OA Musculoskeletal Medicine

Open Access

Frampton H, Potter S, Smith N, Hodgson D, Dixon J, Ryan CG. The effect of unstable footwear on trunk muscle EMG and postural sway in healthy adults. OA Musculoskeletal Medicine 2013 Aug 01;1(2):15.

Competing interests: none declared. **Conflict of interests: declared in the article.**

All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.

All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

Section: Management

The effect of unstable footwear on trunk muscle EMG and postural sway in healthy adults

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Manuscript type: original research study

All authors contributed to conception and design, manuscript preparation, read and approved the final manuscript.

All authors abide by the Association for Medical Ethics (AME) ethical rules of disclosure.

Competing interests: none declared

Conflict of interests: The unstable footwear used in this study were MBT®'s which were provided by Masai marketing and Trading AG to University for research and teaching purposes. Teesside University funded all other costs associated with the project. However,

the company had no input on the content of the article. The authors declare no other conflicts of interest.

ABSTRACT

Introduction: Preliminary evidence suggests that unstable footwear is beneficial for back pain. It has been proposed that the effect may be mediated by challenging balance causing an increase in core stabilising muscle activity. However, no studies have investigated the effects of unstable footwear on core muscle activity. The primary aim of this study was to investigate if trunk muscle activation during quiet two legged stance was affected by unstable footwear in comparison to usual footwear or barefoot conditions.

Method: In this randomised repeated measures design, healthy participants (n=21) stood on a Kistler™ Force platform for 30seconds three times under three conditions - 1) Barefoot, 2) usual footwear, and 3) unstable footwear. Under each condition postural sway and the average intensity of electromyographic activity was collected for three different muscles bilaterally; Transversus Abdominus (TrA), External Obliques (EO) and Rectus Abdominis (RA).

Results: A repeated measures ANOVA found increased postural sway (Centre of pressure velocity) in the unstable footwear condition compared to both the barefoot condition [4.2 (1.7 to 6.7) $mm.s^{-1}$] [mean difference (95CI)], and the usual footwear condition [4.9 (3.2 to 6.7) $mm.s^{-1}$]. However there was no statistically significant difference in trunk muscle activity between conditions.

Discussion: This study found no evidence that unstable footwear can increase/alter trunk muscle activity suggesting that any positive effects of unstable footwear on back pain may be mediated via different mechanisms other than core muscle training effects. However, further investigation with a clinical population over longer time periods, using different functional tasks may be warranted.

INTRODUCTION

Chronic low back pain (CLBP) is associated with trunk muscle dysfunction[1-6]. Deep core stabilisers such as Transversus Abdominus (TrA) have impaired timing patterns[1,7], and reduced activation levels[5] in individuals with CLBP. Additionally there is evidence that patients with CLBP are less able to preferentially activate the deeper stabilisers relative to larger superficial muscles such as the Rectus Abdominus [RA][2]. Thus, clinically, core stability interventions for individuals with CLBP attempt to selectively activate the deep core stabilisers relative to the larger superficial muscles[8,9]. A number of studies have shown that core stability training can normalise trunk muscle activity[9,10] and improve pain and function in patients with CLBP[11,12].

Within core stability exercise regimes the use of unstable surfaces may be helpful for increasing trunk muscle activation. Relative to a stable surface, performing abdominal exercises on an unstable surface, such as a Swiss ball, can increase RA activity and External Oblique [EO] activity[13-15]. However a key problem with these interventions is that they require patient adherence to exercise programs which can be as low as 36% in patients reporting high pain levels[16]. Adherence to exercise programmes may be improved if the exercise regime, or unstable surface which might challenge balance, could be incorporated into everyday activities of daily living.

One potential way by which issues of non-compliance could be overcome for core stability exercises is the use of unstable footwear as part of the individual's everyday life. Unstable footwear can increase postural instability in healthy adults as indicated by increased postural sway when wearing unstable footwear in comparison to usual footwear[17]. This could potentially increase trunk muscle activity during everyday activity. There is preliminary evidence from one RCT that unstable footwear could improve back pain[18]. The authors of the RCT postulate that this effect may have been achieved by *increased engagement of core muscle groups*[18]. This could relate to increased intensity of activity, altered muscle timing or increased co-contraction. While there is evidence that unstable footwear can increase foot and leg muscle activity in healthy individuals[17,19], the effects of unstable footwear on trunk muscle activity in healthy individuals or individuals with back pain have not yet been investigated.

The aim of this study was to investigate if trunk muscle activation was affected by unstable footwear in comparison to usual footwear or barefoot conditions in healthy individuals.

MATERIALS AND METHODS

Participants

A convenience sample of healthy University students was recruited. Inclusion criteria were: ≥18 years of age, no history of low back pain, no previous medical history which may affect their ability to take part, no previous surgery to the back or abdomen, no history of epilepsy, not currently pregnant or recently given birth, and has the capacity to consent. Exclusion criteria were; a history of inner ear problems; a history or falls, an allergy to the EMG conductance gel, alcohol or recreational drug consumption in the past 24 hours. Ethics approval was granted by the School of Health and Social Care Research Governance and Ethics Committee at University (Reference number: 177/11). Written informed consent was obtained from all participants and all work was conducted in accordance with the Declaration of Helsinki (1964).

Design

The study used a within-subject experimental design with participants taking part in testing in each of three conditions – 1) Barefoot, 2) usual footwear, and 3) unstable footwear (Masai Barefoot Technology [MBT]). The order of testing was randomised using a Latin squares design. For each footwear condition the participant stood on a force plate (Model 9286AA, Kistler, Alton, UK) three times for 30 seconds during which muscle activity was measured using surface electromyography (EMG). The average integrated EMG was collected for three different muscles bilaterally; transversus abdominis (TrA) rectus abdominis (RA) and external obliquues (EO). Using surface EMG to measure TrA cannot distinguish between TrA and Internal Obliquues (IO), thus throughout the results of this paper when TrA activity is described we are referring to TrA/IO activity[20]. The balance outcome measures were the range and standard deviation of the CoP displacement in the anterior-posterior and medio-lateral directions (AP range, AP SD, ML range, ML SD respectively, all mm) and the mean CoP velocity ($mm.sec^{-1}$) in the AP and ML directions, and collectively (the overall mean velocity), during bipedal standing. The CoP displacement variables represent the magnitude of CoP movement (a marker of sway) quantified in the AP and ML directions as the range and SD (average deviation from the mean position). The CoP velocity measures represent the speed of postural sway in the AP and ML directions, and overall. Increases in all of these parameters are clinically interpreted as poorer sway or postural control. The muscle activity and postural sway were compared between conditions.

2.3 Instrumentation

Balance data was obtained from a Kistler™ Force platform (Model 9286AA, Kistler, Alton, UK) - W 40 × L 60 x H 3.5cm, sampled at 50 Hz . Surface EMG recordings were collected using a 16-channel Biopac system (Model MP100), using bipolar active surface EMG recording electrodes (Type TSD 150B, 11.4mm diameter, electrode spacing 20mm), with 3dB 12-500Hz bandpass and x330 built in amplification. After cleaning and shaving the skin, EMG recordings were collected from standardised sites on three muscles bilaterally. Standardisation of electrode placement followed the recommendations of Marshall & Murphy[14,20,21]. Each TrA electrode was located approximately 2cm medial and inferior to the anterior superior iliac spine. Each EO electrode was positioned 12-15cm lateral to the umbilicus, oriented 45° to the horizontal[14]. Each RA electrode was located 3cm superior to the umbilicus and 2cm lateral to the mid line[20]. All electrodes were positioned whilst subjects were standing to eliminate movement over the skin surface when moving from supine to a standing position. A pre-gelled ground reference electrode (Blue Sensor ®) was placed at the sternum. The EMG and force plate systems were synchronised.

Unstable Footwear

Unstable footwear has a curved or uneven sole construction which attempts to challenge the balance of the wearer. A number of different companies produce unstable footwear. The unstable footwear used in this study was provided by the company MBT (Masai Marketing and Trading AG, Switzerland) (see figure 1). The specific make of MBT shoes used were Kimondo (for men) & Fora (for women). A range of sizes were available to accommodate the differing foot size of the participants.

INSERT FIGURE 1 HERE

Procedures

All participants carried out standard tests of bipedal quiet standing with eyes open lasting 30 seconds. This is a standard test, commonly used in rehabilitation research for assessment of balance [22, 23]. There were three trials for each condition, making nine trials in total per participant. Each participant carried out all three trials of one condition before testing took place under another condition. The sequence of test condition was randomised using number cards selected by that participant. Due to the unstable nature of the MBT shoes, an acclimatisation period of ten minutes was permitted prior to the commencement of the MBT condition for participants to become accustomed to the sensation of wearing the shoes. During this ten minute period participants were free to stand/walk as much as they wanted within the laboratory.

Participants were instructed to stand with their arms by their side, looking straight forwards and to focus on the middle of a visual target. The feet were spaced approximately 15cm apart and aligned in an anterior-posterior direction on the force plate.

To enable normalisation of the EMG amplitudes during the balance tests, maximal voluntary contractions (MVCs) were carried out before the standing balance procedure. A maximal resisted sit up contraction while lying supine was used for the RA and EO[13]. A maximal draw-in test in 4 point kneeling was used to normalise the TrA data[14]. Both of these MVCs consisted of a 5 second isometric contraction, and participants carried out 3 trials of each, with practice attempts beforehand for familiarisation. All EMG recordings were stored digitally for later analysis.

Data extraction and analysis

ML and AP range and SD were calculated automatically by the force platform for 30 seconds in each trial, using the Bioware software package[22,23]. Three measures of CoP velocity (AP velocity, ML velocity, overall velocity) were calculated using previous methods[24], after low-pass filtering of the raw data at 10Hz. Overall mean COP velocity was calculated using the equations according to Raymakers et al[24]:

$$Vd = \frac{\sqrt{((x_i - x_{i-1})^2 + (y_i - y_{i-1})^2)}}{t_i - t_{i-1}}$$

$$Vm = \frac{\sum Vd}{n}$$

Where x is the position of the COP at time t, i is the participant data set and n is the number of paired data points.

COP Velocity was calculated individually for the AP and ML directions using equations based on those of Raymakers et al [24]

$$Vd_{AP} = \frac{y_i - y_{i-1}}{t_i - t_{i-1}}$$

$$Vm_{AP} = \frac{\sum |Vd_{AP}|}{n}$$

Where Vd is the displacement velocity, Vm is the mean velocity, y is the COP position in mm from the origin in the AP direction, and was substituted for x for the ML direction.

To produce a linear envelope, the raw EMG data were processed with a 20Hz high pass filter and a root mean square moving window of 25ms using the system's AcqKnowledge software (Version 3.7.3, BIOPAC Systems Inc., Santa Barbara, CA, USA). Any ECG artefacts were cleaned from the traces[9,25]. The average integrated EMG was extracted for each muscle in each balance trial. The EMG values for each muscle were averaged over the three trials for each condition. The EMG amplitudes during the balance testing were then normalised to the levels during the MVCs for each muscle. For normalisation purposes, the whole of each MVC burst was used, onset and cessation being determined visually, and the average of the three MVCs was calculated and used as the reference level. Normalisation was carried out by converting the average EMG value during the balance tests to a percentage of that during the MVCs.

To investigate if the deep core stabilisers were preferentially activated compared to the larger superficial muscles the EMG ratio between the TrA and the RA was calculated [TrA/RA ratio][9,14]. To calculate this ratio for each participant, the normalised TrA amplitude was divided by the normalised RA amplitude.

Statistical analysis

Data were analysed using the Statistical Package for Social Sciences (SPSS, Chicago, IL, USA) version 18.0. For each of the variables, a repeated measures analysis of variance (ANOVA) was carried out to determine the effects of the test conditions, with alpha set at 0.05. Where the assumption of sphericity was violated, a Greenhouse-Geisser correction was applied. Differences between each pair of conditions were evaluated using mean differences and 95% confidence intervals.

RESULTS

Participants

Twenty two participants volunteered for this study. One participant had a recent episode of LBP and was thus excluded from participating. The remaining 21 participants (Age 27±7 years; 13 female, 8 Males; BMI 22.9±3.4 $Kg.m^{-2}$) completed the study.

Postural Sway

The postural sway data are compared between each condition in table 1. For all postural sway outcome measures the MBT footwear produced significantly greater sway (poorer balance) than usual footwear, though the overall ANOVA for ML SD and ML range was not statistically significant ($p = 0.053$ and $p = 0.066$, respectively). Similarly, for MBT footwear compared to the barefoot condition, the sway in the AP direction (Range and SD) and CoP velocity in the AP direction and overall was significantly greater. There was no significant difference in postural sway between the barefoot and usual footwear conditions.

Insert table 1 here

EMG

Data for one participant was excluded due to electrical noise. The EMG data are compared between each condition in table 2. There was no statistically significant difference between conditions for any muscles or for the TrA/RA EMG ratios.

Insert table 2 here

DISCUSSION

The aim of this study was to investigate if trunk muscle activation was affected by unstable footwear in comparison to usual footwear or barefoot conditions. While unstable footwear increased postural sway compared to a usual footwear and barefoot condition, there was no difference between conditions for trunk muscle activity.

In keeping with the findings of this study, previous research has shown that unstable footwear can increase postural sway[17]. Thus unstable footwear does create instability. However, it does not appear that this instability is accommodated by any change in trunk muscle activity. Importantly, it should be noted that this bipedal balance test will not have been very challenging for participants, and the ankle strategy will have been the dominant postural control mechanism. Thus the possibility remains that wearing these shoes during more demanding tasks could produce effects on the trunk muscles. There is some evidence that unstable footwear increases muscle activity in the foot and lower leg[17,19]. Thus, it is likely that in this study these lower limb muscles accommodated the instability created by unstable shoes rather than trunk muscles. However, other studies suggest that wearing unstable footwear does not affect lower limb muscle activity[26,27], thus it cannot be stated for certain that this occurred.

There is preliminary evidence that unstable footwear may be beneficial for low back pain and it has been postulated that this benefit may have been brought about through enhanced trunk muscle activity[18]. The current study found no evidence that unstable footwear can increase muscle activity which suggests that the positive effects of unstable footwear on low back pain may be mediated via different mechanisms other than core muscle training effects. However, it is possible that unstable footwear affects core muscle activity timing patterns rather than overall activity levels and further investigation of the effects of unstable footwear on trunk muscle timing is warranted. Additionally, the participants in this study were healthy individuals with no history of low back pain thus their trunk muscle activity was unlikely to be abnormal. If the study was repeated with low back pain participants, with deficient trunk muscle activity, the unstable shoes may have affected muscle activity.

Previous studies comparing core muscle exercises on a stable surface compared to an unstable surface have suggested that unstable surfaces can increase trunk muscle activity[13-15] which is contrary to the findings of this study. One potential reason for this is that the degree of instability imparted by the unstable footwear is less than that created by equipment such as Swiss balls and wobble boards. If unstable shoes produced greater imbalance, this may have an effect on core muscle activity, but this would have to be countered by issues of safety, comfort, and function etc. It is plausible that quiet bipedal stance, as used in this study, does not maximise the imbalance potential of the unstable shoes and greater imbalance may have been created using dynamics tasks such as walking of activities of daily living where the centre of mass frequently moves outside the base of support which would enable a greater extent of the rollover MBT sole to be used. Further research investigating the effects unstable footwear during these activities is warranted.

Limitations

This was a small study (n=21) thus there was a risk of a type II statistical error, however the magnitude of the confidence intervals were small and showed little indication of any clinically meaningful effect independent of statistical significance. The study only looked at the acute effects of the shoes on muscle activity; there is a need to investigate the long term effects. All participants were healthy with no history of back pain; there is a need to repeat this study in a clinical population with potentially impaired trunk muscle activity such as individuals with chronic low back pain. The current study only looked at the magnitude of muscle activity and no inferences can be made about possible effects on important clinical outcomes such as muscle timing. The normalisation contractions may not have elicited maximal activation of all muscles, especially EO, so the % values should be interpreted with caution. This study only looked at standing, and the findings cannot be extrapolated to other functional activities such as walking or running. Finally, when using surface EMG there is a risk of cross talk between muscles especially when attempting to measure the muscle activity of deep muscles such as the TrA. However the method of surface EMG used in this study has been well validated and is widely used in the literature[14,20].

Prior to the MBT tests participants wore the unstable shoes for 10 minutes. The purpose of this was to allow the wearer to habituate to the shoe. The reason for doing this was twofold, firstly, to reduce the risk of a fall due to the individuals base of support suddenly becoming less stable, and secondly, to attempt to ensure that any alterations in balance or muscle activity were not simply due to the immediate effects of the unbalanced shoe which may have worn off within a few minutes of wearing, and thus not have been reflective of everyday use of the shoes. It has been shown that unstable shoes can affect leg muscle function in the immediate term for those who have never worn unstable shoes before (Branthwaite et al.

2012)[28]. Thus the results may have been different if that habituation period had not been provided.

Previous or current use of unstable footwear was not one of our inclusion/exclusion criteria, nor was the data recorded, thus we cannot be certain that all participants were novice unstable shoe wearers, although none of the participants were wearing unstable footwear in the usual footwear condition. Stoggl & Muller (2012) found evidence of different leg muscle EMG activity when wearing MBT’s before and after a 10 week habituation period. Thus, it is possible that any habitual wearers may have responded differently to novice users of unstable footwear.

The type of footwear worn in the usual footwear condition was not recorded (beyond the fact that none were categorised as unstable shoes) thus what effects the type of shoe worn during this condition had on balance/EMG cannot be commented upon beyond that fact that this is the footwear participants usually wore in daily life.

The activity used in this study was quiet bipedal standing. This may not have sufficiently challenged balance in this healthy population, and further study of unstable footwear using more challenging activities may be warranted.

CONCLUSIONS

The aim of this study was to investigate the effects of unstable shoes on trunk muscle activity compared to usual footwear and barefoot conditions. The unstable shoes increased postural sway but had no statistically significant effect on trunk muscle activity. This study does not support the hypothesis that unstable footwear can increase core muscle activity in healthy individuals, though further work in clinical populations may be warranted.

Acknowledgements

The unstable footwear used in this study were MBT®'s which were provided by Masai marketing and Trading AG to [redacted] University for research and teaching purposes. [redacted] University funded all other costs associated with the project. However, the company had no input on the content of the article. The authors declare no other conflicts of interest.

REFERENCES

1. Hodges PW, Richardson CA. Inefficient muscular stabilization of the lumbar spine associated with low back pain. Spine. 1996; 21: 2640-2650.
2. O'Sullivan P, Twomey L, Allison G, Sinclair J, Miller K, Knox J. Altered patterns of abdominal muscle activation in patients with chronic low back pain. Australian Journal of Physiotherapy. 1997; 43: 91-98.
3. Evans C, Oldreive W. A study to investigate whether golfers with a history of low back pain show a reduced endurance of transversus abdominis. Journal of Manual and Manipulative Therapy. 2000; 8: 162-174.
4. Hodges PW, Moseley GL. Pain and motor control of the lumbopelvic region: Effect and possible mechanisms. Journal of Electromyography and Kinesiology. 2003; 13: 361-370.
5. Ferreira PH, Ferreira ML, Hodges PW. Changes in recruitment of the abdominal muscles in people with low back pain: Ultrasound measurement of muscle activity. Spine. 2004; 29: 2560-2566.
6. Hodges PW. Pain and motor control: From the laboratory to rehabilitation. Journal of Electromyography and Kinesiology. 2011; 21: 220-228.
7. Marshall P, Murphy B. Delayed abdominal muscle onsets and self-report measures of pain and disability in chronic low back pain. Journal of Electromyography and Kinesiology. 2010; 20: 833-839.

8. Richardson CA, Jull G. Muscle control - pain control. What exercises would you prescribe? Manual Therapy. 1995; 1: 2-10.
9. O'Sullivan PB, Twomey L, Allison GT. Altered abdominal muscle recruitment in patients with chronic back pain following a specific exercise intervention. Journal of Orthopaedic and Sports Physical Therapy. 1998; 27: 114-124.
10. Tsao H, Hodges PW. Persistence of improvements in postural strategies following motor control training in people with recurrent low back pain. Journal of Electromyography and Kinesiology. 2008; 18: 559-567.
11. Ferreira ML, Ferreira PH, Latimer J, Herbert RD, Hodges PW, Jennings MD, Maher CG, Refshauge KM. Comparison of general exercise, motor control exercise and spinal manipulative therapy for chronic low back pain: A randomized trial. Pain. 2007; 131: 31-37.
12. Macedo LG, Maher CG, Latimer J, McAuley JH. Motor control exercise for persistent, nonspecific low back pain: A systematic review. Physical Therapy. 2009; 89: 9-25.
13. Vera-Garcia FJ, Grenier SG, McGill SM. Abdominal muscle response during curl-ups on both stable and labile surfaces. Physical Therapy. 2000; 80: 564-569.
14. Marshall PW, Murphy BA. Core stability exercises on and off a Swiss ball. Archives of Physical Medicine and Rehabilitation. 2005; 86: 242-249.
15. Imai A, Kaneoka K, Okubo Y, Shiina I, Tatsumura M, Izumi S, Shiraki H. Trunk muscle activity during lumbar stabilization exercises on both a stable and unstable surface. Journal of Orthopaedic and Sports Physical Therapy. 2010; 40: 369-375.
16. Sluijs EM, Kok GJ, Van der Zee J, Turk DC, Riolo L. Correlates of exercise compliance in physical therapy. Physical Therapy. 1993; 73: 771-786.
17. Landry SC, Nigg BM, Tecante KE. Standing in an unstable shoe increases postural sway and muscle activity of selected smaller extrinsic foot muscles. Gait and Posture. 2010; 32: 215-219.
18. Nigg BM, Davis E, Lindsay D, Emery C. The effectiveness of an unstable sandal on low back pain and golf performance. Clinical Journal of Sports Medicine. 2009; 19: 464-470.
19. Romkes J, Rudmann C, Brunner R. Changes in gait and EMG when walking with the Masai Barefoot Technique. Clinical Biomechanics. 2006; 21: 75-81.
20. Marshall P, Murphy B. The validity and reliability of surface EMG to assess the neuromuscular response of the abdominal muscles to rapid limb movement. Journal of Electromyography and Kinesiology. 2003; 13: 477-489.

21. Marshall PWM, Murphy BA. Increased deltoid and abdominal muscle activity during swiss ball bench press. Journal of Strength and Conditioning Research. 2006; 20: 745-750.

22. Hatton AL, Dixon J, Martin D, Rome K. The effect of textured surfaces on postural stability and lower limb muscle activity. Journal of Electromyography and Kinesiology. 2009; 19: 957-964.

23. Hatton AL, Dixon J, Rome K, Martin D. Standing on textured surfaces: Effects on standing balance in healthy older adults. Age and Ageing. 2011; 40: 363-368.

24. Raymakers JA, Samson MM, Verhaar HJJ. The assessment of body sway and the choice of the stability parameter(s). Gait and Posture. 2005; 21: 48-58. Romkes J, Rudmann C, Brunner R. Changes in gait and EMG when walking with the Masai Barefoot Technique. Clinical Biomechanics. 2006; 21: 75-81.

25. Kamei K, Kumar DK, Polus BI. Reliability and validity of surface electromyography (SEMG) to study the functional status of lumbar paraspinal muscles during execution of unsupported sitting posture. Chiropractic Journal of Australia. 2007; 37: 30-37.

26. Demura T, Demura SI. The effects of shoes with a rounded soft sole in the anterior-posterior direction on leg joint angle and muscle activity. Foot. 2012; 22: 150-155.

27. Sacco ICN, Sartor CD, Cacciari LP, Onodera AN, Dinato RC, Pantaleao Jr E, Matias AB, Cezario FG, Tonicelli LMG, Martins MCS, Yokota M, Marques PEC, Costa PHC. Effect of a rocker non-heeled shoe on EMG and ground reaction forces during gait without previous training. Gait and Posture. 2012; 36: 312-315.

28. Branthwaite H, Chockalingam N, Pandyan A, Khatri G. Evaluation of lower limb electromyographic activity when using unstable shoes for the first time: A pilot quasi control trial. Prosthetics and Orthotics International. 2012; 37: 275-281.

Table 1: OA_11.04.13_Table1(r1).docx

Table 1: Postural sway for each condition during quiet standing (n=21)

	BF Mean (SD)	U Mean (SD)	MBT Mean (SD)	ANOVA *p*-value	BF-U Mean (95%CI)	BF-MBT Mean (95%CI)	U-MBT Mean (95% CI)
AP SD (mm)	4.1 (1.5)	4.6 (1.5)	6.7 (2.2)	0.001*gg	0.5 (-0.1 to 1.1)	2.6 (-1.5 to 3.6)*	2.1 (1.2 to 2.9)*
AP range (mm)	22.3 (8.2)	23.4 (7.6)	34.1 (9.3)	0.001*	1.1 (-2.1 to 4.4)	11.8 (6.5 to 17.1)*	10.7 (5.9 to 15.4)*
AP CoP Velocity (mm.s^{-1})	8.2 (1.8)	8.3 (1.3)	13.2 (3.2)	0.001*gg	0.1 (-0.7 to 0.9)	5.0 (3.2 to 6.8)*	4.9 (3.4 to 6.5)*
ML SD (mm)	2.7 (1.8)	2.2 (0.6)	3.2 (1.1)	0.053gg	-0.5 (-1.6 to 0.5)	0.5 (-0.7 to 1.7)	1.0 (0.5 to 1.6)*
ML range (mm)	15.1 (9.3)	13.3 (3.2)	18.0 (5.5)	0.066gg	-1.8 (-6.6 to 2.9)	2.9 (-3.2 to 9.0)	4.7 (1.5 to 8.0)*
ML CoP Velocity (mm.s^{-1})	14.9 (4.5)	14.1 (3.8)	15.8 (4.2)	0.019*gg	-0.8 (-2.0 to 0.4)	0.8 (-0.8 to 2.5)	1.6 (0.6 to 2.6)*
CoP velocity (mm.s^{-1})	18.7 (4.4)	18.0 (3.6)	22.9 (5.2)	0.001*gg	-0.7 (-2.1 to 0.7)	4.2 (1.7 to 6.7)*	4.9 (3.2 to 6.7)*

*p<0.05, gg = Greenhouse-Geisser correction for sphericity, BF = Barefoot, U = Usual footwear, MBT = Masai Barefoot Technology®, AP = Antero-posterior, ML = Medio-lateral, CoP = Centre of Pressure, SD = Standard Deviation.

Table 2: OA_14.08.13_Table2(r1).docx

Table 2: EMG Muscle activity for each condition (n=20)

	BF Mean (SD)	U Mean (SD)	MBT Mean (SD)	ANOVA *p*-value	BF-U Mean (95%CI)	BF-MBT Mean (95%CI)	U-MBT Mean (95% CI)
<u>Left Side</u>							
TrA (%)	29.5 (20.0)	30.8 (21.5)	31.9 (22.2)	0.103	1.3 (-1.2 to 3.7)	2.3 (-0.9 to 5.6)	1.0 (-1.4 to 3.5)
EO (%)	36.6 (41.0)	35.6 (30.7)	32.5 (22.7)	0.578gg	-0.9 (-10.5 to 8.5)	-4.0 (-22.9 to 14.8)	-3.1 (-13.1 to 7.0)
RA (%)	8.0 (6.1)	8.6 (7.3)	7.8 (6.5)	0.625gg	0.6 (-0.8 to 2.0)	-0.2 (-3.7 to 3.2)	-0.8 (-3.8 to 2.2)
TrA/RA ratio	5.2 (4.1)	5.6 (5.0)	6.3 (6.7)	0.247gg	0.4 (-0.7 to 1.5)	1.1 (-1.2 to 3.3)	0.7 (-0.7 to 2.1)
<u>Right Side</u>							
TrA (%)	28.5 (26.3)	28.6 (25.5)	29.8 (27.2)	0.334gg	0.03 (-2.3 to 2.3)	1.2 (-2.2 to 4.7)	1.2 (-0.5 to 2.9)
EO (%)	37.3 (27.0)	40.6 (28.8)	41.1 (30.6)	0.402gg	3.2 (-4.4 to 10.9)	3.7 (-7.3 to 14.8)	0.5 (-4.9 to 5.9)
RA (%)	9.3 (10.0)	9.5 (8.3)	10.0 (10.6)	0.611gg	0.3 (-2.6 to 3.2)	0.7 (-0.3 to 1.7)	0.4 (-2.0 to 2.9)
TrA/RA ratio	4.4 (4.0)	4.5 (4.8)	4.8 (5.5)	0.428gg	0.1 (-0.7 to 0.9)	0.4 (-0.8 to 1.6)	0.3 (-0.2 to 0.8)

**p*<0.05, gg = Greenhouse-Geisser correction for sphericity, BF = Barefoot, U = Usual footwear, MBT = Masai Barefoot Technology®, TrA = Transversus Abdominus, EO = External Obliquees, RA = Rectus Abdominus.

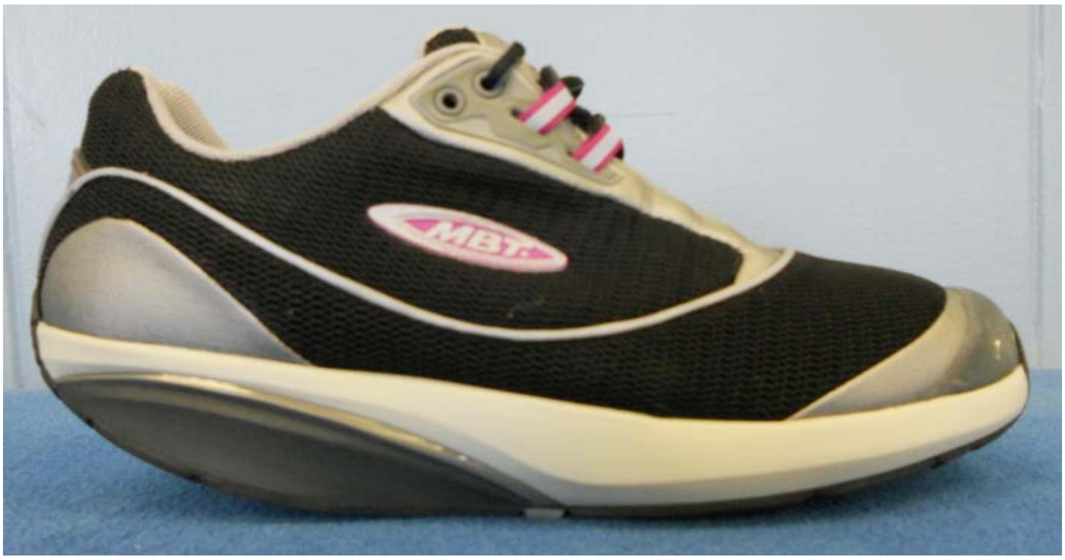

Figure 1: OA_14 08 13_figure1(r1).tif