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Whole Body Kinematics When Walking with an Unstable (MBT) Shoe

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Authors' contributions

This work was carried out in collaboration between all authors. All authors took part in the planning of the study. Authors ÅB and EB performed the gait analysis. All authors PW, ÅB and EB analyzed the data and did literature search. Author PW did the major part off the writing. All authors read and approved the final manuscript.

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ABSTRACT

Background: Many positive biomechanical effects have been attributed to the use of a shoe with unstable sole in the anterior posterior direction. When tested, however, only minor changes have been found in relation to each of the investigated joints and muscles in the lower limb. The purpose of this study was to evaluate biomechanical effects on whole body gait characteristics during walking with the Masai Barefoot Technology shoe (MBT) with focus on lower limb and trunk kinematics.
Methods: 18 healthy volunteers were tested using 3D gait analysis and force plates. Data were collected both for common training shoes and the MBT shoes. Joint and trunk specific data for the two different shoe types were compared using the non-parametric Wilcoxon matched pair test.
Results: The overall gait patterns were very similar when the MBT shoes were compared to normal training shoes. Some angular differences were statistically significant but the absolute changes were very small.
Interpretation: Many people experience positive effects when they use the MBT shoe but the biomechanical and kinematic changes are very small compared to common training shoes.

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1. INTRODUCTION

To modify patterns of human locomotion different devices are available. The Masai Barefoot Technology shoe (MBT) is an unstable shoe with a rounded sole that provides instability in the sagittal plane (Fig. 1). The design attempts to simulate an unstable surface thereby requiring continual activation of stabilizing muscles of the lower limb to maintain proper balance. Biomechanical and neuromuscular changes introduced by walking and running with unstable shoes have been investigated previously [1,2,3,4]. These studies show surprisingly small changes in lower limb kinematics and kinetics. Significant increase in muscular activity has been found for the tibialis anterior muscle during walking. Increased ankle dorsiflexion angle during heel-strike and mid-stance have also been described [2,5]. No statistically significant changes in muscular activity have been found for other leg muscles. Small alteration of hip- and knee-biomechanics has been observed [2]. On the other hand standing with use of unstable shoes create increased muscular activity in extrinsic foot muscles [1]. The use of MBT shoes have also improve static balance [2], and it has also been shown that peak pressure in the forefoot decrease during walking. Compensatory there was an increase of the pressure under the toes during both walking and standing [6].

It has been suggested that the use of the MBT shoes also influence trunk kinematics and kinetics and a previous study has shown that the use of unstable shoes can decrease back pain [7]. To date, however, there is no data available concerning whole body biomechanics when walking with unstable shoes.

Three-dimensional (3D) gait analysis includes measurements of movement from multiple joints described as kinematics. 3D gait analysis is a very accurate way of analysing joint movements in the leg and also whole body kinematics is possible to analyse with markers attached to the pelvis and trunk. The aim of this study was to calculate whole body kinematics during walking with and without the unstable shoe. The hypothesis was that the joint movements in the ankle decreased since this kind of shoe has been used for many years for patients with stiff ankle joints. The hypothesis was also that the trunk motion increased since many positive effects concerning back problems have been suggested.

Fig. 1. Masai barefoot technology shoe

2. MATERIALS AND METHODS

2.1 Subjects

18 healthy volunteers including 14 females and 4 males, with mean age 40 (24-57) years, and mean weight 68 (53-84) kg were tested. Volunteers with any history of serious lower-limb injury or lower-extremity pain within 12 months prior to testing were excluded. Informed consent was obtained from all subjects prior to testing according to the Karolinska Institute guidelines and permission from the local ethical committee in Stockholm. The experimental sample size was estimated with a power analysis [8]. A minimum of 16 subjects were necessary to provide the statistical power (0.80) to detect a parameter difference (degrees of joint motion) of 15%. The unstable shoe tested was the MBT M-walk shoe (Masai Barefoot Technology, Swizerland). This shoe is characterized by rounded shoe sole design in the anterior posterior direction. The sole is composed of two types of materials, one located in the heel region and a different material for the anterior sole section.

Nine subjects were 'routine users', e.g. they had used the shoes daily for more than 2 years. Nine subjects were 'new users', e.g. they had used their shoes for a time period between three weeks and one year. All subject had used their MBT shoes daily during three weeks prior to testing [9].

All participants were also tested in their regular flat sole training shoes.

2.2 Gait Analysis

All subjects were asked to walk along a 10 m long walkway at a self-selected walking speed. The self-selected walking speed is a well-established way for an individual to be able to walk at the same speed during several trails. In this case the subjects also are their own controls since they walk with both MBT shoes and normal shoes and the situations are compared. A 3D gait analysis with an 8-camera motion system (Vicon Motion System®, Oxford, UK) was used. Thirty-four reflective markers (9 mm) were bilaterally attached onto the patient's skin over bony landmarks (head, trunk, arms, pelvis, legs and feet) by the same investigator (E.B.), using the Plug In Gait model (Vicon). Discrete gait kinematic parameters were obtained from an average curve of three trials for each side. Two force plates (40 x 60 cm, 9281CA, Kistler, Basel, Switzerland) were used to collect ground reaction forces. Ground reaction forces were measured to be able to calculate moments and powers used for the Gait Deviation Index. The gait analysis system analyses motion of segments of the body and the limits of each segment is shown to the system with the markers. Each segment, for example the lower limb is treated as a rigid body connected to the next segment via a joint. Each segment has a special weight which is calculated by the system by input of the length and height of the subject. So each segment gives rise to a moment of inertia. The system also continuously calculates the angular and linear motions of all the different segments and measures the joint angles continuously. Many times the data can be used to calculate the so called gait deviation index for different gait situations [10,11]. For this particular study however the total deviations when comparing gait with and without the MBT shoe were so small that the gait deviation index was not meaningful to use.

2.3 Statistical Analysis

The nonparametric Wilcoxon matched pairs test was used for comparisons of mean peak angular data. All statistical analyses were performed using the Statistica Software Package (StatSoftInc, USA). Non-parametric tests were used since normal distribution of the data when walking with MBT shoes was not completely certain. Use of non-parametric tests is also known not to overestimate statistical significances.

3. RESULTS

In general the gait characteristics were very similar between MBT and normal shoes. The maximal angles for the different motions in the trunk, hip, knee and ankle joints were measured and the means of these maximal angles were calculated with standard deviations (Table 1). Some changes were statistically significant. The trunk sagittal motion was increased with MBT shoes ($p<0.01$), hip flexion at initial contact between shoe and ground was decreased with MBT shoe ($p<0.01$) and knee flexion at initial contact was increased with MBT shoe ($p<0.03$). The mean maximal ankle dorsiflexion was decreased with 3 degrees ($p<0.01$). As can be seen (Table 1) the absolute values of the angular changes are very limited with the biggest difference measured for the hip flexion at initial contact of less than 5 degrees.

Table 1. Mean of the maximal angles ± standard deviation during walking with MBT and normal training shoes

Variable	MBT	Normal	p- value
Trunk sagittal plane	4.8±0.6	2.9±0.4	0.01
Trunk frontal plane	4.9±0.6	4.6±0.5	0.1
Trunk rotation	6.0±1.1	6.1±1.0	0.3
Hip flexion initial contact	32.6±4.1	37.5±4.3	0.01
Hip abduction	8.1±2.1	8.6±2.6	0.09
Hip rotation	10.1±2.7	10.6±2.4	0.1
Knee extension	-2.4±0.8	-3.1±0.7	0.07
Knee flexion	57.2±5.2	59.4±5.9	0.1
Knee flexion initial contact	4.3±0.9	2.4±0.4	0.03
Ankle dorsiflexion	11.8±2.1	14.1±2.7	0.01
Ankle plantar flexion	15.2±1.9	15.2±2.3	0.3

4. DISCUSSION

Several companies have recently developed shoes with unstable sole and the shoes have been linked to several positive effects. Examples of positive effects are strengthening of postural muscles in the lower leg and back and to keep a more upright position during walking. The effectiveness of training with unstable devices has been shown previously [12,13,14,15] and it has been suggested that the MBT shoe might have the potential of doing the same. It has been shown that the use of an unstable shoe can increase muscular activity in some selected extrinsic foot muscles [1] but other changes in muscular activity has not been found to be significant [2]. In a recent study where the MBT shoe was used during running no specific biomechanical adaptations were found at the hip or knee [5]. It was however suggested that pelvic or upper body adaptations may have occurred in response to the rounded sole. In the present study whole body kinematics was evaluated in order to detect general motion changes during walking.

The results show very limited changes in general gait pattern when comparing the MBT shoe with a common training shoe. The only change in trunk motion was a statistically significant increase of the sagittal motion with the MBT shoe, indicating slightly more instability. However, the absolute value of the angular change was only 2 degrees, which hardly can be of any clinical significance. The hip flexion angle at initial contact was decreased for the MBT shoe. This indicates that the leg does not need to be lifted so high since the heel stance is easier to perform when the sole is rounded up at the back. The mean difference here was 5 degrees which might be of clinical importance for example for people with severe hip problems related to arthritis or dysplasia. In combination with the decreased need for ankle dorsiflexion with the MBT shoe the step might be a little easier to perform with the rounded sole. One should also have in mind that in the present study all participants were healthy volunteers. Bigger differences in joint kinematics might be detected for people with lower limb dysfunction. Regarding the knee the flexion at initial contact was some degrees larger with the MBT shoe indicating the foot is put down to the ground a little straighter. A clinical importance of this fact is hardly recognized. Even if biomechanical effects of MBT shoes are limited in previous studies as well as in the present study, many of the participants who had never used this type of shoe before continued to use them after the study. The reason for this being that they felt the shoes were comfortable, that they felt less stress on their legs and less fatigue. A couple also mentioned that it felt good for the back. This might indicate that there can be bifacial effects that are hard to analyse with biomechanical evaluation.

5. CONCLUSION

This study was performed to investigate the changes in whole body biomechanics during walking with a shoe with unstable sole since it has been suggested that these shoes might be a powerful tool for manipulating human movement [16,17]. Previous studies have focused on differences in specific joint biomechanics and muscular activity but our approach was to calculate the peak mean joint angles of the trunk and at the hip-, knee- and ankle-joints. We found very limited alterations compared to walking with common training shoes. Nevertheless many of the volunteers were determined to continue to use the shoes as their daily working shoes since the general feeling was that it had beneficial effects for their legs and for some also created a good feeling regarding the back.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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