# THE EFFECT OF RUNNING ECONOMY IN MALE RUNNERS WEARING 3 TYPES OF FOOTWEAR

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The purpose of this study was to identify the effect of running economy in male runners wearing Nike ZoomX Vaporfly Next%2(N), Qiaodan Feiying pb2(Q), and Xtep2(X) footwear. Twelve male middle-caliber runners (mean±SD, age: 21.0±2.0year, maximum oxygen uptake ($VO_{2max}$): 51.2±3.7ml/kg/min) attended 4 sessions. The first session consisted of a $VO_{2max}$ test to inform subsequent RE speeds set at 60%, 70%, and 80% of the speed eliciting $VO_{2max}$ ($υVO_{2max}$). In subsequent sessions, treadmill RE was assessed in the 3 footwear conditions in a randomized, counterbalanced crossover design. Oxygen consumption (ml/kg/min) and energy expenditure (W/kg) was lesser in Q vs. X at 80% of $υVO_{2max}$, and there had a significant difference between Q、N and X ($p<0.05$), while which had a non-significant difference at 60% and 70% of $υVO_{2max}$ ($p>0.05$). Overall, Qiaodan Feiying pb2 improved RE and energy expenditure in middle-caliber male runners at 80% of $υVO_{2max}$ compared to Xtep2, but these improvements had no differences among the 3 types of footwear at 60% and 70% of $υVO_{2max}$.

**KEYWORDS:** footwear, running economy, physiology, running

**INTRODUCTION:** Running economy (RE) is defined as the rate of oxygen consumption at a given submaximal running speed and which is a key measure inked with distance-running performance (Saunders, 2004). Even though runners with a similar $VO_{2max}$ and lactate threshold, and those with a superior RE who generally outperform their peers, which means the better RE, the lesser the energy cost of running (Andrew, 2013), therefore RE is suggested that the best variable in evaluating running performance (Tomas, 1999).
Until recently, given the direct link between RE and footwear (Hoogkamer, 2016), Hunter and Barnes (2019) found that the energy cost of running has been shown to decrease approximately 4% wearing Nike ZoomX Vaporfly4% shoes, which had a foam midsole with considerable energy characteristics and had an embedded carbon fiber plate that increased longitudinal bending stiffness. 2018 Berlin Marathon wearing Nike Vaporfly Next% and was successful in running the marathon distance in under 2 h during the INEOS 1:59 Challenge in 2019 (Burns, 2020). And there are 2 additional types of footwear that are so popular with runners and predict they can decrease the energy cost of running, but no researchers to identify this doubt.
Hence, we aimed to compare RE variables at speeds relative to $VO_{2max}$ of male middle-caliber runners wearing Nike ZoomX Vaporfly Next%2 (N), Qiaodan Feiying pb2 (Q), and Xtep2 (X), and to provide the scientific basis for shoe selection for runners and data support for manufacturers to design running shoes with different functions.

**METHODS:** Twelve male middle-calibre runners (age: 21.0±2.0year, height: 176.0±2.4m, weight: 65.8 ±5.5 kg, BMI:21.2±2.0kg/min, $VO_{2max}$: 51.2±3.7ml / kg/min, shoes size: 41) were recruited. Participants typically ran 10km per week and had been running for at least 2 years. Inclusion criteria were male runners with $VO_{2max}$ ≧ 50ml/kg/min or a 5km run time of approximately 16-25min within the past 3 months, or with a full marathon run time of approximately 3:30. Exclusion criteria were male runners with lower limb injury, hypertension, heart disease, serious illness, or musculoskeletal injury linked with running in novel footwear. Participants were informed of the nature of the study before giving their written consent. 3 types of footwear are shown in figure 1.
The effect of footwear on RE was assessed using a randomized crossover study that required participants to attend 4 laboratory sessions. In the first visit, participants were required to complete a 3-min rest, and then with a 3-min warm-up at 9km/h with their shoes on a motorized

treadmill (h/p/cosmos Mercury 4.0, Germany) prior to completing a $VO_{2max}$ ramp test using an incremental speed protocol and 1% incline to assess maximal aerobic power. The test started at 10km/h and increased 1 km/h per minute until volitional exhaustion during the time wearing a protective vest. At each bout, participants were required to ratings of perceived exertion (RPE) using a 6-to 20-point Borg scale. We spray-painted the 3 types of footwear black to blind the participants to the brand and model details. RE performance in Q, N, and X were assessed in visits 2, 3, 4 using a 1% incline to more rarely reflect the energetic cost of outdoor running (Morgan, 1995) which should be apart one week from visit 1. Participants with a 3-min rest, afterward, ran for 3 min at a self-selected speed as a warm-up in their allocated shoe condition and completed 3*3-min bouts at 60% (11.2±0.8km), 70% (13.1±0.9km/h), and 80% (15.0±1.0km/h) of $\upsilon VO_{2max}$, each footwear condition in a randomized counterbalanced manner (QNX, XQN, NXQ). Running duration between 3 min and 15 min are typically used in RE tests (Barnes, 2015), with 3-min bouts shown to provide valid RE measures (Shaw, 2014). At each 3-min bout, participants rested for 3 mins during which time blood lactate concentration levels from capillary fingertip samples using a Lactate-Pro 2 analyzer were collected. Throughout the 3-min constant-speed bouts set at 60%, 70%, and 80% of $\upsilon VO_{2max}$, heart rate (Polar) was recorded and expired gases were continuously measured using a calibrated metabolic cart (Cosmed $K4b^2$, German) to determine $VO_2$ and respiratory ratio. The mean $VO_2$ registered in the last minute of each bout was used to determine oxygen consumption (ml/kg/min) (Barnes, 2015), energy expenditure (EE) using the Peronnet and Massicotte equation (1991) based on the running speed of each individual. Participants should be required to have adequate sleep 24h before the four tests, no high-intensity exercise: no smoking, drinking, coffee.
Descriptive statistics of the experimental measures are reported as mean ± SD. Data were analyzed using repeated-measures analyses of variance. And Holm-Bonferroni correction was used to explain the multiple T-test. Statistical significance was set at p<0.05 in all analyses.


**Figure 1: 3 types of footwear of the experiment**

**RESULTS:** The mean (95% CI) reduction in running economy (ml/kg/min) of 44.59±4.31, 44.59±4.31, 45.61±3.73, 46.24±4.21 of Q, N, and X were significant (p=0.004) at 80% of $\upsilon VO2max$, respectively. $VO_2$ (ml/kg/min) was lower in Q vs. X (p=0.005). While RE improvement had a non-significant difference at 60% (p=0.443) and 70% (p=0.056) of $\upsilon VO_{2max}$, respectively (Table 1).
Energy expenditure (EE) had a significant difference of Q, N, and X at 80% of $\upsilon VO_{2max}$ (p=0.015). The lower energy expenditure (W/kg) in Q (14.89±2.24) vs. X (15.37±4.21) (p=0.017). While which had a non-significant effect on the EE at 60% (p=0.332) and 70% (p=0.062) of $\upsilon VO_{2max}$ (Table1 and Figure2).

The difference of lactate (mmol/l) of Q, N, and X were not significant at their corresponding 60% (p=0.260), 70% (p=0.365), and 80% (p=0.284) intensities (Table1).

**Table 1: Variables collected from the running economy test from male runners at 60%, 70%, and 80% (n=12) of the speed that elicited $VO_{2max}$.**

| Variable | Intensity | Q | N | X | P |
|---|---|---|---|---|---|
| $VO_2$ | 60% | 35.61±3.15 | 35.33±3.53 | 36.35±2.89 | 0.443 |
| （ml/kg/min） | 70% | 39.95±3.76 | 40.07±3.86 | 40.70±4.04 | 0.056 |
| | 80% | 44.59±4.31$^{QX}$ | 45.61±3.73 | 46.24±4.21$^{QX}$ | 0.004* |
| EE | 60% | 11.71±1.45 | 11.61±1.75 | 11.92±1.51 | 0.332 |
| （W/kg） | 70% | 13.14±1.82 | 13.20±1.90 | 13.39±1.92 | 0.062 |
| | 80% | 14.89±2.24$^{QX}$ | 15.19±2.24 | 15.37±2.36$^{QX}$ | 0.015* |
| Lactate | 60% | 4.39±2.03 | 4.02±2.18 | 5.06±2.06 | 0.260 |
| (mmol/l) | 70% | 4.60±1.95 | 4.67±2.00 | 5.25±2.19 | 0.365 |
| | 80% | 5.57±1.94 | 6.02±2.55 | 5.57±2.27 | 0.284 |

Notes: * and $^{Q, X, N}$ Significant difference (p <0.05) vs. Q, N, and X during post hoc comparisons when the main effect of footwear was significant. Q= Qiaodan Feiying pb2; N= Nike ZoomX Vaporfly Next%2; X= Xtep2；EE= energy expenditure.

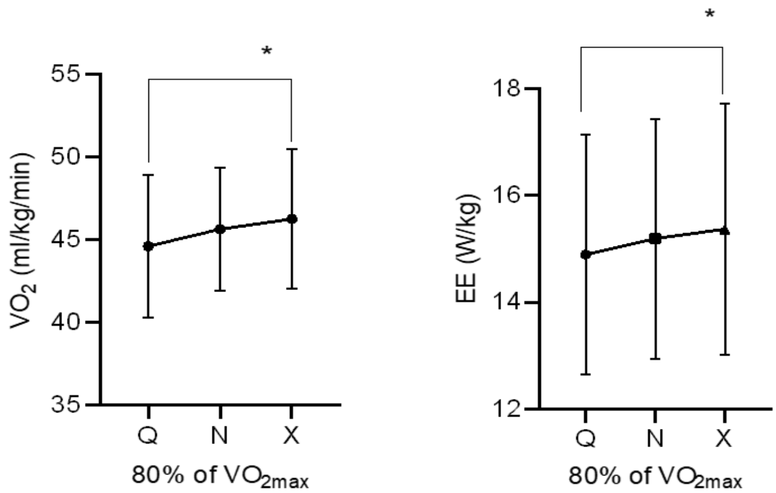


**Figure 2: $VO_2$ (left) and EE (right) from the running economy test from male runners at 80% of the speed that elicited $VO_{2max}$. *Significant difference (p<0.05) during post hoc comparisons when the main effect of footwear was significant.**

**DISCUSSION:** This study aimed to assess the effects of running economy in male runners wearing 3 types of footwear. As expected, our findings of RE align with findings in previous laboratory-based studies conducted with runners (Hunter, 2019) which reported 2.8% oxygen consumption improvement in elite runners wearing VP4 (184g) at 16km/h compared to those wearing Adidas Adios Boost (230g). As for our findings, Q, N, and X had a significant difference in the RE and energy expenditure at 80% of $\upsilon VO_{2max}$ (15.0±1.0km/h), and Q shoes provided a benefit to running economy over X shoes. Compared to X shoes, Q had a lighter mass(191.16g) which indicated that for every 100g of added shoe mass, the energy of running increases by approximately 1% (Rodrigo, 2020). And in addition, Q had a larger bending stress (16.8N) and anti-torque(3.84Nm) which suggested Q had lower energy cost and benefit performance (Hoogkemar, 2018). However, although we had a systematic change in performance at 80% of $\upsilon VO_{2max}$, and had a non-significant difference at 60% (11.2±0.8km/h) and 70% (13.1±0.9km/h) of the speed of that elicited $VO_{2max}$, which disagree with previous research showing an economical benefit to the N shoe (Hoogkamer, 2018) and (Kim, 2020) which reported that approximately 3.0-4.2% improvements in oxygen consumption and energy

cost in VP4 at absolute speeds ranging from 14km/h to 18km/h after equalizing shoe mass (230-250g). The reason for our study had no systematic change in performance between 60% and 70% of $\upsilon VO_{2max}$ which is possible that participants were not being at high relative intensity, the RE speeds in the 2 visits were slower than those examined previously and in different footwear. Participants with different caliber who have significant changes in performance, compared to recreational runners, the elite runners have the better RE and with lesser oxygen consumption (Andrew, 2013), which suggested that a higher intensity of running might get a better RE and performance to them, we should have set higher intensities for our participants of the study, the 60% and 70% intensities are a little low for them. Besides, the number of our runners was above their anaerobic threshold at 60%, 70%, and 80% of $\upsilon VO_{2max}$, reducing the statistical changes. Another limitation is that we only recruited twelve male runners because of shoe cost considerations and the pandemic.
All in all, using laboratory-based data, we provide evidence that Qiaodan Feiying pb2 can be meaningful in male middle-caliber runners. Afterward, we are going to investigate the effect of the biomechanics in male-caliber runners wearing the 3 types of footwear.

**CONCLUSION:** Our study provides evidence that Qiaodan Feiying pb2 improved RE and energy expenditure in male middle-caliber runners at 80% of ʋVO2max compared to Xtep, but these improvements with no differences among the 3 types of footwear at 60% and 70% of ʋVO2max.

**CONFLICT OF INTEREST:** Mengjie Zhang has no conflicts of interest relevant to the content of this article. Hanjun Li is a paid consultant to Qiaodan.

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