Review Article

Do Patellofemoral Pain Patients Have Higher Loading Rate Compared to Healthy Indivalues? A Systematic Review and Meta-analysis

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ABSTRACT

Purpose: Higher loading rates have been associated with injuries, plantar fasciitis, tibia bone stress injuries, knee osteoarthritis, and patellofemoral pain (PFP). The aim of this study is to evaluate the loading rate in PFP patients compared to healthy individuals during weight bearing tasks.

Methods: Search strategy was conducted in databases: Science Direct, Scopus, PubMed and Google Scholar. The outcome measuring: loading rate were during weight bearing tasks. The quality of the studies was evaluated by Down and Black index and it was divided into three groups: low quality (LQ), medium quality (MQ) and high quality (HQ). The standardized mean difference between PFP patients and healthy individuals was used to calculate the effect size.

Results: Seven articles were included of that 4 studies was HQ and 3 MQ were classified. The no significant difference between PFP patients and healthy individuals in the loading rate (p=0.52) ; But strong evidence with medium effect size (SMD=0.50; 95% CI=[-1.01 to 2.00]) indicates a tendency to increase loading rates in PFP patients compared to healthy individuals.

Conclusion: The compensatory mechanism in PFP patients, decrease of active shock absorption which finally leads to higher loading rates that can have effect on the tibiofemoral joint that correlating to the development of pain and knee osteoarthritis.

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Highlights

- Role of abnormal kinetics in the development of patellofemoral pain (PFP) has not been fully investigated.
- Higher loading rates have been associated with knee osteoarthritis and PFP.
- Higher loading rates in PFP patients may correlated to the development of pain and tibiofemoral joint osteoarthritis.

Plain Language Summary

Protective mechanisms in patients with patellofemoral pain (PFP) result in a decrease in the capacity of active shock absorption and higher passive shock absorbency via the viscoelastic properties of bone and cartilage. As a result, higher loading rates may have destructive effects on the tibiofemoral joint and development of knee osteoarthritis.

1. Introduction

Patellofemoral pain (PFP) is a multifactorial condition, which includes almost 30% of all injuries seen in sports medicine clinics [1, 2]. PFP is retropatellar or peripatellar pain during activities, in which patellofemoral joint (PFJ) is subjected to high loads [2, 3]. The annual prevalence of PFP is approximately 22.7% in the general population and 13% in women aged 18-35 years [4]. However, PFP is considered as a of the most challenging musculoskeletal condition to manage, and conservative treatment mostly leads to no long-term clinical results [5] so that 56.7% of cases report unfavorable outcomes 5-8 years after treatment [6].

PFP has been linked to abnormal kinematic and kinetic of lower extremity; however, the role of abnormal kinetics in the development of PFP has not been fully investigated [7, 8]. Overall, It has been suggested that loading rate is among the most important kinetic parameters for evaluation of the overload of lower limb musculoskeletal tissues [9]. Loading rate is a concept to explain the "severity" with that the force enhancement at touchdown [9]. The loading rate is determined as the slope of the primary section of the vertical ground reaction force-time curve [10]. Higher loading rates have been associated with injures, plantar fasciitis, tibia bone stress injuries, knee osteoarthritis, and PFP [8, 11].

Higher loading rates in PFP patients compared to healthy individuals have been explained by faulty knee kinematics [9]. Overall, during weight-bearing activities, an increase in knee flexion will be accompanied by the patellofemoral joint reaction forces (PFJRF) [12]. Consequently, PFP patients possibly utilize compensatory mechanisms at the knee to minimize symptom exacerbation and reduce PFJRF and consequently, reduce pain [12-14]. For example, reduced knee flexion is possibly a protection mechanism to decrease PFJ stress and as a result, relief pain [12, 14]. Nevertheless, it has been shown that a decrease in knee flexion can be a mechanism for higher loading rates [15].

Although the available evidence suggests that altered loading rate may underlie the etiology and progression of PFP, conflicting findings have been reported. For example, Silva et al. reported that patients with PFP compared to healthy individuals had an increase in loading rate while climbing stairs [9]. Esculier et al. reported a tendency to decrease loading rate in patients with PFP [16]. Further research is needed to understand these inconsistent findings related to loading rates in patients with PFP. Furthermore, understanding the factors that affect the body's ability to absorb load may help as part of rehabilitation protocol and prevent lower extremity injuries [17, 18].

Given the mechanical connection between PFP and knee osteoarthritis, the biomechanical investigation of common movement patterns in patients with PFP possibly provide valuable information about protective mechanisms in these patients [9, 17]. Thus, exploration the potential underlying mechanics leading to PFP is critical to effectively treat and prevent this orthopedic condition [17]. Thus, the aim of this review and meta-analysis study was to answer the question "Do patients with PFP have higher loading rate compared to healthy individuals?

2. Materials and Methods

The design and writing of this study were done in accordance with the PRISMA 2009 guidelines.

Search strategy

The research question was determined according to the PICOS framework. Papers were included if they presented outcome of clinical studies (S) on the assessment of loading rate (O) in PFP patients (P) compared with healthy individuals (C). The intervention (I) was not considered. AY and MA independently performed searching of the following electronic databases from October 2020: ScienceDirect, Scopus, Medline, and PubMed. Google Scholar functioned as a complement search engine. Search strategy was involved an extensive complex of search terms and MeSH terms (Table 1). We had no limitation for publication date but only articles in English language were included. In general, the three categories of keywords and relevant synonyms were used. These categories were connected by "AND", and terms of the same category were connected by "OR", and if possible, the insignia * was used to add all the derivations of the terms. All literature collated was imported to reference management Mendeley software version 6.1 and stored alphabetically, and then, duplicates were removed automatically.

Study selection

All articles identified were screened using the eligibility criteria by two reviewers independently (AY and MA). The inclusion and exclusion checking was implemented by two reviewers (AY and MA) according to the title and abstract of the studies included. The full text of titles and abstracts was reviewed, and those found to be eligible were included in the final review. Eligibility criteria were as follows:

Inclusion criteria: case-control studies of human participants, which compared loading rate between PFP patients and healthy individuals during weight-bearing tasks. Furthermore, the selected articles must be published in English language.

Exclusion criteria: letters, conference proceedings, case reports, cadaveric studies, prospective studies, no comparison of patients with PFP with healthy individuals, abstracts, reviews, clinical trials and non-English and Persian language articles were excluded. After an initial screening of title and abstract, the studies were categorized as as A) meeting ("include"), B) may meeting ("potentially"), C) not meeting the criteria ("do not include"). A full-text assessment was checked if the title and abstract were related, with those found to be eligible included in the review. Disagreement in identified papers for inclusion criteria was resolved in a consensus session.

Methodological quality assessment

Two reviewers (AY and MA) independently evaluated the studies included by modified version of the Downs and Black checklist, which has well test–retest (r=0.88) and inter-rater (r=0.75) reliability [19]. This version has 25items, by which the following sub-groups: reporting (items 1,2,3,5,6,7, and 10), external validity (items 11 and 12), internal validity (items 16,18, and 20), and internal validity confounding (items 21,22, and 25) were evaluated [20]. The items were scored as 0 ["no"), 1 ("yes"), except item 5 for the principal confounders, which was scored as 0 ("no"), 1 ("partially"), and 2 ("yes") [21]. Studies with quality scores of 70% or greater were classified as high quality, 40%-69% as moderate quality, and 40% or less as low quality [22]. Disagreement in identified papers for inclusion criteria was resolved in a consensus session.

Outcome measures and data extraction

Two reviewers (AY and MA) independently extracted the demographic information: author name and year of publication, purpose, task and results. The outcome was loading rate during weight bearing tasks. Data was extracted, reviewed, and analyzed by two reviewers (AY and MA). A reviewer (MA) extracted data and this was confirmed by a second reviewer (AY). Where data were not available, the author was contacted. If data were still unable to be sourced, Web Plot Digitizer software with high reliability (Pearson's r=0.999) and validity (r=0.989) designed to extract data from digital plot images, was used [23].

Table 1. Search strategy and keywords

Categories	Keywords
Biomechanical	Biomechanical phenomena (MeSH), Kinetics (MeSH), Kinematics (MeSH), vertical loading, loading rate, ground reaction force parameters
Task	Running (MeSH), Gait (MeSH), Locomotion (MeSH), Ambulation (MeSH), Walking (MeSH), Squatting (MeSH), Weight-Bearing (MeSH), Stair climbing, Stair up, Stair down
Knee	Anterior Knee Pain Syndrome (MeSH), Patellofemoral Syndrome (MeSH), Pain Syndrome (MeSH), Patellofemoral (MeSH), patellofemoral pain

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Statistical analyses

All analyses were performed by Review Manager software version 5.3. Standardized Mean Differences (SMD) and 95% confidence intervals (CI) were extracted to compare loading rate between PFP with healthy groups. We also used a forest plot to facilitate the comparison of results between the two groups. Meta-analyses were performed by calculating the effect size (ES) by SMD in a random-effects model. ES was categorized as: low quality (≥50%), medium quality (51%-74%), and high quality (≤75%) [24]. Random model is often utilized for small sample sizes and sample heterogeneity with selection bias common in the literature. Overall, random-effects model assumes the study populations are varied and different from each other [25].

The I2 statistic was used to specify the value of heterogeneity, where the percentages quantified the magnitude of heterogeneity: 25%=low, 50%=medium, and 75%=high heterogeneity [26]. The I^2 statistic describes the percentage of variation across studies that is due to heterogeneity rather than chance [27]. The level of statistical significance ($P<0.05$) was calculated via Z test. Quality rating was used to determine levels of evidence, based on a modified version of the van Tulder criteria [21]:

- Strong evidence: including at least three high-quality studies.
- Moderate evidence: including at least three moderate-/high-quality studies or two high- quality studies.
- Limited evidence: pooled findings amongst multiple low-/moderate-quality studies, or one high-quality study.
- Very limited evidence: one low-/moderate-quality study.
- Conflicting evidence: one/some studies show significant effects and one/some studies show no significant effects while the CIs of the pooled effect size lead one to accept the null hypothesis.

3. Results

Study selection

The primary search be extracted 433 study that 41 was remove due to duplication. Then, two researchers (AY and MA) screened the remaining 392 study according to the title and abstract of the studies, which resulted in the elimination of 350 studies that were inconsistent with the purpose and eligibility criteria. 42 articles remained for full text evaluation, of which 17 were omitted, because they did not of the eligibility criteria. Seven study related to the patellofemoral joint loading rate, seven study due to lack of healthy group or comparison with other pathologies, two study due to non-reporting of loading rate values and two study that had applied various interventions in the evaluation were removed from the review process. Finally, seven study [9, 11, 16, 17, 28-30] were selected for systematic review and meta-analysis (Figure 1).

Methodological quality assessment

The average score of methodological quality of studies was 72.5% (range 60%-80%), which indicates the medium quality of studies. 58% of studies (n=4) had high methodological quality [11, 16, 17, 29], 42% of studies (n=3) were as medium quality [9, 28, 30] (Table 3). The strength of the quality studies was report particular the expression of the objectives and outcome measures. All studies have poor external reliability scores. In fact, none of the studies have identified the source of the population and how patients are selected. Also, most studies on the internal validity of confounder were poor partly. Only 4 studies reported that patients from the same population and same time period were employed [9, 11, 17, 29]. Also, only 3 studies reported the adequate adjustment for confounding [11, 16, 17].

Characteristics of studies

Table 2 shows the demographic information of studies. There are a total of 490 people (mean age: 29.94 years; mass: 66.07 kg; height: 167.80 cm) in 7 study. Overall, 245 people was healthy individuals (mean age: 29.20 years; body mass: 65.50 kg; height: 168.12 cm) and 245 PFPS patients (mean age: 30.68 years; body weight: 66.65 kg; height: 167.47 cm). Only 2 studies, demographic characteristics were not reported [28, 30]. 57.14 % of studies (n=4) when running [11, 16, 28, 29]; 28.57% (n=2) when stair climbing [9, 17]; and 14.29% (n=1) when walking [30].

Loading rate

7 studies [9, 11, 16, 17, 28-30] peak evaluated loading rate during weight-bearing tasks (Figure 2). Overall, results of meta-analysis showed that from statistical point of view there was no significant difference between PFP patients and healthy individuals in the loading rate (P=0.52) ; But due to the results of the forest plot; strong evidence (4 studies=HQ, 3 studies=MQ, I2=98 %) with medium effect size (SMD=0.50; 95% CI=[-1.01 to 2.00]) indicates a tendency to increase loading rates in PFP patients compared to healthy individuals.

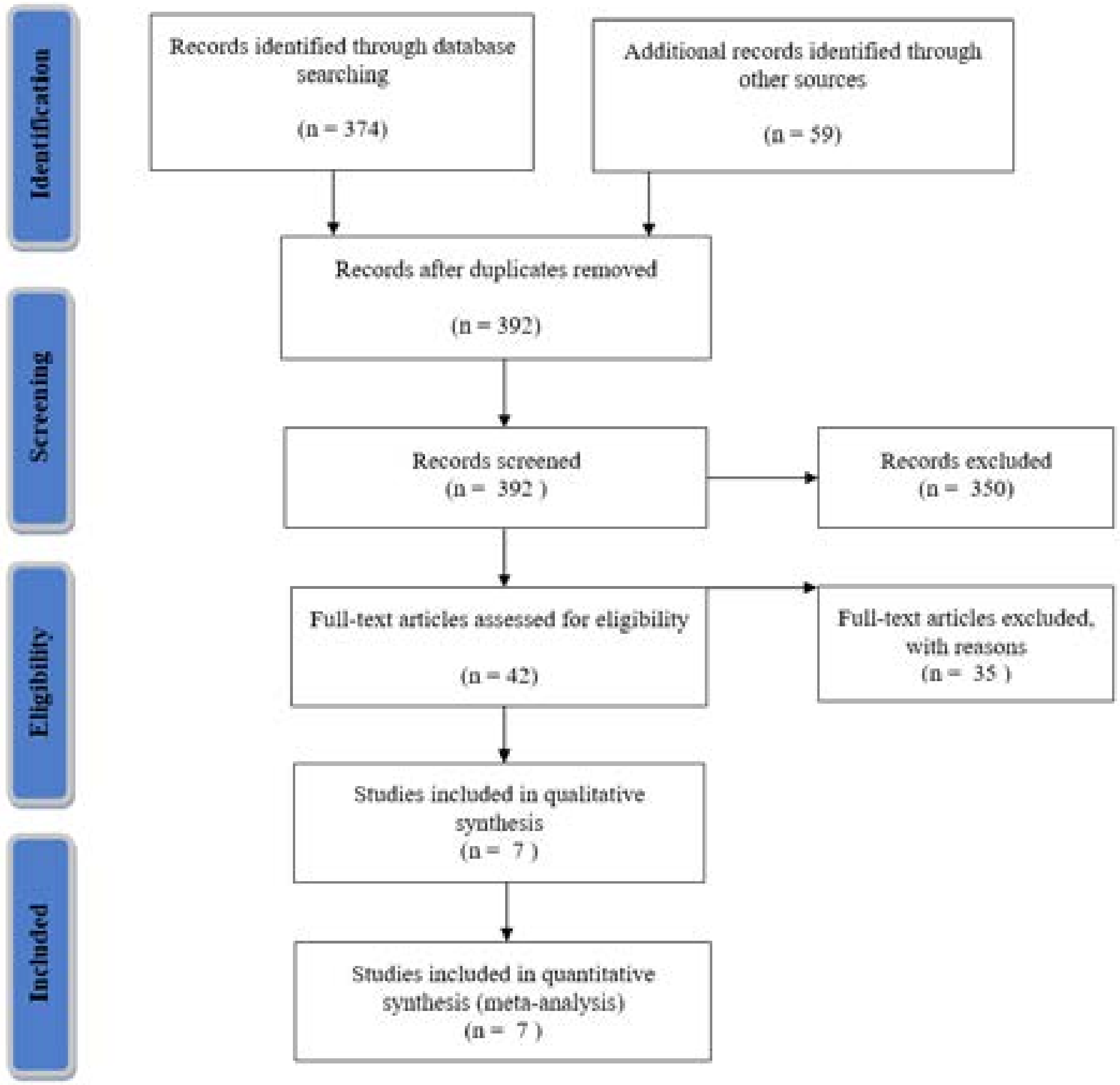

Figure 1. PRISMA flowchart for meta-analysis

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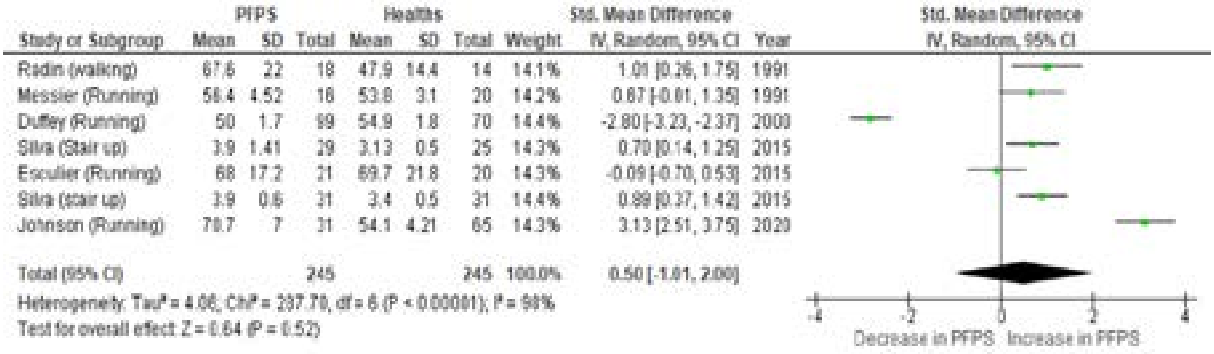

Figure 2. Forest plot shows loading rate outcomes

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Table 2. Demographic information of studies

Author/Year	Purposes	Tasks	Results
Borenstein et al. 2007 [25]	Relationships exist between selected biomechanical factors runners with PFP and healthy individuals	Running	No significant difference was reported between the two groups, but a tendency to increase the loading rate was observed in PFP patients
Verbecque et al. 2021 [27]	The kinematic and kinetic examined the behavior of the legs of young adult with PFP patients	Walking	The PFP group compared to healthy individuals show a increased in loading rate
López López et al. 2019 [26]	The examine differences between a noninjured and and runners with PFP according to selected training, anthropometric, rear foot motion and GRF	Running	The healthy group compared to PFP group show increase the loading rate
Cheung et al. 2015 [8]	The purpose of this study was assessment reducing knee flexion and loading rates in PFP group than to healthy controls	Stair climbing	The PFP group compared to healthy individuals show a reducing knee flexion and higher in loading rate
Briani et al. 2015 [15]	The investigate differences in VGRF between recreational female athletes with PFP and pain-free	Stair up	The PFP group demonstrated that loading rate were increased
Esculier et al. 2015 [16]	The compare GRF during treadmill running in recreational runners with and without PFP	Running	No significant difference was reported between the two groups, but a tendency to increase the loading rate was observed in healthy individuals
Johnson et al. 2020 [11]	Compare GRF components between runners with and without PFP	Running	The PFP group compared to healthy individuals show a increased in loading rate.

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4. Discussion

The aim of this review and meta-analysis was the evaluation of loading rate in PFP patients compared to healthy individuals during weight bearing tasks. The results systematic review and meta-analysis showed a tendency to higher loading rates be in PFP patients than health's individuals.

Overall, higher loading rates in patient populations with PFP have been explained by faulty kinematics of the knee [15]. Evidence suggests that PFP patient to minimize the PFJRF, reduced flexion and extensor moment of the knee [13, 31]. The PFJRF is force between the quadriceps muscles and patella tendon that increases with quadriceps muscle force and knee flexion angle [13]. At tempts to minimize the PFJRF involve alterations to one or both of

Table 3. Black and Downs checklist for methodological quality of studies

Studies \ Checklist	1	2	3	5	6	7	10	11	12
Radin et al. 1990 [30]	1	1	0	0	1	1	1	0	0
Messier et al. 1991 [28]	1	1	0	1	1	1	1	0	0
Duffey et al. 2000 [29]	1	1	1	1	1	1	1	1	0
Johnson al. 2020 [11]	1	1	1	1	1	0	1	0	0
Silva et al. 2015 [17]	1	1	1	1	0	0	1	0	0
Silva et al. 2015 [17]	1	1	1	1	1	1	0	0	0
Esculier et al. 2015 [16]	1	1	1	2	1	1	1	0	0

Study	16	18	20	21	22	25	Rate	Percentage (%)	Quality
Radin et al. 1990 [30]	1	1	1	1	0	0	9	60	M
Messier et al. 1991 [28]	1	1	1	0	0	0	9	60	M
Duffey et al. 2000 [29]	1	1	1	0	1	0	12	80	H
Johnson al. 2020 [11]	1	1	1	1	1	1	12	80	H
Silva et al. 2015 [17]	1	1	1	1	1	0	10	67	M
Silva et al. 2015 [17]	1	1	1	1	1	1	12	80	H
Esculier et al. 2015 [16]	1	1	1	0	0	1	12	80	H

H: high; M: medium; PFP: patellofemoral pain; GRF: Ground reaction force.

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these quantities [32]. In this regard, a systematic review published reported that PFP patients have decrease knee flexion and reduced the demand quadriceps for PFJRF decreases and ultimately reduces pain [4].

The range of motion of the lower limb when the loading phase possible influence on the forces experienced [9]. Cook et al. (1997), reported which reducing knee flexion when movement leading to increase vertical ground reaction forces and lower limb loading rates in health's individuals [33]. Hence, although reduced knee flexion is a logical behavior by which PFJRF can be limited, it may hamper the lower extremity absorption shock mechanisms [9, 15]. While reduced knee flexion possible help protect versus the development of PFP, thus "quadriceps avoidance" behavior my lead to chronic disuse of the knee extensors [31]. Eccentric quadriceps contraction is considered to be the initial dynamic shock absorbent mechanism during weight acceptance and my its decrease had be correlation to higher loading rates [9, 34]. Such compensatory behavior in PFP patients may decrease capacity of active shock absorption via quadriceps muscle contraction and higher passive shock absorption by the viscoelastic virtues of both bone and cartilage [13, 31].

Higher loading rates at the tissue surface can lead to cartilage split or development of surface split, such to the osteoarthritis mechanisms [4, 9, 31]. The diminish in the peak knee extensor moment possible also have a negative effect on tibiofemoral joint loading [31]. Overall, loading rate would not had strong effects on the PFJ by nature of its vertical alignment and the fact that patellofemoral stress is initially affiliate on the value of quadriceps force and the femur direction. Thus, compensatory behaviors to exacerbation reduction of PFP possible have negative effect on the tibiofemoral joint, as a result of its horizontal direction, via axial compression [9, 17, 31]. As a result, studies have reported that there is a correlating between higher in the loading rates with the development of pain and knee osteoarthritis [17]. In this regard, the results of studies have shown that people with knee osteoarthritis be exposed severe and frequent loading of the lower extremities before the stage of the complication [4].

Clinical application

The compensatory movement pattern in PFP patients must be addressed; as it possible have correlation to higher loading rates that can lead to detrimental effects on the knee joints and functional status is consequently reduced [4, 9, 17]. Therefore, first: it is necessary to identify which factors cause this loading rate alteration to promote reestablishment of knee function and consequently reduce the disease progression [17]. Second: rehabilitation programs aimed at gait retraining, using either visual or verbal feedback, seem to be effective in reducing loading rates [34]. Third: since long-time quadriceps avoidance possible lead to quadriceps weakness and atrophy; should be considered the accession of quadriceps strengthening as a needful and effective partial in prevention and rehabilitation approaches to PFP [31].

Limitations and suggestions

There are four limitations to this study. First, because of the case-control nature of the studies, we results is not able to differentiation between cause and effect about loading rate evaluated [9]. Second, alone one dynamic activity function was reported in studies and no comparison another weight bearing activity [17]. Assessment of movement activity which are more challenging in terms of mechanical and muscular demands, similar stairs ambulation, perhaps further contribute to the perception of compensatory mechanisms producing by PFP patient, that possible not be observed when gait [17]. Third, large heterogeneity in this meta - analysis was partly attributed to patients population and methodological differences in movements analyses [11]. Fourth, lack to evaluate the loading rate on the healthy or low - effect leg; because some studies reported that PFP patients tend to action load on healthy leg [29]. Therefore, A) it is recommended that loading rates be evaluated and compared in different challenging tasks B) on both sides in the C) athlete and general population separately.

5. Conclusion

The PFP patient reduced knee flexor angle and extensor moment of the knee to limit the PFJRF. Such a compensatory mechanism, decrease of active shock absorption and greater passive shock absorption which finally leads to higher loading rates. Higher loading rates can have efficacy on the tibiofemoral joint that through axial compression correlating to development of pain and knee osteoarthritis.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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