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Effects of Gait Modification Strategies on Loading of Knee and Spine in Individuals with Knee OA: A Narrative Review

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ABSTRACT

Background and Objectives: Gait is an automatic function in healthy individuals that demands minimal or no attention to maintain a steady pattern. Alterations in gait are associated with multiple factors, yet strongest association is seen with lower limb joint arthritis, osteoarthritis of knee being the commonest. Alterations in gait of OA knee individuals are compensatory strategies to reduce medial knee joint loading and pain. Till date, numerous compensatory gait strategies to alter external knee adduction moment have been identified and reported in the literature. The objectives of current narrative review are to report effects of gait modifications on loading of knee and spine in individuals with knee OA.
Methods: A literature search for current study was performed in electronic databases of PubMed and Google scholar from 1990 to 2019 with "Gait", "Biomechanics" and "OA knee" as key words. 584 articles were assessed, articles assessing gait or fall risk in OA knee following ACL/meniscal injury, total knee replacement or any type of knee surgery, medications or any type of therapeutic interventions were eliminated.
Findings: Increased hip abduction and lateral trunk leaning during swing phase, contralateral pelvic drop, increased anterior tilting of pelvis, increased hip, knee and ankle flexion angles in sagittal plane, increased step width, increased hip internal rotation, weight transfer to the medial foot are common strategies adopted by OA knee individuals to reduce Knee Adduction Moment (KAM). A few studies have reported adverse loading of spine, hip joints and contralateral knee because of gait adaptations seen in individuals with knee OA.
Conclusion: Findings of current review suggests that altered trunk and pelvis kinematics may predispose OA knee individuals to development of degenerative low back pain, which should be given attention while planning rehabilitation strategies for OA knee individuals.

Key Words: OA knee, Gait, Knee adduction moment, Trunk lean

INTRODUCTION

An individual's walking pattern is described as gait. As such walking is an automatic human function that apparently appears to be a very simple task, yet it is one of the most complex motor activity.[1] Alterations in gait are associated with ageing, altered neuromuscular and/or cardiopulmonary function, cognitive impairment, fear of fall, obesity, depression, anxiety etc.[2] Lower limb joint arthritis, particularly osteoarthritis of knee leads to significant impairments in one's walking pattern and triggers compensatory mechanisms.[3]

Osteoarthritis (OA) knee is a common chronic degenerative joint disease, which frequently affects medial tibiofemoral joint. Knee OA is progressive disease that causes damage to articular cartilage, subchondral bone, menisci, as well as periarticular muscles, which leads to joint pain, stiffness, loss of muscle strength, impaired joint proprioception, altered balance and functional disability.[4] As such there is no definite conservative cure for knee OA, most management is focused on diminishing pain, improving functional ability and restoring balance.[5] Clinical guidelines stress the importance of physiotherapy, as drugs and surgical treatments are often associated with adverse effects and complications. According to OARSI guidelines, various forms of exercises, use of gait aids, weight management with diet and exercises and patient education are safe and core treatment options for individuals with knee OA.[6]

Increased dynamic knee joint load, particularly in walking, is a potential contributing factor to pain intensity and knee OA progression, hence individuals with knee OA often exhibit a unique adaptive gait strategy.[3] These alterations seen in gait of OA knee individuals are compensatory strategies to reduce medial knee joint loading, pain, and improvise balancing.[7] The other joints in the kinetic chain, such as the joints of the non-affected side, joints distal to affected knee joint and very importantly, joints of axial skeleton, lumbar spine and pelvis, play an important role in the compensation to obtain a pain free gait.[8]

Till date, numerous compensatory gait strategies to alter external knee adduction moment have been identified and reported in observational studies and systematic reviews.[8,9,10] Various interventional studies have also addressed effects of specific gait adaptations, such as lateral trunk leaning and in toeing on knee mechanics and loading.[11,12] The trunk is the heaviest part of the body, which houses centre of gravity and any excessive motion of trunk can affect the path of the ground reaction force vector and also moments generated about knee joint. Alteration of trunk kinematics has been identified as a potential strategy to reduce knee joint loading and pain for knee OA patients.[13]

There are very few reviews, which have highlighted possible adverse effects of trunk and pelvic related gait changes on loading of proximal joints and progression of degenerative changes in proximal joints.[8,9,10,14,15]

To assess the effects of gait adaptations on locomotive system, longitudinal studies with prospective designs are required to address the deleterious effects. Occurrence of falls, Changes in BMI, use of medications, and presence of other co-morbidities are potential confounding variables that can impose great challenge in designing longitudinal studies. Before we get definitive guidelines from longitudinal studies, any systematic or narrative reviews can be of great help in outlining possible adverse effects of abnormal gait on locomotive system. Due to stringent study selection criteria for conduction of a systematic review, sufficient literature can not be gathered to address adverse loading of proximal joints in individuals with knee OA due to alterations in gait. A narrative review is a good alternative to systematic review, where various levels of research can be gathered and analysed to obtain a broad perspective on the topic. Hence, the objectives of current narrative review are to discuss effects of gait alterations on loading of arthritic knee joint, spine and proximal weight bearing joints of lower limb.

METHODOLOGY

Current review is prepared in accordance with SANRA (Scale for the Assessment of Narrative Review Articles) guidelines for writing narrative reviews.[16] Electronic databases of PubMed and Google scholar were used for searching the research related to gait alterations in individuals with knee OA. A literature search for current

study was performed in electronic databases of PubMed and Google scholar from 1990 to 2020 with "Gait" and "OA knee" as search terms. To widen the search results, additional search was carried out using "Trunk", "Pelvis", "Gait" and "OA Knee" as search terms. Articles assessing gait or fall risk in OA knee following ACL/meniscal injury, total knee replacement or any type of knee surgery were not included in the review. Articles were not included, if written in language other than English. Synthesis of reviewed articles was carried out in three steps:

- Step 1: Brief note on loading of knee joint in individuals with knee OA
- Step 2: Gait modification strategies used by individuals with knee OA
- Step 3: Effects of gait modification on loading of arthritic knee joint and proximal joints

Loading of knee joint in individuals with knee OA:

Though basic parameters such as gait speed, step length, stride length, cadence etc are efficient to characterise the gait of individuals with knee OA, these parameters are not specific enough to provide objective analysis of subtle yet progressive alterations in tibiofemoral joint loading. Therefore, detailed three dimensional analysis of kinetic and kinematic patterns of knee joint during walking is necessary to see loading characteristics of medial tibiofemoral joint.[15] External knee adduction moment is one of the very frequently studied parameter of gait in individuals with knee OA to evaluate loading of knee joint.

KAM can be simplified as a variable indicating load distribution between the medial and lateral tibiofemoral compartments, where larger KAM denotes increased mechanical loading of medial tibiofemoral joint. KAM is generated by ground reaction force that passes medial to the centre of knee joint during stance phase. The perpendicular distance between the vertical ground reaction force vector and centre of knee joint is expressed as external KAM. This moment tends to cause varus force about tibiofemoral joint and eventually grater loading of medial tibiofemoral joint.[17,18,19,20,21,22,23]

KAM has been shown to be increased in individuals with knee OA as compared to age matched healthy individuals. KAM also differs in individuals with mild and severe knee OA, those with severe knee OA have been shown to have higher KAM.[24] In a recent systematic review by N. D'Souza and others, KAM has been shown to be a predictor of disease onset as well as progression of disease in knee OA.[25]

In a systematic review and meta analysis, an interesting variation was identified in KAM of individuals with moderate and severe OA knee. The study found that KAM was significantly different between individuals with mild and severe knee OA, but it did not differ between moderate and severe OA knee. This finding indicates need to explore the strategies used by OA knee individuals to slow down progression of the arthritis in knee.[8,10]

Gait modification strategies used by individuals with knee OA:

- Various gait modifications strategies to reduce KAM have been studied. Gait modification is the simplest and easiest strategy that is adopted in most of the musculoskeletal disorders of lower quarter. Any pathology, affecting lumbar spine, hip, knee or ankle joint can result in painful locomotive activities, which can be automatically compensated by altered walking style that reduces loading of painful joint. Gait strategies of individuals with knee osteoarthritis have been studied extensively to see if the alterations in their gait is due to age or presence of knee osteoarthritis. As reported by previous researches, there is lack of evidence to establish specific effects of alignment of knee, compartment involved (medial or lateral), gender, and symptoms on most of the gait variables

of individuals with knee OA.[24] Various high quality researches were reviewed to summarize gait differences of elderly with and without knee osteoarthritis.[12,14,19,24,26,27]

Changes in parameters of gait:	Abnormality in kinematics of proximal and distal components:
• Decrease in self selected gait speed • Increase in angle of toe out • Increased step width • Increased stance duration • Decreased stride length • Increased cadence • Medial knee thrust • Increased hip internal rotation • Weight transfer to the medial foot	• Increased anterior tilting of pelvis • Increased trunk, hip, knee and ankle flexion angles in sagittal plane • Ipsilateral trunk lean during stance • Contralateral pelvic drop

Among these modifications, lateral trunk lean and increased contralateral pelvic drop are reported to be the most effective strategies to alter loading of knee joint.[28,29,30,31,32] These alteration might be saviour for medial tibiofemoral joint, but on the other hand, it may transfer the load to other unaffected joints in chain. The next step in current review is to see how these adaptations can affect loading of arthritic knee and other joints in kinetic chain.

Effects of gait modification on loading of arthritic knee joint and proximal joints:

Gait modifications are meant to reduce loading of medial tibiofemoral joint by means of altering external moments about the knee joint. Effects of increased lateral trunk lean, increased trunk flexion angle and increased contralateral pelvic drop on KAM in knee OA have been reported in few longitudinal studies. These gait alterations have also been reported to increase with severity of disease.[28,30,31]

Increased lateral trunk lean can produce greatest reduction early stance phase KAM when compared with other gait modifications, such as increased angle of toe out and decreased walking speed. Further research identified that lateral trunk lean progressively increases with severity of knee OA. With increasing severity of knee OA, loading of knee is controlled by compensatory lateral trunk lean, which may explain the reason why KAM does not increase linearly in moderate and severe knee OA. Addition of lateral trunk lean helps in displacement of centre of gravity more laterally and thereby reduces KAM.[28,30,31,33] This also reduces need for contraction of hip abductor muscles during single limb stance phase and eventually causes disuse weakness of hip abductor muscles.[11,34] Hip abductor muscles are powerful contractile forces that have been reported to be protective against progression of knee OA.[35] Contralateral pelvic drop is also a frequently reported feature of gait in individuals with knee OA. This pelvic drop has been linked with hip abductor muscle weakness as well as a potential mediator of KAM. With excessive pelvic drop, KAM progressively increases despite of presence of lateral trunk lean.[32,36]

According to research by Mundermann and others[14], there is abnormal loading of all lower limb joints in individuals with knee OA, which may mediate faster progression of arthritic changes in affected knee joint as well as development of arthritic changes in adjacent joints.[14,33,37]

Lateral trunk lean increases trunk muscle activity as well as energy expenditure while walking. This may induce trunk muscle fatigue and eventually can alter loading of spinal column joints. This dramatic increase in frontal plane motion and loading of spinal column can possibly be the reason of co-existing degenerative low back pain in individuals with knee OA.[10,11,34,38,39]

CONCLUSION

Current review clearly identifies increased KAM in early OA knee and later

development of lateral trunk lean to control KAM in severe knee OA. Lateral trunk lean causes weakness of hip abductors and eventually leads to contralateral pelvic drop. Pelvic drop further increases KAM and a vicious cycle of gait compensation continues to load more joints in locomotive system. Increased frontal plane motion of trunk and pelvis increases chances of development of spinal instability[40] and predispose OA knee individuals to development of degenerative low back pain, which may complicate conservative as well as surgical management for OA knee individuals.

Abnormal loading of spine, hip, ankle and contralateral knee makes gait extremely energy consuming and exhausting for the locomotive system.[41] Hence, mono-articular knee arthritis progresses to become "Geriatric locomotive disorder" with pain and/or degeneration in most of weight bearing joints. The term "Geriatric locomotive disorder" is very meaningful to describe locomotive problems faced by most elderly. This term indicates pain and or weakness in more than one joint or muscles of lower quarter. The pain begins in one joint (commonly in arthritic knee) and then vicious cycle of gait compensations wear out most joints in lower quarter including lumbar spine. And thereafter, walking ability is progressively limited by pain in one or the other weight bearing joints.

There is no benefit of considering KAM as a marker of severity of knee osteoarthritis, as this finding absolutely ignores excessive abnormal loading of adjacent joints. Being a geriatric disorder, the goal of rehabilitation in knee OA is not just improving pain and loading of affected knee, rather the aim is to improve efficiency of the locomotive system as a whole. Locomotion is not solely dependent upon function of the knee joint, it is integrated function of joints of vertebral column and lower limbs. As stated by Steindler[42], "Human gait is a classic example of inverted pendulum, where stability of proximal system is mandatory for optimal ambulation."

Clinical implication:

The review indicates need for further research to explore proximal gait alterations and their effect on loading of healthy weight bearing joints in individuals with knee OA. As warned by gait adaptations, the review recommends inclusion of core stability exercises in rehabilitation of individuals with knee OA.

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