

Impact of BMI and Lifestyle on Early Knee Pain or Patellofemoral Syndrome in College Students

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ABSTRACT

Patellofemoral pain syndrome (PFPS) is a common musculoskeletal condition among young adults, characterized by anterior knee pain that worsens with activities such as stair climbing, squatting, or extended sitting. This study investigates the impact of body mass index (BMI) and lifestyle factors on the start of early knee pain among college students, a group that is especially vulnerable due to sedentary habits, inconsistent physical exercise, and stress-related behaviours. Evidence suggests that high BMI contributes to higher mechanical loading of the patellofemoral joint, decreased quadriceps strength, changed gait biomechanics, and early cartilage deterioration. Furthermore, extended sitting, poor posture, weak hip musculature, and insufficient flexibility worsen patellar maltracking and discomfort. Lifestyle factors such as inadequate food, insufficient sleep, and psychological stress exacerbate inflammation and slow tissue healing. Maintaining ideal body composition through balanced nutrition and regular low-impact exercise (such as cycling, walking, and resistance training) improves muscular endurance and knee stability. Physiotherapy interventions aimed at strengthening the hip and quadriceps, enhancing proprioception, and implementing ergonomic modifications have demonstrated significant pain alleviation and functional enhancement. Early screening for BMI and musculoskeletal health in college settings can help identify at-risk students and implement preventive measures. Overall, multifactorial methods that address mechanical, metabolic, and behavioural aspects are critical for preventing chronic knee problems and improving long-term musculoskeletal health in young people.

Keywords- Patellofemoral pain syndrome; Body mass index; Lifestyle factors; College students.

I. INTRODUCTION

One of the most common musculoskeletal complaints in adolescents and young adults is patellofemoral pain (PFP), which is commonly studied under the term "patellofemoral pain syndrome." PFP is widely defined as anterior or retro patellar knee pain that is made worse by stair climbing, squatting, running, or extended sitting. One of the most prevalent knee complaints among teenagers and young adults is patellofemoral pain (PFP). University and college cohorts are a crucial setting for researching early knee pain because of the high annual prevalence estimates for PFP

and patellofemoral diseases in youth and young adults (several studies report point or annual prevalence in the 20–30% range in active adolescents/young people) [1]. Early knee pain can decrease exercise participation, encourage deconditioning, and set the stage for persistent symptoms or subsequent joint issues [2]. College students are in a transitional era of life where they may experience musculoskeletal problems due to a variety of factors, including altered activity patterns (sport involvement, abrupt increases or decreases in exercise), extended study sessions, irregular sleep and food, and new psychosocial stressors. Significant rates of knee and other musculoskeletal pain are reported in student populations by a number of university cohort studies, which also find

that mental discomfort and physical activity level are significant factors [3].

Regarding BMI as a risk factor for patellofemoral pain (PFP), there is conflicting data. Cross-sectional and imaging investigations reveal that many young adults with PFP are overweight or obese, despite the fact that multiple cohort studies have shown that BMI is not a reliable prospective predictor across groups like runners, adolescents, and military recruits [4]. Increased load on the patellofemoral cartilage and poorer structural alterations has been associated with higher BMI [3]. Changes in gait, elevated joint loading, changed biomechanics from excess adiposity, and low-grade inflammation linked to obesity that affects tissue health and pain perception are some of the hypothesized reasons. Higher BMI increases cartilage strain, according to biomechanical MRI studies [5]. The association between BMI and knee symptoms in university cohorts, however, is not always consistent. According to some cross-sectional surveys, knee issues are more strongly linked to high levels of sport participation or particular high-impact activities than to obesity in general. This suggests that early knee pain may be caused by both excessive load (from higher body mass) and repetitive high-impact exposures (from play/sport) [6].

Young individuals' early knee pain and PFP are significantly influenced by lifestyle factors other than BMI. College students frequently have knee pain as a result of abrupt changes in activity, recurrent high-impact motions, and inadequate load control [7]. Sedentary habits and prolonged sitting, which are typical in academic life, might exacerbate symptoms by decreasing muscle engagement and joint mobility [8]. Patellofemoral stress is further increased by weak hip and quadriceps muscles, a lack of flexibility, and improper movement patterns such knee valgus [7]. Anxiety, psychological stress, and mobility phobia also intensify pain perception and slow healing [6]. Smoking, eating an unhealthy diet, and getting little sleep can all hinder tissue recovery and increase inflammation [9].

A combination of mechanical stress, muscle function, lifestyle, and psychological variables might cause early knee soreness in students. PFP risk and symptom development are influenced by low fitness, sedentary behaviour, activity intensity, and decreased hip/knee strength [10]. Because these factors influence the development of modifiable goals (weight control, activity recommendations, strength and biomechanics training, and minimizing detrimental sedentary behaviours) for early prevention and rehabilitation before chronicity or structural joint disease becomes an issue, it is imperative to investigate the effects of BMI and lifestyle on college students [3]. Given mixed evidence on BMI but clear biomechanical links, interventions should be multifaceted-focusing on hip and quadriceps strengthening, gradual training progression, appropriate weight management, reduced sedentary time, proper

posture, and stress management. Current guidelines emphasize individualized, exercise-based, and load-focused conservative therapy [7].

II. EPIDEMIOLOGY

2.1. Adult population - Occurrence and frequency:

A 10-week incidence rate of 1080.5 cases per 1,000 person-years was seen in one investigation involving female novice recreational runners [11]. An athletic season incidence rate of 1.9% was found in one study involving female amateur collegiate athletes (mean age 19.4). There was a reported yearly prevalence of 22.7% in the total population, 29.2% in females, and 15.5% in men [12]. According to reports, point prevalence in females ranged from 12% to 13%. It was reported that 35% of mixed male and female participants in a multi-day amateur cycling event had points [1].

2.2. Teenagers - Occurrence and frequency:

For female adolescent athletes, the incidence rate was 9.7%–14.9%, or 0.97–1.09 per 1,000 athletic exposures, over the course of one season, according to two studies [13,14]. For adolescents who participated in physical education (sex unknown), the incidence rate was 42.6 cases per 1,000 person-years, according to one study [15]. According to a mixed-sex survey of high school athletes, the incidence rate during a single running season was 5.1% [16]. A meta-analysis included two studies that reported point prevalence on mixed male and female adolescents (Molgaard [17] and Rathleff [18]) since they were judged to be appropriately homogeneous. There was very little statistical heterogeneity ($I^2 = 5.4\%$), and a fixed effects model yielded a pooled estimate of point prevalence of 7.2% (95% CI 6.2%–8.3%). The reported point prevalence among teenagers who were exclusively female was 16.3% [13]. Three studies on female-only adolescent athletes that reported point prevalence (Hall [19], Myer [13], and Steinberg [20]) were judged appropriately homogeneous and were thus also included in a meta-analysis. The pooled estimate of point prevalence using a random effects model was 22.7% (95% CI 17.4%–28.0%), and statistical heterogeneity was high ($I^2 = 85.7\%$). An annual prevalence of 28.9% was recorded in one research of adolescents of mixed sex [21].

2.3. Trends in age

Most PFPS cases begin in youth or early adulthood. Due to rapid development, changes in activity levels, and altered biomechanics during growth, prevalence rises during puberty and late teenage years. The highest rates are observed in mid-to-late adolescence in studies involving children, adolescents, and young adults; many cases first appear during this period [22]. Young adults are mainly affected by the condition, with a significant number of cases reported in the 18–35 age group. A study from Saudi Arabia found that the

prevalence of PFPS in the general population was 30.3%, with similar rates across genders [23].

2.4. Sex Differences

Most epidemiologic research shows that females have higher prevalence and incidence than males (as noted in numerous studies and reviews), with some estimates indicating that female rates are notably higher (e.g., female annual prevalence is usually around 25-30%, compared to lower rates in males). Suspected causes include activity-related exposures, hip and knee muscle strength, neuromuscular control, and sex differences in lower-limb alignment. However, sex differences are not always observed; depending on sampling and methodology, recent adult community surveys sometimes report lower or non-significant differences [24]. Women are more frequently affected by PFPS than men. A study involving medical students found the prevalence was higher in females (23.5%) than in males (5.3%) [24].

III. ROLE OF BODY MASS INDEX (BMI) IN EARLY KNEE PAIN OR PATELLOFEMORAL PAIN SYNDROME (PFPS)

A key factor in determining musculoskeletal loading is body mass index (BMI), which affects joint mechanics, cartilage integrity, and functional ability. Young adults with elevated BMI are more susceptible to pain, inflammation, and muscle weakness because of increased compressive forces across the patellofemoral joint. In addition to raising the risk of PFPS, several studies conducted on college-aged and young adults have shown that a higher BMI is associated with worse knee function and more severe pain [3,26]. Maintaining a healthy BMI throughout adolescence and the early stages of adulthood is crucial because overweight and obesity in early life are linked to long-term degenerative joint changes [27].

3.1. Mechanical Load and Joint Stress

Running, stair climbing, and crouching all result in axial compressive pressures on the patellofemoral joint that are greatly increased by elevated BMI. Particularly in young individuals who are physically active, these recurrent loads hasten anterior knee discomfort, patellar maltracking, and cartilage deterioration. According to 2023 research on young individuals with PFPS, 38% of them were overweight or obese, and greater BMI was associated with worse knee flexion strength and worse functional ability [3]. Similar results were seen in obese people, where lower quadriceps strength and worse Kujala Pain Scale scores were closely correlated with BMI and body fat percentage [28].

3.2. Correlation Between BMI and Pain Severity

In a study among college recreational cricketers (n=91), a moderate negative correlation was observed between BMI and Kujala Anterior Knee Pain scores ($r =$

-0.487 , $p < 0.001$), indicating that higher BMI values were associated with greater PFPS severity [26]. Overweight participants experienced more frequent anterior knee pain and greater limitations in functional activity, confirming BMI as an independent risk factor for PFPS even among recreational athletes.

3.3. BMI as an Early Predictor of Degenerative Joint Changes

Long-term evidence shows that persistent overweight from childhood through early adulthood independently predicts knee pain and osteoarthritis (OA) in later life. A narrative review highlighted that high BMI during adolescence contributes to altered joint alignment, cartilage thinning, and premature joint degeneration, setting the stage for early-onset PFPS. These findings suggest that preventive weight management in youth can delay or prevent the onset of degenerative knee conditions [27].

3.4. Influence of BMI on Foot Alignment and Knee Mechanics

In university students, higher BMI was significantly associated with flexible flatfoot ($p < 0.05$), which leads to abnormal lower limb alignment and increased knee joint stress. A negative correlation between BMI and Kujala score ($r = -0.238$ to -0.366) was found, indicating that excess weight combined with flatfoot deformity exacerbates knee pain. Altered foot posture in overweight individuals may therefore act as an intermediate factor linking BMI and anterior knee pain [29].

3.5. Physiological and Functional Consequences of High BMI

Obese people frequently have decreased lean muscle mass and weak neuromuscular control, which increases aches and instability in their joints. Participants with knee pain had higher BMI (25.6 vs. 24.1 kg/m²), more fat mass, and weaker thigh muscles, according to a study on young adult women. These findings support the idea that body composition imbalances increase the risk of PFPS. Therefore, in order to completely comprehend its influence on the development of knee pain, BMI should be considered along with body fat and muscle mass [30].

3.6. Preventive and Clinical Implications

Reducing BMI through structured exercise programs and nutritional interventions can decrease mechanical load and improve knee strength and function. Rehabilitation programs should include weight management, quadriceps and hip abductor strengthening, and body composition monitoring as key strategies for managing PFPS in young adults [3,26]. Educational interventions in colleges can promote early BMI screening and lifestyle modification to prevent chronic knee pain syndromes.

IV. LIFESTYLE AND BEHAVIOURAL RISK FACTORS AFFECTING EARLY KNEE PAIN OR PATELLOFEMORAL PAIN SYNDROME (PFPS)

Maintaining musculoskeletal health in young adulthood is mostly dependent on behavioural and lifestyle choices. Due to decreased physical activity, extended sitting, improper posture, and irregular exercise habits, college students are particularly susceptible to anterior knee pain and PFPS. These fluctuating behaviours combine with body composition cause joint overload, muscular imbalance, and early-onset knee pain. Numerous studies show that while regular moderate physical exercise has a preventive impact whereas sedentary lifestyles, poor sleep or nutrition quality, and work postures enhance the risk and severity of PFPS [26,28,31]

4.1. Physical Activity and Sedentary Behaviour

Low movement levels and prolonged sitting are primary triggers of PFPS in college populations. Continuous knee flexion during lectures or study sessions elevates patellofemoral joint pressure and leads to anterior knee discomfort. A cross-sectional study among teachers reported that extended sitting hours and limited walking breaks significantly increased PFPS prevalence, highlighting the effect of inactivity on knee stress [26]. Conversely, moderate physical activity—such as walking, cycling, or low-impact sports—enhances quadriceps strength and cartilage nutrition, thereby preventing early knee pain [21].

4.2. Occupational and Postural Risk Factors

Occupation-related activities and habitual postures (e.g., squatting, climbing stairs, crossing legs) can repeatedly stress the patellofemoral joint. Research from Cario demonstrated that BMI, occupation, and age were significant determinants of PFPS among obese adults ($p < 0.05$) [26]. Among college students, extended study hours and use of poorly-designed seating result in sustained knee flexion and patellar compression, aggravating early knee symptoms.

4.3. Behavioural and Lifestyle Habits

Irregular sleep, unbalanced diet, and fast eating correlate with poor knee health and increased BMI. Objectively measured data using wearable devices revealed that lower daily step counts were linked with higher knee pain and reduced functional scores, while BMI and waist circumference were inversely related to sleep duration [31]. These behaviours contribute to metabolic disturbances and inflammation (excess adipokines and cytokines) which leads to mechanical stress on the joint [32].

4.4. Interaction Between Lifestyle and Biomechanics

Unhealthy lifestyle patterns amplify the biomechanical consequences of flatfoot, malalignment, or weak hip muscles. Individuals with higher body fat and

lower lean muscle mass display reduced joint stability and shock absorption, predisposing them to PFPS. Sedentary habits thus intensify the effects of poor biomechanics and excess weight on early knee pain [29,30].

4.5. Preventive Strategies

Encourage structured moderate exercise programs (strengthening and stretching of quadriceps, gluteal, and hamstring muscles). Promote ergonomic seating and movement breaks every 30–45 minutes during study or screen time. Incorporate health education modules in college curricula focusing on posture, nutrition, and physical fitness to reduce early knee pain risk [26,28].

V. PATHOPHYSIOLOGICAL MECHANISM

Patellofemoral discomfort and dysfunction are caused by a complex interplay between mechanical, muscular, and metabolic factors, which collectively disrupt normal shared homeostasis. Contact pressure on the patella's side and the femoral trochlea is continually increased by excessive or inappropriate mechanical loading on the patellofemoral joint, which is commonly brought on by repetitive knee flexion-extension exercises like stair climbing, running, or squatting. An increased Q-angle or changed branch mechanics can lead the patella to become misaligned or maltracked, which increases focal cartilage stress and micro damages the subchondral bone [33,34,35]. Over time, subchondral nociceptors aid in cartilage weakening, fissuring, and discomfort (Fig:1.1) Muscle weakness and strength abnormalities, especially in the quadriceps(vastus medialis oblique vs. vastus lateralis) and hipsterism musculature(gluteus medius, gluteus maximus, and external rotators), also contribute to these mechanical differences (Fig:1.2) Weakness in these muscle groups causes reduced dynamic knee stabilization, which leads to greater lateral patellar displacement and cock, delayed activation time, and abnormal common alignment when moving. The reduced shock-absorbing capacity and impaired proprioceptive control prolong overloading and increase stress across the patellofemoral joint [37,38].

Together with these biomechanical rudiments, metabolic and seditious processes associated with rotundity also contribute significantly. As an endocrine organ, adipose tissue releases cytokines (IL-6, TNF- α , and CRP) and pro-inflammatory adipokines (leptin and resistin) that encourage low-grade systemic inflammation. By increasing chondrocyte catabolic enzymes such as nitric oxide synthase and matrix metalloproteinases (MMPs), these intercessors accelerate cartilage degradation and synovial inflammation. In addition, insulin resistance and oxidative stress in cadaverous muscle led to mitochondrial malfunction, reduce protein conflation, promote muscular atrophy, and induce adipose infiltration (Myosteatorsis) [1] Farther exposing the joint to aberrant lading, this metabolic

dysregulation exacerbates muscle weakness, reduces abundance, and disrupts neuromuscular control. A tone-buttressing cycle is created when the habitual sedentary state also sensitizes nociceptors, which increases pain perception and reduces physical exertion. Deconditioning and more weight gain are the outcomes (Fig:1.3)

When mechanical strain, muscular imbalance, and metabolic inflammation combine, a complicated pathophysiological loop is formed. Inflammation sets up towel deterioration, mechanical stresses harm common structures, and muscle weakness restricts stability and form. Progressive common deterioration, ongoing anterior knee discomfort, changed gait biomechanics, and dropped function are the issues. Breaking this pattern and fostering long-term general health requires optimizing biomechanics through alignment correction and strengthening, lowering sedentary freight through weight operation and metabolic regulation, and reestablishing muscle balance [1,38].

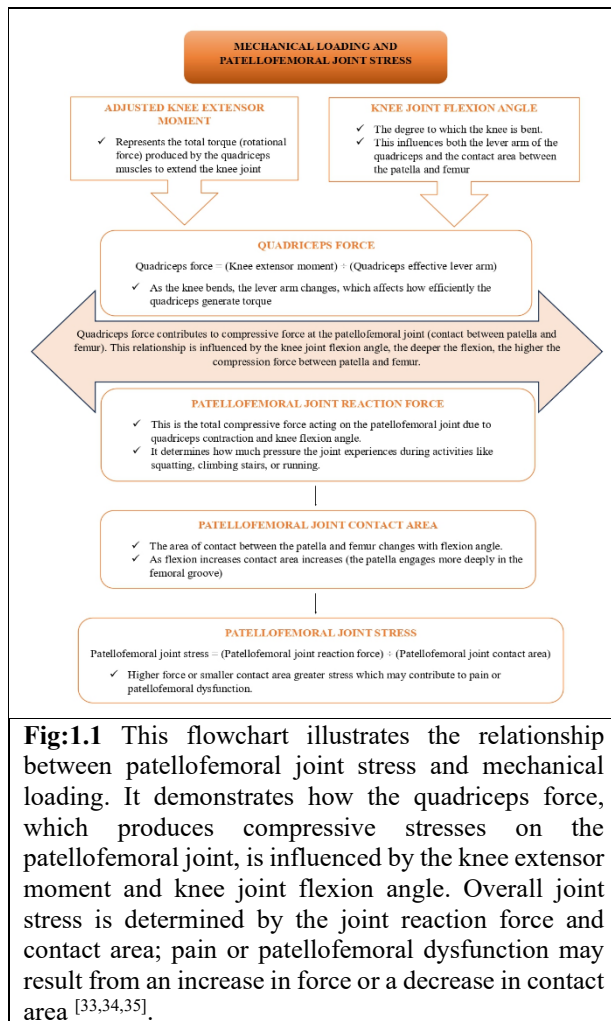


Fig:1.1 This flowchart illustrates the relationship between patellofemoral joint stress and mechanical loading. It demonstrates how the quadriceps force, which produces compressive stresses on the patellofemoral joint, is influenced by the knee extensor moment and knee joint flexion angle. Overall joint stress is determined by the joint reaction force and contact area; pain or patellofemoral dysfunction may result from an increase in force or a decrease in contact area [33,34,35].

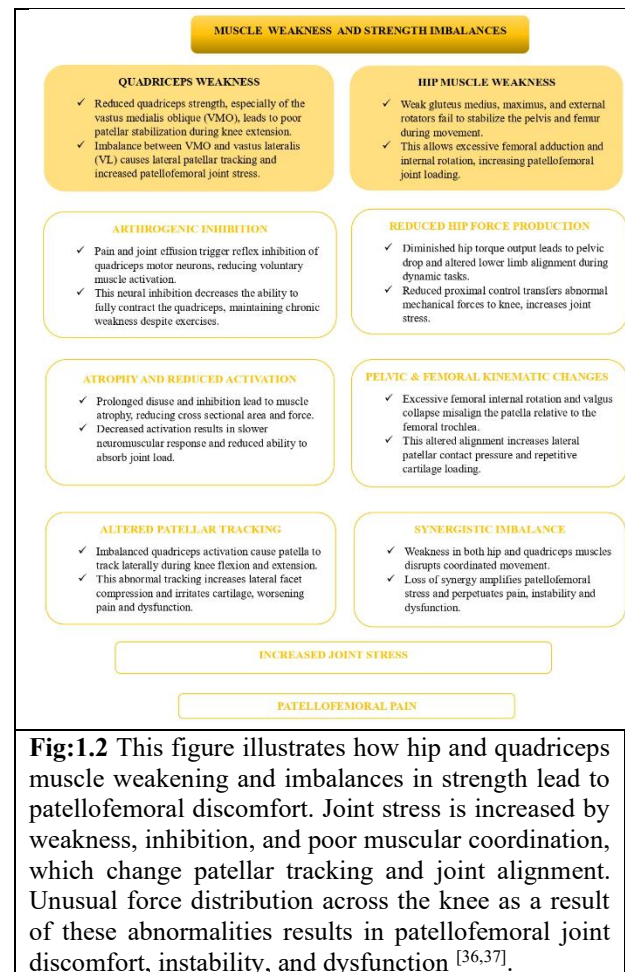


Fig:1.2 This figure illustrates how hip and quadriceps muscle weakening and imbalances in strength lead to patellofemoral discomfort. Joint stress is increased by weakness, inhibition, and poor muscular coordination, which change patellar tracking and joint alignment. Unusual force distribution across the knee as a result of these abnormalities results in patellofemoral joint discomfort, instability, and dysfunction [36,37].



Fig:1.3 This figure illustrates how metabolic and inflammatory alterations brought on by obesity have a

detrimental effect on joint health. Insulin resistance, oxidative stress, and chronic inflammation are caused by the release of pro-inflammatory adipokines and cytokines by excess adipose tissue. In the end, these processes exacerbate pain and dysfunction by weakening muscle, deteriorating cartilage, and increasing stress on the patellofemoral joint ^[1,38].

VI. FUNCTIONAL OUTCOMES IN COLLEGE STUDENTS

Pain severity and activity limitations	Patellofemoral pain syndrome causes anterior knee pain aggravated by squatting, stair climbing, running and prolonged sitting. Mean pain score in students range from 5-7/10, decreasing to 2-3/10 with exercise-based therapy. Hip and knee strengthening programs significantly reduce pain ^[37] . 40-57% of patients may still have persistent or recurrent pain even after therapy ^[1] . Chronic pain limits participation in sports and physical education.
Functional impairment	Functional limitations include difficulty in walking, running, jumping, stair use and kneeling. AKPS score (Anterior Knee Pain Score) show moderate impairment (70-80/100) in students with PFPS. Hip focused training improves biomechanics increasing hip abductor and external rotator strength, restoring patellar tracking ^[37] . Persistent muscle imbalance leads to reduced endurance and compensatory gait patterns ^[38] .
Impact on academic life and daily function	Prolonged sitting during lectures or study session increases pain and stiffness ^[37] . Students often avoid sports or physical classes, contributing to a sedentary-lifestyles. Pain interferes with concentration, reducing academic performance and class participation. Rehabilitations programs help students maintain mobility, comfort during long hours and routine activity.

Quality of life and psychosocial aspects	PFPS significantly reduces physical health, social participation and emotional wellbeing. 49.5% experience anxiety and 20.8% depression related to chronic pain ^[23] . Fear of movement (Kinesio phobia) and social withdrawal worsen disability. Exercise based rehabilitation improves confidence, body image and self-efficacy ^[37] . Long term discomfort without therapy lowers overall life satisfaction and vitality ^[1] .
Gender and biomechanical considerations	Higher prevalence among female students (4:1) due to increased Q- angle, weaker hip muscles and hormonal factors. Hip strengthening is particularly effective for females with internal rotation dominance ^[37] .
Rehabilitation and long-term outlook	Hip + knee strengthening is superior to isolated knee exercises in pain and function improvement. Early intervention prevents chronicity and future patellofemoral osteoarthritis. Combining physical therapy, ergonomic correction and psychological support yield optimal outcomes.

VII. PREVENTIVE AND MANAGEMENT STRATERGIES

7.1. Weight Management and Healthy Lifestyle Interventions

Numerous studies highlight excess body weight as a pivotal modifiable risk factor in the onset and persistence of patellofemoral pain and early knee discomfort among young adults. Ferreira et al. (2023) demonstrated that higher BMI and body fat were significantly correlated with decreased functional capacity and reduced knee strength, emphasizing that overweight and obesity impair joint mechanics and accelerate patellar cartilage stress ^[3]. Similarly, Basharat et al. (2022) and Aboelhassan et al. (2024) reported a strong positive relationship between BMI and the prevalence of PFPS among young women and obese adults, confirming that mechanical overload and adiposity-induced inflammation exacerbate anterior knee pain ^[28,39]. Evidence from Antony et al. (2016) also suggests that elevated BMI in adolescence is a predictor of knee pain and osteoarthritis later in life, reinforcing the

importance of early preventive interventions.^[27] Weight reduction of even 5–10 % has been associated with meaningful improvements in pain and joint function, particularly when combined with balanced nutrition rich in anti-inflammatory components such as omega-3 fatty acids and antioxidants. Encouraging low-impact aerobics activities (cycling, brisk walking, or swimming) helps control weight without exacerbating joint stress. Jeong et al. (2019) further indicated that increased daily step counts, healthy eating speed, and sufficient sleep duration positively affect musculoskeletal outcomes and cardiometabolic health in knee pain populations^[31]. Thus, structured programs promoting dietary moderation, physical activity, and lifestyle balance can substantially mitigate BMI-related joint stress and early patellofemoral dysfunction in college populations.

7.2. Role of Physiotherapy and Exercise Programs

Physiotherapy serves as the cornerstone for both prevention and management of PFPS in overweight or sedentary young adults. Targeted exercise regimens that strengthen the quadriceps, hip abductors, and core musculature have been consistently shown to enhance patellar tracking, reduce pain, and improve functional stability. Ericsson et al. (2021) found that reduced thigh muscle strength and lower lean mass were independently associated with knee pain, suggesting that maintaining muscle balance and endurance is crucial for joint health^[30].

Strengthening programs emphasizing closed-chain kinetic exercises (such as squats, step-downs, and leg presses) and open-chain control movements enhance the coordination of stabilizing muscles around the knee. Additionally, incorporating hip and gluteal strengthening yields superior functional outcomes, as highlighted in contemporary rehabilitation research on PFPS^[3].

Physiotherapy interventions may also include patellar taping, orthotic support, and proprioceptive training to correct malalignment and optimize movement patterns. Jeong et al. (2019) demonstrated that increased step count and physical activity improve KOOS (Knee Injury and Osteoarthritis Outcome Score) subscales, validating that mobility and strength training are essential for symptom relief^[31]. Early engagement in supervised physiotherapy, ideally integrated within college health programs, can prevent progression from transient anterior knee pain to chronic PFPS or degenerative knee changes.

7.3. Awareness and Screening in College Settings

Implementing screening and educational initiatives within universities can play a transformative role in identifying at-risk individuals before irreversible damage occurs. Studies by Khawar et al. (2025) and Ferreira et al. (2023) recommend incorporating BMI assessments, musculoskeletal functional testing, and lifestyle counselling into routine college health evaluations^[25,3].

Awareness programs that emphasize posture correction, ergonomic sitting, proper warm-up techniques, and graded physical activity are essential for

students exposed to prolonged sedentary habits or abrupt sports training loads. Furthermore, Antony et al. (2016) proposed that early-life lifestyle education can delay or prevent future osteoarthritis, underlining the importance of campus-based interventions targeting nutrition, exercise, and weight awareness^[27].

Regular workshops led by physiotherapists can teach self-screening for anterior knee discomfort, proper footwear selection, and early reporting of pain to prevent chronicity. Collaboration among physiotherapists, sports trainers, and dietitians in college health centres can provide multidisciplinary care for students presenting early PFPS symptoms. Establishing annual musculoskeletal health campaigns could reinforce adherence to healthy habits and help curb the rising incidence of knee pain linked to high BMI and poor lifestyle behaviours among young adults.

VIII. EVIDENCE GAPS AND FUTURE RESEARCH DIRECTIONS

8.1 Limitations in Current Literature

Existing literature examining the association between BMI, lifestyle factors, and early knee pain or patellofemoral pain syndrome (PFPS) is constrained by methodological and sampling limitations. Most studies are cross-sectional and rely on small, clinic-based samples, restricting their capacity to infer causality or temporal relationships.

Basharat et al. (2022) conducted a cross-sectional study involving 385 women aged 15–49 years and reported a significant positive association between higher BMI and PFPS severity, yet acknowledged that the design did not establish cause-and-effect relationships^[39]. Ferreira et al. (2023) highlighted strong correlations between body composition and PFPS but noted that their cross-sectional nature limited causal interpretation^[3].

Most existing studies have focused on older adults or clinical populations, leaving a gap in understanding how BMI and lifestyle factors influence younger, college-aged individuals. This is a critical limitation, as early adulthood is a period when sedentary behaviours, diet, and physical activity patterns undergo substantial change, potentially initiating early musculoskeletal strain and knee dysfunction.

8.2 Need for Longitudinal Studies in Young Adults

While cross-sectional research has identified associations between BMI and knee pain, longitudinal evidence is needed to clarify directionality and causation. Ferreira et al. (2023) reported that 38% of young adults with PFPS were overweight or obese, with higher BMI linked to reduced knee-flexion strength and functional capacity; however, they acknowledged that longitudinal data were needed to determine whether these impairments preceded or resulted from pain^[3].

Supporting this, Jindal et al. (2021) emphasized that “childhood and adolescent obesity predict adult obesity and increases lifetime risk of knee osteoarthritis”,

highlighting the need for early monitoring and preventive interventions^[40]. Similarly, Antony et al. (2016) found that high BMI from adolescence into adulthood was an independent predictor of later-life knee pain and osteoarthritis, underscoring the long-term musculoskeletal consequences of early overweight status^[40].

A strong example of longitudinal analysis comes from Ericsson et al. (2021), who followed young women aged 25–35 and found that participants with knee pain at follow-up exhibited higher fat mass and lower lean mass, suggesting that body-composition changes, rather than BMI alone, may predict future knee pain.^[30] This reinforces the importance of prospective, long-term studies among college-aged populations to understand how BMI and lifestyle behaviours influence early knee health.

8.3 Importance of Integrating BMI, Lifestyle, and Functional Assessments

Future studies should employ multifactorial designs that integrate anthropometric, lifestyle, and functional performance measures. BMI alone offers limited diagnostic value, as it does not differentiate between fat and lean mass or reflect functional fitness levels. Ferreira et al. (2022) demonstrated that body fat percentage and skeletal muscle mass were more sensitive indicators of pain and widespread hyperalgesia than BMI, concluding that “BMI alone helps explain self-reported pain, whereas body composition provides stronger explanatory value.”^[3]

Similarly, Callahan et al. (2025) emphasized that PFPS has a multifactorial biomechanical origin, including hip muscle weakness, poor neuromuscular control, and altered patellofemoral joint loading, highlighting the need for functional and biomechanical assessments alongside BMI^[38]. In addition, Aboelhassan et al. (2024) found that BMI, age, and occupational factors significantly predicted PFPS prevalence in obese adults under 40, underscoring the interaction between metabolic and biomechanical stressors^[28].

In the context of college students, research should combine:

- Anthropometric analysis: BMI, body-fat percentage, and lean-mass ratio.
- Lifestyle assessments: physical-activity tracking, sleep, sedentary duration, and dietary patterns.
- Functional tests: step-down test, single-leg squat, and Kujala or SNAPPS knee questionnaires.

This integrated approach would improve understanding of how excess weight, reduced activity, and poor muscle function interact to produce anterior knee pain or PFPS in early adulthood.

8.4 Synthesis and Future Research Priorities

The collective evidence underscores consistent associations between elevated BMI, lifestyle risk factors,

and early knee pain, yet causal mechanisms remain insufficiently understood.

To address this gap, future research should prioritize:

1. Longitudinal designs to establish causality between BMI, activity, and knee pain development.
2. Comprehensive body-composition analyses that go beyond BMI to include fat and muscle distribution.
3. Functional performance evaluations to correlate knee mechanics and muscle function with pain outcomes.
4. Intervention-based studies evaluating the effects of weight management, strength training, and lifestyle modifications on knee health among college-aged individuals.

IX. CONCLUSION

Patellofemoral pain syndrome (PFPS) and early knee discomfort are becoming more common among college students, owing to the combined effects of high body mass index (BMI), sedentary lifestyles, and inadequate musculoskeletal fitness. The transition to college life sometimes includes abrupt changes in physical activity, extended sitting, irregular eating patterns, and psychosocial stress—all of which led to altered biomechanics and increased stress on the patellofemoral joint. Elevated BMI increases joint stress, weakens the quadriceps and hip muscles, and speeds up cartilage degradation, whereas a lack of regular exercise and bad posture impair muscle endurance and stability.

Preventive interventions should therefore emphasize maintaining a healthy BMI through balanced nutrition and regular physical activity. Structured exercise programs that include quadriceps, hamstrings, and hip muscle strengthening, as well as flexibility and proprioceptive training, have been shown to improve knee alignment and minimize discomfort. Furthermore, adopting ergonomic study habits, such as correct seating, taking movement breaks while extended sitting, and avoiding severe knee flexion, can greatly reduce joint strain.

Early intervention relies heavily on physiotherapy, which emphasizes customized rehabilitation, patellar tracking correction, and progressive load progression. Incorporating lifestyle counselling into student health programs can raise understanding about posture, diet, sleep, and mental health, all of which affect pain perception and recovery. Furthermore, incorporating frequent musculoskeletal screening and BMI evaluation into college health checkups can aid in the early detection of at-risk people. Future research studies should use longitudinal and interventional designs to investigate the combined impact of BMI, physical fitness, and lifestyle habits on knee health in young adults. Evaluating body composition, muscle mass, and biomechanical alignment,

as well as psychological aspects like stress and Kinesio phobia, will provide a more complete picture of PFPS.

In conclusion, early knee discomfort in college students is a complex issue that can be effectively prevented and managed with weight management, muscular strengthening, and lifestyle changes. Promoting health education, early screening, and evidence-based physiotherapy therapies in academic contexts can help students avoid chronic knee diseases while also improving their physical performance, academic productivity, and overall quality of life.

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