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Risk Factors of Patellofemoral Pain Syndrome in Endurance Activities

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Abstract. Patellofemoral pain syndrome (PFPS) is one of the most prevalent knee-joint injuries that occurs due to overuse in specific populations like runners or endurance athletes. Hence, the biomechanical contributing factors of PFPS play a vital role in the prevention of such injuries. The analysis of major risk factors for PFPS such as muscle strength, lower-extremity biomechanics, neuromuscular control, anatomical variations and training associated factors is the aim of this paper. The result demonstrates that PFPS is the consequence of intrinsic and extrinsic factors combined. Intrinsically, the weakening of femur-stabilizing muscles typically affects the muscle control by producing the abnormal muscle movements when performing activities. Such abnormal motion of the femur that is present in endurance sporting events are predominantly caused by the thousands of cycles of movements, resulting in abnormal accumulation of stress in the patellofemoral joint. Other extrinsic factors such as abrupt increase in the amount of training or frequent loading furth overload the knee joint. Additionally, there are other indirect influences associated with footwear and exercise methods (etc. cadence and stride length) also contribute to the state of stress of the patellofemoral joint. An in-depth review of the potential risk factors of the patellofemoral pain syndrome would therefore be beneficial to clinicians, athletic coaches, and athletes during the process of formulating the rehabilitation or injury-preventive plans.

Keywords: Patellofemoral pain syndrome (PFPS), overuse injury, injury prevention, endurance training, lower-extremity biomechanics.

1. Introduction

Being often called the "runner's knee," patellofemoral pain syndrome (PFPS) is a highly common form of musculoskeletal injury that is identified with knee pain when subjected to repetitive loading of the lower limb. PFPS is usually a characteristic in runners, hikers, and other endurance athletes who experience over-extended periods of knee flexion and extension. Nonetheless, the true etiology of PFPS is still unclear due to its combined association with biomechanics, muscle strength and training-related variables [1].

Since endurance activities are characterized by the repetition of stress on the knee joint, any minor change in the lower-extremity biomechanics can slowly build up into PFPS. Thus, within the framework of exercise science and injury prevention, the biomechanics and training factors that cause PFPS is an important focus of research. Recently, research has placed more emphasis on

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multifactorial factors of PFPS. Furthermore, most biomechanical studies also have shown that muscle weakness, particularly the hip abductors and external rotators, is also one of the most important intrinsic risks factors that influence the patellofemoral biomechanics [2]. The lack of stabilization in the hips would cause excess femur adduction and internal rotation and thus increasing the Q-angle and changing the patellar tracking [3]. The combination of these biomechanical abnormalities can lead to the uneven distribution of the stress on patellofemoral joint, which raises the incidence of developing PFPS [1].

Moreover, biomechanical studies have also found that the movement pattern in individuals with PFPS often deviates during activities. These patterns consist of augmented hip adduction, femoral internal rotation, and knee valgus. Any alteration in these patterns would cause a lateral strain to the patellofemoral joint. These alterations tend to result in an inefficient distribution of forces and the accumulation of mechanical loads during endurance activities like running and hiking. Currently, PFPS is also an important research area in running biomechanics. Numerous studies on running mechanics imply that an increased running cadence of 5%-10% would reduce the amount of ground reaction force applied to the knee joint [4]. Such biomechanical adjustment may decrease the load on the patellofemoral joint and potentially lower the risk of PFPS and other overuse-related injuries [4].

In addition to the intrinsic biomechanical conditions, extrinsic conditions are also significantly important concerning the development of PFPS. The extrinsic factors include sudden changes in the training quantity, repetitive joint loading, and lack of sufficient recovery. Still, although there is an increasing number of studies focusing more on identifying individual risk factors, the general emphasis has remained on examining the isolated relationships of intrinsic biomechanical factors alongside the extrinsic training factors. Therefore, the combined effect of stress on the joint stress caused by both intrinsic and extrinsic factors has not been fully investigated.

The aim of the review is to display a comprehensive analysis of all the risk factors of PFPS from the biomechanical and training-related perspectives. The primary framework outlines the risk factors into two broad categories of intrinsic (muscular strength deficits, neuromuscular control, and anatomical characteristics) and extrinsic factors (training load progression, repetitive joint loading, footwear and fatigue). Based on these aspects, this review focuses on identifying the most influential mechanical factors of the occurrence of the PFPS, as well as offering the potential prevention measures.

2. Intrinsic risk factors

The Intrinsic factors refer to unique characteristics that are either modifiable or nonmodifiable, and during repetitive activities, these factors can alter the mechanical distribution of forces in the patellofemoral joint. Such factors include muscle weakness, abnormal lower-limb biomechanics, neuromuscular control, movement patterns, and anatomical variations. Together, they determine the vulnerability of the patellofemoral joint to cumulative loading injury. This is due to the fact that these factors significantly contribute to joint positioning and force placement in endurance exercises.

2.1. Muscular strength and torque deficits

PFPS intrinsic factors heavily depend on the muscle strength of lower limbs and its isometric torque which controls the stability and the patellar tracking of the knee joint. Compared to the typical overemphasis on quadriceps strength, the findings of more recent research discover that the weaknesses of the hip abductor and external rotator are among the most influential risk factors [5].

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Moreover, another systematic study of the risk factors of PFPS also concludes that compared to pain-free control group, people who incur PFPS show a tremendous decrease in the hip muscle stabilization, as well as the quadricep muscle strength [6].

When at rest, the quadriceps are responsible to control knee extension and stabilize the patella [7]. Hence, the inability of the quadriceps to provide sufficient strength would cause the patella to be unable to maintain aligned with the femur trochlear groove when the knee flexes and extends [7]. Additionally, these deficits in the hip abductor and external rotator are also critical since they make it difficult to control excessive internal rotation and adduction when doing the activities. For instance, insufficient muscle strength directly leads to abnormal distribution of forces in the musculotendinous unit during endurance activities such as running and hiking where the movements are repeated. This condition of excessive force distribution focuses the stress on the patellofemoral joint, and over time, mechanical overload gradually may be the direct cause of the emergence of PFPS.

2.2. Lower extremity biomechanical abnormalities

In addition to muscular deficits, hip and knee abnormalities—the result of damaged proximal muscles—are also a serious intrinsic factor in PFPS [6]. According to the evidence provided by meta-analysis data, it indicates that when people with PFPS perform a kind of activities such as running or one leg squat, it usually leads to a significant increase of the maximum hip adduction and the change on the hip internal rotation angle [8]. As a result, these biomechanical deviations initiate a pathological reaction chain: a multitude of hip adduction and internal rotation, and both of them will result in the rise of the dynamic Q-angle, which will subsequently cause the lateral shift in the patellar contact pressure.

The altered pattern in the tracking of the patella and the femur trochlea disturbs the appropriate congruency of the patella and the femur trochlea, causing uneven force distribution and raising the local stress on the joints. During prolonged activities, even the slightest biomechanical imbalance can accumulate to chronic joint irritation when repeated through thousands of movement cycles. This abnormal and repeated loading causes PFPS to be gradually developed unlike acute injuries. Thus, the primary objective of preventing injuries and clinical intervention is the ability to manage the proximal hip biomechanics.

2.3. Neuromuscular control and movement patterns

Moreover, the neuromuscular control and movement patterns are also intrinsic factors, with movement patterns including key exercise techniques such as the stride length and cadence that control the impact and distribution of forces. Based on biomechanical meta-analysis, researchers find that patients with PFPS experience altered lower-limb moving patterns during load-bearing activities [8]. These altered patterns are lower knee flexion at the stance and landing stages and the increase in frontal-plane knee valgus displacement [8]. Such abnormal patterns may impair the capacity of the lower-extremity to effectively dissipate impact, which places additional stress on the patellofemoral joint.

Stride length is also an important factor to consider in the running techniques because it directly affects PFPS: a long stride length results in a higher braking force and loading of knee joints [9]. On the other hand, the stress of the patellofemoral joint is inversely correlated with cadence [9]. With a 5%-10 percent increase in cadence, stride length is reduced as excessively adducted hips and internal rotation of the femur are minimized [9]. These deviations are not independent extrinsic

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factors, but modifiable intrinsic components of neuromuscular control. This is because they mirror the subconscious movement patterns through muscle strength and coordination. Thus, during endurance events, repetitive and inefficient movement patterns put focused load on the patellofemoral joint, which enhances progressive damage to the joint.

2.4. Anatomical variations

Finally, the non-modifiable variation in anatomical structure that influences the positioning of lower-extremity and biomechanism of the patellofemoral joint is another significant intrinsic risk factor. Recently, a epidemiological research indicates that females are more likely to be affected by PFPS than males [8]. The increased prevalence is linked with gender-related abnormalities, such as increased pelvic width and increased anterior tibia rotations and Q-angle [8]. These structural characteristics change the alignment of the femur with the patella both at rest and in movement, resulting in a biomechanical disposition in the joint that makes it more prone to abnormal loading.

On their own, anatomic structural variations may not necessarily lead to the development of PFPS, but they induce biomechanical conditions that potentially become harmful and enhance the joint load during their repetitive movement cycles. Such structural characteristics together with the deficits like muscular weakness and poor movement control lead to the abnormal distribution of stress that pose a great risk to damage development. Thus, structural variations in the anatomy are considered the potential rather than direct risk factor since its influences are mediated by neuromuscular and biomechanical factors.

Collectively, all of these intrinsic elements interact with each other to disrupt patellofemoral force distribution, in which modifiable muscular, biomechanical deficits are the main contributors, and nonmodifiable anatomical traits as indirect contributors. These intrinsic characteristics significantly enhance the process of the development of PFPS in endurance exercises that correlate with a long period of time and the recurring knee loading.

3. Extrinsic precipitating factors

Extrinsic precipitating factors are external influences that are subject to change that involve training, environment, and equipment that contribute to acute and cumulative mechanical loading on the patellofemoral joint. These aspects by themselves may not contribute to the development of PFPS but with their combined loading exceeding the adaptive ability of an individual, they could stimulate preexisting risk factors in an individual. These extrinsic factors are primarily sudden changes in the amount of training, loading a joint repetitively, improper footwear, and muscle fatigue caused by the exercise.

3.1. Abrupt training load progression

Among the major extrinsic factors, one is the sudden, unprogrammed increase in quantity, intensity, frequency, or duration of training without giving enough time to recover [8]. Analytical studies on the causes of running-related overuse injury explain that the sudden increase in the training load is highly connected with the percentage overuse acceleration of PFPS development [8]. This is because that the musculoskeletal system is comprised of the cartilage, tendons, and supporting muscles that require slow, gradual load growth in order to accumulate tolerance and adaptation [8].

When training load is rapidly increased, the patella-femoral joint and its surrounding tissues cannot adapt to changes fast enough to withstand the high level of stress. This disequilibrium

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between greater loading and incomplete rest could result in repetitive accumulation of unrepaired micro-damage as inflammation of the joint or chronic irritation. In the case of endurance athletes, this form of over-loading injury is even more damaging since it exacerbates already existing deficits (etc. hip muscle weakness), contributing to the joint being pushed beyond its functional threshold that leads to the development of PFPS.

3.2. Repetitive knee joint loading

Cyclical loading of patellofemoral joint through repetitive, cyclical activities is inevitable in endurance sports such as running, hiking, and stair-climbing, which is also a fundamental extrinsic cause of PFPS development. Biomechanical experimental studies show that the patellofemoral joint can withstand 2-3 times the body weight when walking, however, it becomes 4-6 times when running or going down the stairs [5]. Nevertheless, this does not mean that one loading cycle during running does not fall within the normal physiological range, but given the enormous cumulative stress on the joint, when performed thousands of times during one training session, the stress becomes tremendous.

Unless the athlete is given adequate rest and recovery after every training session, this repeated loading would impede the repairing of the tissues, causing continuous inflammation, which would eventually aggravate the patellofemoral joint irritation. This chronic repetitive stress is particularly harmful in combination with inherent biomechanical abnormality since it would be excessively placing abnormal forces on vulnerable areas of the joint rather than evenly distributing forces on the overall lower-extremity.

3.3. Inappropriate footwear

Footwear is other manipulative extrinsic factor as it changes the conditions of loading biomechanics on the patellofemoral joint of lower-limb indirectly during the repetitive movement [10]. Proper footwear is essential in running and other related activities because the it would be able to control the absorption of impact, rearfoot movement, and transfer of ground reaction forces. All of which could affect the proximal conditions of the hip and knee mechanics. Shoes that are insufficient cushioning to absorb the impact of the landing, poor arch support, or inadequate stabilization aids are incapable to properly dissipate ground impact and thus causing a higher chance of high impact transfer towards patellofemoral joint.

In endurance activities, small impairments in footwear action can cause major alteration in the lower-extremity position due to the accumulation. For example, over-pronation can trigger secondarily induced femoral internal rotation and hip abduction, which increase the lateral patellofemoral stress of the joint and break the normal repositioning of the patellar. Therefore, although improper footwear would not necessarily result in the development of PFPS, it would still aggravate preexisting deficits in the intrinsic muscles and biomechanics, thereby adding to the pressure in the joints and the risk of injury [10].

3.4. Exercise-induced muscle fatigue

A secondary effect of the endurance sports is muscle fatigue. It acts as a strong confounding variable between extrinsic loading and intrinsic neuromuscular dysfunction rather than as an extrinsic independent variable. In endurance exercises, long-term neuromuscular contractions result in

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impaired neuromuscular control, which weakens the hip abductors, external rotators, and quadriceps in stabilizing the patellofemoral joint [9].

The pre-existing deviations in the movement patterns and biomechanical abnormalities are more pronounced as the level of fatigue increases, developing into involuntarily increased hip adduction and knee valgus. The negative effect of repetitive loading is increased through a lack of muscle control due to fatigue, which places concentrated abnormal stress on the patellofemoral joint. Consequently, the relation between extrinsic loading and intrinsic functional deficits as a consequence of muscle fatigue contributes to the onset of PFPS in people engaged in endurance sports.

Overall, extrinsic factors play the role of stimulating the effect of intrinsic factors and causing the stress on the patellofemoral joint to surpass its limits during endurance activities. Especially close attention is paid to the regulation of extrinsic factors with structured progress in training, adequate recovery, proper footwear, and appropriate fatigue management to reduce the risk of developing PFPS, particularly in people with predisposing intrinsic factors.

4. Conclusion

Patellofemoral pain syndrome (PFPS) is a prevalent knee overuse injury in runners, hikers, and other endurance athletes. According to this review, the relationship between intrinsic biomechanical and extrinsic training-related factors is the complex mutual interaction in the development of PFPS. Disruption of the lower-extremity biomechanics due to weaknesses in hip abductors and external rotators enhances the internal rotation of the femur and lateral stress of the patella. Alterations in movement patterns, which include unnecessary increase in dynamic knee valgus and stride length, enhance joint loading accumulation during endurance activities. On the extrinsic level, aspects as sudden increase of training amount, repetitive loading of knee joints, muscle fatigue, and inappropriate shoes further complicate preexisting intrinsic vulnerabilities. All these mechanisms combine to produce environmental accumulation of overuse which is continually stressing the patellofemoral joint. PFPS is likely to develop if not promptly and appropriately addressed. Accordingly, the findings indicate the necessity of an integrated intervention and rehabilitation plan, which in addition to focusing on the biomechanical weaknesses, also emphasize extrinsic training-related factors in order to prevent the development of PFPS among endurance athletes.

The research methods and population presented in this review are limited such that arduous athletic groups are not readily examined and analyzed. The traditional approach of most of the studies is either the cross-section or the observational technique that limits engagements on validating the direct cause-and-effect between intrinsic and extrinsic factor in the development of PFPS. Moreover, numerous studies cannot take into account the combination of various risk factors or the cumulative effect of prolonged repetitive loading. Thus, future studies ought to be directed towards standardized and multi-centered longitudinal investigations that would address how the combined effect of intrinsic deficiencies and extrinsic training conditions would affect the PFPS development and how to prevent and recover from such injury.

References

[1] Bump, J. M., Lewis, L. Patellofemoral Syndrome. [Updated 2023 Feb 13]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2026 Jan-. Available from: https: //www.ncbi.nlm.nih.gov/sites/books/NBK557657.

[2] Alammari, A., Spence, N., Narayan, A., Karnad, S. D., & Ottayil, Z. C. (2023). Effect of hip abductors and lateral rotators' muscle strengthening on pain and functional outcome in adult patients with patellofemoral pain: A

DOI: 10.54254/2753-7048/2026.33303

systematic review and meta-analysis. Journal of back and musculoskeletal rehabilitation, 36(1), 35–60. https: //doi.org/10.3233/BMR-220017.

[3] Raz, E., Shapiro, M., Mir, O., Nossek, E., & Nelson, P. K. (2021). Arterial and Venous 3D Fusion AV-3D-DSA: A Novel Approach to Cerebrovascular Neuroimaging. AJNR. American journal of neuroradiology, 42(7), 1282–1284. https: //doi.org/10.3174/ajnr.A7103.

[4] Figueiredo, I., Reis E Silva, M., & Sousa, J. E. (2025). The Influence of Running Cadence on Biomechanics and Injury Prevention: A Systematic Review. Cureus, 17(8), e90322. https: //doi.org/10.7759/cureus.90322.

[5] Nunes, G. S., Pellenz, M. M., Piussi, J. B., Wageck, B., Signori, L. U., Solner, M. W., & Dangui, A. J. M. (2026). Which factors correlate with muscle strength capacity in people with patellofemoral pain? A systematic review with meta-analysis. The Knee, 60, 104358. Advance online publication. https: //doi.org/10.1016/j.knee.2026.104358.

[6] Xie, P., István, B., & Liang, M. (2022). The Relationship between Patellofemoral Pain Syndrome and Hip Biomechanics: A Systematic Review with Meta-Analysis. Healthcare (Basel, Switzerland), 11(1), 99. https: //doi.org/10.3390/healthcare11010099.

[7] Alonazi, A., Hasan, S., Anwer, S., Jamal, A., Parvez, S., Alfaiz, F. A. S., & Li, H. (2021). Efficacy of Electromyographic-Biofeedback Supplementation Training with Patellar Taping on Quadriceps Strengthening in Patellofemoral Pain Syndrome among Young Adult Male Athletes. International journal of environmental research and public health, 18(9), 4514. https: //doi.org/10.3390/ijerph18094514.

[8] Szybist, S., Houser, A., Corletto, J., & Maloy, W. (2025). Patellofemoral Biomechanics Considerations: Analysis of Factors Contributing to Patellofemoral Pain. Current sports medicine reports, 24(9), 275–280. https: //doi.org/10.1249/JSR.0000000000001284.

[9] Esculier, J. F., Bouyer, L. J., & Roy, J. S. (2023). Running gait modifications can lead to immediate reductions in patellofemoral pain. Frontiers in sports and active living, 4, 1048655. https: //doi.org/10.3389/fspor.2022.1048655.

[10] Ge, Q., Zhou, H., Xu, D., Zhang, Z., Qu, X., Yuan, Y., & Gu, Y. (2025). Does shoe cushioning space affect patellofemoral pain risk? A study based on the integrated finite element model. iScience, 28(11), 113635. https: //doi.org/10.1016/j.isci.2025.113635.