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Editorial

The secrets to running economy

Every once in a while, a sport is revolutionized by a discovery or a new invention. In the mid-1980s, cross-country skiing was changed forever by the introduction of the skating technique. Dick Fosbury revolutionized high-jumping when he won the Olympic Games by crossing the bar "backwards", and the development of the "klapp-skate" led to vast improvements of world records in speed skating.

Recently, Nike introduced a running shoe, the Vaporfly 4%, claiming it provided dramatic improvements in running economy, which is the amount of oxygen required while running at a given speed.[1] Running economy is known to be a major factor in performance in long-distance events.[2] Running in a prototype of this shoe, Eliud Kipchoge broke the marathon world best time by an unprecedented 1 min and 18 s, and in a non-sanctioned time trial, he was the first human being to run a marathon distance in less than 2 h (1:59:40). The improvements in running economy and performance have been associated with the light weight, the highly resilient sole, and the curved carbon fiber plate inserted into the sole of this new shoe. Controversy ensued over whether or not wearing such shoes should be allowed in international competitions, but as of this moment, there are no bans in place,[3] and national records and personal bests are being broken at an unprecedented rate.

Much of the current issue on running mechanics and physiology is devoted to the topic of this new shoe design and its underlying advantages. Hébert-Losier et al. not only demonstrate improved running economy for the Vaporfly 4% shoe compared to 2 other running shoes, but also found a substantial improvement in running time for a 3000-m time trial. Whiting et al. further demonstrate improved running economy for the Vaporfly 4% shoe for downhill and uphill running at a gentle slope (±3°), but the improvement in running economy is slightly reduced on the sloped compared to a level surface. In an attempt to identify the cause of the reduction in running economy for the Vaporfly 4%, Healey and Hoogkamer eliminated the effects of the curved carbon fiber plate by cutting it at 6 strategic points, thus eliminating the plate-induced stiffness of the shoe. Doing this, they found no difference in running economy between the original and modified shoes, suggesting that the carbon fiber plate alone explained little of the improved running economy. Comparing stiff shoes with a carbon fiber plate insert and regular shoes (no plate), Cigoja et al. found that lower limb joint work distribution in the stiff shoe occurred later in a 10-km run when compared to the soft shoe condition. Implications about improved metabolic cost were drawn, but metabolic cost was not measured.

The 5 remaining contributions to this special topic on running are devoted to changes in running technique over time and injury assessments in long-distance running. Mohr et al. measured the electromyography (EMG) activity of 6 lower limb muscles and found that muscle activity tended to decrease over the first 7 min of a run, suggesting that this might be a neuromuscular adaptation that occurs to optimize running economy. Interestingly, 7 min is also the approximate time that is required to reach a metabolic steady state at the beginning of a run. Therefore, the change in EMG activity may reflect the change from the initially less economic anaerobic start of a run to the more economic aerobic running achieved once the cardiovascular system reaches its steady state. Khassetarash et al. studied the mechanics of downhill running in the context of the repeated bout effect (the effect wherein eccentric muscle action leads to less injury and less pain when repeated on a second occasion). They identified changes in biomechanics in the repeat downhill run and found good evidence for the protective effect of repeated bouts, but running economy was not affected. Honert et al. studied the effects of work distribution in a long (58 min), variable paced run. They found that work performed by the foot increased while work at the ankle decreased at all speeds throughout the run. Focused on long-distance racing, Swanevelder et al. studied the risk factors for multiple running-related injuries in 75,401 runners participating in a half-marathon or a 56-km race for 4 consecutive years. Not surprisingly, risk factors for multiple injuries included old age, running for more than 20 years, and ultra-marathon racing; somewhat surprisingly, they also included an increased chronic disease score and an increased susceptibility to allergies. Finally, Van den Berghe et al. followed a not so typical runner (55 years, 1.81 m, 92 kg) performing 100 marathons over 100 consecutive days. They identified some rather unusual characteristics of this runner compared to a control group of matched runners, including a vastly reduced peak vertical force loading rate and peak vertical ground reaction force, a substantially

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reduced peak breaking force, a high duty ratio (0.41), and an excessive foot angle at first contact (29.5°). They argued that this low impact, low mechanical demand running style allowed for the successful completion of the 100 marathon runs without injury.

While running performance and running economy have dramatically changed with the shoe design initially promoted with the Nike Vaporfly 4%, the precise factors causing this vast improvement remain unknown, and the way in which reductions in running economy translate into improvements in running performance are not fully understood. Furthermore, the reasons for the differences in the reduction in running economy across runners with the Vaporfly 4% are intriguing and might reveal characteristics responsible for differences in running economy among athletes. The changes in neuromuscular control in long distance running on uphill and downhill slopes might provide insights into running-related injuries. Studying exceptional performances and performers who seem to be immune to running-related injuries, as was done here, might be an alternative avenue for approaching ever-evasive questions related to what causes running injuries and how they might be prevented effectively. Maybe studying runners who never get injured despite high-mileage running over decades will prove more insightful than the continued study of runners who do.

Competing interests

The author is a consultant with Nike. This role had no involvement in the study design and writing of the manuscript or the decision to submit it for publication.

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Appendix A. The articles of this special topic

No.	Corresponding author	Title
1	Kim Hébert-Losier	Metabolic and performance responses of male runners wearing 3 types of footwear: Nike Vaporfly 4%, Saucony Endorphin racing flats, and their own shoes
2	Laura A. Healey	Longitudinal bending stiffness does not affect running economy in Nike Vaporfly Shoes
3	Sasa Cigoja	Can changes in midsole bending stiffness of shoes affect the onset of joint work redistribution during a prolonged run?
4	Clarissa S. Whiting	Metabolic cost of level, uphill, and downhill running in highly cushioned shoes with carbon-fiber plates
5	Maurice Mohr	Systematic reduction of leg muscle activity throughout a standard assessment of running footwear
6	Guillaume Y. Millet	Neuromuscular, biomechanical, and energetic adjustments following repeated bouts of downhill running
7	Eric C. Honert	Changes in ankle work, foot work, and tibialis anterior activation throughout a long run
8	Martin Schwellnus	Predictors of multiple injuries in individual distance runners: A retrospective study of 75,401 entrants in 4 annual races−SAFER XX
9	Pieter Van den Berghe	One hundred marathons in 100 days: Unique biomechanical signature and the evolution of force characteristics and bone density

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