XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

SOLE SEARCHING- EXPLORING THE SPRING FUNCTION OF THE ARCH OF THE FOOT ACROSS DIFFERENT FOOT STRIKE TECHNIQUES USING A NOVEL INSOLE APPROACH.

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SUMMARY

This study investigated the contribution of the spring in the arch of the human foot to the energy cost of running. Using custom shoe orthotics designed to reduce or eliminate arch compression, we find that the spring function of the arch may contribute to a ~10% reduction in the energy cost of running. The role of the arch spring is less pronounced when habitual rear-foot strike (RFS) runners adopt an imposed fore-foot strike (FFS). Additional experiments are being conducted to explore whether FFS runners utilize the spring properties of the tendons, ligaments and fascia that make up the arch to a greater extent than a runner who strikes the ground with a RFS, and whether this contributes to a lower energy cost of running.

INTRODUCTION

The arch of the foot plays an important mechanical role during running. Ker et al [1] estimated that a 70kg male running at 4.5ms^{-1} stores approximately 17 Joules of elastic energy in the tendons, ligaments and fascia that make up the arch of the foot. These authors concluded that the majority of this energy is returned to the runner during propulsion, and contributes approximately 17% to the total mechanical energy cost of running.

It has since been suggested that the ability of the arch to store elastic energy is affected by a runner's foot strike technique. Specifically, it has been argued that a runner who strikes the ground with the fore-foot first has a greater ability to store energy in the arch than a runner who makes initial ground contact with the rear-foot [2]. This would theoretically lead to a reduction in work by the lower limb muscle and make running more efficient. This may be a contributing factor to the larger percentage of elite runners who FFS [3].

This study explored the effect of foot strike technique on the contribution of the arch to running energetics using a novel shoe insole approach that prevented the arch from storing energy. Rigid custom-made orthotics were fitted to participants feet to prevent the arch from compressing and hence not allowing energy to be stored in the tendons, ligaments and fascia. Rates of oxygen consumption were measured to determine the effect on the energy cost of running when the arch of the foot was no longer capable of contributing to the mechanical work of the body through stored elastic energy.

This study also investigated the possible effect that the spring in the arch of the foot has on the metabolic cost in runners switching between their natural and imposed foot strike technique.

We hypothesized that there would be a greater effect on the metabolic cost in FFS participants compared to RFS when wearing custom insoles that prevent energy storage/return in the arch of the foot, regardless of the habitual or imposed nature of the technique. Furthermore, we hypothesized that the elevation in the energy cost of running would approximate the estimated percent contribution of the arch spring to the mechanical work of running (~17%).

METHODS

Habitual RFS (n=7) and habitual FFS (n=7) runners were recruited to participate in the study. All participants were fit recreational runners (>30km/week), aged 26.7 ±3.3 years (mean ± SD), had no current injuries to their feet or lower limbs, wore a US size 10-12 running shoe and had neutral feet as determined by the Foot Posture Index (mean: 1.0, SD: 2.8, range: -3 to +5). New Balance Minimus road MR00 shoes were provided to all participants, shoes had an approximate weight of 181 grams and a zero heel to toe drop.

Two pairs of custom made insoles were created for each participant. Both insoles were made from 4mm polypropylene, had a high density arch fill (shore value ~350-400), a 4 degree intrinsic rear foot grind, balanced fore foot intrinsic and maximum arch congruency. One insole was designed to completely fill the participants arch, theoretically allowing zero arch compression: Full arch insole (FAI). The second insole had an arch height 5mm lower, with the aim of allowing ~50% arch compression: Half arch insole (HAI). The 5mm reduction was chosen based on pilot work and previous studies by Perl et al [4].

Participants ran on a motorized treadmill at 3.0 ms^{-1}, each condition lasted five minutes during which oxygen cost was measured using a metabolic cart. Conditions included; barefoot, shoe only, HAI and FAI. All conditions were performed using both a RFS and FFS technique as confirmed by a high speed video camera placed sagittal to the treadmill. Weights were added to the ankles in order to standardize the weight across all conditions. A custom marker set was used to assess arch compression in both barefoot and shod conditions using high-speed video (1000 Hz).

RESULTS AND DISCUSSION

Preliminary results from habitual RFS participants demonstrate a large effect of restricting arch compression on the metabolic cost of running, particularly in the RFS conditions. During RFS trials we observed a 5.1% increase in VO2 with HAI and an 8.7% increase in FAI compared to normal shod running. Although the increase in energy use is lower than that predicted from the data of Ker et al [1], the increase is substantial and appears to be related to the degree of arch compression. Compared to the barefoot condition, navicular drop was 30% less in the HAI and reduced by 50% in the FAI.

In contrast to our hypothesis, the imposed FFS condition did not result in a larger increase in energy use compared to RFS. Furthermore, the increase in energy use did not follow the same linear relationship with orthotic condition as RFS. This may be due to the imposed nature of the condition.

We cannot rule out that addition energy cost required to run in the custom insoles is attributed to factors other than the elimination of the elastic energy storage in the arch of the foot. For example, increased energy use may instead be a result of a general alteration in biomechanics (e.g. increased stability cost). However we observed that the energy cost of walking (1.1ms^{-1}) and incline running (5° incline at 3ms^{-1}) were not statistically different when wearing the FAI compared to the shoe only condition. This finding is important since in both walking and incline running the spring function of the arch may not play as large of a role in supplying the mechanical cost of locomotion. In walking the plantar fascia is stretched less than it is during running [5] therefore does not store the same magnitude of elastic energy and hence contributes less to the cost of locomotion. In running the storage and release of elastic energy in the Achilles tendon and plantar fascia is the same during level running as it is when running on a five degree incline [6] therefore the percentage contribution to the total metabolic cost is much smaller. Since the energy cost of walking and incline running are not affected by the custom orthotics this suggests that general biomechanical alterations may be minimal.

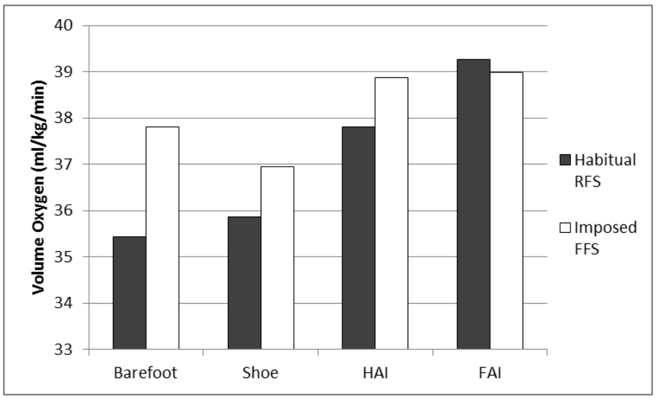

Figure 1: Volume of oxygen (ml/kg/min) consumed when using a habitual rear-foot strike (RFS) and an imposed fore-foot strike (FFS) during different conditions; barefoot, shoe only, half arch custom insole (HACI) and full arch custom insole (FACI).

CONCLUSIONS

This study re-confirms the importance of the arch during running. When custom insoles designed to prevent the arch from collapsing were worn during running the energy cost increased by almost 10% when using a RFS and 5% during FFS. Additional data on habitual FFS runners is currently being collected to test the hypothesis that they will use the passive-elastic mechanisms in the arch of their foot to a greater extent than RFS runners, and subsequently experience the largest increase in energy cost when running with a restricted arch compression.

ACKNOWLEDGEMENTS

We would like to acknowledge Orthotech laboratories in Blackburn Victoria, Australia for their support in constructing custom insoles for participants.

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