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The Role of Artificial Intelligence in Bodybuilding: A Systematic Review of Applications, Challenges, and Future Prospects

Mahmood A. Al-Shareeda[1, 2], Ahmed Abdulazeez Obaid[3], Amjad Abdul Hamid Almajid[4]

[1] *Department of Electronic Technologies, Basra Technical Institute, Southern Technical University, 61001, Basra, Iraq*
[2] *Department of Communication Engineering, Iraq University College (IUC), 11800, Basra, Iraq*
[3] *Political Science, Iraq University College (IUC), 11800, Basra, Iraq*
[4] *College of Basic Education, Physical Education and Sports Science, Al Mustansiriyah University, Baghdad, Iraq*

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ABSTRACT

Artificial Intelligence (AI) is making more and more impact on bodybuilding and helps providing data driven insights for improved training, nutrition, performance analytics, injury prevention and supplementation. This article systematically reviews the impact of AI on five key aspects of bodybuilding. For example, the adaptive workout plans and real-time training feedback in AI-Based Training Optimization improve progressive overload and movement accuracy. Second, it is AI-Driven Nutrition & Diet Planning that will refine macronutrient tracking, each meal customization, and genetics-based diet optimization. Thirdly, AI in Performance Monitoring & Biomechanics uses wearables and computer vision to correct exercise form and analyze body composition. The fourth challenge AI solves is in Injury Prevention & Recovery - using world-class predictive models for muscle strain detection, personalized rehabilitation, and optimized rest protocols. Finally, it forms a part of the AI in Supplementation & Pharmacology encompassing supplement initiatives, hormonal regulation, performance-enhancing drugs, and its detection. However, existing AI systems encounter difficulties, including limited adaptability to individual physiology, inherent dataset biases, privacy issues, and the absence of regulatory frameworks for AI-assisted supplementation and doping detection. Looking ahead, we will have smart gym gear, hybrid AI and human coaches, nutrigenomics supported by AI, and regenerative medicine methodologies. This review highlights the excesses of bodybuilding and the potentiality of AI in moderating bodybuilding under the normative edges of ethics, regulations, and human expertise.

Keywords: Artificial Intelligence, Bodybuilding, Machine Learning, AI in Fitness, Performance Monitoring, AI in Nutrition, Injury Prevention, AI in Supplementation.

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*Corresponding author. Email: mahmood.alshareedah@stu.edu.iq

1. Introduction

Artificial Intelligence (AI) is a game-changer in many fields—from sports science to fitness and bodybuilding [1, 2]. AI in bodybuilding and its implication on training/ performance tracking, recovery, nutrition and the world of supplementation. With technologies such as artificial intelligence, ma- chine learning, computer vision, wearable devices, and neural networks, it is now possible to track exercise form, muscle activation, fatigue levels, and dietary requirements with a high level of accuracy [3, 4]. This enables more data-driven, personalized, and adaptive approaches to bodybuilding than the traditional ways of training and nutrition.

Use of artificial intelligence in generating, tracking or advising about workout thus has helped tremendously in reducing time spent on training and improving muscle hypertrophy. Sophie, Alex - Artificial intelligence driven dietetic programs and nutrigenomics are also growing, providing tailored meal plans and dietary supplement advice according to personal measurements and genetic factors [5]. AI also contributes significantly to the detection of performance-enhancing drugs (PEDs), tracking hormone levels, and optimizing post-cycle therapy (PCT), further highlighting its use in natural and professional bodybuilding[6, 7].

However, there are still challenges facing the adoption and efficacy of AI in bodybuilding. AI models are as good as the dataset used to train them, and the recommendations provided by the AI-based systems may sometimes not account for the subtle differences between people in real time[8]. More- over, privacy issues, ethical concerns around AI-facilitated doping detection, and regulatory oversight regarding AI-prompted supplementation recommendations must also be considered [9].

Figure 1 summarizes the key motivations and contextual developments that support the integration of Artificial Intelligence (AI) and Machine Learning (ML) technologies in the biopharmaceutical industry [10]. The figure is divided into three interconnected segments that highlight intrinsic challenges, industry 4.0 transition, and emerging trends, each of which drives the adoption of AI-ML solutions.

This paper systematically reviews the relevant literature on AI in body- building and its applications in training optimization, nutrition and dietetics, biomechanics, injury prevention, and supplementation. It also explains the challenges faced by AI in this area and the possibilities of integrating AI into more effective bodybuilding in the future. Filling the void between innovation in technology and reality in dynamic movement, this research examines the role AI has in redefining the future of bodybuilding.

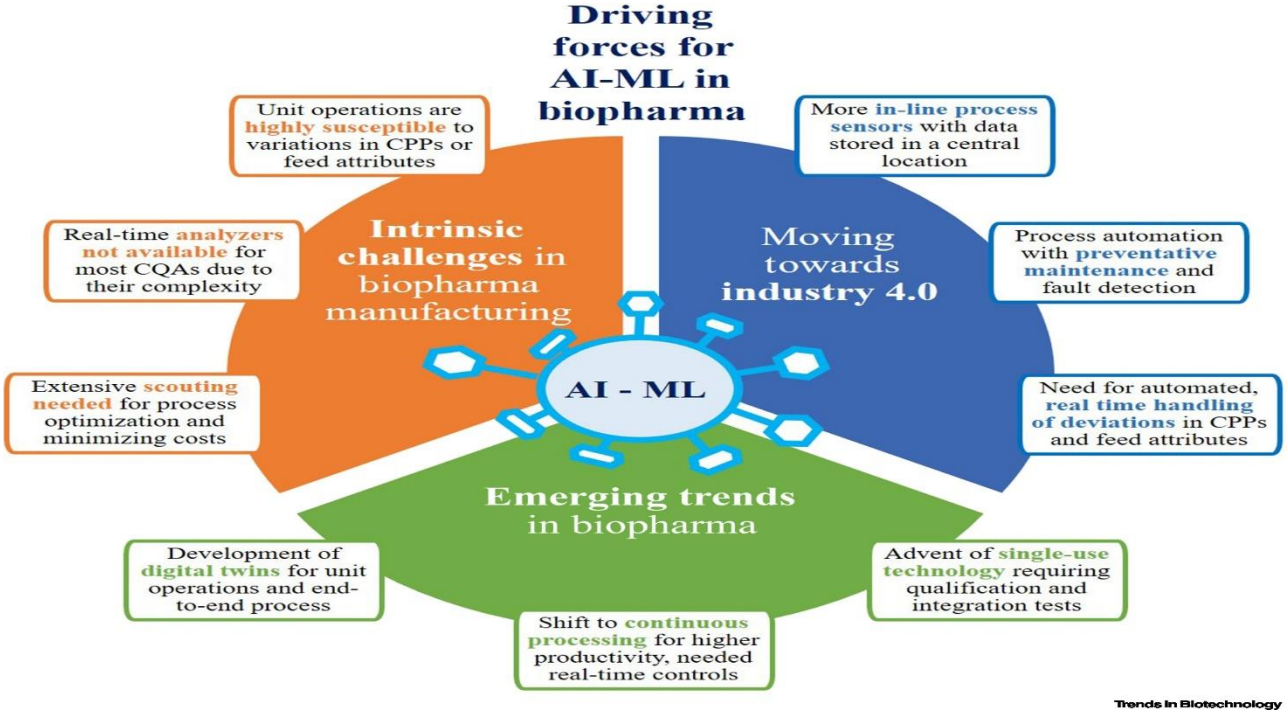

Figure 1. Artificial intelligence and machine learning applications in biopharmaceutical manufacturing [10].

2. Background

In fact, the use of Artificial Intelligence (AI) within the sports and fit- ness industry has developed dramatically over the past 10 years, integrating training optimization (e.g. smart watches), performance tracking, injury prevention, and nutrition management. Bodybuilding, the practice of progressive resistance exercise, specific macronutrient intake, and detailed activity tracking, has started taking advantage of AI powered capabilities to improve training efficacy (hypertrophy, recovery, and supplementation).
The integration of VANETs into smart city infrastructure has also been a key focus. A Comprehensive Review of Recent Developments in VANET for Smart Cities (2024) provided an extensive analysis of data acquisition devices, clustering techniques, and energy-efficient routing protocols that enable VANETs to function effectively in urban environments. The findings highlighted scalability and real-time data management as major challenges in the adoption of VANETs for traffic management and intelligent transportation systems (ITS). Another study, PLUG: A City-Friendly Navigation Model for Electric Vehicles with Power Load Balancing upon the Grid (2023), developed a navigation model for electric vehicles (EVs) that utilizes real-time VANET data to optimize power distribution in smart cities. These studies underscore the importance of VANETs in enabling sustainable and efficient urban mobility.

2.1.Evolution of AI in Sports and Bodybuilding

Traditionally, bodybuilding has been dependent on experience-driven training protocols, whereby coaches, trainers, and athletes develop training and nutrition strategies based on trial-and-error methodologies, anecdotal data, and generalized scientific laws [11]. Now, with machine learning, deep learning, and wearable technology, AI offers Real-Time, data-driven insights that allow us to take a more accurate and tailored approach to training and nutrition. Gone are the days of AI just being for elite athletes, fitness apps, smart wearables and virtual coaching systems are making AI-assisted bodybuilding training available to a wide audience.

Some of these innovations are powered by biomechanical analysis, computer vision, and predictive analytics. The enzymes and hormones related to our performance were analyzed, the glycogen and serotonin levels were noted down and the peak energy phases were recorded so we could perform the best at our workout sessions and there was no concept of AI available to assist using these methods to enhance our fitness goals, and you can go through the above application of AI in the fitness industry which helped them to take their fitness solutions to the next level and attain optimum results.

2.2.Key AI Technologies in Bodybuilding

Several technological advancements help us understand the role of AI in bodybuilding:

• Machine Learning & Neural Networks: AI-driven algorithms learn past workout data and can forecast optimal training loads, rest periods, and variations of exercises for an individual, based on their muscle adaptation and fatigue levels.
• Computer Vision & Biomechanics — AI-driven motion analysis systems can offer immediate feedback on workout form, helping users avoid injury while keeping alignment and biomechanics ideal for strength training.
• Wearable Technology & Biometric Sensors: Wearables such as smart- watches, heart rate monitors, and muscle activation trackers capture real-time physiological data, allowing AI to modify workouts live in response to fatigue and stress levels.
• Nutrigenomics and AI in Nutrition: AI tools analyze macronutrient intake, devise meal plans, and tailor diets based on genetic profiles, ensuring bodybuilding nutrition complements metabolic needs.
• AI in Supplementation & Pharmacology: Answers how much to supplement, when to supplement (protein, creatine, etc.) and helps detect performance-enhancing drugs and monitor hormonal balance.

2.3.AI's Impact on Traditional Bodybuilding Practices

Previously, bodybuilding was dominated by static training regimes and broad-spectrum diets, however, AI has brought with it a dynamic, personalized approach:

• Training Customization: Traditional methods usually deploy generic workout templates to deliver workouts, whereas, with AI, workouts are created within a training union and customized based on an athlete's training history, recovery speed and strength progression.
• Recovery Analysis: AI can determine the level of muscle fatigue, analyze sleep cycles, and prescribe recovery periods for optimization.

• Precision Nutrition: AI proactively adjusts dietary recommendations based on individual metabolic responses and genetic tendencies, minimizing the risk of stagnation or ineffective meal plans.

Figure 2 illustrates the diverse and growing roles of artificial intelligence in transforming various aspects of the sports industry. At the center is the athlete, representing the human element that AI supports through technology-driven insights and automation. Surrounding the athlete are five key application areas where AI significantly enhances performance, decision-making, and user experience.

One major application is in recruiting and scouting, where AI algorithms analyze large volumes of player performance data, biomechanics, and historical statistics to identify top talent with greater accuracy and efficiency. This data-driven approach minimizes human bias and improves talent acquisition strategies. Another important domain is match predictions, where machine learning models process historical game data, player form, team dynamics, and other contextual variables to forecast game outcomes. These predictions are valuable not only for coaching strategies but also for betting and fan engagement. In terms of the business and entertainment side of sports, AI is used for tickets and forecasting, enabling dynamic pricing models and demand prediction based on historical attendance, opponent strength, and even weather conditions. Similarly, streaming and broadcasting is being revolutionized by AI through personalized content recommendations, automated highlight generation, and real-time analytics that enhance the viewer experience. From a performance and health standpoint, AI supports the customization of diet plans and exercise regimens tailored to individual athletes based on their biometrics, goals, and recovery needs. This level of personalization helps prevent injuries, optimize performance, and ensure holistic athlete well-being. Overall, the figure encapsulates how AI is reshaping the sports ecosystem—empowering athletes, teams, fans, and organizations alike. Its integration fosters smarter decisions, better experiences, and more efficient operations across all levels of the sporting world.

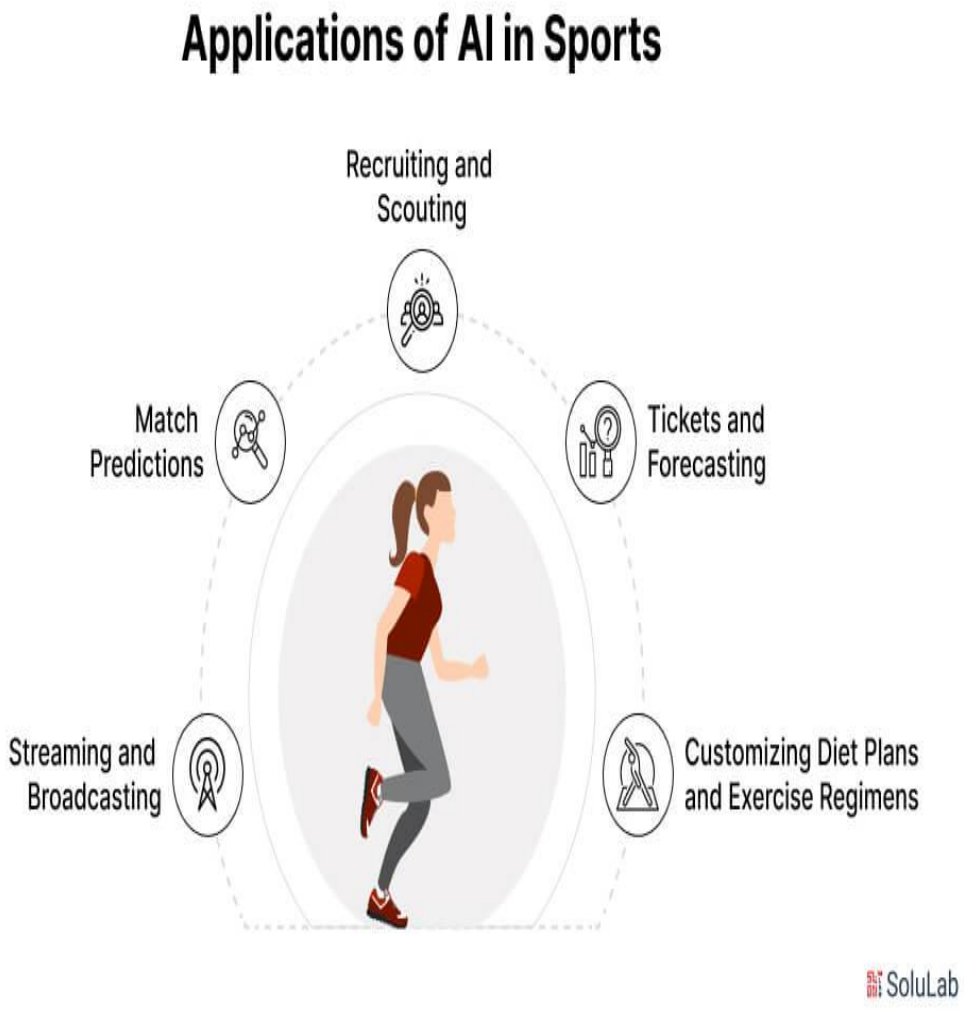

Figure 2. Applications of AI in Sports.

3. Proposed Taxonomy of AI Applications in Bodybuilding

3.1 AI-Based Training Optimization

Mikolajewska et al. [11] presents the role and impact of artificial intelligence (AI) on rehabilitation and physiotherapy, focusing especially on strength training, rehabilitation engineering, and biomechanical, interesting patterns of artificial intelligence in treating physical-rehabilitating traumas. Wan et al. [12] examined how machine learning and data driven models are being applied to model and improve athlete training regimes. It presents OA-EC-FS, which systematically selects prominent performance-related features from the type of sport domain. Han et al. [13] presents AI-based next-generation sensors designed for the rehabilitation monitoring of elderly patients with stroke, cerebral hemorrhage, and muscle atrophy. Based on motion recognition algorithms and virtual rehabilitative environments, it can provide personalized rehabilitation plans, increasing engagement with audio- visual stimuli.

3.2 AI-Driven Nutrition & Diet Planning

Kassem et al. [14] describes the applications of AI in nutrition research, with a focus on its use in dietary assessment, personalized nutrition and disease prediction/management for diseases such as cardiovascular diseases, diabetes, cancer and obesity. AI also helps food-health linkages at individual and community levels through data-driven insights and tailored interventions. Liang et al. [15] explored artificial intelligence (AI)-driven nutrition tools and discussed 177 AI nutritionists regarding their methodologies, functionalities, and applications. Prasad et al. [16] investigates how AI-driven personalized nutrition applications could play a pivotal role in promoting the practice of preventative healthcare and management of lifestyle diseases.

3.3 AI in Performance Monitoring & Biomechanics

Onyelowe et al. [17] report on combined ensemble-based machine learning and symbolic regression to predict compressive, flexural, and splitting tensile strengths of self-compacting geopolymer concrete (SCGPC) containing GGBS, FA, and alkali activators as industrial waste-based materials. Using Deep Learning and Machine Learning, Jagani et al. [18] investigates hu- man posture estimation for real-time performance analysis and feedback in the fitness business. Then utilizing MediaPipe for pose recognition, enabling the system to track exercise form, repetitions, and offer recommendations on corrections on datasets and live video. Tannoury et al. [19] propose a CNN-based approach for estimating human pose, which allows estimating the location of joint points in images and videos. The technique has inter- esting applications for gaming, robotics and animation, but it's also looking particularly promising for physical therapy rehabilitation from a distance.

3.4.AI in Injury Prevention & Recovery

Chaabane et al. [20] centered on computer vision and AI–based biomechanics, but it showcases that how computer vision and AI can be implemented as low cost bodybuilding performance enhancement motion tracking and feedback. AI recognizes bad postures, monitors muscle activation, and takes automated corrective and that for optimal shapes. Garosi et al. [21] reviews the multifaceted domain of ergonomics in pursuit of optimization of health, performance, and workplace safety, highlighting the significance of prevention of musculoskeletal disorders (MSDs). Shigapova et al. [22] discuss the utility of electro physiological approaches to study the brain and spinal cord dysfunction, assess overgeneralization and evaluate treatment effects in clinical and preclinical scenarios. Such bio-electrical activity data in animal models can be seen as robust objective correlate of the animal phenotype in the view of studies of neurological diseases and generalization.

3.5.AI in Supplementation & Pharmacology

Luo et al. [23] presents work investigates the implementation of transfer learning (TL) in common DCNN models to predict and evaluate the mechanical properties of PBF-LB produced AlSi10Mg and Ti–6Al–4V for different processing parameters. Using domain-knowledge based data fusion methods, prediction accuracies were obtained as high as 97.4%. Sharma et al. [24] addresses the clinical withdrawal symptoms related to illegal anabolic- androgenic steroid (AAS) use, mostly associated with young men using AAS as image and performance enhancing drugs. Therefore, due to the common practice of misuse of anabolic steroid their addictive-ness should be accounted by clinicians. Leciejewska et al. [25] examines the adverse effects of Selective Androgen Receptor Modulators (SARMs), which are widely used as performance-enhancing drugs despite lacking FDA or EMA approval. While SARMs promote muscle growth and bone reconstruction, their long-term health risks remain unclear.

4. Discussion

Table 1 outlines strengths and limitations in AI and its applications in five different areas: Training Optimization, Nutrition & Nutrigenomics, Performance Monitoring & Biomechanics, Injury Prevention & Recovery, and Supplementation & Pharmacology. Artificial Intelligence in Sports:

Personalized training through adaptive workout plans and real-time statistics; limitations include high variability between individuals and requirement of large datasets for accurate outputs. AI can customize meal planning according to macros tracked but it is not adjusted for types of gut microbiomes, or inputs. AI wearables track biometrics and movements to provide insights in real-time in performance monitoring, but face data privacy challenges and misinterpret complex movements. AI-enabled injury prevention which is useful in predicting risks and helping recovery, is limited to improving performance over the short term and certain injury types. When it comes to supplementation, the role of Ai in optimizing hormonal balance and the detection of performance enhancing drugs is undeniable, but challenges in terms of how we factor in regulation and ethics as well as the potential for an over-reliance on AI instead of medical professionals still exist. This makes AI-based tools immensely more efficient in assisting bodybuilders in achieving their goals, but its limitations also makes a clear cause for careful integration of its tools into the aspiring bodybuilder's workout plan as well as the need for human oversight in their use.

Table 1. Strengths and Limitations of AI Applications in Bodybuilding

AI Application	Strengths	Limitations
AI-Powered Technology Training Optimization	Adaptive and customized workout programs. Progressive overload via AI for optimal gains. Coaching in real time, virtually.	May not scale to huge individual variability. Un- founded mind-muscle connection knowledge. Train on large datasets to be precise.
Nutrigenomics & AI-Driven Nutrition	Diet plans generated by AI to help you achieve your bodybuilding goals.	Gut microbiome variations may not be captured by AI. Quality of input is key for food recognition apps.
AI in Performance Monitoring & Biomechanics	Wearables that are powered by AI give you live data. Exercise form correction. Advanced body composition analysis with- out human bias.	Motion tracking if complex type of movement AI. Bio- metric and body tracking data privacy concerns.
AI for injury prevention & recovery	AI Forecasts potential injury risks before occurrence.	AI can get the optimal level of muscle fatigue wrong. Insufficient studies on the long-term effects.
AI in Supple-mentation & Pharmacology	Biometric performance depends on supplementation recommended by AI.	The AI-generated supplement recommendations may not be regulated. Ethics.

5. Challenges and Future Prospects

5.1. Challenges in AI Implementation for Bodybuilding

Although AI offers many benefits in the realm of bodybuilding, some obstacles prevent its complete integration and efficiency. These issues fall into the categories of technical, ethical, physiological and regulatory concerns.

• Dimension of Failure: Individual Adaptability and Personalization: Though AI models use historical training and nutritional data, individual physical differences of genetics, metabolism, recovery rates, and susceptibility to injury remain challenging to codify within AI. Moving towards a real-time, highly personalized bodybuilding experience, however, presents challenges for current AI capabilities, limiting its potential given that continuous adjustments and refinements to dynamic learning models will be needed.

• Limitations and Exceptions in Data: That said, predictive modes are the basis of many AI-powered sport performance tracking tools and wearable devices, but the machine learning algorithms might distort complex movement patterns, overestimate the amount of caloric expenditure during exercise or underestimate the levels of muscle fatigue. However, AI models trained on limited or non-representative datasets can lead to faulty workout recommendations misaligned to an individual's actual capability.

• Ethical and Privacy Concerns: AI Wearables Biometric tracking is on the rise, but with it comes concerns over data privacy, security, and potential misuse. AI systems involve the collection and storage of sensitive health-related information, making them susceptible to cybersecurity threats and unauthorized access. Furthermore, the use of AI for doping detection poses ethical dilemmas, especially related to false positives and the risk of unjust punishments in competitive sports.

• Sports and Supplementation: The guidance of diet and supplementation is a massive challenge for AI particularly around scientific validation and regulatory approval. Most AI-based supplement optimizations do not go through clinical trials and regulatory checks, and therefore prove unreliable even for professional athletes.

• Human Intelligence vs. AI Dependency: AI can help simplify and optimize training, nutrition, and rehabilitation but will never substitute the expertise of a coach. Data and inferences generated by AI are imperative, but they need to be interpreted, and this is where the role of coaches, sports scientists and physiotherapists becomes critical in not only interpreting the baselines data and AI, but also making the final call based on their real-world experience and every athlete's nuances.

5.2. Future Prospects

Ultimately, moving forward with a developing AI technology, integration in bodybuilding will allow for greater precision and sophistication. AI in bodybuilding will be highly personalized, real-time and ethical, and this is how this future will unfold.

• Smart gyms and virtual training powered by AI: The future wave of AI in bodybuilding will probably come in the form of AI-enabled smart gym equipment that monitors biomechanical movements and modulates resistance in real time, providing immediate feedback on one's performance. Also, AI-powered digital coaching aide with voice recognition and natural language processing (NLP) will provide personalized motivation and guidance on improving format.

• Hybrid model of AI-Human training: the future of AI in fitness, or rather, Hybrid AI-Human Coaching. The AI in you will assist you in your fitness, instead of replacing you in your fitness! AI, as a decision- support assistant, will provide data-based training recommendations, but human coaches will optimize them according to emotional, psychological, and physiological aspects.

• Artificial Intelligence-Enabled Nutrition: Nutrigenomics and epigenetics powered by AI will enhance diet and supplementation planning through the analysis of a person's DNA, gut microbiome, and metabolic profile. AI will create personalized meal plans that maximize muscle growth, recovery, and overall health based on genetic make-up.

• Machine learning for injury prediction and regenerative medicine: Advancements in AI applications for injury prevention and rehabilitation, which includes predictive modeling of muscle strain and injury risk from wearable biosensors, motion capture and other kinematic data. AI will also improve recovery for strength athletes through AI-assisted regenerative medicine via stem cell therapy, AI-based tissue engineering, and rehabilitation robotics.

• Training, Ethics, and Fairness in Competitive Bodybuilding with AI: While AI continues to get adapted more into the bodybuilding and sports scene, governing bodies of the sports will soon create ethical AI rules and guidelines to preserve a culture of fairness, transparency, and security of data. There will be more accurate models for AI doping detection with

lowered false positives, and AI will undergo scientific scrutiny and be regulated by anti-doping regimes when it comes to hormonal optimization.

6. Conclusion

AI has revolutionized bodybuilding by improving traditional training, nutrition, performance, injury prevention, and supplements. The introduction of AI-enabled algorithms and data, including AI-based machine learning, computer vision systems, biometric monitoring, and predictive analytics, has allowed bodybuilders to implement tailored, data-driven training programs to maximize their performance, recovery, and general efficiency.

This analysis sensitively reviewed the five focal spheres which AI is significantly influencing bodybuilding: AI-Powered Training Optimization: optimal workout programming and progressive overload algorithms to maximize muscle growth and strength adaptation. AI-Based Nutrition & Diet Planning, customizing macronutrient tracking and genetic-based meal plans for optimal nutritional management. AI in Performance Monitoring & Biomechanics Sports observers to wear a smart t-shirt that promotes exercise form and minimizes injury risks. AI for Injury Prevention & Recovery, leveraging predictive modeling and rehabilitation apps to ensure proper recovery and reduce long-term damage. AI in Supplementation & Pharmacology which assists with the detection of performance enhancing drugs (PEDs), the optimization of hormonal homeostasis, and the tactical monitoring of supplementation strategies. AI in bodybuilding, albeit beneficial, has drawbacks, such as limited adaptability to individual variations, accuracy concerns, ethical and privacy issues, and lack of regulatory oversight in AI-generated supple- mentation and training recommendations. Last but not least, AI cannot lead the process on its own, psychologic motivation, intuition, mental focus and other aspects still need humans to operate those.

To summarize, future developments in the world of AI and bodybuilding may lead us to experience AI-enhanced gym equipment, hybrid AI-human coaching approaches, and nutrigenomics with AI assistance, and predictive monitoring systems for injury prevention. More advanced AI algorithms that can adapt better and faster in a real-time environment will enable more precise body building techniques to be adopted in a personalized way that stays ethical.

Overall, we can expect AI to revolutionize bodybuilding and make it ex- citing, effective, and affordable, but it will need to be used in conjunction with human knowledge and experience to truly reach its potential. In conclusion, while AI technology is no doubt a powerful tool, its future in bodybuilding and sports as a whole will be suspended in perfect balance with the time it takes to improve AI capabilities to become more flexible, accurate with data, and ethically and morally aligned with the ethos of the sport so that athletes feel at peace working together with AI.

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Conflicts Of Interest

The authors declare no conflicts of interest.

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Dr. Mahmood A. Al-Shareeda received the B.S. degree in communication engineering from Iraq University College (IUC), the M.Sc. degree in information technology from Islamic University of Lebanon (IUL), in 2018, and the Ph.D. degree in advanced computer network from University Sains Malaysia (USM). He was a Postdoctoral Fellowship with the National Advanced IPv6 Centre (NAv6), Universiti Sains Malaysia. He is currently an Assistant Professor of communication engineering with IUC. His current research interests include network monitoring, the Internet of Things (IoT), vehicular ad hoc network (VANET) security, and IPv6 security. mahmood.alshareedah@stu.edu.iq

Ahmed Abdulazeez Obaid, Political Science, Iraq University College (IUC), 11800, Basra, Iraq.

Amjad Abdul Hamid Almajid, College of Basic Education, Physical Education and Sports Science, Al Mustansiriyah University, Baghdad, Iraq.