Invited lecture/Research

Effects of Therapeutic Approaches in Treating Varus Malalignment of the Knee Joint

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Abstract:
Knee malalignment is shown to be an independent risk factor for osteoarthritis progression. The knee adduction moment is directly correlated with varus malformation and can be decreased with changes in gait pattern, external foot rotation and external support. The aim of this literature review was to determine the effects of different therapeutic approaches in treating varus malalignment of the knee joint. The literature search was conducted in the PubMed and EBSCO databases. We used a combination of English keywords. Studies were screened regarding the inclusion and exclusion criteria. We included five studies investigating the effects of therapeutic approaches in participants with or without osteoarthritis onset. Statistically significant decrease in knee adduction moment was reported in one study, which was implementing modified gait pattern with real time feedback. Other outcome measures were also indicative of potential efficacy in different therapeutic approaches. There is a bigger potential for treating varus malalignment before osteoarthritis (OA) onset. The results indicate that weight-bearing exercise and gait modification in combination with a corrective training protocol provide a potential useful approach to reduce varus malalignment.

Keywords:
Varus malalignment, knee joint, knee adduction moment, therapeutic approaches

1. Introduction

1.1. Mechanical forces of the lower extremity

The lower extremity is in the frontal plane aligned through a mechanical axis which is in a neutral positioned extremity running from the hip joint, medially or through the middle of the knee joint to the ankle joint (Tetsworth and Paley, 1994). A malalignment is present when the axis is shifted medial or lateral of the knee joint, creating a moment arm and causing a disturbance in the load bearing of the joints (Sharma et al., 2010). Those changes can be visualized in the frontal plane as a dynamic worsening of the varus alignment as the lower extremity accepts weight in the stance phase (Chang et al., 2010). In young individuals the changes in the frontal plane are shown to be directly associated with changes in the transverse plane including increased internal foot placement and increased tibia rotation (Stief et al., 2014).

1.2. Varus malalignment and OA

Knee malalignment is shown to be an independent risk factor in OA progression (Tanamas et al., 2009). Where greater knee varus at baseline is associated with greater odds of medial compartment OA progression (Sharma et al., 2010). OA is among others one of the most prevalent diseases in older adults and is limiting independence and functional activities, such as stair climbing, home chores, carrying bundles (Guccione et al., 1994). The knee adduction moment (KAM) is directly corelated with varus malalignment (Foroughi et al., 2009) and is consequently together with other mechanical forces, such as varus thrust associated with higher chances of OA progression in the medial compartment of the knee joint (D'souza et al., 2022).

1.3. Treatment of varus malalignment

The KAM and the load on the medial knee compartment can be reduced by changing the gait pattern, external foot rotation or external support (Tetsworth and Paley, 1994). Conservative approaches can include knee bracing. Considering the results of the systematic review Yan et al. (2022) valgus braces could reduce symptoms of OA through decreasing the KAM and the varus angle and with it the improper distribution of load forces. In patients with unicompartmental OA in early degenerative stages high tibial osteotomy can be indicated to correct the varus deformity. The surgical procedure can decrease the symptoms and delay the need for knee replacement (Dowd et al., 2005).

1.4. Purpose

The aim of this literature review was to determine the effects of different therapeutic approaches in treating varus malalignment of the knee joint.

2. Methods

The literature search was conducted in the PubMed and EBSCO databases. The last review was carried out on the December 5, 2023. Following combinations of keywords were used: varus AND knee AND treatment; knee adduction moment AND varus AND treatment; knee adduction moment AND varus AND gait. Inclusion criteria were articles in English language, populations of subjects with varus malalignment with or without OA, interventions addressing the varus malalignment directly or through changes in KAM. Studies that investigated effects of orthotic interventions and studies that didn't measure the change in varus malalignment or KAM were excluded.

3. Results

After screening and eligibility assessment, five studies published between 2010 and 2021 were included in the review (Barrios et al., 2010; Bennell et al., 2010; Bennell et al., 2014; Choi & Shin, 2021; Jafarnezhadgero et al., 2018).

The characteristics of the participants in the included studies are presented in **Table 1.** In three of the included studies (Barrios et al.,2010; Choi & Shin, 2021; Jafarnezhadgero et al., 2018) the mean age of participants was between 11.21 and 23.0 years. In two studies (Bennell et al., 2010; Bennell et al., 2014) the mean age of participants was between 62.2 and 64.6 years.

Table 1: Characteristics of the participants in the included studies.

Study	Pathologies	Samples (n)	
		F	M
Barrios et al. (2010)	Varus, no OA	1	7
Bennell et al. (2010)	Varus, with OA	43	46
Bennell et al. (2014)	Varus, with OA	52	48
Choi & Shin (2021)	Varus, no OA	4	4
Jafarnezhadgero et al. (2018)	Varus, no OA	0	28

OA: osteoarthritis; F: female; M: male

In three of the studies (Bennell et al., 2010; Bennell et al., 2014; Jafarnezhadgero et al., 2018) the participants were divided in to an experimental and a control group which enabled a between group comprehension. In two studies (Barrios et al.,2010; Choi & Shin, 2021) only an experimental group was present and comparison of the outcome measures before and after the implementation of the intervention was performed. The interventions and outcome measures used in the included studies are presented in **Table 2.**

Table 2: Interventions and outcome measures and time of assessment used in the included studies.

Study	Intervention	Outcome measure	Time of assessment
Barrios et al. (2010)	Gait retraining with real-time feedback. 8 weeks	Gait analysis Effort	Baseline After intervention After 1 month
Bennell et al. (2010)	Hip strengthening exercise 12 weeks	Gait analysis Knee pai, physical function Strength measures Other	Baseline After 13 weeks
Bennell et al. (2014)	Neuromuscular vs quadriceps strengthening exercise 12 weeks	Gait analysis Pain, physical function Strength measures Physical performance Health related quality of life Other	Baseline After 13 weeks
Choi & Shin (2021)	Medial foot loading in gait 8 weeks	Gait analysis Adverse effects	Baseline After initial training After 8 weeks
Jafarnezhadgero et al. (2018)	Corrective training protocol 16 weeks	Gait analysis Joint kinematics Quadriceps angle	Baseline 6 days after intervention

In the gait retraining study (Barrios et al., 2010) there was a statistically significant reduction in peak KAM in comprehension of the baseline and after intervention modified gait ($p = 0.027$). In comprehension of the baseline and after 1 month follow up modified gait a reduction in KAM was again present ($p = 0.019$). When comparing the baseline and both post intervention natural gaits no differences were observed. In the hip strengthening exercise study (Bennell et al., 2010) there were no between group differences for the KAM found ($p = 0.193$). In the neuromuscular vs quadriceps strengthening exercise study (Bennell et al., 2014) there was no withing group differences for changes in peak KAM from baseline for both groups. There were also no between group differences in changes of peak KAM ($p = 0.23$). The primary outcome measure used in the medial foot loading study

(Choi & Shin, 2021) was the knee adduction angle which served as an indicator of KAM. A significant change in the knee adduction angle was found at initial contact, mean angle during gait cycle and maximal abduction and adduction angle ($p < 0.01$). Similarly, the KAM wasn't directly measured in the corrective training protocol study (Jafarnezhadgero et al., 2018). Within and between group differences were found for some of the hip, knee, and ankle joint angles for the dominant and nondominant lower extremity compared to baseline ($p < 0.05$). Statistically significant differences in other outcome measures used in the included studies are presented in **Table 3** and **Table 4**. Results for within group differences were also presented for the outcome measures in the studies Bennell et al. (2010) and Bennell et al. (2014) although the statistical significance was not determined.

Table 3: Within group differences for other outcome measures - before and after intervention.

Study			**Other outcome measures**
Barrios et al. (2010)	Modified gait	Post intervention	SS ↑ peak hip IR
		Follow up	SS ↑ peak hip IR
	Natural gait	Post intervention	No difference
		Follow up	No difference
Choi & Shin (2021)			SS ↑ walking speed, step length SS ↓ knee ADD angle (initial contact, mean, maximum) SS ↓ knee ABD angle (stance phase) SS ↑ hip ADD angle (initial contact, mean, maximum) SS ↑ ankle eversion (initial contact) SS ↑ foot ER (initial contact, mean, maximum)
Jafarnezhadgero et al. (2018)	EG	Dominant extremity	SS ↓ peak DF, foot IR, knee IR, hip ABD and ER SS ↑ peak knee ER
		Nondominant extremity	SS ↓ peak ankle inversion and eversion, foot IR, knee IR, hip ABD and ER

SS: statistically significant; ↑: increased; IR; internal rotation; ↓: decreased; ADD: adduction; ABD: adduction; ER: external rotation; EG: experimental group; DF: dorsal flexion

Table 4: Between group differences for other outcome measures.

Study	**Other outcome measures**	
Bennell et al. (2010)		SS ↑ ipsilateral pelvic drop – EG SS ↓ pain – EG SS ↑ physical function – EG SS ↑ strength (hip ABD and ADD, knee EXT) – EG
Bennell et al. (2014)		SS ↑ single leg stance – NS
Jafarnezhadgero et al. (2018)	Dominant extremity	SS ↑ knee ER – CG SS ↓ peak foot IR, knee IR, hip ER and ABD – EG
	Nondominant extremity	SS ↑ peak ankle inversion – CG SS ↓ peak ankle eversion, foot IR, hip ER – EG

SS: statistically significant; ↑ higher; EG: in favor of the experimental group; ↓: lower; ABD: abduction; ADD: adduction; EXT: extension; NS: in favor of the neuromuscular group; ER: external rotation; CG – in favor of the control group; IR: internal rotation

4. Discussion

The results are indicating that effectiveness of the therapeutic approaches is greater when they are implemented to younger participants with no OA present (Barrios et al.,2010; Choi & Shin, 2021; Jafarnezhadgero et al., 2018). This coincides with the fact that the loss of bone and cartilage as a result of OA can also contribute to malalignment progression (Tanamas et al., 2009). Another possible explanation for more encouraging results in these studies could be usage of load bearing therapeutic approaches. Those are directly addressing the varus trust present as worsening of the varus malalignment when the lower extremity bears weight (Chang et al., 2010). However, it needs to be considered that the number of included participants was low (Barrios et al. (2010); Choi & Shin (2021) n = 8; Jafarnezhadgero et al. (2018); n = 28).

As seen in the study by Barrios et al. (2010) the gait retraining program caused changes in the modified gait through time with gait becoming a less difficult task to perform. Since changes didn't transfer into the natural gait pattern, this indicates that a 8-week training program was too short for a permanent change to occur. Nevertheless, the potential of this results is supported by the systematic review Richards et al. (2016) where gait retraining with real-time biofeedback was shown to be useful to reduce KAM in healthy controls. To improve the motor learning of gait modification, it's also important to consider the practice structure in a blocked or random manner, the amount and timing of feedback provided and social-cognitive-affective aspects of learning such as motivation and attention (Charlton et al., 2020).

The mayor limitation of this review is a small number of studies eligible for inclusion. Heterogeneity between the studies was limiting a direct comparison of their results. There were also limitations of the included studies such as low number of participants (Barrios et al., 2010; Choi & Shin, 2021; Jafarnezhadgero et al., 2018), no control group (Barrios et al.,2010; Choi & Shin, 2021; Jafarnezhadgero et al., 2018; Bennell et al., 2014) and no follow-up assessment except in one study (Barrios et al., 2010).

An important question to consider is how the change in the gait pattern would affect not only the knee but also the other joints of the lower extremity. An impact reduction walking used in the study Tajima et al. (2018) was shown to decrease the ground reaction force, the external joint moments and loading rate. This approach of gait changing could potentially be useful for individuals with varus malalignment.

Different therapeutic approaches have shown to have different impact on treating varus knee alignment. There is a bigger potential for treating varus malalignment before OA onset. Where weight-bearing exercise and gait modification in combination with a corrective training protocol provide a potential useful approach to reduce varus malalignment. Future research on bigger samples with lengthy protocols and direct varus alignment measures is needed to determine the effectiveness of this approaches.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Barrios JA, Crossley KM, Davis IS. Gait retraining to reduce the knee adduction moment through real-time visual feedback of dynamic knee alignment. Journal of biomechanics. 2010; 43(11): 2208-2213. DOI: https://doi.org/10.1016/j.jbiomech.2010.03.040
2. Bennell KL, Hunt MA, Wrigley TV, et al. Hip strengthening reduces symptoms but not knee load in people with medial knee osteoarthritis and varus malalignment: a randomised controlled trial. Osteoarthritis and cartilage. 2010; 18(5): 621-628. DOI: 10.1016/j.joca.2010.01.010
3. Bennell KL, Kyriakides M, Metcalf B, et al. Neuromuscular versus quadriceps strengthening exercise in patients with medial knee osteoarthritis and varus malalignment: a randomized controlled trial. Arthritis & Rheumatology. 2014; 66(4) :950-959. DOI: 10.1002/art.38317
4. Chang A, Hochberg M, Song J, et al. Frequency of varus and valgus thrust and factors associated with thrust presence in persons with or at higher risk of developing knee osteoarthritis. Arthritis Rheum. 2010; 62(5): 1403-1411. DOI: 10.1002/art.27377
5. Charlton JM, Eng JJ, Li LC, Hunt MA. Learning Gait Modifications for Musculoskeletal Rehabilitation: Applying Motor Learning Principles to Improve Research and Clinical Implementation. Phys Ther. 2021; 101(2): pzaa207. doi: 10.1093/ptj/pzaa207

6. Choi S, Shin G. Effect of medial foot loading self-practice on lower limb kinematics in young individuals with asymptomatic varus knee alignment. The Knee. 2021; 30: 305-313. Doi: 10.1016/j.knee.2021.04.018
7. Dowd GS, Somayaji HS, Uthukuri M. High tibial osteotomy for medial compartment osteoarthritis. Knee. 2006; 13(2): 87-92. DOI: 10.1016/j.knee.2005.08.002
8. D'souza N, Charlton J, Grayson J, et al. Are biomechanics during gait associated with the structural disease onset and progression of lower limb osteoarthritis? A systematic review and meta-analysis. Osteoarthritis and Cartilage. 2022; 30(3); 381-394. DOI: 10.1016/j.joca.2021.10.010
9. Foroughi N, Smith R, Vanwanseele B. The association of external knee adduction moment with biomechanical variables in osteoarthritis: a systematic review. Knee. 2009; 16(5): 303-309. DOI: 10.1016/j.knee.2008.12.007
10. Guccione AA, Felson DT, Anderson JJ, et al. The effects of specific medical conditions on the functional limitations of elders in the Framingham Study. Am J Public Health. 1994; 84(3): 351-358. DOI: 10.2105/ajph.84.3.351
11. Jafarnezhadgero AA, Majlesi M, Etemadi H, Robertson DG. Rehabilitation improves walking kinematics in children with a knee varus: Randomized controlled trial. Annals of physical and rehabilitation medicine. 2018; 61(3): 125-134. Doi: 10.1016/j.rehab.2018.01.007
12. Richards R, van den Noort JC, Dekker J, Harlaar J. Gait Retraining With Real-Time Biofeedback to Reduce Knee Adduction Moment: Systematic Review of Effects and Methods Used. Arch Phys Med Rehabil. 2017; 98(1): 137-150. doi: 10.1016/j.apmr.2016.07.006
13. Sharma L, Song J, Dunlop D, et al. Varus and valgus alignment and incident and progressive knee osteoarthritis. Ann Rheum Dis. 2010; 69(11): 1940-1945. DOI: 10.1136/ard.2010.129742
14. Stief F, Böhm H, Dussa CU, et al. Effect of lower limb malalignment in the frontal plane on transverse plane mechanics during gait in young individuals with varus knee alignment. Knee. 2014; 21(3): 688-693. DOI: 10.1016/j.knee.2014.03.004
15. Tajima T, Tateuchi H, Koyama Y, et al. Gait strategies to reduce the dynamic joint load in the lower limbs during a loading response in young healthy adults. Hum Mov Sci. 2018; 58: 260-267. doi: 10.1016/j.humov.2018.03.002
16. Tanamas S, Hanna FS, Cicuttini FM, et al. Does knee malalignment increase the risk of development and progression of knee osteoarthritis? A systematic review. Arthritis Rheum. 2009; 61(4): 459-467. DOI: 10.1002/art.24336
17. Tetsworth K, Paley D. Malalignment and degenerative arthropathy. Orthopedic Clinics of North America. 1994; 25(3): 367-377. DOI: https://doi.org/10.1016/S0030-5898(20)31921-0
18. Yan Y, Liu G, Zhang L, et al. Biomechanical Effect of Valgus Knee Braces on the Treatment of Medial Gonarthrosis: A Systematic Review. Appl Bionics Biomech. 2022; 2022:4194472. DOI: 10.1155/2022/4194472