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Title: Neither internal nor external nasal dilation improves
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Abstract

Objectives: Research is equivocal regarding endurance performance benefits of external nasal dilators, and currently research focusing on internal nasal dilators is non-existent. Both devices are used within competitive cycling. This study examined the influence of external and internal nasal dilation on cycling economy of motion and 20-km time trial performance. Design: The study utilised a randomised, counterbalanced cross-over design. Methods: Fifteen trained cyclists completed three exercise sessions consisting of a 15 min standardised warm up and 20-km cycling time trial while wearing either a Breathe Right® external nasal dilator, Turbine® internal nasal dilator or no device (control). During the warm up, heart rate, ratings of perceived exertion and dyspnoea and expired gases were collected. During the time trial, heart rate, perceived exertion, and dyspnoea were collected at 4-km intervals and mean 20-km power output was recorded. Results: No differences were observed for mean 20-km power output between the internal (270±45 W) or external dilator (271±44 W) and control (272±44 W). No differences in the economy of motion were observed throughout the 15-min warm up between conditions. Conclusions: The Turbine® and Breathe Right® nasal dilators are ineffective at enhancing 20-km cycling time trial performance.

Keywords: exercise performance; aerobic; exercise physiology; sport, dyspnoea

Introduction

Within sport, developing a competitive edge which provides additional speed or power to an athlete or conserves energy is of great interest. In endurance sports, the mechanics of respiration are often overlooked; however, provide an opportunity for manipulation which could result in improved performance. During intense exercise, redistribution of blood flow from locomotor muscles to those of respiration[1-3] has been shown to decrease exercise tolerance[4-6] and results in early termination of exercise.[5, 7, 8] Furthermore, respiratory muscle fatigue can increase perceived exertion and dyspnoea, both negatively influencing exercise performance.[4, 6, 9] Thus, interventions which aim to unload respiratory muscles during exercise have the potential to enhance performance[10-12].

During exercise, ventilation is achieved through both the oral and nasal passages with some 27% of ventilation originating through the nasal passage during intense exercise (90% of maximal oxygen consumption).[13] Due to the narrow cross-sectional area, the nasal valve is the flow-limiting segment during oral-nasal ventilation increasing respiratory resistance[12, 14] which can lead to increased respiratory fatigue.[3, 8, 15] Increasing nasal valve area decreases respiratory resistance and may result in enhancements in performance.[10-12] External nasal dilator strips are commonly used by endurance athletes to increase the nasal valve area[3, 16, 17] and have shown a 31% reduction in nasal airway resistance leading to a 50% decrease in the work of nasal breathing.[18] These changes can increase exercise performance[3,16] and economy of motion;[19] however, these findings are not consistent within the literature.[11] Internal nasal dilating systems, such as the Turbine® and Nozovent®, work from within the nose expanding the nostril walls laterally increasing the cross-sectional area of the nasal valve. Internal nasal dilation is more effective at lowering nasal resistance than external methods[19] thus may present a novel method to reduce airway resistance during exercise and improve performance. To the authors' knowledge, no studies have been conducted to determine the performance benefits of internal nasal dilation.

The purpose of the current study was to examine the influence of internal and external nasal dilation on 20-km cycling time trial performance in trained cyclists. Specifically, we examined the Breathe Right® external nasal dilator and the Turbine® internal nasal dilator as both devices are currently used within competitive cycling. We hypothesised that compared with a control condition both nasal dilators would improve performance during a 20-km cycling time trial with internal nasal dilation resulting in superior performance compared with external dilation. We also hypothesised that the internal and external nasal dilators would decrease perception exertion, and dyspnoea during, and reduce respiratory muscle fatigue following a 20-km time trial.

Methods

Fifteen male participants volunteered to for this study (age: 40 ± 10.5 y; height: 181.1 ± 4.3 cm; weight: 78.50 ± 7.25 kg; maximal oxygen consumption: 60.7 ± 10.6 $\text{ml}\cdot\text{kg}^{-1}.\text{min}^{-1}$). At the time of data collection, all participants were cycling at least 150km per week and had previous racing/time-trialling experience. Also, participants were required to meet the minimum standard for maximal oxygen consumption of 55.0 $\text{ml.kg}^{-1}.\text{min}^{-1}$ for inclusion into the study. The risks and benefits of participation were provided in writing, and informed consent was obtained prior to data collection. This study received ethical approval from the necessary institution prior to commencement and conformed to the Code of Ethics of the World Medical Association (Declaration of Helsinki).

This study utilised a randomised, counterbalanced cross-over design. Participants were required to attend four laboratory sessions with no less than two days and no greater than ten days between sessions. All cycling was completed using an electronically braked cycle ergometer (Velotron, Racermate, USA) in a temperature control environmental chamber at 24^{o}C and 40% relative humidity. During the initial session (familiarisation), participants completed a 15 min standardised cycling warm-up (five min at 75 W, five min at 150 W and five min at 200 W) followed five min later by a 20-km cycling time trial. During the time trial, power output was recorded at a frequency of 1 Hz with the mean 20-km time trial power output recorded for use during the remaining sessions. Fifteen min after completing the time trial, participants undertook a modified maximal exercise test. This test consisted of cycling for one min at 80% of the mean power output recorded during the 20-km time trial with step increases in power of 35 W.min^{-1} until volitional fatigue. During the test, mean 15 s oxygen consumption was measured using a Parvo TrueOne metabolic cart (Parvomedics; USA). Maximal oxygen consumption was defined using the following criteria; 1) heart rate exceeding 85% of age predicted max, 2) respiratory exchange ratio greater than 1.1 and 3) a plateau in oxygen consumption ($\dot{V}O_2$) over a minimum of three consecutive 15 s recordings. The highest 15 s value measured within the plateau was recorded as the participant's maximal oxygen consumption.

The remaining three sessions were completed in a randomised and counterbalanced order. Each session consisted of a standardised 15 min warm-up and 20-km cycling time trial. Before the start of exercise, participants completed a pulmonary function test after which they were provided with either one of two nasal dilation devices; internal nasal dilation (Turbine®; Rhinomed, Australia) or external nasal dilation (Breathe Right® strips; GlaxoSmithKline, USA) or no device as the control condition. Each device was fitted to the manufacturer's specifications. Participants were then asked to rest for five min before the warm-up to allow them to become familiar with the feel of the device. The warm-up started with three min of rest with the participants seated on the cycle ergometer. After this time, participants were required to complete three 5-min bouts of cycling (total 15 min) at a constant cadence of 90 rpm at 30% (82 ± 12 W), 50% (136 ± 21 W) and 70% (190 ± 29 W) of the mean 20-km time trial power output recorded during the familiarisation session. During the warm-up, $\dot{V}O_2$ and minute ventilation ($\dot{V}_E$) were recorded using a metabolic cart and Hans Rudolph Face Mask (Hans Rudolph Inc., USA) to accommodate the nasal dilation devices. Perceived exertion (Borg scale[20]; scale: 6 – 20; 6- no exertion at all; 20- maximal exertion) and dyspnoea (modified Borg Dyspnoea Scale[21], 0- nothing at all; 10- maximal) were assessed at the completion of each stage. Five min after completing the warm-up, participants completed a 20-km cycling time trial. During the 20-km cycling time trial, no gas collection occurred. Five min after completion of the time trial participants completed a second round of pulmonary testing. During the entire session heart rate was recorded at a frequency of 1 Hz using a Garmin heart rate monitor (Garmin Ltd., USA). Fifteen min after completing the time trial, participants were asked to rate their session perceived exertion and to rate the efficacy of the internal and external nasal dilation using a 14 cm visual analogue scale (0cm = none, 7cm = moderate and 14cm = great deal) for the questions; "Did the device help breathing a) at rest, b) during the warm-up, c) during the time trial and d) during recovery?"

Respiratory muscle fatigue was assessed by maximum inspiratory pressure (cmH_2O; MIP) measured using a MicroRPM™ (Respiratory Pressure Meter; CareFusion, USA). The test was conducted in triplicate with one minute recovery period between tests. Participants were required to exhale completely then while breathing through the MicroRPM, inhale as forcefully as possible, for as long as possible during which time inspiratory pressure was continuously measured with the peak value provided at cessation.

Oxygen consumption was collected throughout the standardised warm-up (three 5-min stages). Only data collected during the final two minutes of each stage were used for analysis to ensure physiological steady state. Mean $\dot{V}O_2$ recorded during the three min pre-warm up period was subtracted from the mean $\dot{V}O_2$ recorded in the final two min during each five min stage. Economy of motion was calculated using the following formula;

Economy of motion = W. $\dot{V}O_2^{-1}$

Where W is the prescribed wattage for the stage and $\dot{V}O_2$ is the final two min mean oxygen consumption (L.min^{-1}) for the corresponding stage minus the mean $\dot{V}O_2$ recorded during the three min warm up.

All time trials commenced from a standing start with a set gear ratio of 52x17. Participants were instructed to complete the distance as fast as possible with only distance completed provided as feedback. During the effort, perceived exertion (Borg Scale) and dyspnoea (modified Borg Dyspnoea Scale) were measured at 4-km intervals. Heart rate and power output were collected at a frequency of 1 Hz using a Garmin heart rate monitor and the internal velotron software (VelotronCS, Racermate, USA); respectively.

Differences in pre- and post-time trial measures of MIP, as well as 4-km measures of heart rate, perceived exertion and dyspnoea during the time trial between the Turbine®, Breathe Right® and control condition were analysed using a two-way analysis of variance (ANOVA) with repeated measures. Main effects or interactions were analysed using a Fisher's least significant difference test. Differences in perceived effectiveness of the Turbine® and Breathe Right® nasal dilators measured at rest, during the warm-up, time trial, and recovery were analysed using a paired sample t-test. All other measures were assessed for differences between conditions using a one-way ANOVA. Statistical analyses were completed using SPSS (IBM® SPSS® Statistics, USA) with an alpha level of 0.05. Individually, 20-km time trial completion times were assessed against the smallest worthwhile change

(± 0.3%) necessary to indicate a benefit or detriment to performance [22, 23]. All data are presented as mean ± standard deviations unless otherwise noted.

Results

No differences were observed in total time (p=0.65) or mean power output (p=0.78) between the Turbine® (1802.8 ± 114.4 s, 270 ± 45 W; respectively), Breathe Right® (1802.4 ± 114.0 s, 271 ± 44 W; respectively) and control (1796.1 ± 113.5 s, 272 ± 44 W; respectively) conditions. Using the smallest worthwhile change to indicate a benefit or detriment to performance, when compared with the control condition, 27% of participants showed a benefit and 40% a detriment during the Turbine® trial, while 40% of participants demonstrated a benefit and 53% a detriment during the Breathe Right® trial.

Heart rate, perceived exertion, and dyspnoea measured at 4-km intervals during the 20-km time trial are presented in Figure 1. A main effect for time was observed for heart rate ($p<0.01$), with a progressive increase in heart rate observed across all time points. Similar results were observed for perceived exertion ($p<0.01$) and dyspnoea ($p<0.01$). No differences were observed for heart rate (p=0.54), perceived exertion (p=0.66) or dyspnoea (p=0.54) between conditions at any time points.

Mean economy of motion, V_E, heart rate, perceived exertion and dyspnoea during the standardised warm-up are presented in Table 1. No differences were observed for the mean economy of motion, V_E, heart rate, perceived exertion between conditions at 30%, 50% or 70% of the familiarisation 20-km time trial power output. Perceived dyspnoea measured during the 30% stage was lower during the Turbine® (p=0.13) and Breathe Right® (p=0.03) compared with the control condition; however, no other differences were observed.

No differences (p=0.46) were observed for the maximal inspiratory pressure measured pre- and post-time trial between the Turbine® (92 ± 26 cmH_2O; 90 ± 23 cmH_2O respectively), Breathe Right® (93 ± 21 cmH_2O; 88 ± 20 cmH_2O respectively) and control (93 ± 20 cmH_2O; 89 ± 21 cmH_2O respectively) conditions.

Ratings of perceived effectiveness of the Turbine® or Breathe Right® compared to the control condition are highlighted in Table 2. Perceived effectiveness of the nasal dilator during the time trial was greater during the Breathe Right® compared with the Turbine® condition. During the 20-km time trial, 40% (n = 6) of participants perceived the Turbine® nasal dilator to provide greater than a moderate effect (score 7 out of 14), while during the Breathe Right® condition 47% (n = 7) perceived the effectiveness to be more than moderate. In only four instances, isolated to two individuals (10% of the sample population), did a participant perceive a nasal dilator to provide more than a moderate effect and have enhanced performance during the 20-km time trial. Conversely, 33% (n = 5) and 27% (n = 4) of participants during the Turbine® and Breathe Right® trials respectively, perceived the nasal dilator to provide less than a moderate effect while also displaying a decrease in 20-km time trial performance.

Discussion

The purpose of the present study was to examine the influence of internal and external nasal dilators on performance in trained cyclists. The novel findings of this study were; 1) no improvements were observed in 20-km time trial performance when using either nasal dilator compared to a control, and 2) internal and external nasal dilation did not improve economy of motion compared to the control condition.

External nasal dilators can increase nasal airflow[1, 17] and may provide benefits to aerobic performance;[3, 16, 24] however, these performance benefits have been equivocal in the literature.[1, 11, 25] The use of internal nasal dilators can improve nasal airflow above external dilatation[19] thus possibly providing greater stimuli to enhance performance. Our findings indicate neither internal nor external nasal dilation increased performance during a 20-km cycling time trial when compared with a control condition. This finding contradicts Tong *et al.*,[3] who observed a 4.9% increased power output during a 30-min intermittent all-out cycle exercise (20 s at 160% of $\dot{V}O_{2peak}$ and 40 s of active recovery) in healthy male athletes (of various sports) under nasal dilation conditions when compared to control. These differences are likely due to the intermittent nature of the exercise prescribed by Tong *et al*,.[3] as during the recovery periods participants would have transitioned back to predominantly nasal ventilation[3] allowing the nasal dilator to have greater influence during this time, possibly enhancing aerobic recovery. Although not measured in this study, our use of a 20-km time trial would have resulted in sustained high ventilation rates[26] leading to greater oral ventilation[13] thus reducing the impact of nasal dilation on overall performance.

During moderate duration endurance based events, conservation of energy is essential.[24] With increasing intensity, a concurrent increase in ventilation is associated with a greater oxygen cost of breathing and subsequently greater energy consumption.[27] The ability to unload respiratory muscles during set intensity exercise can reduce the energy cost of breathing[1, 2, 25], thus increasing economy of motion. Our data indicates internal and external nasal dilation had no influence on the economy of motion measured at 30%, 50% and 70% of each participant's 20-km time trial power output (Table 1). Our findings are not consistent with Griffin *et al.*,[24] who observed a decrease in $\dot{V}O_2$ of participants cycling at 100 W (1.3 $L.min^{-1}$ with device VS. 1.4 $L.min^{-1}$ with no device) and 150 W (1.9 $L.min^{-1}$ with device VS. 2.0 $L.min^{-1}$ with no device) while using external nasal dilation. During this study, participants were instructed to switch from nasal breathing to oral-nasal breathing when they felt it necessary thus increasing the awareness of their breathing patterns.[24] It is possible changes in breathing pattern may have influenced the measure of $\dot{V}O_2$.[4, 24, 27] In the current study, no such instructions were provided as we allowed participants to change naturally from nasal to oral-nasal breathing.

Although neither the internal or external nasal dilation provided a benefit to performance, it is possible such manipulation could still result in both physiological and perceptual benefits through the influence of bio-feedback.[28, 29] Sustained heavy exercise can increase heart rate and dyspnoea[5, 6, 12] which can increase perceived exertion.[5, 6, 26] During the 20-km time trial, heart rate and perceived dyspnoea and exertion increased in a time-dependent manner in all conditions (Figure 1); however, neither nasal dilation condition resulted in a decrease in heart rate or perceived dyspnoea or exertion compared with the control. Furthermore, during the standardised warm up neither nasal dilator resulted in observable differences in heart rate or perceived exertion, at any intensity (Table 1). Of note, perceived dyspnoea at the lowest warm up intensity was less in both nasal dilation conditions when compared with the control. Notwithstanding this difference, heart rate, perceived exertion and dyspnoea recorded during both the warm up and time trial indicates neither nasal dilator is likely to provide a physiological or perceptual benefit through means of bio-feedback.

The current study provides novel information into the efficacy of internal and external nasal dilators on physiological changes and performance during a 20-km cycling time trial. However, we acknowledge issues with the methodology used in this study, specifically the lack of a sham treatment condition, could have influenced the performance measures through either a placebo or nocebo effect [30]. Unfortunately, the mechanical nature of both the Turbine® and Breathe Right® nasal dilators would not allow for a sham treatment as it was not possible to apply either device with a genuine feel without also resulting in nasal dilation. Nevertheless, individual performance and perceived effectiveness data indicate a lack of placebo effect as only two of the 15 participants reported the devices to provide a benefit and demonstrated improved performance. Furthermore, negative assessment of the device also did not appear to influence performance outcomes as 33% of participants in the Turbine® condition and 27% in the Breathe Right® condition rated the device to provide less than a moderate benefit and performed worse compared to the control condition.

Conclusion

The use of nasal dilation assisting devices, irrespective of the mechanism (internal or external), does not provide performance enhancement during a 20-km cycling time trial. While it has previously been suggested that nasal dilation can unload respiratory muscle thus reduce the oxygen cost of breathing, our findings do not support this claim. Furthermore, individual responses to both the Turbine® and Breathe Right® nasal dilators do not indicate the presence of a placebo or nocebo effect. The efficacy of such devices in a competitive sports setting should be questioned.

Practical implications

- During a 20-km cycling time trial (~30 min) neither internal or external nasal dilation are likely to provide any performance benefits.
- Perceived exertion is not influenced by nasal dilation during a 20-km cycling time trial.
- Neither internal or external nasal dilation is likely to improve economy of motion while cycling at moderate intensity.

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Tables

Table 1. Mean economy of motion, minute ventilation (V_E), heart rate (HR), ratings of perceived exertion (RPE) and dyspnoea recorded during the standardised warm-up at 30%, 50% and 70% of familiarisation mean time trial (Fam. TT) power output.

		Turbine®	***Breathe Right®***	***Control***	***P value***
Economy of motion ($W.LO_2^{-1}$)					
	30%	53.9 ± 5.8	53.2 ± 7.8	53.9 ± 7.2	0.86
	50%	65.7 ± 5.6	64.2 ± 8.5	65.3 ± 7.6	0.67
	70%	69.9 ± 3.5	68.1 ± 7.9	69.1 ± 6.5	0.74
V_E ($L.min^{-1}$)					
	30%	29.0 ± 4.0	29.7 ± 4.6	29.4 ± 3.9	0.75
	50%	41.0 ± 6.4	42.3 ± 7.1	41.5 ± 5.8	0.61
	70%	54.9 ± 9.6	56.4 ± 9.8	55.0 ± 9.3	0.61
Mean HR (bpm)					
	30%	100 ± 18	97 ± 9	100 ± 22	0.74
	50%	117 ± 19	114 ± 12	115 ± 16	0.75
	70%	130 ± 13	127 ± 10	126 ± 8	0.26
RPE (units)					
	30%	8 ± 1	8 ± 1	8 ± 1	0.87
	50%	10 ± 1	10 ± 1	10 ± 1	0.48
	70%	12 ± 1	12 ± 1	11 ± 2	0.14
Dyspnoea (units)					
	30%	0.7 ± 0.4[a]	0.7 ± 0.2[a]	1.1 ± 0.6	0.02
	50%	1.8 ± 0.8	1.7 ± 0.9	2.0 ± 0.7	0.14
	70%	2.7 ± 1.0	2.8 ± 1.0	2.8 ± 0.7	0.71

[a] Less ($p < 0.05$) than control condition.

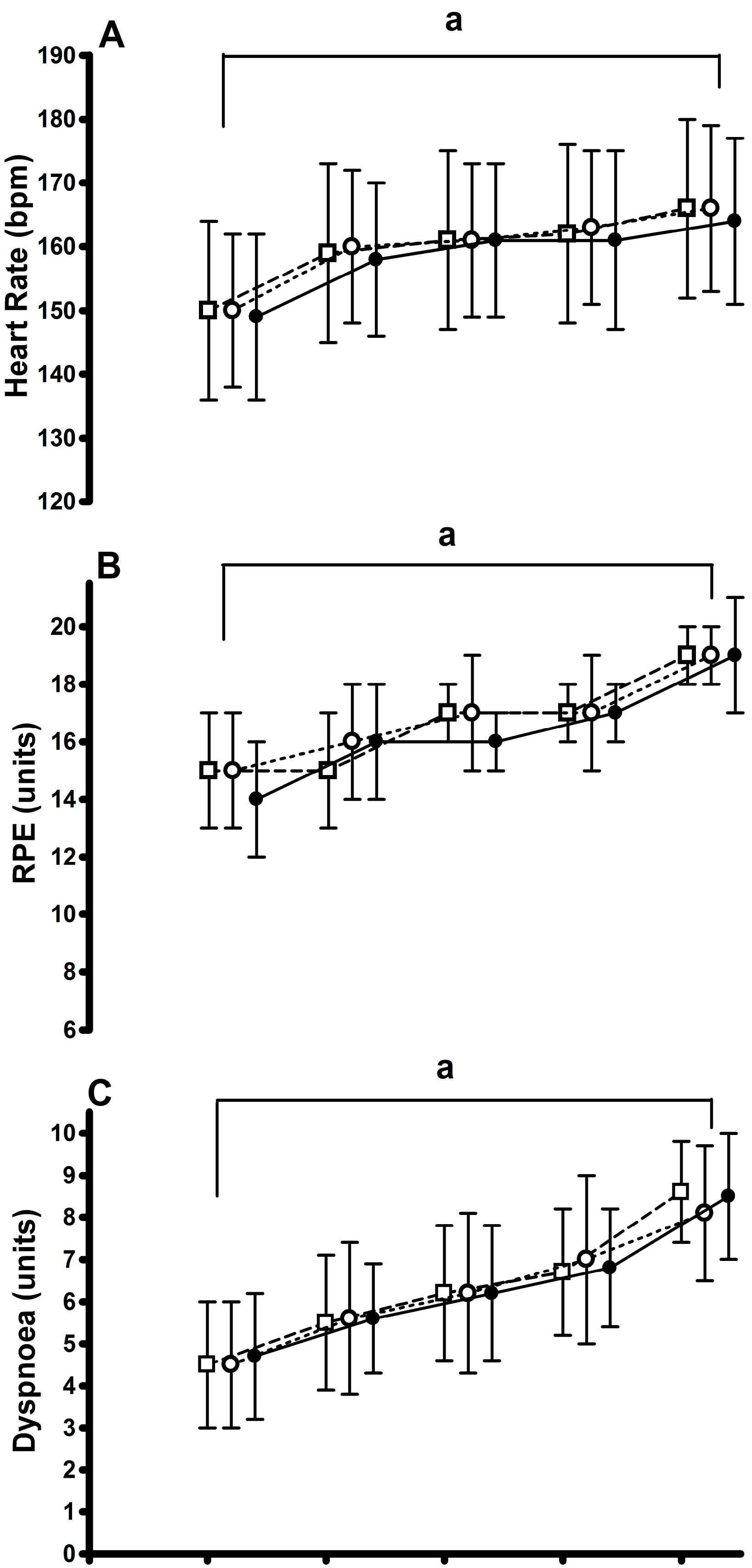
Table 2. Perceived effectiveness of Turbine® and Breathe Right® Nasal dilation conditions when compared with the control condition measured on a 14cm visual analogue scale.

	Turbine®	**Breathe Right®**	**P value**
At Rest	4.3 ± 3.5	5.0 ± 3.2	0.40
During the Warm-up	4.3 ± 2.4	5.4 ± 3.0	0.18
During the TT	3.7 ± 3.2	6.1 ± 4.3	0.02
During Recovery	3.6 ± 2.7	5.4 ± 4.0	0.06

Note. Recovery = 15 min post time trial. Response to question: “Did the device help breathing?”

Figure Captions

Figure 1. Mean heart rate (A), ratings of perceived exertion (RPE; (B)) and dyspnoea (C) measured at 4-km intervals during the 20-km cycling time trial in the Turbine® (□), Breathe Right® (○) and control (●) conditions. [a] Main effect for time: all time points greater than preceding time points.


A
a
Heart Rate (bpm)
190
180
170
160
150
140
130
120
B
a
RPE (units)
20
18
16
14
12
10
8
6
C
a
Dyspnoea (units)
10
9
8
7
6
5
4
3
2
1
0
0
4
8
12
16
20
Distance (km)