



## THE IMPACT OF BIOMECHANICAL FACTORS ON ENHANCING SPORTS PERFORMANCE AND INJURY PREVENTION

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### ABSTRACT

**Background.** Biomechanics is an important part of modern sports science because it looks at the mechanical rules that regulate how people move to improve performance and avoid injury. As evidence-based training becomes more important, it's important to know how biomechanical aspects like movement patterns, joint mechanics, and muscle activity affect safety, efficiency, and endurance in different sports. **Objectives.** This study seeks to examine the influence of biomechanical parameters on enhancing performance outcomes and mitigating the risk of sports-related injuries. **Method.** Utilizing a descriptive-analytical methodology, data were gathered from prior experimental investigations and performance reports in sports, swimming, and cycling to assess biomechanical interventions. **Results.** The findings indicate that biomechanical modifications markedly enhance athletic efficiency: optimizing platform length and stride length enhances running performance by 8%, altering swimming technique increases propulsion efficiency by 5%, and achieving optimal cycling posture boosts power output by 10% while decreasing air resistance by 7–10%. Moreover, biomechanics-based training programs markedly diminished the occurrence of anterior cruciate ligament (ACL) injuries among female athletes. **Conclusion.** The results indicate that incorporating biomechanical principles into training and performance assessment can lead to quantifiable enhancements in technique and injury prevention. In summary, biomechanics connects scientific knowledge with athletic practice, making it possible to create evidence-based therapies that improve performance and keep athletes healthy. This study adds to the body of research by emphasizing the significance of biomechanical analysis as a basis for enduring and secure sports performance.

**Keywords;** biomechanics, sports performance, injury prevention, technology integration.



## A. INTRODUCTION

Original and the development of biomechanical analysis in sports The systematic application of biomechanical principles for sports performance returns to work leading by Nicolai Bernstein in the 1930s. His groundbreaking research on movement coordination and motor control established theoretical overview to understand complex athletic movements. The term Bernstein's "degree of freedom" is fundamental to modern biomechanical analysis, and says how many common movements in the body are coordinated in effective, targeted functions. In the 1970s, James She marked the seminal work of the first extensive use of Newlyonian Mechanics for sports techniques. His biomechanical analysis of athletics events set up quantitative parameters for optimal performance, which revolutionized coaching methods. Olonitudinal studies of O and colleagues demonstrated that technology changes based on biomechanical principles compared to traditional coaching methods improved 7-12% performance goals.

The development of sports biomechanics is closely associated with technological progress. Preliminary research from Dilman and colleagues (1975) is dependent on registering 64 frames per second on 16 mm film cameras, and requires labor -intensive manual digitalisation. Despite these technical boundaries, his comparative study of the elite threw the first quantitative model for the optimal liberation criteria. The introduction of winter and video-based speed analysis in the 1980s expanded research skills, which enables a more detailed study of common kinematics. Comparison of aristocracy and sub in his 1984 study

Biomacionics is one of the basic sciences in sports fields, which focuses on studying and analyzing human movement and forces affecting the body. This science completes two important aspects: analysis and technology improves sports performance through development and protect athletes from injuries. Biomacionics provides a deep understanding of the performance correction mechanisms by studying the right body movements and analyzing joint forces and relating muscle activity.

Technical development, physical endurance and strategic planning depend on biomechanical principles used to increase athletic performance of athletes and coaches. Sports researchers and coaches can develop optimal training programs by understanding

forces that affect the body, develop sports products and create personal rehabilitation programs for athletes, Through biomacronics, sports skills can be improved and subptimal movements can be detected before actual damage to the wrong ways.

## **B. BIOMECHANICS AND SPORTS PERFORMANCE ENHANCEMENT**

Biomechanics in the modern scientific world of sports has undergone a dramatic change in the sportsmen's training and competition. Sporting careers get extended while their physical costs decrease because biomechanical analysis serves as a crucial companion for both elite professionals and recreational athletes. This is because as new technology is developed biomechanics will be central to the advances in sporting related injuries and physical abilities.

### *Running Mechanics*

Thus, running is widely examined as one of the subjects in biomechanics. In the previous works, it was discovered that it was possible to enhance the economy of running by about 8 percent through interventions in stride length, cadence, and ground reaction forces (Yoganandan, Nahum and Melvin, 2015). For example, the elite long-distance runners' cadence ranges between 170 and 190 steps per minute so as to increase the time off the ground and thus conserve energy. Specifically, exercises like gait rectification and postural changes have been associated with reduction of energy cost for distance runners by about 20 percent. These enables the athletes to run for a longer distance with greater speeds while experiencing minimal exhaustion.

### *Swimming Efficiency*

:In swimming field, biomechanics is very important in improving and enhancing the techniques in the four swimming styles with an aim of increasing the force exerted on the water and at the same time reducing the force the water exerts on the swimmer. Researchers have concluded that adjustments of 30cm in the arm pull force and the manner in which the hand enters the water can increase performance by as much as 5% (Schmitt et al. 2014). For example, the pull underwater trajectory can save 0.5 – 1 second each 50 meters that is most beneficial in swimming races. The equipment such as underwater video and force platforms

used by the coaches in training have made it easy to incorporate effective exercises that enhance lesser use of energy in water.

### *Cycling Performance*

Cycling biomechanics aim on anatomical fit to the bike, cycling force and power exerted and the aerodynamics. Scholars have posited that coming in the right setup position and balance between the right and left sides of the body while pedaling can enhance power by a 10% (Forman et al, 2019). Self-assessment and biomechanical assessments of the professional cyclists resulted in enhancement of 5 to 8 watts/ kgs in power output thus making them cover a race distance in shorter time. Also, there is an improvement of the aerodynamics that can cut the drag by between 7 and 10 percent through certain positioning that requires less effort to maintain given speeds.

### *Strength Sports*

Biomechanics factor has been particularly useful in weightlifting and powerlifting disciplines to ensure that the athlete develops and applies the maximum force possible with limited of harm on the body. To maintain proper lift, it is necessary to use correct spine and joint positioning as well as the bar path of the planned lift. It is evident through various research that biomechanical training increases 1RM lifts by between 8 percent and 12 percent in a training cycle (Schmitt et al. In weightlifting and powerlifting, biomechanics should be utilized in force production and force reduction procedures to ensure the health of the muscles being used for lifting of weights. Of five key aspects of movement, correct positions of the spine and joints during the lift as well as bar path are essential. Research has it that one gets to have increased by 8-12% his or her 1RM lifts over the given training period once the athlete undergoes biomechanical training (Schmitt et al. 2014). This way, the amount of stress affected on the spine and joints is minimized and lifters can work out to an optimum level safely.

### *Team Sports*

Mecklin state that biomechanics are also very fundamental in teamwork activities such as basketball, soccer, and football. In basketball, the study has it that shooting at a 45-degree

angle and wrist flexibility gives one best shot at the hoops. Soccer biomechanics that evaluate various kicking techniques the test confirms that a thirty to forty five degree foot attitude yields the greatest ball velocity while considering the accuracy. GPS tracking devices have also showed that there exists a possibility of enhancing or increasing the technical factors that affect sprints by about 15%, thus boosting the players.

### *Reducing ACL Injuries*

There are several sports common for ACL injuries for instance football, basketball and volleyball. The biomechanical analysis made by various researchers has demonstrated that increased INCD as seen in figure, particularly during jump and landing has been described to be a potential cause of ACL injuries. Proper training and exercises such as landing mechanics, strength training for the knee, and balance exercises significantly has reduced ACL injuries by forty percent especially among the female athletes since they are at 2 to 8 times more susceptible to these injuries than male counterpart (Forman et al. 2019).

### *Baseball Pitching Mechanics*

In baseball, improper pitching mechanics are related several types of injuries particularly to pitchers at the shoulder and elbow. Thus, biomechanical analysis has brought down such injuries by 20% due to the revelation of such malraslems such as excessive external rotation and late arm cocking (Schmitt et al. 2014). Through monitoring the angles developed with the arms as well as the position of the wrists, it is possible to prevent as much stress being placed on the sigment as possible and in so doing, lessen the probability of a persons suffering from an ulnar collateral ligament (UCL) injury.

### *Tennis Overuse Injuries*

High repetitive high impact swings bowling, tennis and golf players all have this in common that they suffer overuse injuries like rotator cuff tears and tennis elbow. Ergonomic improvements in racket design, grip size and stroke mechanics, due to biomechanical research has helped to reduce overuse injuries by 30% (Yoganandan, Nahum and Melvin 2015). Shipu also found that people can reduce strain on tendons by adjusting their grip position and how they activate their forearm muscles.

### *Contact Sports and Concussion Prevention*

In sports such as Football or Rugby, biomechanics has been very useful in reducing the risks of concussions and spinal injuries. This study has been able to build helmets with better shock absorption, reducing the risk of concussion by 30% (Al-Ghabban, Saleh, and Al-Awsi 2020). Also, teaching players with a so-called 'head up' technique to tackle has been successful at reducing the incidence of these cervical spine injuries. In rugby, having proper position on the body when scrumming and tackling has reduced deuce dislocations and fractures 35%.

### *Equipment and Surface Design*

Sports equipment, playing surfaces, and other products have also become less injurious as a result of biomechanics' driving of innovations. Running shoes with improved shock absorbence and stability have reduced incidence of such stress fractures among long distance runners by 25% (Fahlstedt 2015). Research has found that according to other researchers, ACL injuries are 1.6 times more likely to occur on artificial turf than natural grass, and synthetic field technology has improved (Forman et al. 2019). Knee braces, mouth guards, and wrist supports have all advanced tremendously, which is believed to have reduced joint related injuries by 20% in all sports (Schmitt et al. 2014).

Gone are the days when the only way to monitor movement patterns was through the film rolling at a distance. Accelerometers and gyroscopes placed within clothing and footwear allow athletes to know their joint angles, stray length and impact forces instantly and adjust by wearing a new piece of clothing or footwear. For instance, wearable sensors have been utilized to enhance understanding of the mechanics of jumping and landing in basketball with resultant reductions in injury rates to 18% of elite players (Nakshabandi, Almukhtar and Al-Wattar 2016)

Sports performance has been improved and most likely dangerous injuries have been prevented through biomechanics. With highly detailed motion analysis, force assessments and technological advancement, athletes can be more efficient at their best technique and make sure they do not cause any injuries. Biomechanics has expanded its influence in sporting fields, influencing not only refining of running mechanics, but more and more, developing safer tackling techniques on contact sports. Real time feedback; wearable

sensors; improved equipment all integrate to make its possible for the athletes to reach their maximum potential while being sure they are long term healthy and safe with biomechanics.

## **C. RESULTS AND DISCUSSION**

### **Results**

Fast development in technology offered a groundbreaking way of investigating human movement and athletic performance in the field of biomechanics. Integration of the highly developed processes of three dimensional (3D) motion capture systems, wearable sensors, electromyography (EMG) with AI-driven analysis has improved the accuracy to a great degree in the biomechanical assessments. Based on these technologies, researchers, coaches and sports scientists are able to collect real time data, adjust training regimens as well as apply injury prevention strategies with a greater precision.

Someone's ability to analyze sport motion has greatly improved through implementing three-dimensional motion capture technology. Digital cameras installed around a player track joint angles and body movement together with limb velocity with near-perfect accuracy. After data collection a virtual image of the athlete's movement emerges from the processing results. Scientific research proves that basketball training benefits from motion capture technology which raises shooting effectiveness by 10% when athletes optimize wrist movement during shooting.

Motion tracking improved tennis players' serve through more accurate movements that increased accuracy by 8% plus reduced pressure on their shoulders. Motion capture data helps sprinters increase their stride length and speed which raises their sprinting performance by 4 to 6% according to Forman and colleagues (2019). High-speed cameras that can take multiple thousands of pictures per second help experts to study quick athletic actions in sports like baseball pitching, martial arts combat, and gymnastics discipline. Through detailed frame breakdown biomechanists find motion problems to stop small technique failures and avoid damage from repeated movements.

Biomechanical data collection methods have totally changed because of wearable technology use in sports. Biomedical devices located within clothing and sports items observe various athletic performance variables such as joint movements and forces to transmit users real-time performance data. Coaches can track player workload better so they

can prevent pain injuries because GPS trackers show how hard their players work now with soccer and American football teams according to Nakshabandi, Al-mukhtar, and Al-Wattar (2016). Combat sports fighters use IMUs with gyroscopes and accelerometers to find their most effective striking style because these devices show them punch speed and power numbers. The system finds running overpronation and supination problems so stress-related injuries reduced by 30% among marathon runners according to Fahlstedt's research (2015).

Device sensors send right-time measurements which help athletes fix their movement behavior and avoid damage. Biomechanical feedback displays during training decrease track and field athlete injuries by 20% as proven through research (Forman et al. 2019).

#### *Electromyography (EMG) for Muscle Activation Analysis*

1. EMG tests the electric muscle signals that occur as muscles work during physical actions. Through muscle activation testing sports science professionals check if athletes use right muscles effectively or develop hurtful methods when they work out.
2. Keeping the core muscles activated correctly reduces lower back stress by 25% according to weightlifting EMG studies by Schmitt et al. 2014.
3. Using EMG tests in cycling research helped athletes improve their endurance by 12 percent through better quadriceps and hamstring usage.
4. EMG technology monitors muscle use during rehabilitation to help patients heal faster by 30% by preventing damage to weak zones (Beillas et al. 2012).

#### *Artificial Intelligence (AI) and Machine Learning in Biomechanical Analysis*

1. The use of artificial intelligence and machine learning has started a new way of analyzing biomechanics through machine-scale data processing and it helps predict sports injuries and adjust training plans for every athlete. The system analyzes huge numbers of movement records to find patterns that a person alone could not recognize.
2. The training system predicts overuse injuries with 85% precision according to Al-Ghabban et al. (2020) which lets trainers protect athletes from harm at an early stage.

3. The technology can assess golf and tennis swing mechanics to detect specific areas developers require for better results. Its application led to a 6% improvement in shot accuracy.
4. Physical therapy methods that use AI to analyze body movements enable healthcare professionals to design better program plans which helps patients recover faster than usual treatment options by 20%.

#### *Virtual Reality (VR) and Augmented Reality (AR) in Biomechanics*

1. Both virtual reality and augmented reality help sports biomechanics through better training settings. axed athletes can learn their steps in virtual settings because these systems reveal how well they use their muscles during training.
2. VR training through soccer simulations helps soccer players make faster decisions on defense which resulted in a 9% better defensive positioning.
3. Players use AR overlays to see their swing path in golf which lets them make 7% more effective putting strokes.
4. The use of VR-based training tools in sports rehabilitation enables better muscle control after injuries and enables athletes to return to their sport sooner by about 15 to 20% more rapidly (Yoganandan, Nahum, and Melvin 2015).

#### **Discussion**

Biochemical technology makes regular changes to enhance athlete training programs and treatment methods. Various computer systems are now better meeting their potential to help athletes reach excellent performance while lowering injury risk. Digital improvements will appear in future applications. When the athlete moves AI detects the motion and changes it to create high efficiency. Through genetic biomechanics any athlete can receive training programs that perfectly match their natural body movements. The use of exoskeleton devices can help trains athletes while adding automatic mechanical resistance during defined movements. Modern technology has brought new ways to understand human movement which athletes and coaches use nowadays. The combination of new technology elements has made clear progress in helping athletes perform better without getting hurt while their picture of recovery gets better. New technologies help American sport athletes

perform better by 15% and lower by 20% the number of track and field injuries. As sports science progresses biomechanics keeps being the main tool for achieving top athletic performance and protecting athletes from injuries.

Recent research by Thompson et al. (2023) has challenged the traditional "one-shaped-all" approach for biomechanics. His extensive studies of 345 elite athletes in many sports have shown that 23% variation in the "optimal" movement pattern may exist among individuals with similar performance results. This concept of "biomechanical fingerprints" suggests that individual biomechanical profiles can be more effective than forcing them to comply with standardized technical models. A longitudinal study by Ramirez and Johnson (2024) showed that training programs corresponding to individual biomechanical properties improved the performance meters with 18–24% compared to standardized approaches. His research used the machine learning algorithms to identify unique movement signatures and develop individual adaptation strategies, respecting the underlying biomechanical tendency during the correct problematic pattern.

The new region of neurobio mechanics, which is a leading of Yamamoto and colleagues (2023), examines the intersection of nerve control systems and biomechanical design. Using EEG and 3D movement capture simultaneously, their research documentation of their strange nerve activation patterns before optimal movement sequences with 180–220ms. This east-activation signature was seen in aristocratic athletes in various sports continuously. Richardson's team (2024) expanded this concept with the development of the neurophyidback training protocol based on the optimal nerve pattern identified this concept. His controlled study of 128 developing athletes improved 16% movement efficiency

#### **D. CONCLUSION**

Scientists who study sports now use biomechanics as their essential tool for protecting players during sports while boosting their athletic results. Through biomechanical research of motions and muscle forces coaches and athletes receive proven techniques to perform better with lower risks of harm. Research proves that specific technique refinements enhance athlete results by 8% in running fuel economy, 5% in swimming speed, 10% in cycling power, and 8–12% stronger weightlifting movements. Coaches in team sports improve their athletes' precision by modifying bowling position in basketball and soccer. Preventing

injuries forms a main part of our program. Biomechanical testing every so often helps protect athletes from possible injury risks in this range. Athletes achieve better results since neuromuscular training minimizes ACL injuries by 40% in female athletes and improves baseball pitching methods prevent 20% of shoulder injuries. Employees involved in tennis now get 30% fewer work-related injuries because of their ergonomic equipment upgrades. Integrating proper sports equipment and tackling rules in contact sports succeeds in lowering concussion and shoulder injury threats by 30-35%. Stories that measure human movements have become basic tools for biomechanics thanks to AI processing technology. The new technology methods enhance basketball and soccer performance by 15 percent and lower track and field injuries by 20 percent. These models use artificial intelligence to determine potential injuries 85% of the time and let teams take actions for prevention and treatment. Mankind will use biomechanics to transform sports through automation of data analysis and genetic material study plus immediate physical condition assessment. Through body control practices combined with technology support the best athletic performance and disease prevention. Biomechanics now forms the basic function of today's sports as it allows players to seek their boundaries without damaging their long-term playing abilities.

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#### **F. AUTHOR CONTRIBUTION STATEMENT**

Sajjad Hassan Maktoof Jabara is the sole author of this research. She independently designed the study, developed the research instrument, Jassim Jabara Jassim Ati collected and analyzed the data, interpreted the findings, and wrote the manuscript.

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