Drafting improves 3000m running performance in elite athletes: Is it a placebo effect?

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Abstract: PURPOSE: The study was designed to determine the effect of drafting on running time, physiological response and rate of perceived exertion (RPE) during 3000m-track running. METHODS: Ten elite middle and long distance runners performed three track-running sessions. The first session determined maximal oxygen uptake (VO2max) and maximal aerobic speed (MAS) using a lightweight ambulatory respiratory gas exchange system (K4B2). The second and the third tests consisted of non-drafting 3000m running (3000mND) and 3000m running with drafting for the first 2000m (3000mD) performed on the track in a randomized counter-balanced order. RESULTS: Performance during the 3000m (553.59±22.15 s) was significantly slower ($p<0.05$) than during the 3000mD (544.74±18.72 s). Cardiorespiratory responses were not significantly different between the trials. However, blood lactate concentration was significantly higher ($p<0.05$) after the 3000mND (16.4±2.3mmol.L-1) than after the 3000mD (13.2±5.6mmol.L-1). Athletes perceived the 3000mND as more strenuous than the 3000mD ($p<0.05$) (RPE = 16.1±0.8 vs. 13.1±1.3). Results demonstrate that drafting has a significant effect on performance in highly trained runners. CONCLUSION: This effect could not be explained by a reduced energy expenditure or cardio-respiratory effort as a result of drafting. This raises the possibility that drafting may aid running performance by both physiological and non-physiological (i.e. psychological) effects.

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DRAFTING IMPROVES 3000M RUNNING PERFORMANCE IN ELITE ATHLETES: IS IT A PLACEBO EFFECT ?

Submission Type: Original Investigation

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Abstract

Purpose: The study was designed to determine the effect of drafting on running time, physiological response and rate of perceived exertion (RPE) during 3000m-track running.

Methods: Ten elite middle and long distance runners performed three track-running sessions. The first session determined maximal oxygen uptake (VO_{2max}) and maximal aerobic speed (MAS) using a lightweight ambulatory respiratory gas exchange system ($K4B_2$). The second and the third tests consisted of non-drafting 3000m running (3000mND) and 3000m running with drafting for the first 2000m (3000mD) performed on the track in a randomized counter-balanced order.

Results: Performance during the 3000m (553.59±22.15 s) was significantly slower ($p<0.05$) than during the 3000mD (544.74±18.72 s). Cardiorespiratory responses were not significantly different between the trials. However, blood lactate concentration was significantly higher ($p<0.05$) after the 3000mND (16.4±2.3mmol.L^{-1}) than after the 3000mD (13.2±5.6mmol.L^{-1}). Athletes perceived the 3000mND as more strenuous than the 3000mD ($p<0.05$) (RPE = 16.1±0.8 *vs.* 13.1±1.3). Results demonstrate that drafting has a significant effect on performance in highly trained runners.

Conclusion: This effect could not be explained by a reduced energy expenditure or cardio-respiratory effort as a result of drafting. This raises the possibility that drafting may aid running performance by both physiological and non-physiological (*i.e.* psychological) effects.

Keywords: track running, endurance, pacing, highly trained, Rating of perceived exertion.

Introduction

It is now well established that the distribution of work output during any exercise task, the pacing strategy, influences the overall exercise performance.[1] Yet the optimum pacing strategies for different athletic events are not well established. This lack of certainty can be explained, at least in part, by the fact that the optimal pacing strategy during competition can be influenced by several external factors, such as the specific activity being performed, the race duration, the course geography and the environmental conditions.[1]

In middle distance running events when athlete aims to cover a set distance in the quickest possible time, the usual advice to this athlete is to maintain an even pace. In fact, now it is well understood that a fasted start produced the worst performance while even pacing produced the fastest time.[1]

On the other hand, performance in middle distance running events depends also on the tactical choices made by each athlete.[2,3] One such tactical choice is the use of “drafting”. The term “drafting” describes the practice of performing an activity in a sheltered position. Drafting has been investigated in many sports including cycling,[4] kayaking,[5] roller-skating,[6] triathlon,[7,8] cross-country skiing,[9] swimming[10,11] and middle-distance running.[12] All these studies have shown that drafting could improve performance in all endurance sports and that the benefit would likely increase with increasing speed of performance. Whilst biomechanical factors contributing to success differ between sports, the study of Pugh[14] has shown that drafting also improves performance in weight-bearing activity like running.

For example the original study of Pugh[12] showed that at a speed of 6 m/s, 80% of the oxygen (O_2) cost of overcoming air resistance was eliminated by running close behind another runner, which in real track events may increase a speed by about 1 sec every 400m lap. Indeed, modern runners understand the importance of drafting as a tactical choice to improve their likelihood of success, either in winning or setting world records.[9] Indeed pace setting played a major role in the most famous running record of all time, the first sub-four minute mile.[13] We are unaware of any modern studies other than that of [12,14] which document the extent to which drafting is likely to enhance performance neither in middle-distance running nor of studies attempting to explain the physiological or psychological effects produced by drafting in real-life competitive running races.

The present study was designed to investigate the effects of drafting on some physiological responses, performance and perceived exertion during a 3000m track-running race. We specifically wished to document the magnitude of the effect and to determine whether physiological or psychological factors may explain any beneficial effects of drafting.

Methods

Subjects

Ten highly trained athletes, specializing in middle and long distance running volunteered to participate in this study. The athletes were all members of the Tunisian National Track and Field team as a result of their best 3000m performances. These athletes were engaged in 6-7 training sessions per week for at least 4 years and were successful in national (n=10) and international (n=4) running competitions. Anthropometric characteristics and best performance of the subjects are listed in Table 1. All subjects consented to participate in the experiment upon being informed of the purpose of the study and the protocol, and provided written informed consent, which was approved by the local ethics committee of the University of Rennes II (CCPPRB) in accordance of the Declaration of Helsinki.

Design

All participants performed three running sessions between May and June on the same outdoor track, separated by at least 3 to 7 days. To minimize any effects of diurnal variation, the three testing sessions were conducted within 2 h of the same time of the day. There was no wind (<

1 m.s^{-1}) on the testing days, and the weather conditions remained constant throughout the testing period (temperature 15-20°C, humidity 30-45%). During the first test maximal oxygen uptake (VO_{2max}) and maximal aerobic speed (MAS) were measured in each athlete. The second and the third test, 3000m with (3000mD) and 3000m without (3000mND) drafting, were performed using a random selection while reproducing similar competition conditions. All the tests took place in the afternoon (between 3.00 and 4.00 p.m) 3 to 4 h after participants had eaten a standardized lunch (10 kcal/kg body mass, 55% of which came from carbohydrates, 33% from fat and 12% from proteins, as determined by an experienced nutritionist). Between the end of the standardized lunch and the beginning of the tests, the subjects were allowed to drink water "ad-libitum" without exceeding 250 ml per hour. The same clothing (competition shirts and shoes with spikes), as during competitions, was used by the participants for the three running sessions.

Methodology

Anthropometric measurements were determined before the tests for each subject. Body height and body weight were measured using standard techniques to the nearest 0.1 cm and 0.1 kg, respectively. For calculation of percent body fat according to the method of Durnin & Rahaman,[15] skinfold thickness were measured at four sites on the left-side of the body (triceps, biceps, subscapular and suprailiac) using a Harpenden skinfold calliper (British Indicators Ltd., Luton). The morphological characteristics and the best 3000m performances of the runners are presented in Table 1.

For each test, oxygen uptake (VO_2), ventilation (VE), rate of carbon dioxide production (VCO_2), ventilatory frequency (Freq.), respiratory exchange ratio (RER) and tidal volume (V_T) were recorded continuously by means of a gas exchange telemetric system ($K4B_2$, Medical Graphics, Minnesota, USA). The $K4B_2$ system is lightweight (~740g) with the main sample unit attached to the back and a battery pack on the chest for improved comfort. This design allows high-level running performance, as it does not interfere with the range of motion during running.

Before each test, the O_2 analysis system was calibrated using ambient air and two precision reference gasses of known concentrations. Ventilatory data were averaged every 5 s for subsequent analysis. During the course of the experiment, the receiving unit of the $K4B_2$ was positioned beside the running track in the outdoor stadium. Heart rate (HR) was measured and recorded continuously with a portable heart rate monitor (Polar Accurex Plus, Finland) on each athlete. To determine blood lactate concentration ($[La]_b$), a capillary blood sample was collected from a fingertip into 25 µl heparinised capillary tubes (Microzym-L analyzer, SGI, Toulouse, France) at rest, 3 minute after the end of a standardized warm-up both for the 3000mND and 3000mD and 3 min after the end of each test from the tip of a finger.

Maximal exercise test

Each running test took place on a 400-m marked outdoor track. During the first day each subject performed an incremental running test to determine VO_{2max} and MAS according to the protocol developed by Léger and Boucher.[16] The pace was given by sounds emitted through a speaker controlled by a computer software program to ensure precise control of running speed. Each subject was encouraged to exert a maximum effort. The test was stopped when the athlete could not maintain the required speed, and the mean value in VO_2 during the last elapsed minute at this stage was used to determine VO_{2max}. Achievement of VO_{2max} was accepted when subjects fulfilled at least three of the five following criteria: a plateau in VO_2 despite an increase in running speed, a respiratory exchange ratio greater than 1.10, a maximal HR near the predicted maximal theoretical HR (220-age in year), a blood lactate concentration higher than 8.0 $mmol.l^{-1}$, and the apparent exhaustion of the subjects. MAS (in $km.h^{-1}$) was then defined as the lowest running speed at which VO_{2max} occurred during the incremental exercise protocol.

Track-running events: 3000mND or 3000mD

On day 2 or 3, all the participants performed either a 3000mND or 3000mD in a randomised order. Upon arrival at the stadium, before each trial the athletes engaged in a standardized warm-up consisting of 15-min jogging at a low speed (about 50% of VO_{2max}) and 10-15 min of stretching and three to five 60- to 80-m "run-throughs" at increasing speeds. Following stretching, the $K4B_2$ base harness was placed on the participant and the $K4B_2$ system was attached to the athlete's torso. The participant then performed the run-throughs before calibration procedures were employed as described previously. Once the participant was prepared, measurement of VO_2 started and the athlete proceeded to the start line. At the start line, the participant was given the standard starting commands, at which point they approached the start line and then began the time-trial. The time-trial was recorded with a digital camera. Following completion of the time-trial, $K4B_2$ measurement was ceased and the harness was detached from the participant who then performed a gentle "cool down" exercise. For the 3000mND without drafting, the runner completed the distance alone as the sole competitor. For the 3000mD (with drafting), the runner completed the distance running behind two pace makers, the first pace maker ran until the 1500m and the second until the 2000m. The 2 pacers were positioned next each other and were asked to run as close to the tested runner as possible as during competitions (around 2 m in front of the runner). Pace makers were chosen on the basis that they were of similar 3000m running ability as the tested runner. The pacers determined the pace and not the participant (*e.g.* runner). For both the 3000mND and the 3000mD the runners were asked to maintain the speed constant (around 95-100% of MAS) until the 2000m and to increase the speed progressively between the 2000m and 2600m and to finish as fast as possible the last 400m. For the two trials, the runners were informed of their pace by skilled personnel with chronometers and who were located every 100m. The runners were informed whether they needed to run faster or slower, and by how many seconds they had to adjust to achieve the required pace during the first 2000m of each event. Thereafter subjects were permitted to run the final 1000m as quickly as they were able.

Statistical analysis

Data are reported as means (x) and standard deviation (SD). On the basis of a power analysis (desired power = 0.80 and an alpha error = 0.05), we determined that a sample size of n = 6 would be sufficient to study the drafting effect on performance and physiological parameters. Comparisons across events of performance, physiological responses, $[La]_b$ and RPE were made by analysis of variance (Two-way ANOVA, Trials (3000mD *vs.* 3000mND) x Lap Times)). A value of $p<0.05$ was accepted as the minimal level of statistical significance. All statistical analysis was conducted on statistical software (STATISTICA 6, Stat soft., Inc: 1984-2002).

Results

Table 1 shows the physiological parameters determined at the end of the maximal graded exercise test. Heart rate reached 198 ± 12 bpm, $[La]_b$ 11.5±3.9 $mmol.l^{-1}$ and MAS (maximal aerobic speed) 20.2±0.4 $km.h^{-1}$. VO_2 determined during the last stage of the graded test was 68±6 $ml.min^{-1}.kg^{-1}$ and was considered as VO_{2max}.

Table 2 lists the final and intermediate times recorded during the two 3000m races. Runners completed the 3000mD (544.74±18.72s) significantly faster ($p<0.05$) than the 3000mND (553.59±22.15s). These performances corresponded to around 93% (3000mD) and 90% (3000mND) of their personal best 3000m performances. The first 500m was run significantly faster during the 3000mND than during the 3000mD ($p<0.05$). However, the intermediate times recorded from 1000 to 2600m were not significantly different between trials. This is in accordance with the trial design, which required that subjects run the first 2000m of both races in the same time. This was successfully achieved (2000m time -Table 2).

Running times and the intermediate lap times during the two trials are presented in Table 3. As shown in Table 3, intermediate lap times were significantly faster during the 3000mD in the second and third 500m, unlike the first and the fourth lap times. Between 2000-2600m, there was no difference between trials. Larger variations in velocity (time recorded at each 500m) were observed during the 3000mND than during the 3000mD. Performance recorded during the final 400m was significantly faster in the 3000mD even though athletes were no longer receiving the benefit of drafting by that stage of the trial.

$[La]_b$ at rest and after the warm-up were not significantly different between trials (Table 4) but maximal $[La]_b$ determined 3 min after the end of the 3000m races were significantly higher after the 3000mND as were the RPE values.

Table 5 lists the physiological parameters (HR, VO_2, VE and RER) of the runners determined at intermediate points during the two 3000m trials. There were no statistically significant differences in any parameter between the 3000mND and the 3000mD either in the presence (0-2000m) or absence of pace makers (>2000m). The high heart rates, rates of ventilation and RER during the final 1000m indicate the intense levels of effort expended by subjects during both trials.

Figure 1 shows that there were no significant differences concerning the VO_2 values of the subjects determined at intermediate and final times during the 3000 m track running with and without drafting. These VO_2 values are expressed as percentages of VO_{2max} determined during the maximal graded test.

Discussion

The primary findings of the present study are that 3000mD performance was significantly faster in comparison with 3000mND despite the lack of differences in physiological parameters. To the best of our knowledge, this is the first study examining the effects of drafting on performance; physiological parameters and perceived exertion during simulated 3000m track running races using specific "in-race" measurements in highly trained subjects.

The only previous study of which we are aware studied the effects of drafting on the energy cost of running at constant but different speeds on a laboratory treadmill.[12] On the basis of the reduced energy cost of running produced by drafting, the authors concluded that running behind another runner virtually eliminated air resistance and reduced VO_2 by 6.5 % at middle distance speed.

Interesting, the measured physiological parameters (HR, VO_2, VE and RER) of these runners were not statistically different between trials (Table 5 and Figure 1). Thus surprisingly, the markedly superior performance in the 3000mD cannot be explained by an expected reduction in VO_2 as a result of drafting as seen in many other sports including middle distance running.[12] For example, Davies, [19] studied the aerobic energy cost (delta VO_2) of running at different speeds with and against a range of wind velocities in a wind tunnel on three healthy male subjects and observed that the energy cost of overcoming air resistance on a calm day outdoor was calculated to be 7.8% for sprinting (10 $m.s^{-1}$), 4% in middle-distance (6 $m.s^{-1}$), and 2% in marathon (5 $m.s^{-1}$) running. In our study, the velocity during the 3000mD was around 5.51 $m.s^{-1}$ and 5.41 $m.s^{-1}$ during the 3000mND, fats enough to expect a reduced VO_2 with drafting. However, a reduced energy cost of overcoming air resistance during these trials cannot explain the performance differences observed in the current study. Bilodeau et al.[9] reported a mean reduction of 9 $beats.min^{-1}$ (a significant reduction of 5.6%) when a cross-country skier drafted behind a leading skier as compared to leading the same skier. In that study, the estimated energy saving with drafting was 13% compared to the energy cost of the leader.[9] Differences in results can be explained, at least in part, by the experimental designs. For example, physiological parameters were measured during a simulated trial in our study. This is was not the case in the study of Bilodeau et al. [9]

Surprisingly despite a much greater speed in the final 1000m when subjects were paced for the first 2000m, they had lower post-run blood lactate concentrations and RPE values (Table 4). This is paradoxical. The lower blood lactate concentrations suggest a reduced contribution of oxygen-independent glycolysis to energy production, which should be reflected as a lower RER during exercise, but this was not found (Table 5). Similarly the much lower RPE values appear unrealistic for an all-out effort but suggest that subjects found the presence of pace makers beneficial in ways that cannot be explain on the basis of the physiological parameters that we measured (Figure 1). Another factor that must be taken into account in the current study is that during the 3000mD the pace was controlled externally (2 pacers) and not by the athlete himself so that the athlete did not have to think about controlling his pace. This "psychological" effect may, at least in part, explain the better performance observed during the 3000mD. However, even during the 3000mND, when the athlete ran alone, he received his running times each 100m. As shown in table 3 there were large and significant differences between times recorded each 500m. In fact, during the 3000m without pacers, runners began too fast the first 200m and then the first 500m (92s vs. 94s) but reduced their speed during the second (102s vs. 92s) and the third 500m (99s vs. 92s) before increasing the speed during the fourth 500m (90s vs. 93s) and so on. But during the 3000m with pacers the speeds were much more constant. Consequently, these large variations in velocity during the 3000m without pacers may explain, at least in part, the performance benefit we measured with drafting and pacing. In fact, it was demonstrated that a faster start produced the worst performances while even pacing produced the fastest times.[1]

This raises the strong possibility that pace makers act either as a "placebo" effect or as a distractor, the effect of which is to increase motivation[20] to run faster during the final 1000m. Clearly this is a possibility that requires serious consideration. However, in the current study not all possible physiological and psychological factors were measured, so that the results might be explained by other physiological or non-physiological that were not studied. In fact, other factors, namely biomechanics/aerodynamics may also explain, at least in part, our results. Hence some changes in power losses due to pacing and drafting that are also not visible in VO_2, may lead to a slower end time due to higher power losses. In addition, technique and efficiency might be different between the trials, which can also lead to a difference in final time, while VO_2 is equal. Consequently, other more complete investigations are needed to better explain performance differences during running with and without drafting. Interestingly the superior performance in the drafting trial was achieved with an increase (not significant) in VO_2 (Table 5) suggesting that motivation to perform better produced a real increase in the effort subjects were prepared to expend.

Our study confirms that drafting produced a significantly faster overall 3000m performance. Importantly, however, the trial design was such that in both trials, the running performance of the subjects was regulated for the first 2000m of the race so that completion times for the first 2000m were approximately identical (Table 3). However, performance over the last 1000m was faster by 8.5s (4.8%) in the 3000D.

Performance in both trials was however slower than the athletes' personal-best performances (90% for 3000mND and 93% for 3000mD). This can be explained by the fact that the experiments took place in the pre-competitive period, six to eight weeks before the selection competitions for the African Championships, when the athletes were not yet at the peak level of their fitness. Furthermore the trials were not national or international competitions so that there was little motivation to produce an absolutely maximal performance. However performance during both trials was at a high intensity (95-100% of their VO_{2max} determined during the maximal graded tests) (Figure 1).

These results are similar to many other sports events. For example, in cross-country skiing[9] and in roller skiing[17] in which skiing 2-3 m behind another competitor decreased drag by about 25%; in kayakers, too.[5] In triathlon, when drafting in the cycling leg improves performance in the running leg.[7,18] The same results are also observed in swimming[10,11] and in running.[12,14]

Practical Applications

Results from our study clearly demonstrate that drafting may result in a significant time benefit for athletes during middle-distance racing over 3000m. This has implications for the design of training programs and competitive strategies for runners. The psychological benefits of this practice need also to be considered.

Conclusion

In conclusion, the results of this study show that running performance in the final 1000m of a 3000m running race was significantly improved when runners were paced for the first 2000m. However this effect was not due a drafting-induced reduction in cardio-respiratory effort during the first 2000m of the races. Surprisingly pacing for the first 2000m significantly reduced end-effort RPE and post-race blood lactate concentrations despite a 4.6% increase in running speed over the final 1000m. None of these findings can be explained on a purely physiological basis; raising the possibility that drafting has unrecognized benefits in addition to the well-documented physiological advantages (e.g. psychological factors, biomechanics/aerodynamics factors…).

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Table 1: Morphological characteristics, best 3000m performance time and physiological parameters determined during the maximal graded exercise test of the subjects.

	Age (years)	Height (cm)	Body mass (kg)	Body fat (%)	VO_2 max (ml.min.kg^{-1})	Best Performance (s)	MAS (km.h^{-1})	HR_{peak} (bpm)	$[La]_{b\ End\ test}$ (mmol.L^{-1})
Mean	25.6	177.1	62.9	10.3	68	515.5	20.2	198	11.5
SD	± 3.1	± 7.1	± 7.1	± 2.5	± 6	± 21.7	± 0.4	± 12	± 3.9

MAS indicates maximal aerobic speed; HR, heart rate; $[La]_b$, blood lactate concentration

Table 2: Intermediate and final times (s) of the subjects during the 3000 m track races with and without drafting.

	500m	1000m	1500m	2000m	2600m	3000m
With Drafting	94.7±2.7	187.9±6.7	280.1±8.7	374.9±10.9	479.8±14.4	544.7±18.7
Without Drafting	92.2±3.8*	185.8±7.0	284.1±11.9	375.2±11.9	485.8±16.0	553.5±22.1*

Data are presented as means±SD,

*: Significantly different from with drafting values (p<0.05)

Table 3: 500m lap times (s) (0-2000m) and final 400m split times of the subjects during the 3000 m track races with and without drafting.

	0-500m	500-1000m	1000-1500m	1500-2000m	2000-2600m	2600-3000m
With Drafting	94.7±2.7	92.8±5.6	92.8±8.4	93.5±8.1	106.2±6.0	64.4±5.0
Without Drafting	92.2±3.8*	102.9±34.5*£	99.6±7.5*	90.3±8*	110.6±6.4	67.7±6.6*

Data are presented as means±SD,
*: Significantly different from with drafting values. *: $p<0.05$.

Table 4: Blood lactate concentration, heart rate and RPE of the subjects during the 3000 m track races with and without drafting.

	$[La]_{rest}$ (mmol.l^{-1})	**$[La]_{warm-up}$(mmol.l^{-1})**	**$[La]_{peak}$ (mmol.l^{-1})**	**HR_{peak} (beat.min^{-1})**	**RPE**
With drafting	3.4±1.1	3.9±1.9	13.2±5.6	203±14	13.1±1.3
Without drafting	3.7±1.0	3.5±1.6	16.4±2.3 *	198±7	16.1±0.8**

Data are presented as mean±SD, [La]=Blood Lactate; HR= Heart Rate; RPE = Rate of Perceived Exertion.

*: Significantly different from with drafting values *: $p<0.05$; **: $p<0.001$.

Table 5: Physiological parameters measured at intermediate points in subjects racing 3000 m with and without drafting.

		HR (beat.min^{-1})	VO_2 (ml.min^{-1})	VO_2 (ml.min^{-1}.kg^{-1})	VE (L. min^{-1})	RER
500m	With Drafting	182±15	3786.9±373.5	60.3±4.9	110.1±11.1	1.09±0.06
	Without Drafting	179±12	3706.4±614.9	58.8±7.8	108.4±22.8	1.07±0.12
1000m	With Drafting	186±12	4037.2±464.8	64.6±6.5	119.9±12.2	1.07±0.07
	Without Drafting	184±11	4016.2±568.4	63.9±7.4	121.1±16.5	1.07±0.07
1500m	With Drafting	189±9	4272.0±451.3	68.1±6.7	129.2±14.3	1.05±0.07
	Without Drafting	186±7	4130.0±546.1	65.6±6.5	128.1±16.8	1.05±0.053
2000m	With Drafting	191±7	4238.1±449.2	67.4±5.0	139.9±15.3	1.12±0.09
	Without Drafting	190±8	4158.0±589.3	66.1±7.5	136.4±15.9	1.08±0.06
2600m	With Drafting	194±8	4302.8±446.2	68.3±6.0	154.7±15.8	1.14±0.11
	Without Drafting	192±9	4161.6±632.6	66.3±7.7	143.1±21.1	1.09±0.07
3000m	With Drafting	198±10	4114.1±405.2	68.6±6.9	158.6±21.4	1.17±0.15
	Without Drafting	194±7	3885.5±427.9	64.9±8.3	139.9±17.7	1.07±0.08

Data are presented as mean±SD,

HR=Heart Rate, VO_2= Oxygen uptake; VE=Ventilation, RER=Respiratory Exchange Ratio.

Figure 1: Percentages of VO_{2max} of the subjects determined at intermediate and final times during the 3000 m track running with and without drafting.