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Article

Biomechanical analysis and rehabilitation strategies of common lower limb injuries in sprinters

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Abstract: Lower limb injuries are established among sprinters, often ensuing from repetitive pressure and biomechanical disorganisations. Considering these injuries' mechanisms and emerging actual rehabilitation approaches are crucial for enhancing performance and preventing repetition. This research aims to evaluate the biomechanical influences associated with common lower limb injuries in sprinters and measure the efficacy of targeted reintegration strategies. A randomized sample of 56 sprinters with a history of lower limb injuries participated in this research. An inclusive biomechanical analysis was employed using 3D motion capture technology to assess running mechanics. Variables such as joint angles, ground reaction forces, and patellar chasing were restrained. Biomechanical analysis convoluted evaluating running form and recognizing specific movement outlines linked to injuries. Based on these assessments, modified rehabilitation strategies were designed, including strength training, flexibility exercises, and real-time response to running technique. The logistic regression analysis revealed important associations between specific biomechanical deviations and injury occurrence. Post-rehabilitation assessments indicated developments in joint function, reduced pain levels, and enhanced running performance among participants. Implementing a biomechanical analysis mutual with personalized rehabilitation strategies effectively reduces lower limb injuries in sprinters, promoting better performance outcomes.

Keywords: rehabilitation strategies; common lower limb injuries; biomechanical analysis; rehabilitation strategies

1. Introduction

Sports biomechanics research has long been dominated by mechanisms. Kinematics studies have been beneficial in diagnosing and studying motion technology, but it usually exhibits the outside manifestation of motion without fully addressing its internal workings. Consequently, the mission of efficiently integrating precise, extremely good training methods remains unresolved [1]. Understanding these underlying mechanisms is important for comparing the biomechanical elements associated with commonplace lower limb injuries in sprinters. Understanding the distinctions among best sprinters and common individuals in terms of morphology and function is critical to sports biology and talent selection. There is a growing public interest in tasks that facilitate simple modifications to exercise loads [2]. Sprinting, characterized by its distinct benefits and fitness ideals, attracts people from diverse backgrounds.

As a high-intensity team sport, it involves significant physical exertion and competition. However, sprinters are particularly vulnerable to injuries, with the knee joint being the most susceptible [3]. Evaluating the prevalence of these injuries will help to identify the specific movement patterns linked to injuries, enhancing the understanding of injury mechanisms. The vulnerability, combined with knowledge gaps and a lack of awareness regarding athletes' physical conditions, contributes to the risks associated with sprinting. Effective athletic movement requires stability of muscular tension and relaxation [4]. High-pace sprinting relies on the everyday alternation of these muscular states. Some kinetic investigations focus on analyzing ground reaction forces with the use of dynamometers to evaluate unique movement technology capabilities and the outcomes of motion strategies [5]. However, isolating the appropriate mechanical properties of principal joint muscle groups in the course of movement remains difficult, as ground reaction forces simplest reflect the collective distraction of the body's joints and muscles. To deal with those demanding situations, the observation will utilize comprehensive biomechanical evaluation to evaluate jogging mechanics, which is important for growing powerful rehabilitation strategies [6]. Muscle activity monitoring offers valuable insights into various muscular conditions, together with the degree of muscle integration, kinds and force of contractions, and ranges of muscle fatigue and damage. This makes it critical for assessing the contributions of the most important muscle mass concerned in sports activities and understanding their activation sequences [7]. In analyzing knee joint injuries, it's vital to become aware of which muscles take part in coordinated moves and to assess the period and intensity of contractions vital to performing particular obligations.

By knowing those elements, the purpose is to create individualized rehabilitation strategies to enhance electricity and versatility in sprinters [8]. The multi-body interactions approach to modeling the human body divides into the top, neck, trunk, and limbs based on anatomical concepts. It allows researchers to pick out precise joint chains for evaluation, associating every section with rigid structures characterized using mass, center of mass, and movement inertia. Consequently, the human body may be simplified into a multi-rigid model with a restricted range of motion [9]. However, human body movements at high speeds make it increasingly complicated to assess the position of muscle fibers due to various inertial and biochemical factors that restrict mobility. This complexity underscores the significance of the examination, which seeks to evaluate the efficacy of centered rehabilitation techniques to enhance performance in general and protect from injury occurrence among runners [10].

Aim and contributions of the study

This research aims to explore the biomechanical variables linked to mutual lower limb injury in runners and to evaluate the effectiveness of positive rehabilitation techniques.

- In this article, 56 sprinters with previous records of lower limb accidents were covered in a chosen pattern. To evaluate sprinters' mechanics, an intensive biomechanical investigation was performed using 3D motion recording technologies.
- Measurements have been made for factors, which include joint interpretations, ground reaction forces, and gait styles. Assessing running form and coming

across positive motion patterns associated with accidents were a part of the biomechanical analysis process.

- The consequences of the investigation confirmed a robust relationship between a number of the frequency of injuries and specific biomechanical abnormalities using logistic regression. Post-rehabilitation critiques showed that contributors' joint health had improved, their pain ranges had decreased, and their running potential had progressed.

The article is structured as follows: Relevant investigation is offered in Part 2, a thorough methodology is presented in Part 3, the experiment's findings are examined in Part 4, and the conclusion is provided in Part 5.

2. Literature survey

To address the issue of knee joint injuries among sprinters [11] investigated knee flexion movement using a 3-dimensional (3D) image registration knee joint movement assessment approach. The findings demonstrated that meniscus and medial collateral ligament damage, which accounted for 24%, 7%, and 22.4% of every kind of injury to the knee joint were similarly, more prevalent, with just 5.6% of cases, lateral collateral ligament injuries were rather uncommon. Additionally, studies have shown that the leg was a method for identifying strength curves based on the biomechanical characteristics of runners. The computerized structure of the knee joint was an advanced and comprehensive approach to lessen injuries to sprinters' knee joints, and it could improve runners' knee replacements.

Using clever Partial Least Squares (PLS) applications [12] based on the primary data analysis to identify these investigations produced relevant findings, such as descriptive statistical evaluation, the range of confidence, and the significant analysis among groups. The goal of the biomechanical evaluation was to improve performance to stabilize the body and more stability results in effective proficiency. According to the study, there was a strong correlation between the factors and biomechanical analysis. An athlete might increase their body's speed by understanding how to use their muscles correctly, which was made possible by studying biomechanics analysis.

In sports where sprinting was involved, hamstring strains are among the most prevalent injuries, which were thought to occur from a combination of the muscle's capacity to withstand tension and the physical strain that was imposed. The purpose of the article [13] was to examine the existing information in favor of the theorized mechanical relationship between hamstring strain injuries and the principles of sprint running. By following, it seeks to provide professionals with knowledge of the mechanical factors that might influence hamstring strain injuries while simultaneously throwing up topics for more investigation.

A prospective investigation, of relationships between deficiencies in collegiate sprinters' sprinting biomechanics, hamstring operation, and framework, and the recovery time from acute hamstring strain injuries were presented in [14]. 72 individuals were chosen from a college running and field team using a planned cohort approach. The speed of running loss in the running-specific test was connected with the loss in the active single-leg lift testing and the recovery time to form. Lower limb biomechanical deficits were not as highly correlated with the time to return to peak efficiency in the running-specific assessment as kinetic inadequacies were.

The most recent comprehensive data on muscle injuries associated with trail running, along with treatment techniques to prevent injury and promote safe participation, were presented in [15]. Patient awareness of training modifications and early signs of musculoskeletal discomfort can assist stop injuries from worsening and becoming severe overuse injuries. Similar exercise regimens would be part of therapy after an accident, but depending on the kind of damage, rest and active rest would be included.

Using Ground Reaction Forces (GRFs) to their fullest potential was crucial for running biomechanics. Several findings from past studies have demonstrated using proper mechanics enables the efficient usage of GRFs in running. Additionally, athletes, especially Indian sprinters, would undoubtedly benefit from the appropriate use of many Individual Performance Parameters (IPP) covered in [16]. They worked to improve their running mechanics and achieve optimal performance with the lowest possible risk of injury. To provide a theoretical explanation for speed development, it has finally addressed the significance of stride frequency against stride length.

The purpose of the research [17] was to examine the consistency of lower limb joint kinematics in runners who had never sustained an injury linked to running. To look at the variations across groups and joints, a mixed examination of variance was employed. The SampEn values of individuals with a history of past injuries were lower than those of individuals without such a history. According to the findings, past injuries might have an impact on the regularity of movement patterns even in runners who were not experiencing any symptoms. Additionally, each joint's regularity varied. The lowest regularity was seen in the ankle, confirming the various roles that joints in the lower limbs played during running.

Research [18] examined the use of sports biomechanics in the prevention and treatment of injuries related to sports. It also provided an overview of the main biomechanical evaluation tools and methodologies, including motion capture systems, electromyography, and ground reaction force measurements, and provided examples of how they were used in athlete training, equipment design, and methodology optimization. While investigating the potential future, with a focus on the possible applications of AI and machine learning (ML) in enhancing methods for injury prevention recovery and emphasizing the value of multidisciplinary cooperation in developing the use of sports biomechanics.

To assess rehabilitation techniques that might hasten the return to full involvement after hamstring injury was explained in [19]. 33 athletes, 22 men and 11 women were examined in preparation for their last big tournament. Accordingly, 17 athletes with injuries to their hamstrings were involved in the research and were further split into A (n = 8) and B groups. The results showed that an early return to full involvement could be facilitated by a technical sprint program. For track and field athletes, the research might serve as a roadmap for expedited and comprehensive hamstring injury recovery.

The goal of the study [20] was to examine suggested treatment protocols for muscle injuries and provide a succinct, useful overview. The three-phase rehabilitation plan is used for the cautious care of second-hand, more prevalent, and challenging intrinsic muscle injuries. The intentional objective, the ideal professional, and the most effective course of treatment based on available data were stated for each step up until the point at which the patient was able to resume training and participating in sports. The last segment, which includes an organized explanation schedule, focuses on the targeted exercise rehabilitation for each of the four major muscle groups.

3. Methodology

This section offers an outline of lower limb injuries in sprinters, with a focus on Patellofemoral pain (PFP). The regularly occurring condition characterized by knee pain is explored in detail, discussing its signs and symptoms, contributing factors like muscle imbalances, and anatomical concerns. It additionally outlines participant demographics, which include age, gender, injury level, and running experience, imparting complete information about the establishment considered. Recovery techniques for PFP are emphasized, including rest, strengthening physical activities, flexibility training, biomechanical corrections, orthotics, and gradual back-to-sprinting, all designed to promote the most advantageous healing and prevent future injuries.

3.1. Lower limb injuries

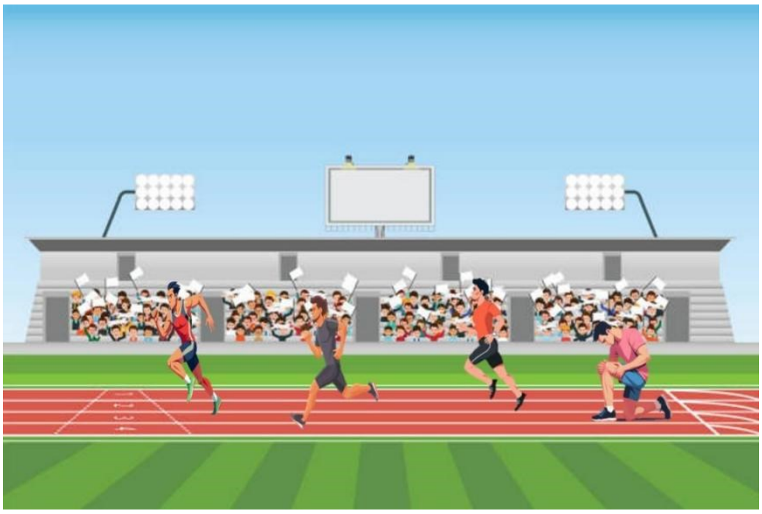

Figure 1. Lower limb injury.

Lower limb injuries in sprinters are common and often stand up, because of the extreme physical demands of the sport. These injuries typically occur in the muscles, tendons, ligaments, and joints of the legs and it can notably affect athletic performance. Among the most common injuries are hamstring traces, which end up resulting from overstretching or excessive contraction of the hamstring muscles in the back of the thigh. Calf lines are also common, occurring due to sudden acceleration or changes in direction, leading to pain and restricted mobility. Achilles tendinopathy entails infection or degeneration of the Achilles tendon, frequently resulting from repetitive stress all through sprinting, resulting in pain in the back of the ankle. Another common injury is patellar tendinopathy, also called jumper's knee, which influences the tendon connecting the kneecap to the shinbone, causing pain around the kneecap, mainly in athletes who often jump or sprint. **Figure 1** shows a track and field scenario with many sprinters, one of them appears to be injured as kneels on the track. This emphasizes the significance of appropriate injury prevention techniques and the dangers of lower limb injuries in sprinters.

Iliotibial band syndrome is a few other overuse injuries that occur even in the iliotibial band, which runs along the outside of the thigh and turns tight or inflamed, leading to pain on the outside of the knee. Lower limb injuries regularly stem from repetitive strain, incorrect biomechanics, or unexpected adjustments in pace or course. Factors, which include muscle imbalances, awful flexibility, insufficient warm-up, and fatigue, can increase the chance of those injuries, alongside environmental elements like going for running surfaces and footwear. Understanding the character and causes of decreased limb accidents in sprinters is crucial for prevention and retaining maximum appropriate athletic performance.

3.2. PFP

- Definition and Symptoms: PFP is a common condition characterized by pain around or within the lower back of the kneecap (patella). This pain is irritated by means of activities that involve bending the knee, including going for walks, squatting, or hiking stairs. Individuals with PFP can additionally experience a dull ache or sharp ache inside the front of the knee, and it can be accompanied by the usage of sensation of grinding or popping at some stage in movement. These signs and symptoms can significantly affect daily sports and athletic performance.
- Prevalence and Population: PFP is common among sprinters, especially sports activity performers who have activities that involve repeated knee flexion such as walking, jumping, and cycling. It is a condition which affects everyone from young athletes to elderly seniors and it is commonly referred to as jumper's knee. The most traditional case of the condition is found among youngsters and adults reflecting the extended demands on the knee placed on the joint due to participation in sports activities.
- Contributing Factors: Improvements in PFP include more than one element, overuse, muscle imbalances, and biomechanics. Overuse results from repetitive strain without recovery when the knee is subjected to infection of the patellofemoral joint. Muscle imbalances, especially when one is weak inside the quadriceps or hip muscle mass, can bring about changes in tracking of the patella with pain as a result. Unsuitable footwear or some form of difficulty in the iliotibial tendon can also worsen this condition.
- Anatomical Considerations: Anatomical variations can subsidize an individual's weakness to PFP. Concerns such as an improved Q-angle, that is the angle formed by means of the connection of the quadriceps muscle and the patellar ligament, can result in a flawed arrangement of the patella inside the femoral

indentation. The biomechanics of the lower limbs can be compressed by flat feet or overexertion, which can put greater pressure on the patellofemoral joint, and hasten the start of discomfiture.

- Knee Joint Angles: Assessing the knee's procedure throughout a program needs information on the knee joint angles. Abnormal flexion or addition angles can imply improper arrangement and monitoring of the patella, which might influence PFP. Dimension of these angles in the development of sports supportively with jogging or squatting enables picking out eccentricities from the best gesture patterns. Considerate knee joint angles allow clinicians to expand focused interferences toward correcting biomechanical disorganizations. This valuation is critical for preventing PFP and cultivating athletic overall presentation.
- GRF: GRF are the services used on the ground at the structure action along with running. The implication and direction of those forces play a big occupation in knee joint loading and mutual biomechanics. Enlarged GRF can result in higher result forces on the patellofemoral joint, contributing to PFP. Examining GRF authorizes selecting how forces are distributed at some point of measure, considering alterations in method and training. This record is vital for information on the connection between the loading circumstances and the risk of growing PFP.
- Patellar Tracking: Patellar checking refers to the movement of the patella along the femoral groove through knee flexion and extension. Appropriate monitoring is serious for maintaining knee characteristics and decreasing pressure at the patellofemoral joint. Irregular monitoring, which contains lateral movement, can cause augmented friction and strain at the joint, subsidizing PFP. Evaluating patellar monitoring through movement evaluation permits apprehending any eccentricities that can be imposing pain. This valuation is critical for increasing rehabilitation methods expected in the direction of restoring suitable patellar alignment.
- Knee Valgus Angle: The knee valgus approach considered the inward movement of the knee during weight-bearing activities, is a significant variable in the biomechanics of PFP. Improved knee valgus can alter patellar placement, employing better stress at the patellofemoral joint. Computing this position in the progression of energetic moves permits clinicians to assess the risk of harm and find out folks who may be predisposed to PFP. Addressing excessive knee valgus through centered consolidation and adapt ability to physical sports actions can support alignment and decrease aches. Understanding this variable is essential for effective prevention and accomplishment of PFP.
- Joint Angle Measurement: The joint insolence dimension includes enumerating the angles regularly designed at the knee joint in the development of various sports. Precise assessment of joint angles is essential for statistics and the biomechanics related to PFP. Anomalous joint approaches can merely mistake movement arrangements that could contribute to patellar disorder and pain. Expanding movement seize period or goniometers for the inimitable duration of these approaches throughout dynamic sporting. This assessment offers treasured

insights that inform restoration techniques aimed at restoring the most suitable knee feature and preventing damage.

3.3. Biomechanical for PFP

This study focuses on accepting the movement mechanism and forces, performed on the knee during sports accomplishments. This study applied 3D motion capture knowledge to assess running procedures in detail, specifically examining joint angles, GRFs, and patellar tracking. By apprehending the athlete's motion in real-time, the expertise allows for the precise identification of biomechanical deviations that may contribute to pain or dysfunction. Key variables, such as stride length, knee alignment, and distribution, are examined to detect inefficiencies in movement. These findings help in developing personalized interventions to correct improper mechanics. Through targeted strength training, flexibility exercises, and real-time feedback on running technique, the risk of injury is reduced. This approach aims to improve overall performance while minimizing the recurrence of injury, particularly among athletes prone to PFP.

3.4. Participant details

Table 1 summarizes the demographic characteristics of 56 sprinters, providing insights into their age organizations, gender distribution, pain locations, and years of experience, injury level, running distances, and speeds. A great part of members are in the younger age range, with a barely higher illustration of males. The most common location of pain is around the kneecap, specifically at the front, highlighting a frequently occurring issue among sprinters. The distribution reveals a wide range of training backgrounds, with many participants having several years of experience. Additionally, most contributors indicate bearable harm levels, with a majority running mild distances at varying speeds. **Figure 2** provides an overview of the demographics of sprinters who suffer from lower limb injuries, detailing three pie charts that break down major components: gender distribution, location of pain, and injury level. The gender pie chart shows a significant proportion of males; the data indicate approximately 53.6% of males, compared to females about 39.3%. The chart of the location of pain shows that the most common location is in front of the kneecap, which is approximately 52% of all reported cases, while the sides of the kneecap contribute to the rest of the cases. The last chart of the level of injury shows that the number of sprinters, which is approximately 60.7%, feel that the pain is tolerable, and this is the point that gives an important difference in the way the athletes perceive the pain. As such, this information points out generalized prevalence in terms of patellar injury and thereby implies that while most athletes are tolerant to discomfort, most tend to cope within the limit of tolerated injuries an issue of important consideration within policy in terms of coaching as well as rehabilitation.

Table 1. Details of the sprinters.

Demographic Characteristic	Categories	Frequency	Percentage (%)
Age Group	18–24	20	35.8
	25–30	18	32.1
	31–35	18	32.1
Gender	Male	30	53.6
	Female	26	46.4
Pain Location	Kneecap (front)	32	57.1
	Kneecap (sides)	24	42.9
Experience (years)	1–3	15	26.8
	4–6	18	32.1
	7–10	23	41.1
Injury Level	Bearable	34	60.7
	Unbearable	22	39.3
Distance Run (Km)	1–5	12	21.4
	6–10	24	42.9
	11–15	20	35.7
Speed (mph)	< 8	15	26.8
	8–10	24	42.8
	> 10	17	30.4

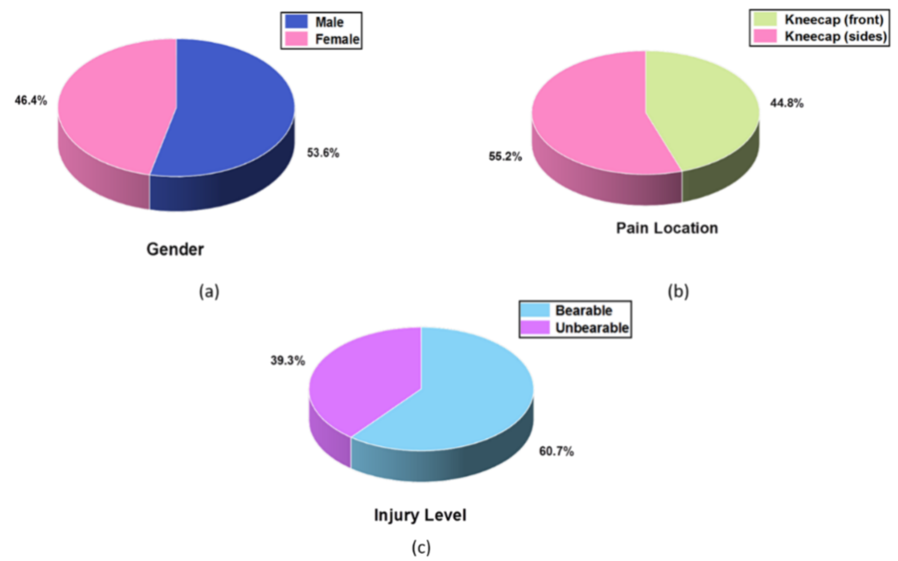

Figure 2. Demographic and Injury Characteristics Distribution of Runners. **(a)** Gender; **(b)** Pain location c) Injury level.

3.5. Recovery strategies for sprinters with PFP

This section specializes in the recovery techniques for sprinters, especially those dealing with PFP. It emphasizes the importance of relaxation and interest change to lessen stress at the knee, at the side of centered strengthening physical activities for muscle imbalances. Flexibility education, which includes stretching of key muscles like the quadriceps and hamstrings, is highlighted as essential for improving mobility. Biomechanical corrections and gait evaluation are also discussed to address improper running mechanics. Additionally, the usage of orthotics, footwear adjustments, ice therapy, and a sluggish return to sprinting are mentioned as powerful measures for complete recovery and harm prevention.

- Rest and Activity Modification: For sprinters managing with PFP, ordering relaxation and augmenting running activities is dangerous for recovery. It's critical to temporarily avoid high-impact running or repetitive knee-bending activities until the pain subsides. Gradually reinstating sprinting and pace work at an applied speed, while monitoring pain levels, will assist runners in returning to their normal deprived of exacerbating their condition.
- Strengthening Exercises: Employing absorbed consolidation physical sports is serious for addressing muscle inequities usually noticeable in runners. Focus on establishing the quadriceps, hamstrings, and hip muscles to enhance patellar intensive care and decrease tension in the knee. Movements that encompass lunges, step-ups, and unconventional squats can be exactly powerful, and equipped, they can be completed with proper form and progressively better quality in issues such as pain perms.
- Flexibility Training: Incorporating flexibility training is important for sprinters getting higher from PFP. Stretching the quadriceps, hamstrings, and iliotibial band can relieve anxiety on the patellofemoral joint and enhance typical flexibility. Regularly scheduled stretching lessons and foam rolling can enhance muscle elasticity, promote joint mobility, and assist in preventing future accidents.
- Biomechanical Corrections: Correcting biomechanical inefficiencies in gait assessment is essential for sprinters experiencing PFP. Utilizing 3D evaluation or analysis or capture technology can help identify improper walk mechanics contributing to pain. Coaches and sports activity analysts can provide feedback on form and approach, permitting sprinters to alter their running style and decrease pressure on the knee joint.
- Use of Orthotics and Footwear Adjustments: For sprinters, the use of orthotics or making adjustments to running shoes can provide additional guidance and improve decreased limb alignment. Custom or pre-made orthotic insoles can help with accurate problems such as overpronation or flat toes, which can additionally lead to patellar monitoring troubles. Choosing appropriate footwear with sufficient moderating and stability tailored to the runner's specific foot type is vital for harm prevention and restoration.
- Ice Therapy and Pain Management: Post-training ice application can be used to reduce some degree of contamination and PFP-related pain. Sprinters need to apply ice to the knee for 15–20 min after participation in sporting events to provide relief of symptoms. Beyond that, over-the-counter pain relief medications, NSAIDs, can be used to deal with pain but shall be taken, as mentioned in technical information.
- Gradual Return to Sprinting: A gradual return to operating and speed exercises is essential for retrieval after signals and signs have improved. Runners should follow an organized strategy that allows for slow growth in running strength

and distance. Monitoring hurt ranges carefully and making sure passable recuperation among training sessions will help runners accurately regain their pre-harm overall performance levels whilst minimizing the risk of intentional troubles. Feedback from athletes regarding their retrieval highlighted key areas for growth, highlighting the need for adapted recovery procedures and improved facilities. This input can inform future training events and optimize presentation significance.

3.6. Statistical analysis

By examining important components, the logistic regression estimation in this study evaluates how PFP injuries affect athletes along with knee joint arrangement, quadriceps power, and hamstring suppleness. The impost memorable important submissions among those variables and the likelihood of PFP, highlight the reputation of biomechanical fundamentals in harm risk. SPSS software was utilized for this analysis, providing robust statistical insights. Retrieval methods are well-informed with the aid of the analysis, emphasizing focused strengthening bodily exercises and attention alteration to mitigate pain. Overall, this method gives valuable visions into the connection between harm risk rudiments and powerful recovery approaches for sprinters. The findings highlight the need for suitable rehabilitation programs to optimize athletic typical performance whilst minimalizing re-harm dangers.

4. Result and discussion

4.1. Logistic regression to analyze the PFP injure impact

Logistic regression analysis is a strong statistical method for determining the effect of various physical characteristics on the risk of PFP injury in athletics. The outcome of the evaluation is a binary value consultant that shows whether PFP occurs or not. Several independent variables are measured, including knee joint alignment, quadriceps power, hamstring flexibility, IT band tightness, and hip joint balance. Each independent variable gets a coefficient that depicts the dating with the threat of PFP. The method of a positive coefficient method is that an increase in variable correlates with the greater threat of PFP. On the other hand, a negative coefficient reflects that the impact is protective because improvements in that variable would be associated with decreased odds of experiencing knee pain. The odds ratio (OR) is a critical measure yielded from the coefficients. This would measure the effect of the individual independent variable by using proportion of an increasing PFP. If the OR value is significantly less than 1, the likelihood for injury is lower. Increased risk is there when OR is greater than 1. For example, in case of positive association with IT band tightness as risk of PFP incidence with there being a significant OR in case of IT band stiffness.

The use of p-values is used to assess statistical significance. Its significance in damage risks is confirmed by a p-value of less than 0.05, which indicates that the relationship between some of the variables and PFP does not appear to be the result of a random occurrence. Furthermore, the 95% confidence interval (CI) provides a selection inside which the actual OR is probably to fall. If the CI does not include 1, it reinforces the significance of that aspect. This evaluation serves realistic applications in athletic preparation and physical training. By figuring out risk factors with high-quality coefficients, inclusive of knee joint alignment difficulties, practitioners can increase centered interventions to correctly deal with one's problems. Additionally, it specializes in elements with corrupt coefficients, like quadriceps power and hamstring flexibility, for enhanced training correspondences aimed toward harm prevention. Overall, logistic regression assessment gives precious insights into the multifaceted nature of PFP injuries, guiding powerful strategies for prevention, rehabilitation, and overall performance enhancement in sprinters. Instructors can assist runners minimize their risk of PFP while simultaneously maximizing their physical abilities by sharing information about such links.

The knee joint's realignment coefficient is 0.60, meaning that there is a positive correlation between proper positioning and a higher risk of PFP with OR = 1.82. This suggests that improved knee joint alignment significantly increases the likelihood of experiencing PFP. The *p*-value of 0.005 confirms this relationship is statistically significant, and the confidence interval (1.23, 2.68) indicates a reliable association that does not include 1. In assessment, additional factors that include quadriceps power and hip joint stability exhibit negative values, indicating that enhancements in these areas could help protect against PFP. In general, **Table 2** and **Figure 3**'s results emphasize the importance of knee joint alignment to skill and reducing the likelihood of PFP injuries.

Table 2. Impact of PFP.

Body Part	Coefficient	OR	*p*-value	Confidence Interval (95%)
Knee Joint Alignment	0.60	1.82	0.005	(1.23, 2.68)
Quadriceps Strength	−0.45	0.64	0.023	(0.44, 0.93)
Hamstring Flexibility	−0.30	0.74	0.045	(0.55, 0.99)
IT Band Tightness	0.55	1.73	0.015	(1.10, 2.73)
Hip Joint Stability	−0.40	0.67	0.035	(0.48, 0.93)

Figure 3 highlighted knee joint alignment possesses the greatest odds ratio hence implying the utmost significance towards the avoidance of injury for sprinters. Following it is that quadriceps strength also provides a great level of effects towards the avoidance of the injury. Conversely, hamstring flexibility and IT band tightness can be illustrated with lesser implications towards the propensity of having PFP injuries because the odds ratios shown are significantly low. Similarly, stability at the hip joint decreases the likelihood of injury. Collectively, these findings suggest that proper knee alignment and strength conditioning during training can be a good means to prevent PFP injuries and optimize athletic performance.

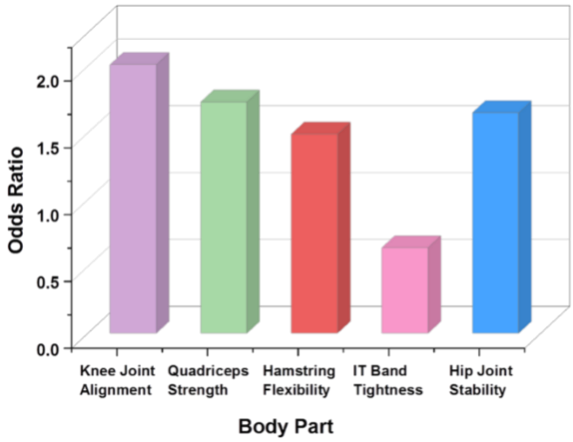

Figure 3. Graphical representation of the impact of PFP.

4.2. Recovery strategies for the impact using logistic regression

Recovery from PFP injuries can be efficaciously analyzed using logistic regression to evaluate the effect of various rehabilitation factors on the probability of improvement. The established variable remains the presence or absence of PFP, while independent variables consist of knee joint alignment, quadriceps power, hamstring flexibility, IT band tightness, and hip joint stability. Each variable's coefficient is famous for its position in recovery, positive coefficients suggest that enhancements in these areas are related to a better likelihood of recuperation, while negative coefficients suggest that these elements may additionally hinder recovery. The OR for each independent variable provides similar insights into restoration prospects. An OR greater than 1 means that improving that precise element will increase the possibilities of recovery from PFP, at the same time an OR much less than 1 indicates a reduced chance of development. For instance, if knee joint alignment indicates an eccentric coefficient and an excessive OR, it emphasizes the importance of correcting alignment problems for powerful recovery. Statistical significance is assessed through *p*-values, with values beneath zero.05 confirming the super impact of the variable on recuperation results. Additionally, the 95% CI reinforces the reliability of the findings, mainly if it does now not represent 1. This suggests a strong association between a number of the variables and recuperation from PFP.

Practitioners can develop targeted rehabilitation approaches with the help provided by this examination. Rehabilitation plans may be tailored to effectively improve the characteristics by giving priority to independent factors with positive coefficients, such as increasing hip joint stability and quadriceps strength. Moreover, addressing negative factors, like IT band tightness, can help improve PFP symptoms and promote recovery. Finally, logistic regression evaluation serves as a treasured tool for understanding the recuperation approach from PFP injuries. It gives important insights into how diverse physical attributes affect recovery chances, guiding athletes and practitioners in growing effective rehabilitation techniques that optimize restorative and restore functions. By leveraging those facts, sprinters can decorate their restorative effects and reduce the chance of destiny injuries, facilitating a faster return to their sport. The provided logistic regression **Table 3** and

Figure 4 highlight the impact of diverse body parts on recovery from PFP, with a particular focus on knee joint alignment.

Table 3. Recovery strategies for sprinters.

Body Part	Coefficient	OR	*p*-value	Confidence Interval (95%)
Knee Joint Alignment	0.70	2.01	0.002	(1.40, 2.89)
Quadriceps Strength	0.55	1.73	0.015	(1.10, 2.73)
Hamstring Flexibility	0.40	1.49	0.030	(1.05, 2.10)
IT Band Tightness	−0.45	0.64	0.022	(0.44, 0.93)
Hip Joint Stability	0.50	1.65	0.012	(1.10, 2.48)

Figure 4 illustrates the recovery strategies for sprinters. The coefficient for knee joint alignment is 0.70, indicating that improved alignment significantly increases the likelihood of recovery, with an OR of 2.01, meaning that individuals with better alignment have double the odds of recovering from PFP compared to those with poor alignment. The *p*-value of 0.002 confirms the statistical significance of this relationship, while the 95% confidence interval (1.40, 2.89) further reinforces the reliability of this finding, suggesting a strong positive association between knee joint alignment and recovery outcomes. In contrast, the negative coefficient for IT band tightness (−0.45) suggests that greater tightness is associated with lower recovery odds, highlighting the importance of addressing alignment issues and tightness in rehabilitation strategies for effective recovery from PFP.

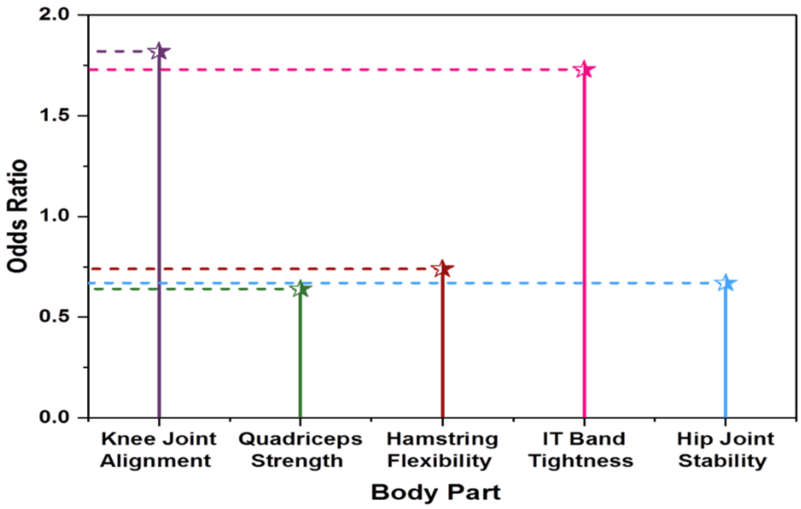

Figure 4. Outcome of recovery strategies.

4.3. Discussion

The study affords an in-depth examination of lower limb injuries among sprinters, highlighting the advantage and nature of situations along with PFP, which substantially influences athletic performance. It also contributes to the understanding of PFP in young sprinters by demonstrating the importance of focused therapies based on biomechanical parameters, such as muscle imbalances and knee joint alignment. It also emphasizes the value of tailored rehabilitation techniques and efficient recovery methods for improving sports performance and averting further injuries. With a demographic focus on more youthful athletes, the studies well-known show that pain across the kneecap is in particular not unusual, indicating an urgent need for targeted interventions. Biomechanical elements, such as knee joint angles, GRF, patellar tracking, and knee valgus angles, are identified as important members of PFP. Abnormal knee joint angles and expanded valgus can lead to mistaken patellar alignment, resulting in accelerated pressure at the patellofemoral joint. This aligns with existing literature that underscores the role of biomechanics in harm threat. The analysis also highlights that elevated GRF at some stage in high-impact sports exacerbates knee pain, emphasizing the need for cautious tracking of going for walks mechanics. Moreover, the findings underscore the importance of addressing muscle imbalances, as weaknesses in the quadriceps and hip muscle groups can adjust patellar monitoring, in addition to contributing to pain. Effective recovery techniques, including relaxation, strengthening physical exercises, flexibility training, and biomechanical corrections, are essential for coping with PFP. The implementation of orthotics and proper footwear is likewise suggested to enhance lower limb alignment and save from injuries. Ice therapy and gradual return-to-sport protocols play vital roles in recuperation, helping sprinters regain their standard performance levels even as minimizing the hazard of re-harm. Overall, this observation emphasizes the need for research into decreasing limb injuries and tailored rehabilitation strategies to guide sprinters in retaining the finest athletic overall performance and preventing future injuries.

5. Conclusion

This research aims to investigate the biomechanical factors associated with frequent lower limb injuries among sprinters and to evaluate the effectiveness of certain rehabilitation techniques. This study involved 56 sprinters with a record of lower limb injuries who were covered in a randomization sample. To compare running mechanics, a thorough biomechanical investigation changed to the use of 3D motion capture generation. Measurements were invented from variables such as joint angles, ground reaction forces, and gait patterns. Assessing running form and investigating certain movement patterns associated with accidents had been part of the biomechanical analysis process. Individualized rehabilitation plans, which include conditioning, sports for flexibility, and immediate suggestions on running form were created based on those instructions. Significant relationships between unique biomechanics abnormalities and the frequency of injuries were observed by using the logistic regression analysis. It is constructed to predict the impact of PFP and the recovery method for sprinters. This research considerably enhances the understanding of injuries of the lower limbs in sprinters by identifying specific biomechanical factors and assessing customized rehabilitation techniques. Findings can lead to interventions targeted to enhance recovery, improve performance, and reduce the incidence of injury in young athletes.

Limitation and future scope

- Limitation: This study's findings may be controlled by the small configuration size of fifty-six sprinters, which won't represent the broader populace of athletes. Additionally, the reliance on self-reported injury history may introduce bias, and the observer's attention on unique biomechanical factors may also overlook other contributing factors, including mental or environmental effects.
- Future Scope: Future studies could increase the number of participants and incorporate a more varied athlete group to improve the findings' generalization. Longitudinal research exploring the lengthy-term results of individualized rehabilitation strategies on injury prevention and overall performance would offer valuable insights. Additionally, investigating the interaction between psychological elements and biomechanical efficiencies can lead to more comprehensive harm prevention programs for sprinters.

Ethical approval: Not applicable.

Conflict of interest: The author declares no conflict of interest.

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