EFFECTS OF ENERGY BOOST AND SPRINGBLADE FOOTWEAR ON RUNNING ECONOMY AND SUBSTRATE OXIDATION

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Abstract The current study aimed to investigate the influence of energy boost, spring and conventional footwear on running economy and substrate usage. Ten male runners completed 5 min steady state runs in energy boost, spring and conventional footwear. Running economy and percent contribution of carbohydrate to total calorie expenditure were assessed. Participants also subjectively indicated which shoe condition they preferred for running. Differences between footwear were examined using repeated measures ANOVA. The results showed firstly that running economy was significantly improved in the energy return (33.36 ml.kg.min^{-1}) compared to spring (34.83 ml.kg.min^{-1}) and conventional footwear (34.65 ml.kg.min^{-1}). In addition, percent carbohydrate was significantly lower in the energy return (74.51%) in comparison to the spring (78.56%) and conventional (78.52%) footwear. As running economy was improved and carbohydrate utilization reduced in the energy return footwear, this study indicates that they may be associated with improvements in running performance.

Key words Running, economy, VO_2, footwear

Introduction

Endurance capacity in runners relates to the ability to maintain a given velocity (Jones, 2006). Aerobic exercise requires the re-synthesis of ATP via oxidative phosphorylation in order to provide energy, and necessitates both the delivery of oxygen and also the availability of carbohydrates and fats. The economy of running represents the amount of inspired oxygen that is required to maintain a given steady state running speed (Saunders et al., 2004). Importantly running economy is strongly linked with running performance (Williams, Cavanagh, 1987), and has been demonstrated as a better predictor of performance that indices of maximum oxygen uptake (Hanson et al., 2010). Superior running economy indicates that a runner is able to exercise at the same velocity, whilst functioning at a lower percentage of their maximum work output. given its proposed relationship with running performance, economy is of substantial interest to both runners and researchers alike.

Running footwear has been advocated as a mechanism by which running economy may be influenced. The results from previous work has provided conflicting results, with some showing that footwear can mediate alterations in running economy and others indicating that footwear is not influential. Both Bosco, Rusco (1983) and Frederick et al. (1986) demonstrated that running in footwear with viscoelastic cushioning properties significantly enhanced running economy. Similarly, the observations provided by Woboret et al. (2014) demonstrated that a footwear with the softest midsole improved running economy in relation to a control shoe during overground and treadmill running. Some research has however shown that running footwear does not influence the economy of running. Nigg et al. (2003) examined footwear with distinct midsole cushioning properties and showed that the did not significantly affect the oxygen requirements of steady state running. Similarly, Sinclair et al. (2014) examined footwear with different shock attenuating properties which did not have any effect of running economy.

The concept footwear energy return is now a novel subject area in the field of biomechanics. The energy boost concept designed by Adidas were the first to commercialize the energy return principle, using a polyurethane thermoplastic midsole designed to reduce energy loss relation to traditional ethylene-vinyl acetate materials. There has been only limited research into the effects of these footwear. Sinclair et al. (2014) investigated the effects of conventional and energy boost footwear on the kinetics and kinematics of running. Their results showed that the conventional running footwear were associated with significantly reduced tibial accelerations and peak eversion angles in comparison to energy boost. Sinclair et al. (2015) demonstrated that the energy return footwear significantly improved running economy in comparison to a conventional running shoe. In addition, Sinclair et al. (2016) showed that energy return shoes improved running economy and reduced the bodies reliance on carbohydrate as an energy source in comparison to minimalist and maximalist footwear of equal mass.

In addition to the energy boost shoes, a further footwear design, the springblade has been introduced more recently by Adidas which similarly is designed to increase the energy returned from the midsole. These footwear feature 16 curved blades which are designed to store and release energy. Currently there is only one investigation which has examined the biomechanics of running in the springblade footwear. Sinclair and Dillon (2016) examined the kinetics and kinematics of running in the spring footwear in relation to conventional footwear. Their observations showed that spring footwear were associated with significant increases in peak eversion and tibial internal rotation. To date there has still yet to be any published work which has investigated the effects of spring footwear on running economy, given the importance of running economy research of this nature would be of both practical and clinical significance.

The aim of the current study was to explore the effects of energy return, spring and conventional footwear on running economy and substrate oxidation during steady state running. A study of this nature may provide additional information that will help to understand the mechanisms by which different footwear may influence running economy.

Methods

Participants

Ten male runners volunteered for this work. The mean characteristics of the participants were: age 22.11 ±2.14 years, height 177.44 ±4.27 cm and body mass 73.47 ±5.24 kg. All participants were free from lower extremity injury and were not taking any prescribed medication at the time of data collection. Written informed consent was obtained from all runners in accordance with the declaration of Helsinki. The procedure utilized for this work was approved by the University of Central Lancashire, Science, Technology, Engineering and Mathematics, ethical committee (Ref: 422).

Procedure

Participants ran in each footwear at 12.5 $km.h^{-1}$ on a laboratory treadmill (HP Cosmos, Nussdorf-Traunstein) with maintained at a gradient of 0% (Sinclair et al., 2015). The velocity of the treadmill belt has been validated previously (Sinclair et al., 2014). The order that the experimental footwear were worn was randomized (Frederick et al., 1986). Breath by breath gas analysis was undertaken via an ergospirometry system (MetaLyser 3B system, Cortex Biophysic, Leipzig, Germany). Participants were asked to continue their customary dietary intake in the 48 hours before data collection testing and undertook data collection 4 hours postprandial.

Data collection firstly required baseline data to be obtained this involved 10 minutes of quiet sitting whilst the volume of inspired oxygen (VO_2) was measured (Gruber et al., 2013). Participants were also required to undertake a 3 min habituation period in all footwear conditions, during which they ran at the required velocity prior to the commencement of data collection (Hanson et al., 2010). Participants then completed 6 min steady state runs in accordance with the protocol used by Nigg et al. (2003). All metabolic data was collected within the same testing session with rest in between. The subsequent footwear condition was not examined until VO_2 returned to within 0.025 $l.min^{-1}$ of baseline measurements.

Data reduction

The second five minutes of the baseline data were averaged to obtain a resting VO_2 measurement. This value was subtracted from the mean VO_2 obtained during the running trials to provide a net value of oxygen consumption ($ml.kg.min^{-1}$). The metabolic substrates in grams per minute that were used during exercise were determined using the amounts of inspired oxygen (VO_2) and expired carbon dioxide (VCO_2) in accordance with the below (McArdle et al., 2010).

$$\text{Carbohydrate} = 4.58 \times VCO_2 - 3.23 \times VO_2,$$
$$\text{Fat} = 1.70 \times VO_2 - 1.69 \times VCO_2.$$

To calculate the energy expended in kilocalories during each run the amount of carbohydrate and fat in grams utilized during the trials were multiplied by 4 for carbohydrate and by 9 for fats and then adding together the contribution from the two substrates. To quantify the relative contribution of carbohydrates to total kilocalories (percent carbohydrate) the number of kilocalories derived exclusively from carbohydrate by the total kilocalories was divided by the total number of kilocalories.

Finally, following each run participants were asked to provide their rating of the comfort of each shoe. This involved a 100 mm visual analogue scale with the extreme left side being indicative of ‘not comfortable at all’ and the extreme right of the scale labelled as ‘most comfortable condition imaginable’ (Mündermann, et al., 2002).

Experimental footwear

The footwear used during this study consisted of conventional footwear (New Balance 1260 v2), energy boost (Adidas energy boost) and spring (Adidas springblade drive 2) footwear, (shoe size 8–10 in UK men's sizes) (Figure 1).

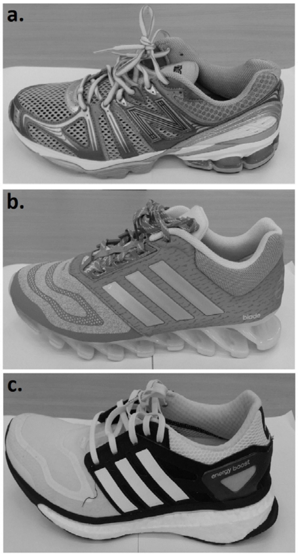

Figure 1: Experimental footwear (a. conventional, b. spring, c. energy boost).

Statistical analysis

Means, standard deviations and 95% confidence intervals were calculated for each outcome measure for each footwear condition. Differences in between footwear were examined using one-way repeated measures ANOVAs, with significance accepted at the $P \leq 0.05$ level (Sinclair et al., 2013). Effect sizes were calculated using partial eta^2 ($p\eta^2$). Post-hoc pairwise comparisons were conducted on all significant main effects. In addition to this percentage differences were also calculated for all statistically significant effects. All statistical actions were conducted using SPSS v22.0 (SPSS Inc., Chicago, USA).

Results

Table 1. Mean, standard deviation and 95% confidence interval, metabolic and shoe comfort parameters for each footwear condition

	Energy return			Spring			Conventional		
	mean	SD	95% CI	mean	SD	95% CI	mean	SD	95% CI
Net VO_2 (ml.kg.min^{-1})	33.36	2.47	31.29–35.42	34.83	2.79	32.49–37.17	34.65	2.68	32.41–36.90
% CHO	74.51	7.46	68.27–80.75	78.56	6.86	72.82–84.29	78.52	7.08	72.60–84.44

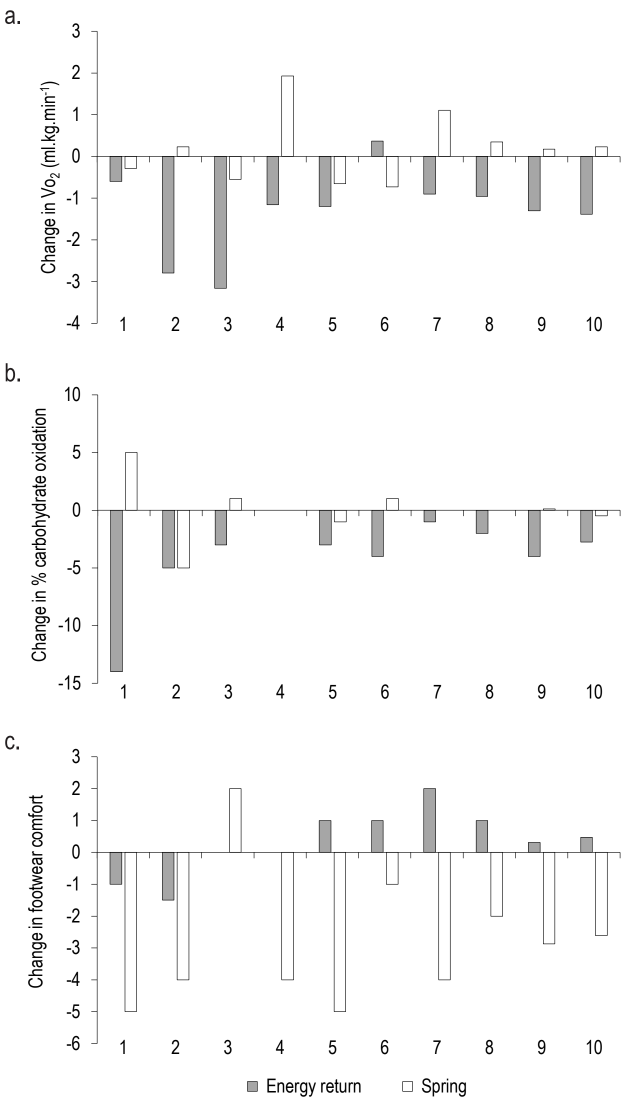

Figure 2. Differences in a. – net VO_2, b. – percent carbohydrate oxidation and c. – footwear comfort between the energy return/spring footwear in relation to conventional running shoes. Positive indices indicate that values were greater the energy return/spring footwear

Net VO_2

A significant main effect ($P < 0.05$, $p\eta^2 = 0.50$) was shown for net VO_2. Post-hoc analyses showed that net VO_2 was significantly lower in the energy return footwear in comparison to the spring ($P = 0.026$) and conventional ($P = 0.015$) conditions.

Substrate usage

A significant main effect ($P < 0.05$, $p\eta^2 = 0.35$) was shown for percent carbohydrate. Post-hoc analyses showed that percent carbohydrate was significantly lower in the energy return footwear in comparison to the conventional ($P = 0.034$) condition.

Shoe comfort

A significant main effect ($P < 0.05$, $p\eta^2 = 0.61$) was shown for shoe comfort. Post-hoc analyses showed that shoe comfort was rated as being significantly lower in the spring footwear in comparison to the energy return ($P = 0.010$) and conventional ($P = 0.012$) condition.

Discussion

The aim of the current investigation was to study the influence of energy boost, spring and conventional footwear on running economy and substrate oxidation during steady state treadmill running. To our knowledge this work represents the first examination of the effects of spring footwear on running economy and a study of this nature may give important information to runners regarding appropriate footwear selection and also improve our understanding of the manner by which different footwear may influence running economy and the substrates that are used to fuel exercise metabolism.

The current study showed firstly that the energy return shoes were associated with significantly reduced net VO_2 in comparison to the conventional and spring footwear, indicating that economy was enhanced in this condition. This observation supports the findings of Sinclair et al. (2015) and Sinclair et al. (2016) who showed that the energy boost footwear were most economical in relation to conventional, minimalist and maximalist shoe conditions. Given the proposed association between running economy and performance, this indicates that the energy return footwear may be associated with increased performance in relation to the conventional and spring footwear. Ultimately the mechanisms that mediated this improvement in economy is impossible to determine accurately, however Sinclair et al. (2015) suggested that the potential increase in returned energy from the shoe midsole could be responsible. The effects of the energy return footwear on running performance in relation to the spring and conventional conditions can be appraised by taking into account the observations of Burkett et al. (1985) who showed that every 1.0% increase in steady-state VO_2 mediated a subsequent 0.17 $km.h^{-1}$ reduction in running velocity. As such application of the reductions in net VO_2 observed in the energy boost footwear indicates that this condition would translate into a 13 min and 11 min reductions in marathon times in relation to the spring and conventional footwear respectively.

A further important finding from this work is that carbohydrate oxidation was shown to be significantly lower in the energy return footwear in relation to the spring and conventional shoe conditions. This result is also in agreement with the findings of Sinclair et al. (2015) and Sinclair et al. (2016) who also showed that energy return footwear reduced the bodies' reliance on carbohydrate. This result may be similarly important as distance running is known to rely heavily on carbohydrate metabolism as an energy source a (Rapoport et al., 2010). Therefore, a reduced contribution of carbohydrate to energy expenditure during running may be significant in long distance events, as it may prevent the onset of glycogen depletion, which is known to be a limiting factor in prolonged aerobic performance (Rapoport et al., 2010).

Finally, a further key observation from this investigation is that the energy return and conventional footwear were rated as being subjectively more comfortable in relation to the spring shoe condition. Luo et al. (2009) showed that running economy was greatest in footwear rated as being the most comfortable, an observation supported by the observations of Sinclair et al. (2015) and Sinclair et al. (2016). The results from the current investigation provide only partial support for these findings as both energy return and conventional and footwear were rated as being most comfortable in the current investigation, although the energy return condition was shown to be the most economical. The improved footwear comfort noted by Sinclair et al. (2015) and Sinclair et al. (2016) was used to explain the increases in running economy in these studies, however this study shows that the association between comfort and running economy may be more complex than previously anticipated. Therefore, further work investigating the relationship between footwear comfort and running economy is still required.

The results from the current study highlight the complexities of the interaction between biomechanical and physiological data. This study confirms the findings of previous work in that the energy return footwear may be associated with performance benefits in relation to other footwear conditions. However, the study of Sinclair et al. (2014) who examined the kinetics and kinematics of running in energy return and conventional footwear, showed that energy return footwear were associated with increased tibial acceleration and peak eversion parameters that have been linked to the aetiology of injury (R). As such it appears that whilst the energy return footwear may be able to mediate performance benefits, they may place runners at increased risk from chronic injuries.

In conclusion whilst the effects of energy return footwear on running economy have been investigated previously there has yet to be an examination of running economy and substrate utilization when running in spring footwear. This study therefore gives new information regarding the effects of spring footwear on running performance in relation to energy return and conventional footwear. As both net VO_2 and carbohydrate utilization were lower when running in the energy return footwear in relation to conventional and spring shoes, this investigation indicates that the energy return footwear may be associated with improvements in running performance.

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