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Altered Hip Mechanics and Patellofemoral Pain. A Review of Literature

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SUMMARY

Patellofemoral pain (PFP) is a common knee disorder in orthopedic clinics. In the last decade, several investigations have considered the role of proximal factors in addition to local and distal factors in development of PFP. There is a hypothesis which suggests that impaired neuromuscular control and altered hip joint kinematic affect tibiofemoral and patellofemoral biomechanics. Hence, PFP may develop as a result. This article reviews studies assessing the relationship between altered hip mechanics and PFP.

The Medline and PubMed databases were searched between January 2004 and October 2014. Two authors independently selected related articles using the same search strategy and key words.

Among 149 articles, 16 met the review inclusion criteria. The study results were described in three sections: 1) kinematic studies, 2) muscle activity studies, and 3) postural stability studies.

Increased hip adduction and internal rotation, gluteal muscle weakness, and neuromuscular impairment were common findings in patients with patellofemoral pain. Precise assessment of hip mechanics, including hip kinematic, muscle performance and postural stability, should be considered in the examination of patients with patellofemoral pain.

Key words: patellofemoral pain, altered hip mechanics, postural stability, muscle activity

BACKGROUND

Patellofemoral pain (PFP) is the most common overuse injury, with a higher incidence in physically active individuals [1,2]. PFP accounts for 25-40% of knee problems in orthopedic sports clinics [3,4]. PFP is characterized by anterior knee pain, retropatellar pain or prepatellar pain and exacerbated by activities that impose compressive stresses on the patellofemoral joint, such as squatting, stair climbing, running, jumping and prolonged sitting [5,6]. In addition, studies have reported that 70% to 90% of adolescents with PFP have chronic or recurrent pain [5,7]. PFP occurs more frequently in recreational or professional athletes. About 2.5 million runners with PFP will be identified per year. Females are 2.23 times more likely to develop PFP compared with males [5,7]. The prevalence of PFP in Iranian female athletes is 13.68% in soccer players, 20.38% in volleyball players, 16.66% in runners, 13.33% in fencers and 26.31% in rock climbers [8].

The etiology of PFP is multifactorial. Recently, much attention has been paid to a relationship between PFP and etiologic factors that are classified as local (patellar alignment and mechanics), distal (foot mechanics) and proximal (hip strength and mechanics) [5,7]. These multifactorial etiologies of PFP require multimodal conservative approaches, including specific vastus medialis obliquus (VMO) exercises, patellar taping/bracing, foot orthoses and hip strengthening. The aim of these interventions is to correct patellar tracking and reduce compressive forces on the patellofemoral joint and surrounding structures [3,5,7,9].

Recent studies suggest that the causes of knee problems may have a proximal origin [7]. In addition, several studies have demonstrated a relationship between hip muscle weakness and knee injury [7,10,11]. Investigations have emphasized that hip joint control has an important role in trunk and pelvic stability and may result in improving lower extremity alignment [2,7]. Additionally, there have been some investigations into the effect of hip muscle performance on postural control in the frontal and sagittal planes [12-15]. Fatigue of hip muscles causes impairment in postural control and increases center of pressure (COP) excursion velocity in the frontal plane [14,16].

Altered hip kinematics were observed in females with PFP in the frontal plane across functional activities [17,18]. Some studies have shown that these altered kinematics may appear as an increased hip internal and/or external rotation in the transverse plane [18-20]. There is evidence of hip external rotator and abductor weakness as a main cause of PFP in females [11,21]. However, other studies have denied weakness of these muscles as a proposed risk factor [1,22].

In this review, we turn our attention to studies that assessed hip kinematics, hip muscle activation and postural control in patients with PFP. Therefore, the current study reviews studies that assessed altered hip mechanics in patients with PFP.

MATERIAL AND METHODS

The Medline and PubMed databases were consulted for relevant articles from January 2004 to October 2014. The search was limited to English studies. The following key words were used as search terms: patellofemoral pain, altered hip mechanics, postural stability, and muscle activity. All articles that assessed hip mechanics in patellofemoral pain were considered. Empirical research, letters to the editors, conferences and case reports were excluded.

The titles, keywords, and abstracts of all research articles were read to confirm whether they related to this review study. Full texts of all included articles were obtained for analysis and data extraction. To confirm the accuracy of the search strategy, a second investigator re-reviewed the articles using search terms as listed above.

RESULTS

Of 149 articles relating to hip mechanics and PFP, the sixteen most relevant articles were selected (Table 1) and 3 relevant sections were described, namely, kinematic studies; muscle activity studies; and postural stability studies.

DISSCUSION

The general idea of this review article was to indicate relationships between altered hip mechanics and PFP. Therefore, to facilitate understanding, the discussion has been divided into categories describing these relationships.

KINEMATICS STUDIES

Recent studies have demonstrated altered hip kinematics in individuals with PFP across daily activities such as running, jumping or landing. These alterations have been seen in the frontal and transverse planes [17,19,20,23]. However, the findings have been inconsistent. Some studies have investigated increased hip adduction in the frontal plane and others have not. Additionally, conflicting results about kinematic alterations in the transverse plane have been reported [19,24]. Souza and Power reported increased hip internal rotation for females with PFP [19]. However, Willson and Davis concluded that females with PFP showed less hip internal rotation across daily activities such as single leg squats, running, and single leg

Tab. 1. Cross sectional studies: Altered Hip Mechanics and Patellofemoral Pain

	Age (year)	participants	Sample Size	Instrumentation	Test	Result
Gribble, 2004	21.4	Male and Female	13 healthy	Force plate Dynamometer	Single leg stance	There was a greater effect of localized fatigue of the frontal mover of hip compared to ankle on maintenance of postural control in SLS.
Dierks, 2008	18-45	Male and Female	20 healthy, 20 PFP	Motion analysis Dynamometer	Prolonged run	Runners with PFP indicated hip abductor muscle weakness that was associated with an increase in hip adduction during running.
Cowan, 2009	40	Male and Female	27 healthy, 10 PFP	Surface EMG Dynamometer Inclinometer	Stair climbing	Delays in activation of gluteus maximus and vastus medialis were observed in PFP group.
Souza, 2009	18-45	Female	20 healthy, 21 PFP	Motion analysis EMG	Running, Jumping, Step down	Females with PFP had greater hip internal rotation and decreased hip torque production compared to the control group.
Willson, 2009	18-35	Female	20 healthy, 20 PFP	Motion analysis Dynamometer	Single leg jump	PFP group showed less hip abduction, hip external rotation and trunk lateral rotation compared to control group.
Thijs, 2011	38	Female	77 healthy	Dynamometer Goniometer	Start to run	Isometric hip muscle strength might not be a predisposing factor for the development of PFP
Aminaka, 2011	21	Female	20 healthy 20 PFP	Surface EMG Motion Analysis	Stair ambulation	PFP subjects showed longer activation duration of the AL during stair ascent and shorter activation durations of the VMO and GMed during stair ascent and descent.
Willson, 2011	21	Female	20 healthy 20 PFP	Surface EMG Motion Analysis	Running	Females with PFP showed delay and shorter GMed activation compared to healthy group. Activity of GMax was not different between groups.
Bolgla, 2011	36	female	18 healthy 18 PFP	Dynamometer Surface EMG Motion Analysis	Stair-stepping, Single leg stance	Females with PFP showed hip muscle weakness. Also, they indicated greater EMG activity of GMed and vastis muscles.
Lee, 2012	27	Female	19 healthy 20 PFP	Force plate Dynamometer	Step down	Findings indicated that females with PFP showed impaired medial-lateral postural stability compared to control group.
Nakagawa, 2012	18-35	Male and Female	40 healthy 40 PFP	Isokinetic Dynamometer	Single leg squat	Subjects with PFP had greater ipsilateral trunk lean, contralateral pelvic drop, hip adduction, and knee abduction compared to healthy subjects.
Willy, 2012	18-40	Male and Female	40 healthy 40 PFP	Visual 3-D Inclinometer	Single leg squat, Running	Males with PFP showed increased knee adduction. In contrast, females with PFP indicated greater hip adduction and less knee adduction.
Nakagawa, 2013	18-35	Male and Female	40 PFP	VAS 3-D motion analysis	Step down	Results showed greater peak hip adduction, hip internal rotation and knee abduction in males and females with PFP.
Bolling, 2013	27	Male and Female	15 PFP	Isokinetic dynamometer 3-D motion analysis	Jump-landing	The results showed decreased eccentric strength of the hip external rotators and abductors that was correlated to increased frontal plane motion at the hip and trunk, respectively.
Hollman, 2014	18-36	Female	42 healthy	Kodak video camera Dynamometer Surface EMG	Single leg squat	Findings showed that increased hip adduction/medial rotation and decreased GMax recruitment correlated with increased knee valgus.
Nakagawa, 2014	18-35	Male and Female	30 healthy 30 PFP	Dynamometer Surface EMG 3-D motion analysis	Single leg squat, Curl up, Trunk Extension	PFP subjects showed increased ipsilateral trunk lean, hip adduction and knee abduction accompanied with decreased trunk isometric strength.

jumps [20]. The investigations suggested that altered hip kinematics increases retropatellar stress and may aggravate PFP symptoms [2].

The findings of recent studies support the effect of gender on hip kinematics in individuals with PFP [20-22]. Nakagawa et al. showed lower extremity kinematic differences between males and females with PFP. Their findings indicated increased ipsilateral trunk lean, contralateral pelvic drop, hip adduction and knee abduction during a single leg squat in males and females [25]. In addition, females with PFP showed increased hip internal rotation [24]. Willy et al. noted greater hip adduction and knee abduction angle during single leg stance in females compared with males [26]. Graci et al. noticed that females had different lower extremity kinematics during a single leg squat. They also suggested that females displayed a different trunk and pelvic movement pattern that increased the risk of injury and pain among them [27].

Excessive hip adduction and internal rotation during weight bearing activities may affect lower extremity kinematics [3]. Abnormal hip joint motions may influence the knee joint and patellofemoral joint kinematics and may cause functional impairment in all directions. Furthermore, these movements may cause the knee joint center to displace medially relative to the foot. As a result, a compensatory movement occurs at distal joint. This leads to dynamic knee valgus. Accordingly, excessive dynamic knee valgus has been shown to be related to lateral patellar displacement and contribute to multiple knee injuries such as patellofemoral joint disorders [7].

Findings from cadaver and magnetic resonance imaging (MRI) studies have demonstrated that excessive hip internal rotation increases lateral patellar displacement and patellofemoral joint stress [28]. This kinematic alteration has been observed in such activities as single leg stance, single leg jumping and single leg landing [1,18,29].

By considering hip and knee joint kinematic alterations in the frontal and transverse planes and increased risk of PFP, in quality of life studies, increased hip adduction and internal rotation have been suggested to be associated with increased pain and decreased functional status in males and females with PFP [30].

This review of the literature relating to lower extremity kinematics determines a strong link between altered hip kinematics and PFP. These alterations are found in the frontal and transverse planes as increased or decreased hip adduction/abduction and hip internal rotation/external rotation. Females display a different lower extremity movement pattern during activities. Accordingly, females may be at greater risk of developing PFP associated with hip kinematics. As a result, detailed assessment of lower extremity kinematics should be necessary in individuals with PFP.

MUSCLE ACTIVITY STUDIES

Several studies have assessed the relationship between hip muscle activity and PFP [10,11,22,31,32]. Most of these investigations reported hip muscle weakness in females with PFP [11,32]. Decreased hip muscle performance is a common finding in females with PFP [10]. A systematic review of 6 studies compared hip muscle performance between females with PFP and healthy subjects, demonstrating weakness of the hip extensors, abductors and external rotators [10]. The studies by Boling et al and Barton et al are inconsistent with these findings [1,10]. Abductor and external rotator muscle weakness is a cause of kinematic alterations (increased hip adduction and internal rotation) in individuals with PFP [7]. Hip abductor weakness results in excessive lateral trunk motion as a compensatory mechanism to maintain the center of pressure (COP) in the center of mass (COM) [7]. In addition, Prins and Wrulf found evidence for weakness of the external hip rotators, abductors and extensors in females with PFP [11]. Barton et al. reviewed studies that assessed the relationship between gluteal muscle activity and PFP. Their findings showed delayed and decreased gluteus medius activity during ascending and descending stairs [10]. Additionally, limited evidence was related to delayed and decreased gluteus maximus activity during running and increased gluteus maximus activity during stair ascending [1, 31]. A prospective study by Thijs et al. suggested that hip muscle weakness was not a predictor for the development of PFP [22].

Souza and Power assessed differences in hip muscle strength between individuals with and without PFP. This study enrolled 22 females with PFP and 20 healthy subjects. Hip muscle activation was assessed during running, jumping and a step-down activity. Their results showed decreased hip muscle strength in females with PFP [23]. Furthermore, increasing gluteus maximus recruitment was seen in order to stabilize the hip joint. This finding supports the proposed relationship between abnormal hip function and PFP [23]. In contrast, Hollman et al reported that gluteus maximus recruitment may control knee motion in the frontal plane during single-leg squatting. Their results indicated that decreased gluteus maximus recruitment in combination with increased hip medial rotation and adduction correlated with increased knee valgus [33].

Several studies have assessed changes in the gluteus medius in subjects with PFP [28-30]. Brindle et al. assessed electromyographic changes in the gluteus medius during ascending and descending stairs in individuals with PFP. They showed a delayed onset and shorter duration of the gluteus medius in ascending and descending stairs [12,13,34]. Aminaka et al. suggested the same results in assessing the electromyographic activity of gluteus medius during ascending and descending stairs [12]. Boling and his colleagues assessed the relationship between hip muscle strength with trunk and lower extremity kinematics during a jump-landing task in subjects with PFP [13]. The results of this study showed a significant correlation between decreased strength of the eccentric hip external rotators and abductors and increased motion at the hip and trunk in the frontal plane [13].

Rathleff et al illustrated hip muscle weakness in males and females with PFP compared with healthy subjects. A limited number of prospective studies also indicate that there may be no association between hip muscle strength and PFP. Therefore, diminished hip muscle strength may be a result of PFP rather than the cause [35].

Overall, as the results of these studies show, there is a variety of evidence supporting a relationship between hip muscle weakness and PFP. Most of them point to weakness of hip extensors, abductors and external rotators in individuals with PFP. Accordingly, strengthening of the hip musculature should be applied carefully in the treatment programme of these patients.

POSTURAL STABILITY STUDIES

Hip joint control plays an important role in pelvic and trunk stability. Multiplanar hip motion is needed to diminish postural sway in standing in different directions [7]. Gribble and Hertel evaluated the effect of hip and ankle muscle fatigue on postural control [11]. A total of 13 healthy subjects were requested to participate in the study. Measures of fatigue were obtained with an isokinetic machine. In addition, postural control was assessed using unilateral stance before and after fatigue measurement. Their results suggested that deficits in postural control in both frontal and sagittal planes may be due to fatigue of hip muscles. Additionally, fatigue of hip abductors relative to ankle stabilizers led to greater impairment in postural stability in the frontal plane [16]. Negahban et al. compared the effect of fatigue of hip abductors and knee extensors on postural stability between individuals with and without PFP. The results of this study demonstrated that fatigue of hip abductors generated greater postural instability than knee extensors [15].

A study by Lee et al. showed the effect of hip abductor muscle performance on dynamic postural stability in females with PFP. This study enrolled 20 females with PFP and healthy subjects. Postural stability was measured with a force platform. The results suggested that females with PFP exhibited greater impairment of postural stability than healthy subjects. Furthermore, the use of a hip stabilizing brace led to improvement in mediolateral postural stability in females with PFP. These findings indicate that hip abductors were an important contributor to medial-lateral postural stability [36].

Several investigations have used improvement in postural stability indices as an assessment tool to evaluate different treatment strategies in individuals with PFP [7,37]. Aminaka and Gribble assessed the effect of patellar taping on hip and knee kinematics in patients with PFP. Their findings illustrated that patellar taping may alleviate pain symptoms and improve postural stability during star excursion balance test (SEBT) in patients with PFP [37]. In addition, Miller et al compared the effects of lateral gluteal Kinesio taping and lumbopelvic hip manipulation in patients with unilateral PFP. Their findings indicated improvement in postural stability by facilitating gluteus medius activity in the Kinesio taping group [3].

As the results of the reviewed studies indicate, altered hip kinematics and weakness of hip muscles are two common findings that are consistently found in subjects with PFP. These kinematic alterations are seen in the frontal and sagittal planes. Systematic review studies indicate weakness of the hip abductor, external rotator and extensor muscles in individuals with PFP. Moreover, a postural stability deficit has also been observed in limited studies. In these studies, there was a relationship between lower extremity muscle fatigue and impaired postural control. The investigations suggested that there was a greater effect of hip muscle fatigue compared to the knee and ankle on maintenance of postural control. In addition, fatigue of the knee and hip flexor and extensor muscles resulted in postural stability impairments in both the frontal and sagittal planes, while ankle muscle fatigue resulted in minor postural stability impairments in the sagittal plane.

CLINICAL APPLICATION

A systematic biomechanical evaluation of the lower extremities including kinematics, strength and postural control is important for clinicians in the assessment, diagnosis and management of patients with PFP [2]. It is not surprising that an understanding of factors influencing lower extremity mechanics will aid clinicians in designing more effective management strategies [13,38-40]. Accordingly, acquired impairments resulting from muscle weakness, kinematic alterations and/or poor neuromuscular control should be addressed [13]. If, during the diagnostic work-up of a patient with PFP, the clinician identifies a lower extremity abnormality, he/she should make a decision to investigate the cause of the observed deviation [2].

CONCLUSION

Based on this review of the literature, we conclude that there is a strong relationship between lower extremity mechanics and PFP. Evidence shows hip joint kinematic alterations in the frontal and transverse planes in individuals with PFP. Compensatory strategies are used to correct kinematic alterations. Proximal impairments, including altered kinematics, weakness of lower extremity proximal muscles and impaired postural stability are seen almost exclusively in females with PFP compared with males. Gluteal muscle strengthening programs may improve performance in people with PFP. Therefore, further studies are needed to assess the effect of impaired muscle strength on treatment and improvement in the quality of life. Accordingly, hip mechanics assessment should be included in the examination of individuals with PFP.

In conclusion, further investigations are needed to evaluate the associations between hip joint mechanics and PFP. It appears that such investigations may be effective in selecting proper treatment strategies.

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