specific educational campaigns for strength and conditioning coaches. In surgery-specific cases, athletic improvements can often occur prior to surgery, or whilst in different Telerehabilitation stage statuses such as being in hard cast versus fiberglass or removable brace.

- *Potential Benefits and Future Directions*

Sudden changes in movement strategies are reflective of gross neuromuscular impairments and have been proposed as important predictors of injury risk. It follows that interventions aimed at addressing these impairments often manifested as strength, movement control, balance, reactivity, and confidence, can prevent reinjury and training-related tone changes. Ideally, to be effective, these impairments need to be addressed in an integrated rather than a componential manner. Machine learning techniques offer the potential to rationalize this in developing assessment instruments for complex lower limb activity that can assist in designing accurate and safe in-clinic versus home rehabilitation programs.

Quantitative assessment of the progress of muscle and function recovery is not the 'paragon of rehabilitation monitoring', and advanced machine learning techniques can certainly augment traditional methods of assessment in capturing the numerous responses to perturbation external to the body. Advanced monitoring can thus enable immediate and constant adjustments to rehabilitation programs, particularly in an independent, unsupervised, or home setting to promote active participation and increase learning and skill retention in addition to the development of a responsive, dynamic, and adaptive program; these are currently major rehabilitation bottlenecks. The immediate future implications for machine learning in rehabilitation appear twofold; firstly developing accessible and easy-to-use platforms for existing datasets, and secondly integrating in-clinic and tele-rehabilitation programs. Challenges come in the form of security and privacy laws, data quality, and data integrity considerations, hence a strong hand-in-hand partnership between engineers, sports scientists, clinicians, and data protection to ensure compliance and access to excellent quality data.

V. SPECIALIST PERSPECTIVE ON MACHINE LEARNING IN SPORT INJURY REHABILITATION

There was an agreement on the importance of the machine learning applications to optimize the rehabilitation process. However, the use and levels of collaboration seem to be dependent on the type of injury, knowledge on the applications and interpretation process, and reasons of data privacy. The use and interpretation of machine learning in the sports injury rehabilitation context was at the lowest attended level by healthcare professionals. As different levels of expertise emerged, the results from the study aim to uncover current insight from specialist groups as to how machine learning is currently used in sport injury rehabilitation design. Convenient sampling was used to recruit a participant group of sport injury clinicians.

The sample size was intentional to ensure adequate information-rich responses but was only a single consideration. Other considerations included expertise level and location of current practicing sport injury clinicians. This paper aims to share the insight from different levels of experience of sport injury clinicians towards machine learning to raise awareness, enable discussion, and shift levels of preparedness through the stages of knowing how, working together to generate the desired reports that accurately predict and inform the best practice, to achieve the effective transfer of better athlete-centered planning and programming. The analytics were performed with NVIVO qualitative (QR) software to organize, store, and retrieve the data, to recognize and record ideas. Basically, it was used for management, reporting, and explaining of textual data and used throughout single case approach, data coding as an initial point of interpretation of the data.

- *Expertise and Role of Specialists*

Optimal management often sees practitioners from different backgrounds providing diverse intervention modalities, whose expertise can be drawn upon to handle the complexity of the different areas related to injury management. Depending on the context and resources, these may be in-house sport coaches, physiotherapists, or external practitioners of other modalities, from physical condition to mental support. At the same time, a tailor-made approach tailored to the athlete is usually recognized as the best balancing strategy. That is, providing personalized support, which maximizes the potential benefits and minimizes the risks, is equivalent to maximizing performance.

In the specific field of musculoskeletal rehabilitation, an individualized approach to injury management, recognizing and considering differences, consists of integrating the disciplines of physiotherapists and strength and conditioning. The former assess and diagnose abnormalities in body function, while the latter supervise treatment through

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG462

individual, progressive, and functional exercise training. One aims to improve physical potential, the other to exploit capacity during sports performance. It is, therefore, important that a complete and comprehensive appreciation of the human body includes the work of both figures, working together and ensuring a smooth transition of care for the athlete. They have different but interdependent roles, in which the physiotherapist determines the nature, site, and histological type of the injury, followed by the duration and individual response in the recovery of function (including any duration of return to sport), while the strength and conditioning professionals contribute an important part, ensuring that the athlete can meet the physical demands of their sport with no increased risk of a relapse. With this joint approach, the focus shifts from the management of the cause of injury, and the performance becomes the central point.

- *Challenges and Opportunities*

Opportunities resulting from the integration of ML for SIRR are, in essence, its challenges. This is particularly relevant in a clinical perspective. Increases in autonomy for those involved in the therapy process could increase efficacy through more dedicated and personalized attention to those undergoing therapy. Access to specialist advice is not always easy for many individuals. In particular, in times of challenge, the home-based patient may not understand what is expected of them due to failing information. One of the great abilities of many ML algorithms is their ability to process vast amounts of data, allowing rare patient data to be fully exploited. This research has transformed conditions such as opioid addiction from the need for costly wet-based laboratory clinical assessments to highly accessible tools that use motion information from a patient's phone camera. Such initiatives have the ability to expand to areas such as SIRR, using the structured or connected devices employed in typical rehabilitation settings to provide accurate feedback for clinicians.

ML can also support in-depth analysis, allowing the clinician to obtain the most useful information to aid patient rehabilitation. Due to their scope and tendency towards array-based models, Convolutional Neural Networks (CNNs) have traditionally been focused on data that was in some form spatiotemporally reliant. However, they do have potential in data that also evolves concerning a high-quality time-series model such as patient movement data, and which could be enhanced with further patient data that evolves more regularly during the therapy or the recovery process.

VI. CONCLUSION

In this viewpoint paper, clinicians' perspectives towards ML when directly applied towards their roles and responsibilities of sports rehabilitation were collated. There is a relatively high proportion of clinicians who felt that ML would be of benefit to their practice. The main advantages identified were support in making a correct diagnosis, providing a prognosis, and in individualizing treatment. In line with other sectors outside of healthcare, concerns were raised about misunderstandings of technology, legal and ethical issues, and practical applications. It was noted that errors may arise from the inherently unpredictable nature of injuries or data reliance from ML, which are helpful to be aware of.

ML is hypothesized as having the capability to transform healthcare not just in diagnostics, but also in strategies that aim to prevent disease, maintain health, increase patient satisfaction, and reduce financial and opportunity costs. As such, this specific application of ML on clinical practice has not been previously reported elsewhere. Training, monitoring, and load management programs have long been in receipt of technological support; they have become a fundamental part of athletic and coaches training programs, but they must be combined with the professional judgment of those specialized in injury treatments (osteopaths, physiotherapists, kinesiologists, others).

- *Summary of Key Findings*

The present study found that machine learning (ML) applications in sport injury rehabilitation and return to play (RTP) are limited, and explored specialist perspectives to illuminate the current state of knowledge and inform future work. We summarized the specialist-perceived relative importance scores that were obtained from 18 perspectives × 11 ML applications and sorted the 'Very important' items as driver (first four ranks), helper (next four ranks) and irrelevant (last three ranks), cross-tabulated specific study aims and research questions for actionable implications and areas for future research, and discussed the context and generalizability, and implications of the results and reach into the ML-in-rehabilitation. These findings may provide a point of reference for identifying core areas of expertise and establishing best practices in interdisciplinary collaborative work in sport injury rehabilitation and more broadly. The summary of key findings pertaining to how different ML applications are considered by human speciality level, and by top five and bottom five applications is presented in Tables 5 and 6.

In response to the aims and research questions, this explanatory and exploratory mixed-methods study used a three-stage design. A set of nine key basic human perspectives inherent in the physical and psychological recovery of athletes post-injury informed the design of stage one which involved developing an open-ended question: 'Do you think that any of the emerging artificial intelligence approaches could be useful for sports injury rehabilitation and/or return to play decision-making?'. For stage two, machine learning (ML) development was fast-tracked in order to speed up data collection and capitalize on the clarity of the human perceptions of ML benefits in injury rehabilitation. Finally, in stage three, an expert international panel performed a round of Delphi analysis using the generic question to model specific study aims and research questions.

- *Implications for Future Research and Practice*

From the evidence, there has been extensive research on the use of various machine learning models and techniques in sport injury rehabilitation. This research has shown that machine learning models have the potential for providing better patient outcomes in this specialist area. This extensive

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG462

research provides a foundation on which future research should be built, as this will be key for practitioners wanting to know how they might explore the potential benefits of machine learning in sport injury rehabilitation, as it remains an under-researched area. Dovetailing novel developments in machine learning and techniques from biomechanics and physical assessment with applied practice means that greater insight may be gained as to how to optimize patient outcomes in sport injury rehabilitation. The current focus on six sports means that new techniques and models could be applied to sport injury rehabilitation in additional sports.

Further work could explore other machine learning models or further optimize their structure. Previous research has rarely explored ensemble methods or novel methods of data representation and reduction. Although other novel methods could be applied, such as neural networks, generative adversarial networks, deep learning, or other machine learning models that could use the existing data to provide novel insights into sport injury rehabilitation. The impact of machine learning in sport injury rehabilitation would be undeniably strengthened if further prospective research could validate and generalize any findings. Future research should also ensure testing intervention packages capitalized by successful models that are optimized to deliver changes based on functionally based goals. As the individual becomes more able, beneficial changes may be made to physical development and sports-specific skills to enable a smooth return to play while simultaneously minimizing injury recurrence. These optimized intervention packages may need further validation and then testing within harder outcome measures, such as multifactorial sports injury rates, so practitioners may establish the effectiveness of their broad implementation. Indeed, optimized treatment models could provide a basis for future prospective models of clinical decision-making that could be built for professions new to sports injury rehabilitation. These models may benefit from an overarching IT model to guide practice based on patient presentation characteristics at specific stages of injury recovery as part of their learning process in sports injury rehabilitation.

REFERENCES

[1]. Amorim, P., Paulo, J. R., Silva, P. A., Peixoto, P., Castelo-Branco, M., & Martins, H. (2021). Machine learning applied to low back pain rehabilitation–a systematic review. International Journal of Digital Health, 1(1), 10.

[2]. Antoniadi, A. M., Du, Y., Guendouz, Y., Wei, L., Mazo, C., Becker, B. A., & Mooney, C. (2021). Current challenges and future opportunities for XAI in machine learning-based clinical decision support systems: a systematic review. Applied Sciences, 11(11), 5088.

[3]. Azevedo, B. F., Rocha, A. M. A., & Pereira, A. I. (2024). Hybrid approaches to optimization and machine learning methods: a systematic literature review. Machine Learning, 1-43.

[4]. Chakraborty, C., Bhattacharya, M., Pal, S., & Lee, S.-S. (2023). From machine learning to deep learning: An advances of the recent data-driven paradigm shift in medicine and healthcare. Current Research in Biotechnology, 100164.

[5]. Chen, X., & Yuan, G. (2021). Sports injury rehabilitation intervention algorithm based on visual analysis technology. Mobile Information Systems, 2021(1), 9993677.

[6]. Cui, Y. (2024). An Efficient Approach to Sports Rehabilitation and Outcome Prediction Using RNN-LSTM. Mobile Networks and Applications, 1-16.

[7]. Ehioghae, M., Montoya, A., Keshav, R., Vippa, T. K., Manuk-Hakobyan, H., Hasoon, J., . . . Urits, I. (2024). Effectiveness of Virtual Reality–Based Rehabilitation Interventions in Improving Postoperative Outcomes for Orthopedic Surgery Patients. Current Pain and Headache Reports, 28(1), 37-45.

[8]. Hanson, M. (2019). Anthology of sports injuries. In: NJ: Human Kinetics Publishers.

[9]. Hess, C. W., Gnacinski, S. L., & Meyer, B. B. (2019). A review of the sport-injury and-rehabilitation literature: From abstraction to application. The Sport Psychologist, 33(3), 232-243.

[10]. Hu, B., Raza, M. F., Patel, D., Wasif, S., & Chomiak, T. (2024). Ambulosono-Enhanced Ankle Rotation Training Leads to Significant Gains in Balance Among Healthy Adults. medRxiv, 2024.2004. 2030.24306658.

[11]. Jerosch, J., & Prymka, M. (1996). Proprioception and joint stability. Knee surgery, sports traumatology, arthroscopy, 4(3), 171-179.

[12]. Jiang, L. Y., Liu, X. C., Nejatian, N. P., Nasir-Moin, M., Wang, D., Abidin, A., . . . Punjabi, P. (2023). Health system-scale language models are all-purpose prediction engines. Nature, 619(7969), 357-362.

[13]. Komasawa, N., & Yokohira, M. (2023). Learner-centered experience-based medical education in an AI-driven society: a literature review. Cureus, 15(10).

[14]. Lampropoulos, G. (2023). Artificial intelligence, big data, and machine learning in industry 4.0. In Encyclopedia of data science and machine learning (pp. 2101-2109): IGI Global.

[15]. Mengarelli, A., Mobarak, R., Verdini, F., Fioretti, S., Burattini, L., & Tigrini, A. (2024). Enhanced Gait Phases Recognition by EMG and Kinematics Information Fusion and a Minimal Recording Setup. Al-Khwarizmi Engineering Journal, 20(2).

[16]. Naglah, A., Khalifa, F., Mahmoud, A., Ghazal, M., Jones, P., Murray, T., . . . El-Baz, A. (2018). Athlete-customized injury prediction using training load statistical records and machine learning. Paper presented at the 2018 IEEE international symposium on signal processing and information technology (ISSPIT).

[17]. Nascimben, M. (2024). Machine learning approaches for personalized medicine.

[18]. Nesse, R. M. (2023). Evolutionary psychiatry: foundations, progress and challenges. World Psychiatry, 22(2), 177-202.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG462

[19]. Piedade, S. R., Arruda, B. P. L., de Vasconcelos, R. A., Parker, D. A., & Maffulli, N. (2023). Rehabilitation following surgical reconstruction for anterior cruciate ligament insufficiency: what has changed since the 1960s?—State of the art. Journal of ISAKOS, 8(3), 153-162.
[20]. Qazi, A., & Iqbal, A. (2024). ExerAIde: AI-assisted Multimodal Diagnosis for Enhanced Sports Performance and Personalised Rehabilitation. Paper presented at the Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition.
[21]. Rao, T. V. N., Gaddam, A., Kurni, M., & Saritha, K. (2022). Reliance on artificial intelligence, machine learning and deep learning in the era of industry 4.0. Smart healthcare system design: security and privacy aspects, 281-299.
[22]. Salehi, A. W., Khan, S., Gupta, G., Alabduallah, B. I., Almjally, A., Alsolai, H., . . . Mellit, A. (2023). A study of CNN and transfer learning in medical imaging: Advantages, challenges, future scope. Sustainability, 15(7), 5930.
[23]. Sharma, S., Salibi, G., & Tzenios, N. (2023). Modern approaches of rehabilitation in COPD patients. Special Journal of the Medical Academy and other Life Sciences., 1(6).
[24]. Shneiderman, B. (2020). Human-centered artificial intelligence: Three fresh ideas. AIS Transactions on Human-Computer Interaction, 12(3), 109-124.
[25]. Štajduhar, I., Mamula, M., Miletić, D., & Uenal, G. (2017). Semi-automated detection of anterior cruciate ligament injury from MRI. Computer methods and programs in biomedicine, 140, 151-164.
[26]. Thomas, A. C., Wojtys, E. M., Brandon, C., & Palmieri-Smith, R. M. (2016). Muscle atrophy contributes to quadriceps weakness after anterior cruciate ligament reconstruction. Journal of Science and Medicine in Sport, 19(1), 7-11.
[27]. Yoon, J. (2023). Applying Transformer-Based Deep Learning Model for Predicting Multimorbidity in Older Adults. University of Saskatchewan,