Investigation of a New Evaluation Method for Economy by One-Minute Supramaximal-Intensity Running

Running Head: Sprint Economy in 800 Meter Runners

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Abstract

Running economy is an important aerobic energy capacity for 800-m running performance of highly trained runners. The intensity of the running speed in 800-m race exceeds that of 120% of maximal oxygen uptake (VO\textsubscript{2}max). Therefore, we hypothesized that the economy of supramaximal-intensity running (sprint economy [SE]) was strongly associated with running performance, rather than with running economy. The aim of this study was to clarify the association of the SE in highly trained runners to the performance of 800-m running. Seven male middle-distance runners with the personal best time in 800-m of 1'48''9 ± 1''0 participated in this study. They underwent 1-minute running at 120%VO\textsubscript{2}max to be measured the SE. The SE was evaluated as the sum of energy expenditure from aerobic energy, which was calculated using oxygen uptake and respiratory exchange ratio, and from anaerobic energy, which was calculated using accumulated blood lactate concentration. The SE was not significantly associated with 800-m running performance, whereas SE was significantly associated with the VO\textsubscript{2}max and speed of 120%VO\textsubscript{2}max. These results suggest that the running speed strongly depended on the subject’s aerobic capacity because the running speed was determined by VO\textsubscript{2}max.

Keywords:
Sprint economy; maximal oxygen uptake; middle-distance running; performance
1. Introduction

In 800-m races, the peak running speed occurs from the start to the 200-m point, and the speed decreases gradually to the finish. Kadono et al. (2008) argued that both the higher peak running speed during the first 200-m and the smaller decrease of the running speed in the second half of the race would result in the higher performance in the 800-m running. The peak running speed in the initial 200-m section of the 800-m running is associated with the maximal capacity of the energy metabolism, such as the maximal oxygen uptake (VO\(_2\)max) and the maximal accumulated oxygen deficit (Nevill et al., 2008). These capacities are associated with 800-m running performance (Nevill et al., 2008; Ramsbottom et al., 1994), but these are not necessarily correlated to that performance in highly trained runners (Craig and Morgan, 1998; Lacour et al., 1990).

Findings that are similar to the above results have been reported from the analyses of races that were 1,500m and longer. In addition, the running economy (RE) might determine running performance because highly trained runners have similar- and high-level of maximal energy metabolic capacity. Tanji et al. (2017a) demonstrated that the RE, which is evaluated at high-intensity running (110% of lactate threshold [LT]), close to competitive speed, was more strongly associated with the performance in 1,500-m running than was the RE, which was evaluated at conventional lower intensity running (90% of LT). In addition, the authors of that research reported that this RE at high-intensity running reflects capacity to run comfortably until the final phase of the race.

Not only 1,500-m running, RE at high intensity running would be a factor to determine
the 800-m running performance due to the similar and high maximal energy metabolism capacity.

Furthermore, this RE at high intensity may be associated with the small decrease in running speed in the second half of the 800-m race; for example, Tanji et al. (2017b) demonstrated that the 800-m running performance was more closely associated with the RE at high intensity (90% \( \dot{V}O_2 \text{max} \)) than with the RE at low intensity (65% \( \dot{V}O_2 \text{max} \)).

The intensity of 800-m running exceeds 120% of \( \dot{V}O_2 \text{max} \), the required energy of anaerobic system is over 40% of total energy metabolism demands during 800-m running. Therefore, the RE would be evaluated better with higher running intensity than with the method reported by Tanji et al. (2017b). However, running intensity, which exceeds 120% of \( \dot{V}O_2 \text{max} \), is too high to maintain for 3 to 4 min; therefore, it is necessary to evaluate RE in a shorter time period. In this study, the economy was evaluated in the energy expenditure during supramaximal-intensity running for 1-minute (sprinting), and it is defined as sprint economy (SE).

The aims of this study were therefore to clarify the association among the 800-m running performance and SE in highly trained runners. We hypothesized that lower energy expenditure for supramaximal-intensity running is related to superior 800-m running performance.

2. Methods

2.1. Participants

Seven male middle-distance runners participated in this study (age, 21.9 ± 2.1 years; height, 173.0 ± 3.1 cm; body mass, 62.5 ± 4.1 kg). Their personal best time of 800-m was 1’48”9 ±
10. After being informed the purpose of this study, all the subjects signed on the written informed consent approved by the Research Ethics Committee at the Japan Institute of Sport Sciences (Issue Number 045).

2.2. Experimental protocol

All the participants underwent two kinds of running tests within one day, wherein they ran on a treadmill (BM-1210; S&ME Co., Ltd., Tokyo) at grade of 1%. The first test was conducted in the morning, during nine to twelve a.m. and the second test was conducted in the afternoon, during three to six p.m.

The first test was a multi-incremental load test to measure $\dot{\text{VO}_2\text{max}}$, RE, LT, and running speed at $\dot{\text{VO}_2\text{max}}$ ($s\dot{\text{VO}_2\text{max}}$). The time for each incremental stages of load in which each subject are running, was set as 3 minutes and the time for the rest was set as 1 minute. These load and rest cycle were repeated up to blood lactate concentration (bLa) exceeds 4.0 mmol/L. The bLa was measured from fingertip blood sample taken after each running stage. The speed of the initial stage was 230 m/min and increased by 20 m/min at each subsequent stage. The rest time was extended to 3 minutes when the bLa exceeded 4.0 mmol/L. Then, the running speed was increased by 10 m/min for one-minute of running until the athletes reached exhaustion. The initial running speed was the one stage before the bLa exceeded 4.0 mmol/L. The second test, subjects performed 1-min running at 120% of $s\dot{\text{VO}_2\text{max}}$ to measure the SE.
2.3. Data analysis

We used the breath-by-breath computerized standard open circuit technique with an expired gas analyzer (Exp Mode, AE310-S Aero Monitor; Minato Medical Science Co., Ltd., Osaka) to measure the \( \dot{V}O_2 \), carbon dioxide excretion (\( \dot{V}CO_2 \)), pulmonary ventilation, and respiratory exchange ratio (RER). The gas analyzer and flow sensor were calibrated using the calibration gas (air equivalent: 21.00% O\(_2\), 0.03% CO\(_2\), and balance N\(_2\); exhalation equivalent: 15.00% O\(_2\), 5.00% CO\(_2\), and balance N\(_2\)) and a flow calibrator (2 L), respectively. Before the test, after each running stage, and after 1, 3, and 5 minutes of exercise to exhaustion, a fingertip blood sample was obtained for bLa measurement (Lactate Pro 2; Arkray Co., Ltd., Kyoto).

\( \hat{\dot{V}}O_2\)max was defined as the highest \( \dot{V}O_2 \) during 1 minute in the first test. To calculate \( \hat{\dot{V}}O_2\)max, we extrapolated the value of \( \hat{\dot{V}}O_2\)max into the data series of speed–\( \dot{V}O_2 \) in the first test and 5.1 mLO\(_2\)/kg/min at y-intercept (Russell et al., 2000) with the equation of regression on the relationships of the speed–\( \dot{V}O_2 \) for that data series. RE was calculated as the total aerobic energy expenditure, which was evaluated with the \( \dot{V}O_2 \) and RER at each stage of running, and the anaerobic energy expenditure, which was evaluated according to the difference in bLa between rest and after each stage running when bLa exceeds 2.0 mmol/L (Kyröläinen et al., 2002). Furthermore, the unit of the total energy expenditure was converted from J to kcal (1 J = 0.239 kcal). We calculated the running speed at LT (sLT) with lactate analysis software (Lactate-E; Newell et al., 2007), using running speed and bLa at each stages of running, and we calculated LT as the intensity of sLT in relation to \( \hat{\dot{V}}O_2\)max.
To evaluate SE, we calculated the total aerobic energy expenditure and anaerobic energy expenditure during 1-minute running. We calculated the aerobic energy expenditure from sum of the energy expenditure during a 1-minute run of the \( \dot{\text{VO}}_2 \) and the RER (Kyröläinen et al., 2002) every five seconds. Furthermore, we calculated the anaerobic energy expenditure from the difference bLa between before and after running (Kyröläinen et al., 2002). With regards to the RE, the unit of the total energy expenditure was converted from J to kcal.

### 2.4. Statistical analyses

SPSS version 24 (SPSS, Inc., Chicago) was used to perform all statistical analyses. To examine the relationships among variables, Pearson's product-moment correlation coefficients were calculated. The level of significance was set at 5%.

### 3. Results

Data are expressed as the mean ± standard deviation. Table 1 lists the results of the first test, and Table 2 lists the results of the second test. Table 3 lists the results of step parameters during 120% VO\(_2\)max running. In addition, Tables 1, 2, and 3 show correlation coefficients for the association with both SE and 800-m running performance to each variable.

No significant association was observed in SE with 800-m running performance \((r = -0.22; \text{Figure 1})\), whereas SE was significantly associated with \( \dot{\text{VO}}_2\text{max} \) \((r = 0.82, P < 0.05)\), \( \acute{\text{VO}}_2\text{max} \) \((r = 0.90, P < 0.01)\), sLT \((r = 0.77, P < 0.05)\), and RE at 230 m/min \((r = -0.78, P < 0.05)\).
In addition, SE was positively associated with running speed at 120% $\dot{V}O_2\text{max}$ ($r = 0.90, P < 0.01$) and with anaerobic energy expenditure during 120% $\dot{V}O_2\text{max}$ running ($r = 0.95, P < 0.01$). Furthermore, SE was negatively associated with the ratio of anaerobic energy expenditure ($r = -0.88, P < 0.01$).

4. Discussion

4.1. The performance of participants

The participants' 800-m running performance (personal best time) in this study was 1'48"9 ± 1"0, and the coefficient of variation for their running performance was 0.9%. The participants constituted a highly homogeneous performance group. In the study by Tanji et al. (2018), the coefficient of variation for 800-m running by high-performance runners (1'53"2 ± 2"2) was 1.9%, which indicated the significant associations between 800-m running performance and the RE. Tanji et al. (2018) emphasized that the RE was important to explain the differences among each performance within the homogeneous performance group. In this study, however, although the correlation coefficients between 800-m running performance and the RE tended to get strong along with increase of intensity, we found no significant association between them. It should be inferred that the small number of subjects or the small coefficient of variation on the caused the lack of significant relationships between 800-m running performance and RE in this study.

Ingham et al. (2008) reported that the $\dot{V}O_2\text{max}$ of subjects with elite performance (1'48"9 ± 2"4) was 72.4 ± 6.1 mL/kg/min. However, Tanji et al. (2018) reported that the $\dot{V}O_2\text{max}$ of
subjects (1'53"2 ± 2"2) was 66.2 ± 4.9 mL/kg/min. The \( \dot{V}O_2 \)max of the subject of the present study (1'48"9 ± 1"0) was 69.5 ± 3.4 mL/kg/min, suggesting that in 800-m runners who performed faster than 1'50, the \( \dot{V}O_2 \)max tended to exceed 70.0 mL/kg/min. The 800-m runners contain athletes with 400-m running (400–800 m type) and with 1,500-m running (800–1,500 m type) as sub event. The \( \dot{V}O_2 \)max tended to higher in the 800–1,500 m type runners and the \( \dot{V}O_2 \)max in the 400–800 m type runners was also 65.0 mL/kg/min or more. These results suggest that \( \dot{V}O_2 \)max is important even in 800-m runners.

4.2. Relationship between sprint economy and 800-meter running performance

It is well known that performance in distance running of highly trained runners can be estimated by the RE. In particular, Tanji et al. (2017a) reported that the importance of RE at high intensity, which is close to that of the races in competition. They demonstrated that RE at an intensity above LT (110%LT) was more closely associated with the 1,500-m running performance than the RE at an intensity below LT (90%LT) (Tanji et al., 2017a). Therefore, we evaluated the sum of energy expenditure as the SE from aerobic and anaerobic energy expenditure during the 1-minute running at an intensity of 120% \( \dot{V}O_2 \)max, which was similar to the intensity of the 800-m race in competition. However, the results of the present study showed no significant association between the SE and 800-m running performance. This lack of significance in the association might be affected by the large dispersion of the running speed at intensity of 120% \( \dot{V}O_2 \)max in the participants of present study.
The SE in the present study has a significantly positive association with the running speed at 120% $\dot{\text{VO}}_2\text{max}$ and the anaerobic energy expenditure during 120% $\dot{\text{VO}}_2\text{max}$ running. The anaerobic energy expenditure increased along with the running speed; therefore, the SE increased (i.e., less economy). Furthermore, $\dot{\text{VO}}_2\text{max}$ greatly influenced the running speed at 120% $\dot{\text{VO}}_2\text{max}$, as evidenced by a significant positively associations with the SE, which suggests that the $\dot{\text{VO}}_2\text{max}$ affects the SE.

The SE was calculated to evaluate the economy at supramaximal-intensity running; however, there was a significantly negative association between the SE and the RE. Therefore, despite the fact that both the SE and RE evaluated economy capacity, there was a difference between the submaximal (i.e., RE) and supramaximal (i.e., SE) intensity. It could be inferred from the abovementioned result that the SE in the present study may not be sufficient as an index for economy.

In general, the RE is evaluated at the same running intensity or the same running speed. We evaluated the RE by the same running speed but the SE by the same running intensity with the method of Kyröläinen et al. (2002). However, the SE by the same running intensity was not associated with 800-m running performance. Moreover, aerobic energy expenditure during 120% $\dot{\text{VO}}_2\text{max}$ running is not associated with running speed at 120% $\dot{\text{VO}}_2\text{max}$. We inferred that the influence of $\dot{\text{VO}}_2$ on difference in running speed was small because the running intensity exceeded 100% $\dot{\text{VO}}_2\text{max}$. Therefore, the difference in anaerobic energy expenditure might affect the SE.

The SE in the present study was evaluated at an intensity defined only by $\dot{\text{VO}}_2$, which is
the gold standard method used to define the running speed at 100% VO₂max or less. However, the metabolism at supramaximal running speed increased from the anaerobic energy; therefore, the SE could not be evaluated well. In the future, it will be necessary to evaluate the SE by changing the method used to set the running speed; for example, the running speed can be set by the relative intensity based on the time of season best in 800-m running or using same running speed. When using the relative intensity based on the time of season best in 800-m running, the SE would be evaluated corresponding to the running performance. However, similar to the present study, the high-performance runners would likely increase their anaerobic energy expenditure and SE because their running speed is high. On the other hand, when the SE was evaluated using the same running speed while following the general evaluation method for the RE, the SE would likely have a positive association with the RE; therefore, it would be associated with the 800-m running performance.

5. Conclusion

The aim of this study was to clarify the association between the SE and 800-m running performance in highly trained runners. The results of the present study showed that the SE evaluated by running speed of 120%VO₂max is not associated with 800-m running performance. The reason of the result above might be the large dispersion of the running speeds among each subject, which were set with VO₂max.
Conflict of Interest

The authors declare that they have no conflict of interest in the authorship and publication of this contribution.

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Figure 1. The relationships between sprint economy and 800-m running performance (a), 120% VO$_2$max (b), VO$_2$max (c), and running economy at 230 m/min (d).
Table 1. Mean (± SD) values of multi-incremental load test and correlation coefficients between these values, the sprint economy, and 800-m running performance.

| Units       | Mean ± SD | vs SE r value | vs 800m running performance r value |
|-------------|-----------|---------------|------------------------------------|
| VO₂ max mL/kg/min | 69.5 ± 3.4 | 0.82*         | -0.22                              |
| sVO₂ max m/min | 345.2 ± 31.5 | 0.90**       | 0.04                               |
| sLT m/min     | 280.3 ± 21.7 | 0.77*         | 0.18                               |
| LT %VO₂ max   | 81.4 ± 4.6  | -0.39         | 0.16                               |
| Lamax mmol/L  | 11.5 ± 2.0  | -0.21         | 0.09                               |
| RE230 kcal/kg/km | 0.97 ± 0.09 | -0.78*       | -0.11                              |
| RE250 kcal/kg/km | 1.02 ± 0.07 | -0.62        | -0.14                              |
| RE270 kcal/kg/km | 1.02 ± 0.08 | -0.72        | -0.33                              |
| RE290 kcal/kg/km | 1.03 ± 0.06 | -0.71        | -0.36                              |

Notes: *, P < 0.05; **, P < 0.01.
Table 2. Mean (± SD) values of energy expenditure during 1-minute running at 120%\(\dot{VO}_2\)max test and correlation coefficients between these values, the sprint economy, and 800-m running performance.

| Units       | Mean ± SD | vs SE r value | vs 800m running r value |
|-------------|-----------|---------------|-------------------------|
| 120%\(\dot{VO}_2\)max | m/min     | 413.3 ± 37.8  | 0.90**                  | 0.04 |
| SE          | kcal/kg/km| 0.851 ± 0.071 | --                      | -0.22 |
| Eae         | kcal/kg/km| 0.559 ± 0.023 | 0.58                    | -0.09 |
| Eana        | kcal/kg/km| 0.292 ± 0.060 | 0.95**                  | -0.23 |
| %Eae        | %         | 66.0 ± 4.4    | -0.88**                 | 0.22  |
| %Eana       | %         | 34.0 ± 4.4    | 0.88**                  | -0.22 |

Notes: **, \(P < 0.01\); SE, Total energy expenditure during 120%\(\dot{VO}_2\)max running (Sprint economy); Eae, Aerobic energy expenditure during 120%\(\dot{VO}_2\)max running; Eana, anaerobic energy expenditure during 120%\(\dot{VO}_2\)max running; %Eae, the ratio of Eae to SE; %Eana, the ratio of Eana to SE.
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