

Knee joint loading in walking in the MBT shoe

(T. Andriacchi et al., USA)

Stanford University Biomotion Laboratory

Stanford California, USA

Katherine Boyer Ph.D.; Katerina Blazek M.S.; Thomas Andriacchi Ph.D.

Internal Report



June 2008

Publication:

- Katherine A. Boyer, Katerina Blazek, Thomas Andriacchi: Effects of an unstable shoe construction in low speed running. Poster presentation, North American Congress on Biomechanics 2008.
- Katerina Blazek (1), Katherine Boyer (1,2), Thomas Andriacchi (1,2): Subject-specific changes in knee loading in response to an unstable shoe intervention. (1) Biomotion Laboratory, Stanford University, CA, USA (2) VA Bone and Joint Rehabilitation R & D Center Palo Alto, CA, USA. Poster presentation, North American Congress on Biomechanics 2008.

MBT Model: Sole 2005

ABSTRACT

Osteoarthritis (OA) is a degenerative joint disease that is characterized by a thinning of the articular cartilage layer, osteophyte formation in the joint, stiffness, pain and decreased physical function. An increasing body of literature suggests that the mechanical environment of the knee during ambulation has a profound influence on the severity (Andriacchi et al.,2006), progression (Miyazaki et al.,2002) and treatment outcome (Prodromos et al.,1985) for osteoarthritis at the knee. Although we can not directly measure the force within a healthy joint, the external joint moments, as calculated using an inverse dynamics approach, can be used as a surrogate measure of the joint force. The magnitude of the load on the medial compartment of the tibia is determined by the external knee flexion and adduction moments. The MBT shoe with its unstable sole construction provides a different stimulus to the neuromotor system than a conventional shoe. Initial evidence indicates that this stimulus elicits changes in muscle activity of selected muscles, joint kinematics, and joint kinetics (Nigg

et al.,2006b; Nigg et al.,2006a; Romkes et al.,2006) and thus may result in a decreased joint load. However, the reported changes in joint pain for a group OA patients was not different from a control shoe (Nigg et al.,2006a). It thus remains unclear if wearing the MBT shoe would be beneficial for a population with medial knee OA.

PURPOSE: To determine if walking in the MBT shoe results in a reduction in the knee joint force or the joint force distribution compared to a casual shoe.

METHODS: 19 healthy volunteers were tested, all with no history of lower-limb injury or pain and who had never worn the MBT shoe before: 11 women (age: 28.9 +/- 7.3 years; BMI: 22.7 +/- 2.9) and 8 men (age: 32.6 +/- 7.5 years; BMI: 23.5 +/- 1.8). Informed consent was obtained from all subjects per Stanford University IRB guidelines. Each subject wore the shoe for a two week period prior to testing. Kinematic marker data and ground reaction forces (GRF) were collected at 120 Hz while each subject walked at a self-selected normal pace in the MBT and the subject's own casual shoe. Intersegmental joint forces and moments were calculated using inverse dynamics and a previously published link model [1]. Paired Student's t-tests were carried out to determine differences in the group response between the two shoe conditions.

GROUP RESULTS WALKING

Kinematics:

- Slight, not significant increase of cadence with MBT
- At heel-strike knee flexion increased ($p < 0.05$)
- At heel strike dorsiflexion increased ($p < 0.05$)
- At mid stance knee flexion increased ($p < 0.05$)
- At mid stance dorsiflexion increased ($p < 0.05$)
- At toe-off knee flexion increased ($p < 0.05$)
- At toe-off ankle plantar flexion decreased (i.e. a more flexed ankle was maintained through out all of stance) ($p < 0.05$)
- In the hip no statistical differences in the sagittal plane
- The foot angle was greater in the sagittal plane (toe out angle)

Ground reaction forces:

- The loading rate of the first peak was greater in the MBT shoe ($p < 0.05$)
- No difference in the magnitude of the first vertical GRF peak
- Second peak of the vertical GRF was lower in the MBT shoe
- No significant differences in the medial lateral or anterior-posterior GRF peaks


























Kinetics






- The differences in the peak joint moment values were not the same for all walking speeds
- At all walking speeds were significant differences in the peak hip extension, internal rotation moments, the peak ankle plantar-flexion moments
- No difference in the peak ankle dorsi-flexion moment ant any of the walking speeds

INDIVIDUAL RESULTS

Knee joint loading

The table represent the average mid-stance joint moment during walking

Group	Hip	Knee	Ankle	Meaning	Subjects (n = 19)
1	Flexion  Adduction 	Flexion  Adduction 	Dorsiflexion 	<ul style="list-style-type: none"> Positive strategy group Increase in the knee flexor muscle activity/ forces may be occurring Decreased knee adduction moment correlates positive to the medial knee joint loading, if there is limited increased muscle co-contraction 	2 women 2 men
2	Flexion  Adduction 	Flexion  Adduction 	Dorsiflexion 	<ul style="list-style-type: none"> Positive strategy group Knee extensors (quads) and knee flexors/ hip extensors (hamstrings) has decreased => total knee joint force is decreased 	3 women 1 men
3	Flexion  Adduction 	Flexion  Adduction 	Dorsiflexion 	<ul style="list-style-type: none"> Positive strategy group Knee extensors (quads) and knee flexors/ hip extensors (hamstrings) has decreased => total knee joint force is decreased 	3 women 1 men
4	Flexion  Adduction 	Flexion  Adduction 	Dorsiflexion 	<ul style="list-style-type: none"> Negative strategy group May be an increase in the total knee joint force and/or a redistribution of the joint force to the medial compartment Increased knee flexion moment suggest an increase in the quadriceps muscle forces and increased knee joint force The increased dorsi-flexion moment in group 4 and 5 suggest a slight increase in muscle co-contraction which contribute to an increase in the total knee joint loading Group 4 and 6 the increased knee adduction moment suggest a redistribution of the joint force to the medial compartment 	2 men
5	Flexion  Adduction 	Flexion  Adduction 	Dorsiflexion 	<ul style="list-style-type: none"> Negative strategy group May be an increase in the total knee joint force and/or a redistribution of the joint force to the medial compartment Increased knee flexion moment suggest an increase in the quadriceps muscle forces and increased knee joint force 	3 women

				<ul style="list-style-type: none"> ▪ an increase of the total knee joint force is expected, but the knee adduction moment is decreased what suggest a shift to the lateral compartment ▪ The increased dorsi-flexion moment in group 4 and 5 suggest a slight increase in muscle co-contraction which contribute to an increase in the total knee joint loading 	
6	Flexion  Adduction 	Flexion  Adduction 	Dorsiflexion 	<ul style="list-style-type: none"> ▪ Negative strategy group ▪ May be an increase in the total knee joint force and/or a redistribution of the joint force to the medial compartment ▪ Increased knee flexion moment suggest an increase in the quadriceps muscle forces and increased knee joint force ▪ Group 4 and 6 the increased knee adduction moment suggest a redistribution of the joint force to the medial compartment 	2 men

OTHER RESULTS

Decrease of knee flexion moment:

- decrease of no change in total knee force
- no increase in antagonist muscle activities, lower quadriceps muscle force is needed for walking in the MBT
- the knee adduction moment is correlated with the load distribution in the knee joint
- males are more likely to have a negative adaptation strategy to the shoe, based on a small population sample.
- subjects who increased their knee force were older, but not significantly, than those who showed a decrease ($p = 0.3$)
- all subjects were normal weight, so it is not clear how overweight or obese subjects would respond to the shoes
- all subjects were healthy, it is not clear how knee OA patients would respond to the shoes.

COMMENT GROUP 1-3:

If similar adaptations were adopted by a group of medial knee OA patients then a reduction in symptoms associated with the disease might be expected.

COMMENT GROUP 4-6:

If similar adaptations to the MBT shoe were adopted by knee OA patients, both medial and lateral, increases of pain and the rate of progression of the disease may occur with regular wearing of the MBT shoe as compared to a traditional shoe.

CONCLUSION:

- The results of this study indicate that for some individuals the changes in joint kinematics, kinetics and GRF's when walking in the MBT shoe may result in a reduction in the forces of muscles crossing the knee joint and thus the knee joint load
- The use of the MBT shoe as a training device to strengthen the lower leg stability muscles and intervention to reduce pain in walking may be beneficial for some medial knee OA patients
- The results of this study also indicate that several different adaptation strategies exist for a healthy population, some positive and some negative in terms of the change in knee joint load

SUMMARY OF MAIN FINDINGS:

- The changes in joint kinematics for walking were small
- Individual locomotion strategies for walking in the MBT shoe were identified

- Three of the locomotion identified could be considered “neutral or positive” changes in terms of the medial knee joint loading. 12 of 19 subjects adopted these strategies
- Three locomotion strategies identified could be considered “negative” in terms of the medial knee joint loading. 7 of 19 subjects adopted these strategies
- The strategies identified were for a young healthy population. Different locomotion strategies and percentages of subjects adopting the “positive” or “negative” strategies might be expected for a pathological population