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Hip Function's Influence on Knee Dysfunction: A Proximal Link to a Distal Problem

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The purpose of this commentary is to describe the multifactorial relationships between hip-joint strength, range of motion, kinetics/kinematics, and various knee pathologies, specifically as they relate across an individual's life span. Understanding the interdependence between the hip and knee joints in respect to functional activity is a necessary and relevant aspect for clinicians to investigate to ameliorate various pathological presentations at the knee that might have a proximal relationship.

Keywords: patellofemoral pain syndrome, anterior cruciate ligament, rehabilitation

Knee pathology, as with other extremity and spinal joint dysfunctions, is often a complex interaction of multiple contributing factors. Rarely does a pathological presentation at the knee result from a single dysfunction at that joint. Although many times the dysfunction can be related to a pathological process directly at either the patellofemoral or tibiofemoral joint or both, it could also be the result of dysfunction more proximally, specifically the hip joint.

The influence of hip dysfunction on the knee joint might affect individuals across the life span. Individuals of different ages can, and often will, have different pathological processes or dysfunctions that are unique to their age group. The best examples of this would include ACL injuries most likely characteristic of adolescent and young adults, compared with knee osteoarthritis, which is more likely to be representative of older adults.

The purpose of this clinical commentary is to summarize the influences of the hip on knee pathology based on the current available evidence (see Table 1). We propose that an examination or intervention of the knee joint is not complete unless the more proximal aspects of the kinetic chain have been considered. We would also like to heighten awareness of the hip and knee relationship and the relevant implications across an individual's life span. Specific characteristics prevalent among individuals of different ages should also be considered in the examination or treatment regimen. Throughout this commentary, we have taken the approach of categorizing studies in our literature review by their design

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Table 1 Level of Evidence Supporting Specific Hip- and Knee-Dysfunction Relationships

Hip and knee relationship	Studies	Level of evidence supporting relationship
Hip influences and predicted lower extremity injury	Tyler et al[9]	Level II
	Tyler et al[10]	Level II
	Nadler et al[6]	Level III
	Leetun et al[7]	Level II
	Hollman et al[2]	Level III
Hip influences and patellofemoral pain	Brody & Thein[12]	Level V
	Thomee et al[13]	Level V
	Fulkerson[14]	Level V
	Doucette & Goble[15]	Level III
	Mizuno et al[16]	Level III
	Ramappa et al[17]	Level III
	Lee et al[18]	Level V
	Elias et al[19]	Level III
	Powers[20]	Level V
	Mascal et al[21]	Level IV
	Ireland et al[22]	Level III
	Robinson & Nee[23]	Level III
	Cichanowski et al[24]	Level III
	Bolgla et al[25]	Level III
	Willson & Davis[26]	Level III
	Piva et al[27]	Level III
	Powers et al[28]	Level III
	Wilson & Davis[29]	Level III
	Dierks et al[30]	Level III
	Natri et al[31]	Level I
	Bolgla & Malone[32]	Level V
	Boling et al[33]	Level III
	Tyler et al[34]	Level II
	Wilk et al[35]	Level V
	Witvrouw et al[36]	Level V
Hip influences and anterior cruciate ligament injury	Ireland[38]	Level V
	Fung & Zhang[39]	Level III
	Hewett et al[40]	Level II
	Ferber et al[41]	Level III
	Lephart et al[42]	Level III

(continued)

Table 1 ***(continued)***

Hip and knee relationship	Studies	Level of evidence supporting relationship
	McLean et al[43]	Level III
	Kernozek et al[44]	Level III
	Lawrence et al[45]	Level III
	Hewett et al[47]	Level II
	Onate et al[48]	Level III
	Pollard et al[49]	Level II
	Mandelbaum et al[50]	Level II
	Gilchrist et al[51]	Level I
	Sigward et al[52]	Level III
Hip influences and iliotibial band syndrome	Grau et al[56]	Level III
	Niemuth et al[55]	Level III
	Fredericson et al[53]	Level IV
	Noehren et al[57]	Level I
Hip influences and knee osteoarthritis	Deyle et al[58]	Level I
	Cliborne et al[62]	Level II
	Currier et al[63]	Level II

(prospective/predictive and cross-sectional or case control/descriptive studies) to highlight the nature of the studies and current levels of evidence.

Hip Influences and Predicted Lower Extremity Injury

Deficits in hip strength are implicated in numerous lower extremity pathologies. Researchers[1] have found increased gluteus medius activity in response to a sudden ankle-inversion maneuver in subjects presenting with and without ankle hypermobility. These findings indicated that the alteration in muscle-recruitment timing might be a compensatory mechanism to reduce postural sway or maintain postural control. Hollman et al[2] revealed that reduced hip-abductor strength relative to the adductors is associated with increased subtalar-joint pronation. Increased subtalar-joint pronation is believed to be implicated in lower extremity injuries, including ACL injury,[3] as well as lower extremity overuse injuries.[4,5] Side-to-side asymmetry in hip-extensor strength also has been observed in females with lower extremity injuries and low back pain.[6]

Leetun et al[7] were among the first researchers to prospectively determine an association between core (or lumbo-pelvic-hip complex) strength and risk of lower extremity injury. Athletes' core stability was measured at the beginning of their respective seasons. These athletes were then followed through an entire competitive season to determine which ones sustained a lower extremity injury.

Overall results indicated that males produced greater hip-abduction and hip-external-rotation strength, as well as greater quadratus lumborum endurance, than females. Athletes who sustained an injury were significantly weaker in hip abduction and external rotation. Logistic-regression analysis determined that hip-external-rotator strength was the only useful predictor of injury status. Evidence from this study revealed not only the relationship between core strength and lower extremity injury but also the greater risk of injury in females. The authors speculated that the significant weakness in females predisposed them to increased transverse- and frontal-plane motions compared with males. This increase in motion could therefore prejudice the female athletes to movements of increased femoral adduction and internal rotation and, therefore, greater potential risk of noncontact lower extremity injuries.

Nadler et al[8] also examined the relationship between lower extremity injury and hip-extensor and -abductor strength. In a group of 236 college athletes, a significant difference in the ratio of hip-abduction to -extension strength was noted on the left lower extremity of athletes with reported lower extremity injury compared with those without injury. Hip-extensor weakness was surmised the likely cause of this difference. Athletes with reported lower extremity injury demonstrated a significant residual difference in the ratio of hip-abduction to -extension strength. They concluded that the differences might be the result of injury-related muscle weakness, altered muscle-firing patterns, central inhibition, or unknown compensatory strategies, all of which might be risk factors for recurrent injury. Reasoning to support the screening of hip strength during preparticipation physicals was also provided. The authors felt that such screening might be an important factor to prevent recurrent injury.

Preseason screening of hip strength has identified athletes at risk for adductor strains. Tyler et al[9] have reported hip-adductor weakness as a predictor of adductor muscle strain in professional ice hockey players. In a prospective risk-factor-prevention study, 33 of 58 National Hockey League players, identified as at risk based on preseason hip-adductor strength, participated in a 6-week preseason prevention program. At-risk athletes were identified by manual muscle testing with use of a handheld dynamometer. Athletes whose abductor-to-adductor muscle-strength ratio measured less than 80% participated in the intervention program. Following the players prospectively for 2 seasons, the authors reported that only 3 sustained adductor strains, compared with 11 in the previous 2 seasons. These findings suggest that identifying those at risk and then performing interventions to target the limitations might help limit time loss resulting from injury.[9,10]

Another muscle group common to the hip and knee, the hamstrings, has also received attention with respect to preseason screening for prediction of athletic injury. In a recent 1-year prospective study[11] it was determined that hamstring injury in 6 out of 30 elite sprinters was associated with unilateral weakness during eccentric action of the hamstrings and concentric action of the hip extensors at isokinetic speeds of 60°/s. Differences in the hamstring:quadriceps and hip-extensor:quadriceps strength ratios were also evident between the injured and uninjured lower extremities. These differences were attributable to deficits in hamstring strength in the injured lower extremity. The authors proposed that the incidence of hamstring injuries might be reduced by identifying unilateral weakness of hip extensors and hamstrings in sprinters.

Hip Influences and Patellofemoral Pain Syndrome

Patellofemoral pain syndrome (PFPS) is one of the most common problems experienced by active adults and adolescents.[12,13] Researchers[14,15] have theorized that abnormal patella tracking causes excessive compressive stress to the lateral patellar facets, resulting in PFPS. Historically, clinicians have believed that an excessive quadriceps angle (Q angle) might contribute to PFPS etiology. Cadaveric[16–18] and computational-modeling[19] studies have both shown a relationship between an increased Q angle and increased lateral patella compressive forces. Powers[20] has theorized that increased hip adduction (femoral movement on the pelvis) might increase the Q angle through medial displacement of the patella relative to the anterior superior iliac spine. Increased hip internal rotation also might increase this angle through medial displacement of the patella relative to the tibial tubercle. Powers[20] further stated that strengthening the hip abductors and external rotators might minimize faulty hip kinematics that can increase patellofemoral-joint stress. Mascal et al[21] have provided preliminary evidence to support this premise. In their case study, a subject with PFPS showed decreased femoral adduction and internal rotation during a step-down maneuver after a 14-week hip-strengthening program.

Researchers[22–27] have further examined hip-abductor and -external-rotator strength and consistently reported weakness.[22–26] More important, Ireland et al,[22] Cichanowski et al,[24] Bolgla et al,[25] and Willson and Davis[26] have reported similar decreased hip-abductor (21% to 29%) and -external-rotator (9% to 17%) force, expressed as a percentage of body weight, for subjects with PFPS. These values are clinically useful because they provide a means of quantifying hip weakness.

Most of the aforementioned studies regarding hip weakness did not simultaneously examine kinematics, thus making it difficult to ascertain relationships between hip weakness and faulty movements. Mascal et al[21] only examined kinematics in a single subject. To our knowledge, Bolgla et al[25] were the first to simultaneously examine hip strength and hip and knee kinematics during stair descent in subjects with PFPS. Their subjects exhibited hip weakness but demonstrated hip and knee kinematics similar to those of matched controls. A limitation of this study was that subjects performed a relatively low-demand task and might have used compensatory patterns[28] to decrease the Q angle.

More recent investigations[26,29,30] have assessed hip and knee strength, kinematics, and kinetics during more demanding tasks. Willson and Davis[29] examined hip and knee kinematics in subjects with and without PFPS during progressively challenging tasks (single-leg squat, running, and repeated single-leg jumping). Subjects with PFPS exhibited greater hip adduction, but also greater hip external rotation, than controls. The researchers did not assess hip strength, thus precluding the ability to note an association between hip weakness and altered kinematics. In a follow-up study, Willson and Davis[26] examined trunk, hip, and knee strength, as well as hip and knee kinematics and kinetics during repeated single-leg jumps. Although subjects with PFPS demonstrated greater hip-adduction excursion, they did not demonstrate differences in hip-internal-rotation excursion. When only analyzing subjects with PFPS, they found a fair correlation ($r = -.40$) between hip-abductor strength and hip-adduction excursion. There was a poor correlation ($r = -.07$), however, between hip-external-rotator strength and hip-internal-rotation excursion. Dierks et al[30] examined hip strength and hip and knee kinematics in runners with and without PFPS before and after prolonged running. Like in the study by Willson and Davis,[26] there was a fair correlation ($r = -.34$) between hip-abductor strength and peak hip adduction at the beginning of the run. After prolonged running, subjects with PFPS demonstrated a higher correlation ($r = -.74$) between hip-abductor strength and peak hip adduction. No association was found between hip-external-rotator weakness and peak hip internal rotation. In summary, these findings[25,26,29,30] suggest that subjects with PFPS might not exhibit altered hip kinematics until their muscle strength falls below a certain threshold. More important, it remains elusive whether hip weakness was the cause or the result of PFPS. Additional research is needed to better understand the association between hip weakness, hip kinematics, and PFPS etiology.

Traditional rehabilitation programs have focused on quadriceps strengthening to treat PFPS. Although quadriceps strengthening is an important component of these programs,[31,32] a subset of subjects might gain additional benefit from hip strengthening. Recently, investigators[21,33,34] reported successful outcomes for patients who participated in a hip-strengthening program. Caution is necessary, however, when interpreting these results. PFPS is a multifactor problem,[35,36] and clinicians must develop and implement interventions based on individual presentation. Future research should focus on delineating a patient cohort that might respond favorably to a hip-strengthening program.

Hip Influences and Anterior Cruciate Ligament Injury

ACL injury is one of the more serious knee injuries, with a high incidence in females.[37] Recently, the National Collegiate Athletic Association[37] reported that female basketball players sustained ACL injury at a rate 2.89 times higher than male basketball players. Although treatment approaches after ACL injury can differ from PFPS, both conditions have similar factors that might contribute to injury.

Ireland[38] has described the “position of no return” mechanism for ACL injury in females. She hypothesized that the following positions might contribute to ACL injury: trunk forward flexion, hip adduction and internal rotation, knee valgus, and tibial external rotation. Using a cadaveric model, Fung and Zhang[39] demonstrated how excessive knee valgus, in combination with increased femoral internal rotation and tibial external rotation, can strain the ACL.

Experimental studies lend support to the potential of altered lower extremity kinematics contributing to increased ACL injury risk among females. Hewett et al[40] found that female athletes who performed athletic maneuvers with increased knee valgus were more susceptible to ACL injury. Moreover, researchers[41–44] have examined the influence of the hip on knee position and reported greater hip adduction, hip internal rotation, and knee valgus in females. Kernozek et al[44] compared kinematics between genders during a drop-landing task before and immediately after neuromuscular fatigue. They reported that females exhibited less hip abduction and more knee valgus after fatigue. McLean et al[43] examined moments during a sidestepping maneuver and found an association between peak knee-valgus moment and hip internal rotation. These authors inferred that females apply greater valgus loads to the knee and that hip position might influence this pattern. McLean et al[43] also concluded that interventions that focus on neuromuscular control at the hip might prevent ACL injury.

More recently, Lawrence et al[45] examined the influence of hip-abductor and -external-rotator strength on hip and knee kinematics and kinetics in females during a single-leg drop landing. Before collecting these data, they assessed hip-abductor and -external-rotator strength in a group of 72 females. Based on the hip-external-rotator strength values, they ranked subjects in order of ascending hip strength. Those in the top 22% tier were classified as stronger, and those in the lower 22% tier were considered weaker. Hip and knee kinematics and kinetics were assessed during the single-leg landing. Lawrence et al[45] found that the stronger females exhibited lower ground-reaction forces during landing and generated lower external knee-valgus moments. These findings provided preliminary evidence regarding the influence of hip strength on lower extremity mechanics.

The biomechanical influences mentioned here represent extrinsic factors amenable to change through interventions. Researchers[46–50] have recommended that ACL-injury-prevention interventions address the neuromuscular, kinematic, and kinetic factors that contribute to ACL injury. Hewett et al[47] showed that a program that emphasized a neutral (minimal knee valgus and knee varus) knee alignment during athletic maneuvers might reduce the risk of injury. Their program also emphasized that athletes should "land softly" so as to dampen vertical ground-reaction forces and minimize peak knee-adduction and -abduction moments. Onate et al[48] incorporated visual and auditory feedback as part of an intervention aimed at reducing ground-reaction forces during a vertical jump. This technique was an effective tool for training athletes to perform a vertical jump using a soft-landing pattern.

More recently, Pollard et al[49] examined hip and knee kinematics during a drop-landing task in a group of female soccer players. After initial testing, subjects participated in the Prevent Injury and Enhance Performance prevention program[50] throughout the soccer season. The researchers then retested subjects at the end of the season. Postseason findings showed no changes in knee-valgus angles during the drop-landing task, but subjects demonstrated significantly less hip internal rotation and significantly greater hip abduction. These findings were important because they were the first to specifically measure hip kinematics when assessing the effectiveness of a neuromuscular training program. Gilchrist et al[51] conducted a larger randomized control trial (clustered) in 1435 female college soccer players. They reported that athletes who participated in the program incurred a noncontact ACL injury 3.3 times less than controls. Together, these findings[49,51] suggest an association between hip function and ACL injury. Much like PFPS, future investigations are needed to better understand this relationship.

Although there is stronger support for the relationship between hip weakness and knee injury, more recent evidence[52] suggests that hip range of motion (ROM) should be considered more for individuals who present with excessive frontal-plane knee excursion during landing maneuvers. Sigward et al[52] reported a negative correlation between increased frontal-plane excursion and hip-external-rotation and ankle-dorsiflexion ROM in young female soccer players. Together, hip external rotation and ankle dorsiflexion explained 27% of the variance in frontal-plane excursion during a drop-landing task. It is noteworthy that hip-strength measures showed a poor correlation with frontal-plane excursion. These findings support the need for additional studies to better understand relationships between hip ROM, strength, and lower extremity kinematics.

Hip Influences and Iliotibial Band Syndrome

Iliotibial band syndrome (ITBS), a condition that makes up 12% of all overuse injuries in running, is the most common cause of lateral knee problems in runners.[53,54] It has been proposed that lateral gluteal muscle weakness might cause inadequate pelvic stability and reduced eccentric control of femoral adduction during the support phase of gait.[54] This has been demonstrated by Fredericson et al,[53] who compared hip-abductor strength in the injured and noninjured limbs of long-distance runners with ITBS with that of controls. Both males and females generated less hip-abductor torque on the affected limb than on the uninvolved limb. In addition, males and females both demonstrated significant increases in hip-abductor strength, and 22 of 24 athletes returned to pain-free running after a 6-week rehabilitation program. At a 6-month follow-up, no athletes reported any injury recurrence. Similar findings regarding hip-abductor weakness in the involved limb of runners with overuse injuries were reported by Niemuth et al,[55] who also found that the injured-side hip abductors and hip flexors were weaker than those on the noninjured side. These similar findings of involved-side hip-abductor weakness appear to demonstrate a favorable response to rehabilitation and the potential for improved pelvic control and, thus, control of femoral adduction.

Alternatively, Grau et al[56] found no significant difference for isometric, concentric, or eccentric peak torque of the hip abductors in controls versus those with ITBS. It is important to note that subjects in the Grau et al[56] study were asymptomatic at the time of testing, despite having been diagnosed with ITBS by a physician clinical examination, as well as having an MRI ruling out intra-articular knee pathology.

Noehren et al[57] prospectively studied various factors associated with ITBS. Their findings substantiated previous findings[41] reporting an association between increased peak hip adduction, increased knee internal rotation, and ITBS. These combined motions might stress the ITB by compressing it against the lateral femoral condyle. Successful treatment interventions[21,32–34,49–51,54] have focused on controlling these secondary-plane movements through strengthening, stretching, and neuromuscular reeducation of the proximal hip musculature. Although these studies focused primarily on ACL-injury prevention, one might reason that similar prevention strategies could be beneficial in preventing ITBS, as well.

Even though no definitive conclusions can be drawn, evidence appears to be mounting that hip-abductor weakness has potential as a predictive factor in ITBS. Other prospective studies are needed to better understand this influence of hip-abductor weakness on ITBS. These future studies should seek to determine whether excessive femoral rotation or adduction is more predictive of injury. Furthermore, based on prior studies, additional investigations with standardized muscle-testing procedures are needed to obtain conclusive results.

Hip Influences and Knee Osteoarthritis

The knee is the joint most commonly affected by osteoarthritis (OA), with more than 30% of adults over 60 years of age experiencing functional limitations caused by knee OA.[58] OA of the knee causes more clinical symptoms and disability than OA in any other joint in the body.[59] Currently there are more than 450,000 knee arthroplasties performed each year in the United States, a number expected to nearly double by 2020.[60]

Knee pain has been reported to arise from the hip and/or lumbar-spine region in a number of different conditions.[61] Significantly more subjects with knee OA demonstrated pain with several hip clinical tests than did asymptomatic individuals.[62] Thus, whether hip impairments in patients with knee OA are independent from, or a result of, gait alterations and altered knee function, the functional squat test might be an important tool for determining overall lumbo-pelvic-hip and knee-complex function. The fact that this test requires movement at the spine, hip, knee, and ankle led to speculation that it would be an appropriate general screen of function in these areas.[62] Given the increased prevalence of painful-hip test findings in patients with knee OA, it follows that evaluating the hip joint might be beneficial in this patient population. The results of a hip examination in this population might identify impairments of the hip region that could be a contributing source of symptoms and might need to be considered in intervention strategies. Therefore, examining the hip in patients with knee OA seems not only plausible but necessary.[62]

Treatment of knee OA has been investigated via different intervention strategies. Cliborne et al[62] investigated the short-term response to hip mobilization in patients with knee OA. An immediate increase in ROM was demonstrated in hip flexion, functional squat, and flexion, abduction, and external rotation (FABER) position after mobilization of the anterior and/or posterior hip capsule. A significant increase in mean composite ROM (sum of hip flexion, functional squat, and FABER ROM) of 12.1° was noticed immediately after mobilization. The authors concluded that examination of and intervention for the hip might be indicated in patients with knee OA because patients experienced increases in ROM and decreased pain, and fewer patients had painful test findings immediately after a single session of hip mobilizations.[62]

A clinical prediction rule investigating this relationship has also recently been developed.[63] This rule identifies subjects with knee OA likely to demonstrate short-term (48 hours) improvement (numerical pain rating and global rating of change scales) in response to hip mobilization. The clinical prediction rule comprises 5 variables: hip or groin pain or paresthesia, anterior thigh pain, passive knee flexion less than 122°, passive hip internal rotation less than 17°, and pain with hip distraction. A likelihood ratio of 5.1 and a successful response to hip mobilization of 92% was found for subjects presenting with 1 of these variables, and a likelihood ratio of 12.9 with a probability of success of 97%, for subjects with 2 variables present.

Muscle-activation level is another area of concern regarding the interdependence of the hip and knee. Because subjects with knee OA have demonstrated increased hamstring-muscle activation while executing activities of daily living,[64] exercise interventions focusing on not only quadriceps strengthening but also increased quadriceps/hamstring muscle balance have been recommended.[65] This recommendation is made primarily because altered muscle activation might interfere with the normal load distribution in the knee in these subjects.[65]

Hip and knee strength and power have been unequivocally correlated with gait speed, stair climbing, and transfers.[65–68] These tasks all require weight-bearing movements that simultaneously involve the hip and knee. Adequate strength and neuromuscular coordination from many lower extremity muscles, especially the quadriceps and hamstrings, are therefore needed to facilitate this type of function.[69]

Although there appears to be benefit from manual therapy and lower extremity strengthening when performed in isolation, the combination of manual therapy techniques (at the hip, knee, and spine) and joint-mobility and strengthening exercises has also been reported to be beneficial for knee OA.[58,70] Improvements in motion (11%), pain (33%), and gait speed (11%) were noted with stretching, strengthening, and manual therapy procedures over a 4- to 6-week period of physical therapy.[70] These findings suggest the need for an intervention designed to meet individual impairments and functional limitations. Additional studies are needed to determine the most efficacious treatment approach.

An interdependent relationship between the lumbo-pelvic-hip complex and knee OA, although not clearly defined, does appear to exist. Relationships between these areas in respect to decreased motion, decreased muscle activation, lower extremity strengthening, and manual therapy intervention strategies need further clarification, with development of clinical prediction rules recommended to help guide general practice.

Conclusion

The current available literature supports a multidimensional influence of the hip on knee dysfunction throughout the life span. A growing body of evidence suggests that hip weakness, as well as altered lower extremity mechanics, might contribute to many knee injuries across the life span. Furthermore, authors from more recent studies have inferred that interventions at the hip can improve knee function. Screening for hip weakness and lack of rotation mobility also seems warranted to prevent potential knee injury. Granted, although many pathological processes at the knee have been demonstrated to be multifactored, we contend that many factors might originate in the hip joint. It is our hope that with continued research, specific criteria will be elucidated that will help clinicians more accurately determine which subjects will benefit the most from interventions that address hip function.

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