Journal of Bodywork & Movement Therapies (2009) xx, 1–10

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ScienceDirect
journal homepage: www.elsevier.com/jbmt

Journal of Bodywork and Movement Therapies

PREVENTION & REHABILITATION: EDITORIAL

Shifting paradigms

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Received 6 January 2010; accepted 6 January 2010

Often a fad may be described, perhaps falsely, as a paradigm shift. In the rehabilitation and prevention section of the previous issue of JBMT, Lederman (2010) challenged what many would consider a paradigm shift that has occurred over the last decade or more as a result of the focus by many bodywork and movement therapists on ''core stability''.

What Lederman's (2010) article highlighted was the fact that, bodyworkers and movement educators have a number of tools in their tool-kit, and an important skill involves the ability to grow with the knowledge base, and not to succumb to trends as ''panaceas''; nor to become too dogmatic regarding beliefs. This is easier said than done, of course. Nevertheless, if such advances can be seen as emergent tools, which may, at some point, become usurped by other more current techniques, this may be judged an appropriate evolution. Equally, it is important to not become dogmatic in the way the tools used by others are judged; too narrow a focus usually results in collisions with unforeseen peripheral concepts and rationale.

One rationale Lederman has previously used was to ask how the human body *should* function by looking for an evolutionary advantage (Lederman, 2000). Clearly, there is rarely a time when a primal human being would be found doing a prone transversus abdominis activation exercise with a biofeedback cuff! Nevertheless, there may be rationale to explain how human physiology could embrace ''core stability'' and other methods, as part of a primal environment (see Textbox 1).

In a recent discussion with a sports medicine physician, a ''tool'' that the author of this editorial has been involved with for just over 2 years, was explained; a footwear product called *Vibram Fivefingers*. This product is one of many on the market that claims to offer a functional benefit to users; fitting it into the emerging category of ''functional footwear'' alongside brands such as Masai Barefoot Technology (MBT), FitFlop, Nike Free's, Vivo Barefoot and Newton running shoes, among others.

The sports medicine physician commented that since there was little research to back use of the Vibram Fivefingers; and that what research there was seemed to suggest a dramatic change of the gait pattern, and the way the user runs (Squadrone and Gallozzi, 2009), they could be dangerous and might well cause as many injuries as might be prevented. This may, of course, be true. However, the fact that this new data correlated closely with barefoot data, but was distinct from shod data, meant that it could be interpreted either as a dramatic change to what the (shod) individual is used to; or a dramatic reversion to what the individual is designed for.

Evolving ideas

Study of the foot offers an opportunity to consider factors such as the possible benefits of barefoot walking. Data searches suggest that there is an abundance of evidence in support of this. (Warburton, 2001; Wallden, 2008; Squadrone and Gallozzi, 2009).

In recent years Masai Barefoot Technology shoes have gained ground in the market place as a new concept. At the same time Nike, the largest producer of sports shoes (originators of the concept of a ''running shoe''), recognized that in order to enhance running performance, and decrease running injuries, their top advisors were recommending that athletes should frequently train barefoot (McDougall, 2009).

Objectively barefoot walking appears sensible, especially when it is appreciated that supporting a structure (in

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1360-8592/$ - see front matter
doi:10.1016/j.jbmt.2010.01.004

Textbox 1: The Survival Reflex (taken from Wallden (2008) *Rehabilitation and re-education (movement) approaches in Chaitow (Ed) Naturopathic Physical Medicine*. Elsevier)

Chek (2000, 2004) has described what he terms a survival reflex where the body will reflexively recruit all muscles it can, to avoid an actual, or a perceived, catastrophic event. Certainly these observations seem to have good founding both in the clinical environment, and in the neurophysiological literature. For example, Davidoff (1992) explains that the capacity of the segmental myotatic reflex system to compensate for changing loads is only modest. What the Swiss ball does not tend to do is to place the body under significant load (as would occur in some sports or in weight-lifting). Davidoff goes on to say that reflexive adjustments at the segmental level may be effective at compensating for perturbation when the errors of position are small and the stretch is rapid. This is exactly what we tend to find with Swiss ball use; a small rapid need to correct the posture. Nitz and Peck (1986) also observe that a characteristic of the deeper, inner unit musculature is that they have an increased concentration of spindle cells making them particularly important for (and reactive to) stability challenges. As Panjabi et al. (1989) discuss, the typically shorter length of the inner unit muscles, and their lower threshold to stimulus, allow them to react more quickly; hence their response to anything that induces a stability challenge, such as a Swiss ball, wobble boards, or balance shoes.

Additionally, Janda (1999) comments that a classic way of combating low back pain utilized by the aboriginal Indians of North America was to run in dried out river-beds. Anyone who has tried to run on the soft sand of a beach will recognize that this probably posed something of a perturbation and/or balance challenge to help reactivate their inner unit.

In contrast, Hides et al. (1996) showed that even 1 year after resolution of low back pain, the lumbar multifidus had not recovered its normal function. They proposed that this may be a mechanism for the onset of chronic back pain. What Hides and co-worker's research implies is that if someone has a pain problem, they cannot properly recover from it unless they see a trained therapist to teach them to consciously activate multifidus/transversus abdominis and other inner unit muscles. However, this may be a somewhat simplified view.

Indeed the implication would be that prior to Hides' research in 1996 — which would include the whole of human evolution — a single bout of low back pain or a back injury would result in compromised inner unit function and therefore presumably, compromised ability to move, to hunt or to evade predators. In short, the prognosis after even one bout of back pain wouldn't be too good. In their paper, Hides et al. do not state how many of their experimental subjects were actively engaged in sports, how many were entirely sedentary — or any shade in between. In an unpublished meta-analysis of the available high-quality literature available on core rehabilitation in 1998, the author concluded that, since there are so many potential methodological flaws with most exercise prescriptions at that time, it would seem that the best way to effectively rehabilitate function of the core musculature, would be to play sports that involved multiple movement patterns. Since then, knowledge has moved on, and effective core activation can be progressed from floor based to Swiss ball based, to standing functional exercises. But to play interactive sports is still a very reasonable piece of advice for core conditioning — assuming that the patient is able to activate their deep stability system when they play their sport. The primal pattern system of assessment described above can be utilized to see if, when and in which movement patterns (motor chunks) the patient is able to activate their core.

This conclusion seemed to coincide somewhat with the concept of the ''survival reflex'' and with the nature of existence in the great outdoors. There is little doubt that in running as fast as the body can manage would allow the climbing of the nearest tree — even perhaps then swinging through the vines to escape a big cat, would be enough to activate both Chek's ''survival reflex'' and the perturbations described by Davidoff — and show some parallels to Janda's river-bed running.

the same way one might support a broken arm in a cast) would ultimately result in weakening of the supporting musculature. To keep the feet strong, and the athlete injury-free, Nike were being encouraged by their advisors to consider a ''barefoot'' alternative, ultimately resulting in the birth of the ''Nike Free''.

The evolutionary experiment

The foot evolved around 270 million years ago (Haines, 1999). In contrast, shoes have been around for a few thousand years at most, making their congruence with optimal biomechanical function of the foot more questionable.

The primary counter argument posed by those who hold strongly to the notion that shoe support, or cushioning, is required, is that humans did not evolve on concrete roads and paths (Downey, 2009).

The best available evidence implies that humans evolved in Africa, where great swathes of the land were baked harder than concrete for at least 6 months of the year and, significantly, where most of the major fossil finds of our hominid ancestors were in rocky environments such as the Rift Valley, Olduvai Gorge or volcanic regions such as Laetoli. Indeed, the African palaeoecological record of the past 2+ million years shows a proliferation of drought-tolerant trees, with moisture-loving trees being less prevalent for the last 2+ million years than they are even today (Stringer and Andrews, 2005). All animals require sufficient functional dexterity so that they can survive and thrive in the environment in which they find themselves; which would rarely be one single substrate, but a combination of hard, soft, rugged, flat and inclined surfaces, and much more besides.

Interestingly, Zipfel and Berger (2007) assessed lesions found in the metatarsals of the three recently evolved human groups (Sotho, Zulu and European) and found that they generally appeared to have more severe pathologies than those found in groups of 35 pre-pastoral (9720 and 2000 years

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before present) remains. They suggest that this result may support the hypothesis that pathological variation in the metatarsus was affected by habitual behaviour — including the wearing of footwear — and exposure to modern substrates.

However, since both recent and ancient groups presented with similar patterns of pathological variation, but notable differences in frequency, Zipfel and Berger (2007) interpret these changes as only, in part, a result of the environment, and to a greater extent ton be a result of differences in habitual behaviour — primarily the wearing of shoes.

When shod versus unshod populations are compared, there is research confirming that unshod populations have better arch development (Rao and Joseph, 1992; Mauche et al., 2008), and that there is a lower prevalence of many of the most common running injuries in barefoot running populations, versus shod running populations including ankle sprain, shin splints, Achilles tendinopathy, plantar fasciitis, iliotibial band syndrome, peri-patella pain, back pain (Warburton, 2001).

From this recognition, a new phenomenon has arisen; the emergence of a market for ''functional footwear''.

Functional footwear

Six current brands of so-called ''Functional Footwear'' are discussed below (the Nike Free, the MBT, the FitFlop, Vivobarefoot, the Newtons, and the Vibram Fivefingers). It is acknowledged that this list is not fully comprehensive, and that there are other products such as Beech Sandals, Earth Shoes, Crocs, and many others besides, who claim (and may well have) functional benefits, however, journal space and the ability to provide a fully exhaustive review in such a growth sector would always dictate the need for a cut-off point.

Conflict of interest

The author of this editorial is UK Distributor, *Vibram Fivefingers*, one of the six brands reviewed in this editorial.

Nike free (Contributor: M. Lafortune, Nike Inc.)

Nike is closely connected with athletes and coaches at all levels, from beginners to elite athletes. At the time of the Sydney Olympics, we started to hear more and more about athletes either warming up for or cooling down from their runs, barefoot. These barefoot warm ups or cool downs typically took place on nice pristine soccer/football fields. In the opinions of coaches and athletes, this leads to better performance and less injury.

> '' *I can't prove this,* but I believe that athletes that have been training barefoot run faster and have fewer injuries. It's just common sense.'' Vin Lananna, Track & Field, University of Oregon (McDougall, 2009; Lafortune, 2009)

Considering that only few athletes (beginners to elites) have access to well maintained and safe grassy surfaces due to locations or climatic conditions, Nike decided to create a shoe that would allow athletes to run on pavement and have their feet function as they function when running barefoot on grass.

Nike developed the Nike Free running shoe in 4 phases: In Phase 1, they gathered information regarding barefoot function while running on grass; in Phase 2 they created a shoe to allow close mimicry of the barefoot kinematics observed in phase 1. For Phase 3, Nike decided to partner with Prof. Peter Brueggemann at the University of Koln to assess the potential benefits of warming up and walking around with the Nike FREE shoes. Brueggemann conducted an unpublished study in which 100 athletes participated. Athletes were randomly divided into a control group and an experimental group. Following 12 weeks of warming up and walking around with the Nike FREE, rather than warming in their own sport shoes (Control group), Brueggemann found that the Nike FREE group increased the flexibility and strength of their feet more than the control group (use of their own sport shoes). He also found that the Nike FREE group improved its balance score while standing on 1 foot (Personal Communication, Mario Lafortune, Nike Inc, 2009). Breuggemann was twice contacted with a request for further detail of this research but no response has been received to date.

Nike concluded that trainers, coaches and athletes they were working with believed that this improvement in flexibility, strength and balance should lead to better performance and lower injury risk.

VivoBarefoot (Contributor: B. Le Vesconte, VivoBarefoot.)

VivoBarefoot shoes are based on the simple principal, that being barefoot is the most natural and healthy way for our feet and bodies to be. Vivobarefoot shoes have an ultra thin, puncture resistant sole.

In their marketing literature they explain that the human foot is a masterpiece complete with 200,000 nerve endings, 28 bones, 19 major muscles, 33 joint centres and 17 ligaments. Six million years of evolution created the perfect foot, then we started wearing shoes...

VivoBarefoot claim that their shoes protect the foot with an ultra-thin (3 mm) puncture resistant sole; that they strengthen the foot naturally by encouraging the muscles of the feet to work; that they stimulate every nerve ending in the feet to enhance sensory perception; and that they realign posture.

Editor's note: Whilst there is no citation of medical references for these claims, there are examples of this kind of information in the medical literature that are easily obtainable, for example, see Warburton, (2001).

Of particular interest in this section is the last claim that the shoes may realign posture. The paper by Siqueira et al., 2010. in this section of this issue of JBMT, looks at postural stability in those with knee hyperextension versus those with optimal knee alignment.

Firstly, such hyperextension of the knee, based on Siqueira et al's work, may, theoretically, be tempered by wearing shoe with inbuilt lability (as with the MBT's and FitFlops), and secondly, hyperextension at the knee is, according to Barker (2005), the most common result of having a heel on a shoe, something deliberately avoided by the VivoBarefoot, the Vibram Fivefingers, and minimized in the Newton's and the Nike Free.

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Linking this to Liebenson's contribution to this section of JBMT on sagittal plane curvatures, the most common biomechanical result of knee hyperextension is a concomitant increase in lumbar lordosis (Barker, 2005). As Janda has stated, an upper crossed syndrome is the ''child'' of a lower crossed syndrome (Chek, 1994). Any alteration in spinal curvature will impact on spinal mechanics (Wallden, 2009), on the function of the spine as an engine in gait (Gracovetsky, 1997), and thereby reduce overall locomotor efficiency and increase injury risk. It may be possible then, that shoes may be a causative factor in stooped posture, as discussed in Liebenson's paper.

Shoes translate loading toward the forefoot, which creates an excitatory response in the quadriceps group, or a *quad-dominant* muscle firing pattern. If this occurs, the quadriceps are firing in a dominant fashion over and above the gluteus maximus and the combination of these two factors results in an increased anterior tilt of the innominate and subsequent lumbar hyperlordosis. (Sahrmann, 2002)

The potentially detrimental sequellae of this, range from increased hallux valgus due to aberrant load of the forefoot, increased stress to the anterior cruciate ligament due to quadriceps dominance (Neumann, 2002a), unlocking and relative instability of the sacroiliac joints due to decreased form closure (Lee, 2005), and facet impingement/irritation due to increased loading through the posterior load-bearing columns (Wallden, 2009).

It has been observed that the fashion for high heels on shoes in Europe historically correlates consistently with climactic events; mini-ice-ages (Lafferty, 2008) The only other rationale for having a heel on a shoe, historically is that it is the part of the shoe that wears out the quickest due to the increased impact at heel strike when walking so a thicker heel means a longer lasting shoe (Neumann, 2002b), and perhaps a longer lasting shoe or being ''well-heeled'' was once perceived as equating with higher social status.

Masai Barefoot Technology (MBT) (Contributor: J. Wies, Director MBT Academy UK.)

The concept behind the MBT is that the foot is not designed to walk on flat hard ground and so, by building a soft spongy heel component into the shoe ''the MBT sensor'', the heel sinks into the shoe (as it would do on sand or a soft forest floor) and that the contour of the sole of the shoe; a convex arch, makes the foot ''roll'' from heel to toe, decreasing impact forces, spreading the load across the foot more evenly and minimizing stresses higher up in the kinematic chain.

Editor's note: Similar to the FitFlop concept discussed below, the MBT creates a labile base of support; particularly, in this instance, in the sagittal plane, which will excite the tonic motoneurons (Davidoff, 1992) and hence the tonic or ''inner unit''/''local system'' musculature of the body.

MBT: MBTs have been shown to change postural alignment to a more upright position by 10° due to equal changes occurring at the knees, hips, pelvis and lumbar spine; probably because of this capacity to excite the tonic musculature or postural musculature of the body. This in turn may lead to more efficient postural muscle and joint function. (New & Pearce, 2006) The regular wearing of MBTs improve both static and dynamic balance (Nigg, 2005)

Editor's note: This presupposes sufficient mobility and elasticity in these joints, especially pelvic and spinal joints, to accommodate such demands, otherwise adaptative stresses could evolve.

MBTs increase muscle activity in the lower limb which MBT claim will reduce joint loading whilst increasing calories burned in standing walking and jogging (Vernon, 2004; Nigg, 2004, 2009; Romkes, 2006; Mueller, 2007; Hoppeler, 2008).

Editors note: This seems counterintuitive, as increased muscle contraction will always increase joint loading. However, it may be that the lability of the surface the MBT provides results in facilitation of the tonic musculature which, whilst designed to compress the joints, does so in a relatively gentle (usually at just around 1—10% of maximal voluntary contraction) and controlled manner (tonic motoneurons have a far fewer muscle fibres they communicate with, increasing their capacity for fine tuning) (Bompa, 1999)

MBT: Clinical benefit have been shown using MBTs for reduction in low back pain, reduction in neck pain, reduction in knee pain secondary to osteoarthritis (Nigg et al., 2006 a,b), improvement in chronic ankle instability (Kälin, 2008), reduction in heel pain and improvements in quality of life measures for workers that stand at work.

Editor's note: MBT provide references for many of these claims, though most are unpublished. MBT suggest that the positive effect of their footwear is ''based on the principle of *natural instability*. An effect which can, in fact, be achieved without the benefit of high-tech footwear: by simply walking barefoot on soft, uneven, natural ground such as sand or moss''.

However, they claim, in today's modern world such barefoot walking on soft ground is not always easy to do and their footwear provides a solution.

MBT say ''From hard, flat surfaces to soft, natural, uneven ground, MBTs activate and strengthen the small supporting muscles which are the body's *natural shock absorbers*''.This is another way of describing what's been already stated above, though the concept of shock absorbers is perhaps a little outdated; and exploitation of a specific energy niche may be a more effective and accurate way of viewing these muscles and their associated fascia.

According to MBT ''The mid-sole, with its integrated [convex] balancing area, requires an active and controlled rolling movement with every step.'' This function of the MBT may be of use for those with functional hallux limitus; though it may equally inhibit the normal flexibility of the 1st MTP in those with ''normally functioning feet; and will certainly curtail any benefits of the windlass[1] mechanism which is most active as the toe hyperextends to around 65°.

[1] Windlass mechanism = classically, as the gait cycle moves from mid-stance to toe-off, the toes move into hyperextension, ideally reaching 65° degrees of extension, the plantar fascia is drawn tight increasing the arch along the medial aspect of the foot creating a spring like mechanism to push the person forward as they toe-off (Neumann c) 2002). Less commonly described, but equally valid, the windlass mechanism occurs in the open chain extension of the toes in the swing phase of gait prior to heel strike prepares the medial longitudinal arch of the foot for loading; and may also be engaged further in runners who forefoot strike, thereby storing elastic energy in the plantar fascia.

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It does of course also raise the point that if the arches of a bare foot are concave, why would a shoe that is convex be called ''barefoot''? MBT's answer is that they have attempted to recreate the way a barefoot moves through sand; not necessarily how it moves on harder surfaces, and so such kinematic analysis shows that the heel sinks somewhat, the midfoot pivots over the ridge created by the displaced sand, in a rocking style motion; and it is this motion that MBT have attempted to recreate in their shoe design.

MBT say that in conjunction with the Masai Sensor, the body's entire musculoskeletal system is activated and exercised, the muscles in the buttocks, stomach and back are strengthened, posture and gait are kept relaxed and upright and stress on the joints and back is relieved.

These points are all of relevance to the bodyworker and movement therapist. It might be noted that the claims of ''increased muscle contraction'' with ''relaxed posture and gait'' would appear somewhat contradictory, though this does depend on which muscles are being assessed; the larger outer unit muscles like the hamstrings and gluteals, or the smaller intrinsic muscles such as the deep multifidus, the gemelli, vastus medialis obliquus, if it is the latter, then it makes more biomechanical and physiological sense and may not be contradictory.

Newton (Contributor: I. Adamson, Newton Running.)

Editors note: Newton running shoes don't so much try to mimic barefoot running as to encourage the wearer to run in a more ''natural'' running gait by promoting a forefoot strike in running gait, as opposed to the more commonly seen ''heel strike'' in those wearing running shoes (Squadrone and Gallozzi, 2009; De Wit et al., 2000).

Newton: Newton claim that their improved shoe geometries encourage a natural running gait, resulting in lower impact to the body. Newton shoes have 4–5 mm heel lift compared to 12–13 mm for traditional running shoes (10 mm for racing flats.)

Editor's note: This, of course, correlates with one of the rationale described by VivoBarefoot in their shoe design (as well as the Nike Free's and the Vibram Fivefingers).

Newton: This allows users to run naturally by loading their leg when their centre of gravity passes over their foot and their joints are flexed. Traditional shoes with a 10–13 mm heel lift load the leg too early in the gait cycle when the joints are locked out and the foot strike is forward of the centre of gravity, resulting in high shock loads and braking. The small lift in Newton shoes allows runners to readjust the soft tissues in the back of their leg (stretch back to their natural length) without being too aggressive. Zero drop has proven too much of an adjustment for most runners.

- Biomechanical top plate (inside the shoe) enhances afferent feedback from the ground to the foot, facilitating the runner's ability to sense and react to the ground naturally. Traditional cushioning (foam, gel, air etc.) dampen afferent feedback, encouraging harder foot strikes.
- Greater shock absorption compared to leading brands. The *Newton Active Membrane Technology* (AMT) provides up to 80% greater displacement on impact, resulting in dramatically increased energy absorption (lower shock to the body.) Leading brands result in up to 100% high shock to the body (see Figure 1).

Editor's note: Newton also report other benefits less related to this discussion such as increased energy return and increased forefoot support, compared to other leading running shoe brands. They also go on to say that most people load the heel portion of their shoe at some point during the gait cycle and, depending on their running style and shoe geometry, this loading may vary from almost negligible to severe impact. Irrespective of this heel loading, significant midfoot forces are generated by all runners as their centre of mass moves anteriorly over the foot before push off. The standard heel-to-toe drop is just over 1 cm in most running shoes; meaning it is difficult to avoid hitting the heel portion of a regular running shoes.

Newton's along with some of the other brands of ''functional footwear'' in this discussion (VivoBarefoot, Nike Free & Vibram Fivefingers) have decreased or nullified the heel-to-toe drop; both allowing more of a midfoot strike (as if running in a natural barefoot state) and reducing shock loads associated with heel strike, see Figure 1.

FitFlop (Contributor: D. James, co-designer FitFlop.)

The FitFlop was developed in 2006 with the brief to develop a shoe-based technology and concept that was biomechanically valid. Since the earlier *Masai* technology was designed from a sagittal plane perspective it seemed intuitive to approach development of a new shoe from

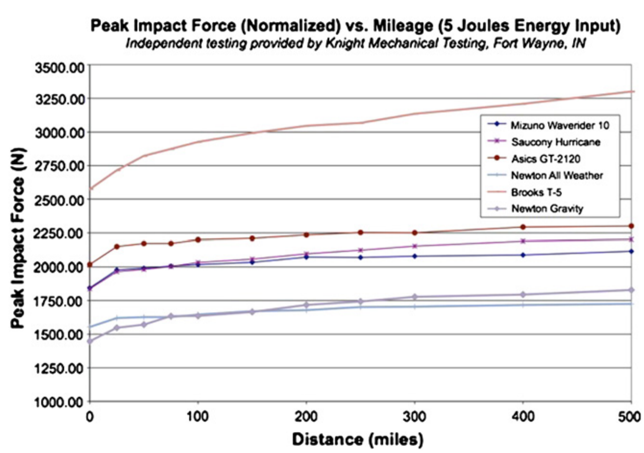

Figure 1 Forefoot strike versus Heel strike. The research conducted by Newton on the peak impact force when wearing their footwear versus other running shoe brands is congruent with other research (McDougall, 2009; Lieberman et al., 2010) suggesting that forefoot strike (which the Newton running shoes mechanically engender) minimizes impact force.

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a medial-lateral standpoint. The concept they developed was what they term ''Micro'wobbleboard'' technology, its goal, to enhance muscle activation patterns.

The FitFlop™ is constructed out of differing mid-sole densities in an innovative vertical arrangement. The concept is to slightly destabilise the user during the weight-bearing phase of the gait cycle, in a way similar to a soft, uneven forest floor or other ''natural'' surface; thus creating a more continuous tension in the supporting muscles in the foot and leg to correct this instability.

Editor: This line of thought; an unstable surface creating increased tensioning of the musculature of the lower limb is consistent with the study presented in this section by Sequeira et al. and also with Janda's description of ''river-bed running'', and the rocker shoes Janda promoted in the rehabilitation setting for the last few decades (Janda 2007). (see Textbox 1 above).

FitFlop™ claims to improve posture, to reduce shock, to increase muscle activity and to reduce foot pain. Research supporting these claims include:

- *Improve posture*. An independent investigation reported the ground reaction force vector during loading response to be directed more centrally towards the trunk in the FitFlop™ when compared to a control shoe (unpublished data). Such a finding might have postural benefits. We have performed acceleration measures recorded at the lower leg and found a 53% increase in low frequency power when compared to a control shoe ($p = 0.006$; $n = 10$; *unpublished data).* This power is indicative of active kinematic strategies, and such adaptations have been noted in the literature in dealing with the forces associated with ground impact (De Wit et al., 2000).
- *Reduce shock*. Our research has demonstrated a 22% decrease in impact-related shock ($p = 0.02$; $n = 10$) at the tibia compared to a control shoe using spectral analysis of the acceleration signal, see Figure 2 (unpublished data).
- *Increase muscle activity*. Peroneus Longus (PL) activity consistently shows significantly increased muscle activity when tested against a control shoe. In our most recent study ($n = 17$), RMS ratio was increased by 11% ($p = 0.007$) (unpublished data). Such a repeatable measure demonstrates the validity of 'Micro-Wobbleboard™' Technology. The PL acts as a stabilizer during mid-stance to assist in the maintenance of an upright posture (Schunk, 1982), and is accentuated further as the foot passes over the soft-density medial section of the mid-sole.

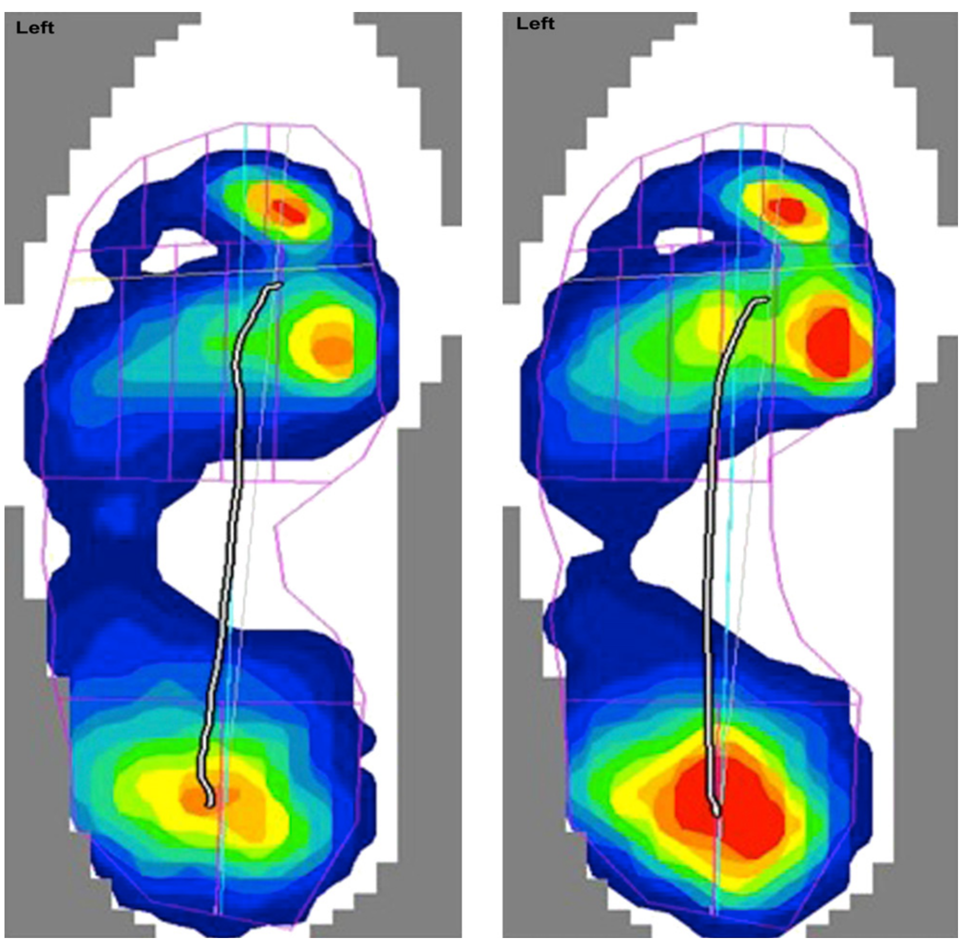

Figure 2 Pressure distribution Fitflop versus control shoe during walking gait. Compare and contrast these with the pressure distributions in Figure 3 below.

Increased activation of Rectus Femoris (6%), Medial Gastrocnemius (4%), and Tibialis Anterior (5%) has previously been reported whilst wearing the FitFlop™; however, these differences were not large enough to elicit a significant effect ($p > 0.05$) when compared against a control shoe.

- *Reduce foot pain* 'Microwobbleboard™' Technology has been shown to reduce the pressure distribution under the plantar surface of the foot when compared to a control shoe, see Figure 2 (unpublished data). In particular, reductions have been demonstrated under the medial and lateral heel, and metatarsals (Figure 2). These observations support the efficacy of our technology along with the notable difference in centre of pressure trajectory. Interestingly pressure distribution is greater under the phalanges. The implications of these findings are not clear until a clinical population is tested; however, it appears that foot functionality is preserved in the FitFlop™.

Editor's note: Similar to the MBT, the FitFlop can be seen to increase muscle activation in walking in, however, there are no claims that this increases gait efficiency; moreover that it stimulates greater muscle contraction in a way similar to walking over uneven ground (Vines, 2005).

Vibram Fivefingers (Contributor & Editor M. Wallden, UK Distributor, *Vibram Fivefingers*)

In contradistinction to the other shoes in this range of functional footwear, the Vibram Fivefingers were not developed with any biomechanical intent in mind. The history of Vibram as the world's leading sole manufacturer meant that, at its core, Vibram's reputation was to produce hard-wearing, sure-gripping soles. The remit of the designers at Vibram was to use this protective grip technology to create a shoe that mimicked the sensation of being barefoot on a sailing boat with the grip and reassurance of a Vibram sole.

However, when Vibram's Fivefingers were taken to the US Market in 2006, it soon became clear that they were attracting attention from fields far outside the anticipated sailing market. With strength and conditioning coaches, running coaches, pilates instructors, yoga instructors, physical therapists and many podiatrists taking a keen interest in the Fivefingers product, Vibram knew that they had to look at providing an evidence base for their recommending customers to refer to.

This first piece of research specifically detailing the biomechanical effect of wearing Fivefingers footwear was published in March 2009 (Squadrone and Gallozzi, 2009) comparing shod running, with barefoot running with "Five-fingered running" and, in brief, concluded with the following points:

- Shod running creates significantly change in angles at ground contact, of the ankle, the knee and the hip compared to the natural barefoot state
- Running in Vibram Fivefingers creates an almost identical posturing of ankle, knee and hip compared to the natural barefoot state

Significance: Barefoot running and running in Vibram Fivefingers results in more of midfoot or forefoot strike, whereas running shod results in more of a heel strike. Barefoot running and running in Vibram Fivefingers increases the stiffness requirement of the lower limb; this may have significant effects on sports performance as stiffness is a factor in top flight running speed and in effective load transfer.

- Shod running is around 2–3% less efficient (in terms of oxygen consumption) compared to barefoot running
- Running in Vibram Fivefingers is 0–1% more efficient (in terms of oxygen consumption) compared to barefoot running

Significance: Running barefoot and in Vibram Fivefingers is more energetically efficient than running shod. This has been known about running barefoot for a long time (Warburton, 2001) but has been assumed to be due to the weight of the shoe on the end of a long lever – the leg. This finding, however, throws that interpretation into question.

- Shod running spreads loading more broadly across the foot compared to the natural condition (see Figure 3)
- Running in Vibram Fivefingers creates a pressure loading spike around the 2nd metatarsal head; almost identical to barefoot running.

Significance: Switching from running shod to barefoot running may result in increased loading (and potential injury) of the 2nd metatarsal head; particularly if a period of adaptation is not built into the transition. However, in order to generate forward power, loading against the ground in toe off, where there is optimal leverage for forward propulsion is required. This may explain the increased efficiency of barefoot and Vibram Fivefingers, versus shod, running.

A major difference between the Vibram Fivefingers footwear and the other shoes discussed are the separated toe compartments. The theory behind this is to allow the foot to function as nature intended; and in doing so, allow the toes to act more proprioceptively, through their entire range of motion and to allow lateral spread; affording greater frontal plane stability.

Discussion

Some of the key discussion points in terms of the functional footwear products discussed are: 1) Labile sole, versus non-labile; 2) Tactile sole versus non-tactile; 3) functional flex points in the sole; 4) Sole modifications to create a soft landing, versus shoe modifications to minimize any protection on landing; 5) Minimal or no heel raise.

1) *Labile versus non-labile*: The function of a labile sole (such as the MBT or Fitflop sole) may be of use in minimizing repetitive strain injuries, in facilitating the tonic system of the body and in training the tilting reflex (useful in most water sports or in any situation where the surface you're standing on moves under you e.g. riding

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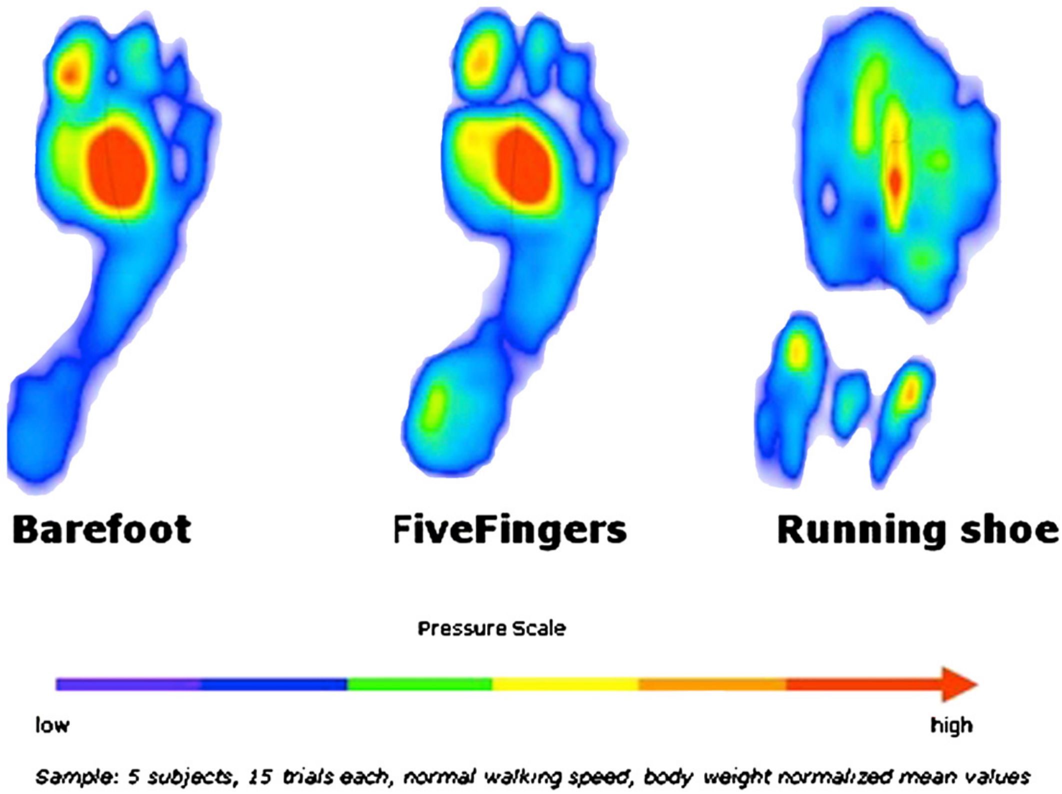

Figure 3 Pressure distribution barefoot versus Vibram Fivefingers versus control running shoe during running gait. Note the pressure spike near the 2nd metatarsal head, this may be optimal for forward propulsion, but may equally lead to metatarsalgia if transition from shod to barefoot (or minimalist footwear) is too rapid to allow for adaptive change.

a bus or an escalator). A non-labile sole, may be of more use in training for sports or activities in which the surface does not move under you; most ball sports, running, walking, dancing, climbing, activities of daily living; anywhere you're using a righting reflex profile.

2) *Tactile versus non-tactile*: This function of the sole may be of use in facilitating proprioceptive feedback and may facilitate afferent neural pathways as well as optimizing efferent muscle recruitment strategies; in an ''*information out can only be as good as information in*'' way.
3) *Functional flex points in the shoe*: This function will allow a full range of motion at all 26 joints of the foot, rather than just the one or two of traditional supportive sports shoes; maintaining functional range of motion and biomechanical function. This may be of particular significance with regard to the metatarsophalangeal joints (esp 1st, 2nd and 3rd) which are so heavily involved in the windlass mechanism.
4) *Sole modification to create a soft landing versus those that minimize protection*: Research by Robbins and Waked (1997), as well as Divert et al. (2005) questions the validity of creating a soft landing through provision of ''soft'' sole materials as it appears that the nervous systems response to this is to ''seek'' for the stability of the ground through the soft sole; thereby increasing strike impact through the shoe to compensate for its softness. Minimalist soles (or going barefoot), on the contrary, evoke a change in biomechanical strategy; a shortening of the stride, a quickening of the cadence and an altered ground contact — usually a midfoot or forefoot strike. This is considered the ''natural'' patterning as it is adopted almost instantaneously by subjects under biomechanical analysis; whereas it takes the same subjects as much as 4 min of running to ''acclimatise'' and adjust their gait to suit the running shoe they may be wearing (De Wit et al., 2000)
5) *Minimal or no heel raise*: As discussed above, the heels on shoes, sports shoe notwithstanding, is a historical (or fashion) artefact which has no biomechanical benefit — and probably only a biomechanical detriment.

To draw this back to the research presented in this section of this issue of JBMT, by Siqueira et al. regarding flexing of the knees under perturbation; as well as the discussion by Liebenson of correcting the sagittal spinal curves, there is a further possible mechanism for the changes in knee flexion we see in the research. De Wit et al. (2000) confirm that knee flexion and leg stiffness is increased when subjects run barefoot versus shod. Squadrone and Gallozzi (2009) agree that this knee flexion occurred in their barefoot runners and their runners wearing Vibram Fivefingers; while Siqueira et al. also find increased flexion in their subject under balance challenge.

Hypotheses

- It could be that flexion of the knee both brings the centre of gravity lower as well as increasing stiffness of the lower limb due to the prerequisite muscle contraction.

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- And if this is the case, it might be that barefoot runners (or equivalent) drop their centre of gravity and flex their knees more due to the fact that they have a smaller base of support.
- Additionally it is possible that MBT and FitFlop users do the same, due to the labile nature of their footwear?
- A question remains as to why stiffness increases, and it may be hypothesised that this is merely an artefact of a flexed lower limb?
- Another possible answer is that a cushioned sole and the increased loading through that sole requires less stiffness to achieve the appropriate raw energy pulse from the ground reaction force, to drive the spinal engine[2], as described by Gracovestky (1997).

Summary

''Functional footwear'' is just one of many of the useful tools that are available both to the bodyworker and movement therapist; as well as to their patient base.

To be able to advise on which of these tools may be most appropriate for clients/patients, based on their needs, has relevance to the effectiveness and integrity of any healthcare practice.

While it may be appropriate to recommend use of MBT to someone with hallux rigidus, the same recommendation to someone who needs to retain full ROM in their first MTP — or who has hallux limitus — may be inappropriate.

It may be inappropriate to recommend barefoot training, or minimalist shoes for someone with metatarsalgia, whereas a runner with a history of plantar fasciitis or Achilles tendinopathy may benefit greatly from barefoot running, due to the lack of heel strike and lighter footfall.

To recommend the wearing of shoes with inbuilt lability to someone who uses a righting reflex profile for their sport or activities of daily living (ie land-based activities) may be a less effective strategy than encouraging them to wear a shoe in which they can feel the ground. In contrast, someone engaged in a sport or activity in which the surface on which they stand moves (a boat, a bus, a surfboard, a horse, or a skateboard), may benefit greatly from a shoe with inbuilt lability.

Duration is another factor that requires consideration. For someone with a longstanding pronation pattern, to introduce a rapid transition to minimalist footwear, would not be advisable. This is why Nike developed a sliding scale, moving from 10 being a standard fully supportive shoe to 0 being barefoot. The Nike Free currently encompasses a ''near full support'' (the Free 7.0) to ''half support'' (the Free 5.0), to ''minimal support'' (the Free 3.0). The VivoBarefoot or Vibram Fivefinger would probably be somewhere between 0.1 and 1.0 on this scale. Recommendation of a long term active rehabilitation/re-strengthening strategy by means of transition from support to no support, in daily increments, combined with a parallel corrective exercise program to rebuild the arch, would be clinically appropriate, whereas the use of an acute ''passive crutch'' which an anti-pronation device offers, is probably only a short term solution.

Similarly, it would make little clinical-sense to place someone on a labile surface all day, when most rehabilitation and conditioning specialists would advise against using a wobble board, or a Swiss ball, for lengthy periods; as the result would be fatigue in the tonic musculature, leaving the user vulnerable to injury or faulty compensatory recruitment patterns.

Conclusion

Choice of functional footwear should not be dependent on products because of their appearance but should reflect clinical and practical needs.

Since the human form spent somewhere between 4 and 7 million years in the making, and the foot a further 265 million years evolving, the recent model (40 years or so) of placing of feet on thick polyurethane soles (with various ingenious contours) between the plantar aspect of the foot, and the ground might be seen to be undesirable. The weight of evidence appears to be tipping towards that perspective (Stacoff et al., 2000; Richards et al., 2009; Mauch et al., 2008; Anderson, 1996; Divert, 2008; Squadrone and Gallozzi, 2009; Robbins and Waked 1997; Nigg et al., 1999; Wolf et al., 2008; De Wit et al., 2000; Divert et al., 2005).

In much the same way that ''core function'' or motor control research can be seen to have correlates with the path we trod to get here (Texbox 1); so too can emerging research on the functional foot. This understanding may help us to select appropriate tools for intervention, based on each individual patient's physiological needs.

[2] The spinal engine theory, (briefly explained in Wallden, 2009) was developed in the 1980s by Serge Gracovetsky and published in his book of the same name in 1988. The theory proposes that the spine optimizes efficacy of motion in the gravitational field by using the spine to propel the legs forwards by capturing the ground reaction force to de-rotate the spinal segments with each step of the gait cycle; storing the ground reaction force as potential energy in the viscoelastic tissues of the lower limb and spine, and then expressing that potential as kinetic energy as the spine derotates.

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Please cite this article in press as: Wallden, M., Shifting paradigms, Journal of Bodywork & Movement Therapies (2009), doi:10.1016/j.jbmt.2010.01.004