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Strategies to reduce joint load in the medial compartment of the knee during gait in individuals with osteoarthritis: a review of the literature

Estratégias redutoras da carga no compartimento medial do joelho durante a marcha em indivíduos com osteoartrite: uma revisão da literatura

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Introduction: Increased joint load on the medial compartment of the knee during gait is a mechanical factor responsible for pain and progression of medial knee osteoarthritis. The knee external adductor moment of force is a kinetic parameter that correlates with the joint load in the medial compartment. **Objective**: The aim of this study was to conduct a narrative review of the biomechanics strategies during gait of individuals with medial knee osteoarthritis that reduce external adductor moment of force of the knee. **Methods**: The review of the literature was conducted in the databases MEDLINE, PUBMED and PEDro and included articles published between 2000 and 2011. It was selected transversal, theoretical, correlational and longitudinal studies as well as controlled clinical trials. Results: Decreased gait velocity, increased external rotation of the foot, increased internal abductor moment force of the hip and lateral trunk inclination to the side of the support limb are compensatory strategies used to reduce the external adductor moment of force of the knee during gait of individuals with medial knee osteoarthritis. The lateral trunk inclination may be beneficial in a short term, however it decreases the activity of the abductors muscles of the hip during the support phase of the gait favoring compensation that could result in the progression of medial knee osteoarthritis. **Conclusion**: Strengthening of the abductors muscles of the

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hip reduces pain, improves the function and prevents compensations that in a long term could possibly accelerate the progression of the medial knee osteoarthritis.

Keywords: Osteoarthritis. Knee. Gait. Kinetics.

Resumo

Introdução: *O aumento da carga articular no compartimento medial do joelho durante a marcha é um fator mecânico responsável pela dor e progressão da osteoartrite medial do joelho. O momento de força externo adutor do joelho é o parâmetro cinético que correlaciona com a carga articular no compartimento medial do joelho.* ***Objetivos****: O objetivo deste estudo foi realizar uma revisão narrativa da literatura das estratégias biomecânicas durante a marcha em indivíduos com osteoartrite medial do joelho que reduzem o momento de força externo adutor do joelho.* ***Métodos****: A revisão da literatura foi realizada nas bases de dados MEDLINE, PUBMED e PEDro, incluindo artigos publicados entre 2000 e 2011. Foram selecionados artigos transversais, teóricos, de correlação e longitudinais, assim como ensaios clínicos controlados.* ***Resultados****: A diminuição da velocidade da marcha, aumento do ângulo de rotação externa do pé e do momento de força interno abdutor do quadril, inclinação lateral do tronco são estratégias compensatórias que reduzem o momento de força externo adutor do joelho durante a marcha em indivíduos com osteoartrite medial do joelho. A inclinação lateral do tronco pode ser benéfica em curto prazo, porém diminui a atividade dos músculos abdutores do quadril durante a fase de apoio da marcha favorecendo compensações que podem acarretar na progressão da osteoartrite medial do joelho.* ***Conclusão****: O fortalecimento dos músculos abdutores do quadril reduz a dor, melhora a função e previne compensações que em longo prazo poderiam acelerar a progressão da osteoartrite medial do joelho.*

Palavras-chave*: Osteoartrite. Joelho. Marcha. Cinética.*

Introduction

Osteoarthritis (OA) is a degenerative chronic disease of multifactorial etiology, with interrelationship between systemic and local factors (1). Systemic factors include ethnicity, older age, gender, hormonal status, genetic factors, bone density and nutritional factors Local factors result in abnormal mechanical stress on the affected joints, and include obesity, changes in the articular mechanics (ligamentous laxity, misalignment joint and muscle weakness), proprioceptive deficits, injury history of the joint, occupational factors and effects of physical and sporting activities (1 - 4).

In the initial stage of OA occurs fibrillation of the articular cartilage surface with deep fissures and calcification of the cartilage layer and subchondral bone sclerosis and osteophyte formation develop with disease progression (1). These structural changes of the articular cartilage and subchondral bone entail an inflammation of the synovial membrane. The result of this pathological process of OA is the reduction of the articular cartilage ability to dissipate loads and maintain joint congruity during weight-bearing activities (5). Studies in developed (6, 7) and emerging (8) countries show that the prevalence of symptomatic knee OA taken from radiography in the elderly, ranged from 5.6% to 8.7% in men and 11.4 to 15%, 4% in women.

The clinical criteria for the diagnosis of OA include pain, age over 50 years, morning stiffness (lasting less than 30 minutes) or the crackling active movement (9). The criteria on the degree of severity of knee OA proposed by Kellgren and Lawrence are extensively used these days and include: grade 0 = no osteophytes (no radiographic changes), 1 = possible osteophytes (uncertainty in radiographic change), 2 = definite osteophytes and possible reduction of the articular space (mild OA), 3 = multiple bone spurs and joint space narrowing, sclerosis and possible deformity of the bone contour (moderate OA), and 4 = large osteophytes, severe sclerosis, defined deformity the bone contour and significant reduction in joint space (severe OA) (10).

In the knee joint, the medial tibiofemoral compartment is the place most affected by OA (11). This susceptibility may be explained by the greater body load that occurs, between 60 and 80% of the gait cycle, in the medial compartment (12, 13).

The increase in joint mechanical loads on the medial compartment of the knee joint is considered an important factor in the development and subsequent progression of the medial knee OA (14, 15). Studies quantifying articular loads in subjects with knee OA have received attention in recent years (13, 15-17). The overload joint can be estimated by calculating the external adductor moment of the knee, obtained through the assessment of gait kinematics and kinetics (11, 18). The moment of force is a result of the combination of kinematic variables, ground reaction forces (GRF) and inertial properties of the body segments (19) and is calculated using the inverse dynamics approach. Applying the third Newton's law, the external moment of force is balanced by an internal moment of equal magnitude but opposite in direction and generated by the muscles, bones and soft tissues (20). Zhao et al. (21) showed a high correlation between the external knee adductor moment and the joint contact forces in the medial compartment of the knee during walking (R = 0.77). Miyazaki et al. (14) found that increased external adductor moment of the knee is a risk factor in the progression of the medial knee OA and an increase of 1% in the kinetic parameter increases 6.5 times the risk of disease progression.

Recent studies (17, 18, 22) reported that individuals with medial knee OA have greater external adductor knee moment throughout the stance phase of gait compared with asymptomatic individuals. Müdermann et al. (23) analyzed the external adductor moment of the knee during gait of 44 patients with OA of the medial knee compartment of varying degrees of severity. The results showed that individuals with mild to moderate OA had lower external knee adductor moment than individuals at an advanced stage of the disease. Thus, the external adductor moment of the knee during walking increases with disease progression. Added to this, some individuals in this study were able to alter the mechanics of the gait in order to reduce load on the medial compartment of the knee in the early stages of the disease.

Therefore, it is important to study the strategies that reduce the external adductor moment of the knee during gait in individuals with medial knee OA to guide the rehabilitation process, in order to decrease pain and slow the progression of this disease (11, 24 - 26). Previous studies had indicated that some spatial-temporal, kinematic and kinetic gait parameters might reduce the external adductor moment of the knee (11, 16, 24, 25). Thus, this review aims to identify these biomechanical strategies and discuss how clinicians could work with their patients to reduce the pain and consequences of the medial knee OA.

Methods

A non-systematic review of the literature was conducted using databases MEDLINE, PUBMED and PEDro. Articles analyzed were published between 2000 and 2011. The keywords used in the search were: osteoarthritis (OA), knee, gait, biomechanics and kinetics.

The literature search was focused on cross-sectional observational studies with following criteria: compared the kinematic, kinetic, spatial and temporal variables during gait in individuals with medial knee OA of varying degrees severity with asymptomatic. It was also included studies that identified the correlation between biomechanical variables and reduced load on the medial knee compartment and on the external adductor at the knee, longitudinal studies examining the effect of strategies that reduced the knee external adductor moment, clinical trials that assessed the efficacy of interventions focused on strategies that reduced load on the medial knee improving pain and function of the individuals.

Articles written in English or Portuguese were selected for the review. However, articles with methodological deficiency, for example, lack of homogeneity among groups of individuals studied, lack of a control group that difficult the integrity of the results and selection of individuals with OA on the tibiofemoral side of the knee, or patellofemoral, were excluded from this literature revision.

The titles and abstracts of the articles were analyzed by the authors. Studies that met the inclusion criteria were obtained in full. Each article was evaluated separately according to the methodological quality, and subsequently, the authors discussed the relevance of the articles for the study. If there was a disagreement between the authors, the articles were analyzed until they reached a consensus. Thus, the articles were included in the review of the literature when both authors agree to do so. Articles reviewed should contain information relevant to the topic that could be compared to other studies in other to be included in the review.

Results

Research in the databases resulted in 42 studies relevant to the topic discussed, all in English. However, atfter careful assessment of titles and abstracts by the authors of this study, on 23 articles were included for the preparation of this review. The main grounds for exclusion of some items were the lack of clarification of the knee joint compartment affected by OA and non-allocation of a control group. The lack of a control group undertakes the causal conclusions of a study.

Of the articles investigate, there was one systematic review (27), one longitudinal study (11), two clinical trials (28, 29), four correlational studies (23 - 25, 30) and the remaining 15 studies were cross-sectional (16 - 18, 22, 26, 28, 29, 31 - 38). The 23 selected articles are summarized on Table 1.

Table 1 - Characteristics of the 23 studies selected for the review (To be continued)

Studies	Design	Population	Variables	Results
Astephen et al., 2008 (17)	Transversal	Group medial OA moderate (n = 60) Group OA medial severe (n = 60) Group control (n =60) Pared by age	Gait Velocity, internal hip abductor moment and EMG activity of the rectus femoris	Gait velocity decreased with disease advance ($p < 0.0001$). OA groups presented greater internal hip abductor moment and EMG activity of the rectus femoris during stance compared to the control group ($p < 0.001$).
Chang et al., 2005 (11)	Longitudinal	Group medial OA (n = 57)	Internal hip abductor moment and disease progression OA.	Greater internal hip abductor moment associated with the probability of disease progression.
Tanaka et al., 2008 (16)	Transversal	Group medial OA (n = 12) Group control (n = 5)	Trunk inclination angle	No significant difference was found.
Mündermann et al., 2005 (18)	Transversal	Group medial OA (n = 42) Group control (n = 42) Pared by age, sex, height and BMI	External adductor moment of the knee internal hip abductor moment	OA group presented higher peak knee external adductor moment and lower peak hip internal abductor moment compared to the control group ($p = 0.039$ and $p < 0.05$).
Linley et al., 2010 (22)	Transversal	Group medial OA (n = 40) Group control (n = 40) Pared by age and gender	External adductor moment of the knee and trunk lateral inclination.	OA group presented higher peak knee external adductor moment compared to the control group ($p = 0.05$). No difference in lateral trunk inclination.
Mündermann et al., 2004 (23)	Correlation	Group medial OA (n = 44) Group control (n = 44) Pared by age, sex, height and mass	Gait velocity and external adductor moment of the knee.	OA group presented higher peak knee external adductor moment compared to the control group ($p = 0.009$). Group OA presented lower external adductor moment when walked at slower velocity (R2= 0.089, $p = 0.005$).
Chang et al., 2007 (24)	Correlation	Group medial OA moderate and light (n = 56)	External rotation angle of the foot and external adductor moment of the knee.	A negative correlation between magnitude of the angle of external rotation and the second peak of external adductor moment of the knee (r = -0.041, p = 0,002). Greater external rotation angle of the foot associated with probability of disease progression.

Table 1 - Characteristics of the 23 studies selected for the review (To be continued)

Studies	Design	Population	Variables	Results
Hunt et al., 2008 (25)	Correlation	Group medial OA (n = 114)	External adductor moment of the knee; trunk lateral inclination and external rotation angle of the foot	Negative correlation between the peaks external adductor moment and external rotation of the foot (r= -0.31, -0.26). Negative correlation between the peaks external adductor moment and trunk lateral inclination (r= -0.39, -0.33).
Rutherford et al., 2008 (26)	Transversal	Group medial OA light and moderate (n = 46) Group OA severe (n = 44) Group control (n = 50)	Gait velocity and external rotation angle of the foot.	Group severe OA presented lower gait velocity compared to the control group ($p < 0.001$). No significant difference in the external rotation angle of the foot between group.
Kaufman et al., 2001 (28)	Transversal	Group medial OA (n = 139) Group control (n = 16)	Velocity and knee range of motion sagittal plane during gait	OA group presented lower velocity and knee range of motion compared to the control group ($p < 0.05$, $p < 0.001$).
Astephen e Deluzio, 2005 (29)	Transversal	Group OA severe (n = 50) Group control (n = 63) Pared by height, mass and BMI	Gait velocity and external adductor moment of the knee	OA group presented lower velocity and greater external knee adductor moment compared to controls ($p < 0.001$).
Thorp et al., 2006 (31)	Correlation	Group OA medial light (n = 66) Group OA medial moderate (n = 23) Group Control (n = 28)	Gait velocity, external adductor moment of the knee and time spent in stance.	Positive correlation (r = 0.302, $p < 0.01$) between OA severity and the duration of the stance phase; negative correlation with gait velocity (r= - 0.341, $p < 0.01$) external adductor moment of the knee increased with disease progression.
Gok et al., 2002 (32)	Transversal	Group medial OA (n = 13) Group control (n=13) Pared by age, height, mass and dominant side	Gait velocity, cadence, stride length, stride time and double support time.	OA group presented lower gait velocity, cadence, stride length (p = 0.05, p = 0.03, p = 0,03), and greater stride time and double support time (p = 0,03, p = 0,01) compared to control group.
Zeni and Higginson, 2009 (33)	Transversal	Group medial OA moderate (n = 21) Group medial OA severe (n = 13) Group control (n = 22)	External adductor moment of the knee, knee angle in the sagittal plane and hip angle in the frontal plane. Variables were compared with self-selected velocities, control (1 m/s) and fast velocity.	OA groups presented significant increase in all variables studied at fast velocity compared to self-select speed ($p < 0.001$). The results showed that the variables are dependents on gait velocity. Individuals with OA reduced gait velocity with the objective to reduce knee load on the medial compartment.
Robbins and Maly, 2009 (34)	Transversal	32 asymptomatic individuals	Peak and impulse of the External adductor moment of the knee during gait at self-selected speed, fast and slow.	With slower gait velocity there was a decrease on the knee load, but an increase in impulse ($p < 0.05$), or, the knee received lower load but for a longer time.

Table 1 - Characteristics of the 23 studies selected for the review (Conclusion)

Studies	Design	Population	Variables	Results
Hunt et al., 2006 (30)	Correlation	Group OA medial (n = 100)	External adductor moment of the knee, ground reaction force (GRF) in the frontal plane and lever arm of the GRF with the knee joint.	There was a significant positive correlation between the external adductor moment of the knee and the GRF in the frontal plane ($p < 0.05$), and between the moment of force and the lever arm of the GRF FRS ($p < 0.01$).
Lynn e Costigan, 2008 (35)	Transversal	Group medial OA (n = 12) Group control (n = 12) Pared by age and sex	Gait with foot external rotation, internal rotation and no rotation, external adductor moment of the knee and EMG activity of the hamstrings.	OA group presented greater external adductor moment of the knee and lower EMG hamstrings activity compared to the control group ($p < 0,05$). The external rotation of the foot decreased in external adductor moment.
Hubley-Kozey et al., 2006 (36)	Transversal	Group medial OA (n = 40) Group control (n = 38)	Gait velocity, EMG activity of the medial and lateral hamstrings	OA group presented lower velocity compared to the control group ($p < 0.005$). OA group presented greater EMG activities of the hamstrings compared to the control group ($p < 0.003$).
Simic et al., 2011 (27)	Systematic Review		Mechanical alterations during gait reduce the external adductor moment of the knee.	Limited evidence to support that mechanical alterations during gait reduce the external adductor moment of the knee. However, trunk lateral inclination and use of contra-lateral crutches showed promising results
Mündermann et al., 2008 (37)	Transversal	19 healthy individuals	External adductor moment of the knee during gait and with trunk inclined laterally	Gait with increased lateral trunk inclination decreased external adductor moment of the knee significantly ($p < 0,001$).
Briem e Snyder-Mackler, 2008 (38)	Transversal	Group medial OA (n = 32). The inferior asymptomatic was the control group	External adductor moment of the knee and internal abductor moment of the hip.	No difference in the external adductor moment of the knee between limbs. Lower hip internal abductor moment on the OA limb during initial stance ($p < 0.001$).
Sled et al., 2010 (39)	Clinical Trial	Group medial OA (n = 40) Group control (n = 40) Pared by age and gender	Effects of strengthening program of the hip abductor on pain (WOMAC), external adductor moment of the knee and function (5-STS	Group OA presented lower isokinetic force of the hip abductor compared to the control group in the beginning of the study ($p = 0.03$) Group OA improved pain, function significantly after the program ($p = 0.03$, $p = 0.02$). No significant reduction of the external adductor moment in the OA group after the program
Thorp et al., 2010 (40)	Clinical Trial	Group medial OA (n = 6)	Effects of a strengthening program on the hip abductors, quadriceps and hamstrings over the external adductor moment of the knee and the pain score at the WOMAC.	Significantly reduction of the external adductor moment of the knee and pain score after the program ($p < 0.05$).

Discussion

Spatial and temporal gait parameters

Studies have shown significant differences in gait of individuals with and without knee OA. The spatial and temporal changes included: reduced gait speed (22, 28, 29, 31, 41), step length and cadence (20, 31, 42, 43) and longer time spent in double support phase (22, 32, 43).

These changes, however, are dependent on the severity of OA. Recently, Thorp et al. (31) showed a positive correlation ($r = 0.302$, $p < 0.01$) between the degree of severity of OA and the duration of the stance phase and a negative correlation with gait speed ($r = -0.341$, $p < 0.01$). Similarly, Astephen et al. (17) demonstrated that individuals with medial knee OA tend to slow the gait with the advance of the disease. The authors attributed these changes to compensatory responses during gait in an attempt to stabilize the knee joint and therefore to decrease pain.

Changes in gait speed have been associated with the biomechanics of the lower extremities in patients with knee OA and asymptomatic (44, 45). Zeni and Higginson (33) demonstrated the importance of gait speed in analyzing parameters that are dependent on the magnitude of the GRF and acceleration of body segments in individuals with medial knee OA and asymptomatic. Asymptomatic individuals with moderate to severe knee OA were assessed on self-selected speeds, controlled (1m/s) and the fastest speed tolerated. The fastest speed was determined as the speed that the individuals felt comfortable and still able to maintain the double support phase. The results showed that the magnitude of the moments of the ankle and knee, the angular displacement of the hip in the sagittal plane and frontal of the knee and the vertical anteroposterior peak of the GRF were dependent on speed. Asymptomatic individuals with moderate OA showed a significant increase in all the variables studied at the fastest speed compared to self-selected speed. However, in the severe OA group this difference was not observed. When the speed was controlled (1m/s) no difference between groups in the variables studied were found. The authors concluded that gait speed is a contributing factor to differences in gait parameters between subjects with and without knee OA.

The GRF is the product of mass times the acceleration of body motion, thus increasing acceleration of the body's center of mass results in a higher magnitude of the GRF, and consequently greater moment of forces. Mündermann et al. (23) reported a linear correlation between the peak external adductor moment of the knee and walking speed, suggesting that individuals with mild to moderate OA of the medial compartment are able to decrease this moment by reducing gait speed. Similar results were reported by Thorp et al. (31) and Deluzio and Astephen (46).

Robbins and Maly (34) found that by reducing the speed of gait of healthy individuals, there was a decrease in peak load on the knee but there was an increase in impulse, i.e., the knee received less load but for a longer time.

Angular displacement of the foot and trunk

Increased foot external rotation angle and lateral inclination of the trunk towards the stance limb are kinematic parameters that reduce the external knee adductor moment consequently decrease pain and slow progression of OA medial knee (16, 24).

During gait, the vector of the GRF has its point of application on the center of pressure on the sole of foot and travels towards the body center of mass (25). The length of the lever arm of the GRF with respect to the center of rotation of the knee joint in the frontal plane is directly proportional to the magnitude of the external adductor moment of the knee (30). Changes in pressure center positions in the foot or the body's center of mass during walking alter the length of the GRF lever arm. Therefore, an increase in the external rotation angle of the foot shifts laterally the centre of pressure and reduces the length of the GRF lever arm, or the distance of the GRF to the center of rotation of the knee joint, thus reducing the external adductor moment of the knee (24, 26).

In the study by Chang et al. (24) a negative correlation between the external rotation angle of the foot and the external adductor moment of the knee in individuals with medial knee OA during the terminal phase of gait support was found. In addition, it was demonstrated that the increase in the external rotation angle of the foot increases the likelihood of progression of the medial knee OA over a period of 18 months. Similarly, Lynn and Costigan (35) observed that increasing the external rotation angle of the foot reduced the electromyography activity of the medial hamstring muscles and increased the activity of the femoral biceps muscle. These changes in neuromuscular control generate an internal abductor, which minimizes the high loads in the medial compartment of individuals with medial knee OA (20, 29, 32, 36).

Hunt et al. (25) in a study with 114 patients with medial knee OA demonstrated a strong correlation between the increased foot external rotation angle and the reduction of the external adductor moment of the knee during the terminal stance, however, lateral inclination of the trunk towards the stance limb was the variable that best explained the variation of the external adductor moment of the knee. In addition, in the systematic review presented by Simic et al. (27) it was reported that increased trunk lateral inclination was the gait change with best scientific evidence in the reduction of the external adductor moment of the knee at initial stance.

The lateral inclination of the trunk towards the stance limb reduces external adductor moment of the knee by moving the body's center of mass laterally, reducing the lever arm of the GRF with respect to the center of knee rotation (25). Mündermann et al. (37) analyzed the relationship between external adductor moment of the knee during gait with the increased and normal trunk inclination in the stance phase of 19 healthy individuals. The results showed that 10 degrees of trunk inclination reduced on average 65% external adductor moment of the knee. In the study by Tanaka et al. (16) there was no significant difference in trunk inclination between asymptomatic individuals with medial knee OA. This result could be explained by the limitations of the study, as cited by the authors, for example, the small number of individuals studied (OA group 12 individuals and 5 in the control group). On the other hand, Linley et al. (22) compared the lateral inclination of the trunk and pelvis during gait among 40 individuals with medial knee OA and 40 asymptomatic pared by age and gender. Using principal component analysis, the results indicated that individuals with medial knee OA had greater lateral inclination of the trunk and pelvis towards the stance limb during initial and mid stance when compared to asymptomatic individuals.

The literature indicates that increased trunk inclination is a modification adopted by individuals with medial knee OA (16, 22, 41). However, it is unknown if this gait modification would be beneficial in the long run or an effective intervention for those individuals. More studies are needed to understand the role of lateral trunk inclination as an effective intervention for patients with medial knee OA.

Kinetic parameters

Another strategy used to prevent the progression of knee OA is increased hip internal abductor (11, 18). The hip abductor muscles during the stance phase of gait are responsible for preventing the drop of the opposite pelvis, thus ensuring a smooth ride of the center of gravity (47). Weakness or decreased force of the hip abductor muscles during stance may lead to a drop of the contralateral pelvis. This would result in a displacement of the body's center of gravity toward the member that is in the swing phase, resulting in an increase of the GRF lever arm with respect to the center of rotation of the knee joint, and therefore increasing the external adductor moment of the knee in stance.

Chang et al. (11) demonstrated the importance of the internal abductor moment of the hip in a longitudinal study conducted with 57 individuals with medial knee OA. The joint space narrowing at the knee joint was the variable used to determine the progression of OA 18 months after the first data collection. The results showed that individuals who had higher peak hip internal abductor moment were less likely to disease progression (odds ratio = 0.48; range of confidence = 0.16 to 0.81). The authors concluded that increasing the forces at the hip abductors while walking reduces the load on the articular medial compartment of the knee, resulting in protecting against the progression of OA.

Astephen et al. (17) reported significant difference in the internal abductor moment of the hip during the loading response and mid stance of gait between individuals with moderate and severe Knee OA. The asymptomatic individuals had greater internal hip abductor moment than the individuals with knee OA. Similar results have been reported by Briem and Snyder-Mackler (38). The authors attributed this finding to the increased lateral trunk inclination to the affected OA side during the stance phase. The lateral shift places the weight of the body closest to the hip joint, reducing the length of the GRF lever arm in relation to the center of rotation of the hip joint and consequently the external force decreases requiring less from the abductors muscles of the hip (38). Sled et al. (39) reported that individuals with medial knee OA have weakness of the abductor muscles of the hip compared to asymptomatic individuals.

Although the strategy of trunk inclination reduces the magnitude of the knee load, it also reduces the demand over the hip abductor muscles during the stance phase of gait leading to weakness of the abductor muscles (38). Therefore, the most efficient way to stop this vicious cycle would be by strengthening the abductor muscles of the hip to prevent the development of compensation in individuals with medial knee OA.

In Thorp's et al. (31) the pilot study a program to strengthen the quadriceps muscles, hamstrings and emphasizing the hip abductors in open and closed kinetic chain resulted in significant reduction of pain and in the external adductor moment of the knee in OA individuals during gait. However, the study had a lower statistical power, a small sample size and no control group, therefore a cause and effect relationship conclusion is impossible.

Moreover, Sled et al. (39) investigated the effect of a home-based program of strengthening the hip abductor muscles on function, pain, on the concentric isokinetic strength and on the external adductor moment during gait in a group of 40 individuals with medial knee OA. The control groups consisted of 40 individuals without diagnostic of OA pared by age, gender with the OA group. The strengthening program had an 8-week period. After the program the medial knee OA group showed significant improvement in pain and function assessed by the test sit-to-stand 5 times (5-STS compared to the control group. The concentric isokinetic strength of the hip abductor muscles increased significantly after the strengthening program in the OA group. However, there was no significant reduction in the external adductor moment of the knee in the OA group. The authors explain this finding by the theory that increasing the strength of the abductor hip muscles could have increased the stability of the trunk, decreasing the lateral bending of the trunk to the stance limb, hence there was an increase in length of the GRF lever arm relative to the knee center of rotation, canceling the reduction in the external adductor moment after knee strengthening program.

Although the interventions that reduce the external adductor knee moment in individuals with medial knee OA include the use of bracing (48), insoles (49) and strengthening of the quadriceps muscle (50), this literature review demonstrates the importance of strengthening the hip abductor muscles for the prevention of compensations, in reducing pain and improving function and in the delay of progression of medial knee OA.

Conclusions

The increase load on the medial compartment of the medial knee during gait is a mechanical risk factor for progression of the disease. The evidence from the literature indicates that the decrease in walking speed, rising up the external rotation angle, the lateral inclination of the trunk towards the limb that is in the stance phase and the increase in the abductor internal moment of the hip are variables that reduce the adductor knee external force during gait in individuals with medial knee OA. Recent studies indicate that the strengthening of the abductor hip muscles reduces pain, improves function and prevents compensation in individuals with medial knee OA. However, there is a need for more randomized clinical trials, since most studies are observational in nature, to clarify the role of the moment of the abductor internal force in hip reduction of external force moment adductor knee during gait.

Refererences

1. Garstang SV, Stitik TP. Osteoarthritis: epidemiology, risk factors, and pathophysiology. Am J Phys Med Rehabil. 2006;85(11 Suppl):S2-11.

2. Richette P, Corvol M, Bardin T. Estrogens, cartilage, and osteoarthritis. Joint Bone Spine. 2003;70(4):257-62

3. Sharma L, Song J, Felson DT, Cahue S, Shamiyeh E, Dunlop DD. The role of knee alignment in disease progression and functional decline in knee osteoarthritis. JAMA. 2001;286(2):188-95.

4. Dawson J, Juszczak E, Thorogood M, Marks SA, Dodd C, Fitzpatrick R. An investigation of risk factors for symptomatic osteoarthritis of the knee in women using a life course approach. J Epidemiol Community Health. 2003;57(10):823-30.

5. Maly MR. Abnormal and cumulative loading in knee osteoarthritis. Curr Opin Rheumatol. 2008;20(5):547-52.

6. Lawrence RC, Helmick CG, Arnett FC, Deyo RA, Felson DT, Giannini EH, et al. Estimates of the prevalence of arthritis and selected musculoskeletal disorders in the United States. Arthritis Rheum. 1998;41(5):778-99.

7. Quintana JM, Arostegui I, Escobar A, Azkarate J, Goenaga I, Lafuente I. Prevalence of knee and hip osteoarthritis an the appropriateness of joint replacement in an older population. Arch Intern Med. 2008;168(14):1576-84.

8. Zhang Y, Xu L, Nevitt M, Aliabadi P, Yu W, Qin M, et al. Comparison of the prevalence of knee osteoarthritis between the elderly chinese population in Beijing and white in the United States: The Beijing osteoarthritis study. Arthritis Rheum. 2001;44(9):2065-71.

9. Altman R, Asch E, Bloch D, Bole G, Borenstein D, Brandt K, et al. Development of criteria for the classification and reporting of osteoarthritis. Classification of osteoarthritis of the knee. Arthritis Rheum. 1986;29(8):1039-49.

10. Kellegren JH, Lawrence, JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis. 1957;16(4):494-502.

11. Chang A, Hayes K, Dunlop D, Song J, Hurwitz D, Cahue S, et al. Hip abduction moment and protection against medial tibiofemoral osteoarthritis progression. Arthritis Rheum. 2005;52(11):3515-9.

12. Hurwitz DE, Sumner DR, Andriacchi TP, Sugar DA. Dynamic knee loads during gait predict proximal tibial bone distribution. J Biomech. 1998;31(5):423-30.

13. Chang A, Hayes K, Dunlop D, Hurwitz D, Song J, Cahue S, et al. Thrust during ambulation and the progression of knee osteoarthritis. Arthritis Rheum. 2004;50(12):3897-903.

14. Miyazaki T, Wada M, Kawahara H, Sato M, Baba H, Shimada S. Dynamic load at baseline can predict radiographic disease progression in medial compartment knee osteoarthritis. Ann Rheum Dis. 2002;61(7):617-22.

15. Hurwitz DE, Sharma L, Andriacchi TP. Effect of knee pain on joint loading in patients with osteoarthritis. Curr Opin Rheumatol. 1999;11(5):422-6.

16. Tanaka K, Miyashita K, Urabe Y, Ijiri T, Takemoto Y, Ishii Y, et al. Characteristics of trunk lean motion during walking in patients with symptomatic knee osteoarthritis. Knee. 2008;15(2):134-8.

17. Astephen JL, Deluzio KJ, Caldwell GE, Dunbar MJ, Hubley-Kozey CL. Gait and neuromuscular pattern changes are associated with differences in knee osteoarthritis severity levels. J Biomech. 2008;41(4):868-76.

18. Mündermann A, Dyrby CO, Andriacchi TP. Secondary gait changes in patients with medial compartment knee osteoarthritis. Increased load at the ankle, knee, and hip during walking. Arthritis Rheum. 2005;52(9):2835-44.

19. Winter DA. Biomechanics and motor control of human movement. Toronto: Wiley-Interscience Publication; 1990.

20. Baliunas AJ, Hurwitz DE, Ryals AB, Karrar A, Case JP, Block JA, et al. Increased knee joint loads during walking are present in subjects with knee osteoarthritis. Osteoarthritis Cartilage. 2002;10(7):573-9.

21. Zhao D, Banks SA, Mitchell KH, D'Lima DD, Colwell CW, Fregly BJ. Correlation between the knee adduction torque and medial contact force for a variety of gait patterns. J Orthop Res. 2007;25(6):789-97.

22. Linley HS, Sled EA, Culham EG, Deluzio KJ. A biomechanical analysis of trunk and pelvis motion during gait in subjects with knee osteoarthritis compared to control subjects. Clin Biomech (Bristol, Avon). 2010;25(10):1003-10.

23. Mündermann A, Dyrby CO, Hurwitz DE, Sharma L, Andriacchi TP. Potential strategies to reduce medial compartment loading in patients with knee osteoarthritis of varying severity: reduced walking speed. Arthritis Rheum. 2004;50(4):1172-8.

24. Chang A, Hurwitz D, Dunlop D, Song J, Cahue S, Hayes K, et al. The relationship between toe-out angle during gait and progression of medial tibiofemoral osteoarthritis. Ann Rheum Dis. 2007;66(10):1271-5.

25. Hunt MA, Birmingham TB, Bryant D, Jones I, Giffin JR, Jenkyn TR, et al. Lateral trunk lean explains variation in dynamic knee joint load in patients with medial compartment knee osteoarthritis. Osteoarthritis Cartilage. 2008;16(5):591-9.

26. Rutherford DJ, Hubley-Kozey CL, Deluzio KJ, Stanish WD, Dumbar M. Foot progression angle and the knee adduction moment: a cross-sectional investigation in knee osteoarthritis. Osteoarthritis Cartilage. 2008;16(8):883-9.

27. Simic M, Hinman RS, Wrigley TV, Bennell KL, Hunt MA. Gait modification strategies for altering medial knee joint load: a systematic review. Arthritis Care Res (Hoboken). 2011;63(3):405-26.

28. Kaufman KR, Hughes C, Morrey BF, Morrey M, An KN. Gait characteristics of patients with knee osteoarthritis. J Biomech. 2001;34(7):907-15.

29. Astephen JL, Deluzio KJ. Changes in frontal plane dynamics and the loading response phase of the gait cycle are characteristic of severe knee osteoarthritis application of the multidimensional analysis technique. Clin Biomech (Bristol, Avon). 2005;20(2):209-17.

30. Hunt MA, Birmingham TB, Giffin JR, Jenkyn TR. Associations among knee adduction moment, frontal plane ground reaction force, and lever arm during walking in patients with knee osteoarthritis. J Biomech. 2006;39(12):2213-20.

31. Thorp LE, Summer DR, Block JA, Moisio KC, Shott S, Wimmer MA. Knee joint loading differ in individuals with mild compared with moderate medial knee osteoarthritis. Arthritis Rheum. 2006;54(12):3842-9.

32. Gök H, Ergin S, Yavuzer G. Kinetic and Kinematic characteristics of gait in patients with medial knee arthrosis. Acta Orthop Scand. 2002;73(6):647-52.

33. Zenir JA, Higginson JS. Differences in gait parameters between healthy subjects and persons with moderate and severe knee osteoarthritis: a result of altered walking speed? Clin Biomech (Bristol Avon). 2009;24(4):372-8.

34. Robbins SM, Maly MR. The effect of gait speed on the knee adduction moment depends on waveform summary measures. Gait Posture. 2009;30(4):543-6.

35. Lynn AK, Costigan PA. Effect of foot rotation on knee kinetics and hamstring activation in older adults with and without signs of knee osteoarthritis. Clin Biomech (Bristol, Avon). 2008;23(6):779-86.

36. Hubley-Kozey CL, Deluzio KJ, Landry SC, McNutt JS, Stanish WD. Neuromuscular alterations during walking in persons with moderate knee osteoarthritis. J Electromyogr Kinesiol. 2006;16(4):365-78.

37. Mundermann A, Asay JL, Mundermann L, Andriacchi TP. Implications of increased medio-lateral trunk sway for ambulatory mechanics. J Biomech. 2008;41(1):165-70.

38. Briem K, Snyder-Mackler L. Proximal gait adaptations in medial knee OA. J Orthop Res. 2009;27(1):78-83.

39. Sled EA, Khoja L, Deluzio KJ, Olney SJ, Culham EG. Effect of home program of hip abductor exercises on knee joint loading, strength, function and pain in people with knee osteoarthritis: a clinical trial. Phys Ther. 2010;90(6):895-904.

40. Thorp LE, Wimmer MA, Foucher KC, Sumner DR, Shakoor N, Block JA. The biomechanical effects of focused muscle training on medial knee loads in OA of the knee: a pilot, proof of concept study. J Musculoskelet Neuronal Interact. 2010;10(2):166-73.

41. Al-Zahrani KS, Bakheit AM. A study of the gait characteristics of patients with chronic osteoarthritis of the knee. Disabil Rehabil. 2002;24(5):275-80.

42. Chen CPC, Chen MJL, Pei YC, Lew HL, Wong PY, Tang SFT. Sagittal plane loading response during gait in different age groups and in people with knee osteoarthritis. Am J Phys Med Rehabil. 2003;82(4):307-12.

43. Messier SP, DeVita P, Cowan RE, Seay J, Young HC, Marsh AP. Do older adults with knee osteoarthritis place greater loads on the knee during gait? A preliminary study. Arch Phys Med Rehabil. 2005;86(4):703-9.

44. Kirtley C, Whittle MW, Jefferson RJ. Influence of walking speed on gait parameters. J Biomed Eng. 1985;7(4):282-8.

45. Huang SC, Wei IP, Chien HL, Wang TM, Liu YH, Chen HL, et al. Effects of severity of degeneration on gait patterns in patients with medial knee osteoarthritis. Med Eng Phys. 2008;30(8):997-1003.

46. Deluzio KJ, Astephen JL. Biomechanical features of gait waveform data associated with knee osteoarthritis. An application of principal component analysis. Gait Posture. 2007;25(1):86-93.

47. Mackinnon CD, Winter DA. Control of whole body balance in the frontal plane during human walking. J Biomech. 1993;26(6):633-44.

48. Pollo FE, Otis JC, Backus SI, Warren RF, Wickiewicz TL. Reduction of medial compartment loads with valgus bracing of the osteoarthritic knee. Am J Sports Med. 2002;30(3):414-21.

49. Kerrigan DC, Lelas JL, Goggins J, Merriman GJ, Kaplan RJ, Felson DT. Effectiveness of a lateral wedge insole on knee varus torque in patients with knee osteoarthritis. Arch Phys Med Rehabil. 2002;83(7):889-93.

50. Fransen M, Crosbie J, Edmonds J. Physical therapy is effective for patients with osteoarthritis of the knee: a randomized controlled clinical trial. J Rheumatol. 2001;28(1):156-64.

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