Sports Training

Effects of a backward running training on backward peak velocity running, $\dot{V}O_{2max}$, $v\dot{V}O_{2max}$ and 3 km forward running performance in male adults: a pilot study

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Associate Editor: Dustin Oranchuk, Sports Performance Research Institute New Zealand, Auckland, New Zealand.

Abstract - Aims: The study aimed to evaluate the effects of a backward running (BR) training program prescribed by the peak backward running velocity (V_{peak_BR}) on physiological variables and a 3 km forward running (FR) performance. **Methods:** Eight untrained running male adults in running took place in the study. All the participants underwent five weeks of BR training prescribed based on V_{peak_BR}. They performed a maximal incremental test on the treadmill to determine the maximal oxygen uptake ($\dot{V}O_{2max}$) and the velocity associated with $\dot{V}O_{2max}$ ($v\dot{V}O_{2max}$). The participants were also tested on the track field to determine the V_{peak_BR} and undertook a 3 km FR performance. All initial assessments were also performed after the training period. **Results:** The results showed statistically significant improvements in 3 km FR performance (14.2 ± 1.2 min *vs*. 13.5 ± 1.0 min) and V_{peak_BR} (8.0 ± 0.8 km·h^{-1} *vs*. 8.5 ± 0.5 km·h^{-1}) after the training period. **Conclusion:** BR training effectively improved 3 km FR performance and V_{peak_BR}, demonstrating that V_{peak_BR} determined according to the protocol proposed in this study can be used for the prescription of BR training. Further, BR training represents an effective training method that can be inserted into an FR running training program.

Keywords: endurance running, exercise test, peak velocity.

Introduction

Backward running (BR) has been presented in the literature as a form of locomotion retrograde to forward running (FR), which presents a unique energetic, biomechanical profile and cardiopulmonary response[1,4]. It is characterized as a low-impact exercise that promotes improvements in neuromuscular performance, reducing the risk of joint damage[1,5]. In this context, BR has been used as a method of maintaining cardiovascular fitness as well as a means of rehabilitating athletes and physical exercise practitioners suffering from joint injuries[4,6,7].

Moreover, BR has been used in sports training programs to increase muscle pre-activation. It is also deployed as a method of promoting improvements in physiological and performance variables [*e.g.*, maximal oxygen uptake ($\dot{V}O_{2max}$), anaerobic power, lower limb strength parameters, and agility][1,2,7]. However, BR has not yet been investigated as a training method for improving FR performance.

Studies on BR training prescriptions have used intensities based on the ability of participants to perform sprints or have been based on self-selected intensities[1,2]. For example, Terblanche et al.[1] found a significant reduction in body fat percentage (2.4%) and demonstrated a decrease in the sum of skinfolds. The authors also found a considerable improvement in the predicted $\dot{V}O_{2max}$ values in the forward 20 m shuttle-run test (5.2%) performed after BR training. Similarly, a previous study reported significant improvement in the 10 and 20 m sprint performances [effect size (ES) = 20.47 and 20.26, respectively] and countermovement jump (CMJ) height (ES = 0.51) of the BR group compared to the FR group. The authors indicated that young male athletes could auto-regulate the BR and FR strategy to achieve desired running intensities 40 to 55% (slow), 60 to 75% (moderate), and > 90% (fast) of the maximal[2].

Despite these outcomes, the studies mentioned above-applied training protocols based on intensities that were self-selected by the runners. Such proposed intensities may be underestimated or overestimated and can cause inaccurate results of this intensity.

However, it is important to use variables that individualize the BR prescription, as the peak velocity (V_{peak}) that is considered a good predictor of endurance FR performance[8,11].

The outcomes of the current investigation can help improve our understanding of BR training and provide evidence that supports BR as a useful method to improve athlete performance.

Therefore, this study aimed to evaluate the effects of a BR training program prescribed by the peak backward running velocity (V_{peak_BR}) on physiological variables and a 3 km FR performance.

Materials and methods

Participants

Eight male adults participated in this study (24.2 ± 4.5 years, 69.3 ± 3.4 kg, 171.0 ± 0.02 cm, 13.1 ± 4.6 % fat). As an inclusion criterion, the participants did not have any cardiovascular or respiratory dysfunction, as well as they did not have muscle or joint injuries in the lower limbs. In addition, they could not be included in any running training program. The exclusion criteria were being injured during the study, not performing the pre- and or post-training tests, and not meeting 90% of the proposed training protocol. The participants in this study provided written informed consent. The procedures performed in this research followed the regulations required by the Declaration of Helsinki and was approved by the Human Research Ethics Committee (# 1.262.502/2015)

Procedures

Participants performed before and after 5-weeks of BR training a FR performance on a 400 m track field and two incremental tests: for V_{peak_BR} determination and other to obtain $\dot{V}O_{2max}$ and velocity associated with $\dot{V}O_{2max}$ ($v\dot{V}O_{2max}$). Evaluations were carried out with an interval of 48 h between them. In all tests heart rate (HR), lactate concentrations [Lac], and the rating of perceived exertion (RPE) were monitored. All tests were performed at the same time of the day (5:00-9:00 pm hours). During the period of the study, in the tests and training on the track, the ambient temperature was around 18-29 °C, and the relative humidity between 56%-72%, among the days. Under standard laboratory conditions, the temperature has been around 20-22 °C and relative humidity between 50-60%.

$\dot{V}O_{2max}$ and $v\dot{V}O_{2max}$ determination

The $\dot{V}O_{2max}$ and $v\dot{V}O_{2max}$ incremental exercise tests were performed on a motorized treadmill (Inbrasport Super ATL®, Porto Alegre, Brazil) with a gradient set at 1%[12]. After a warm-up that consisted of walking at 6 km·h^{-1} for 3 min, the protocol started with an initial speed of 8 km·h^{-1}, followed by an increase of 1 km·h^{-1} every 3 min between each successive stage until volitional exhaustion (*i.e.*, the participant was unable to continue running)[9]. Gas exchange was collected to determine the $\dot{V}O_{2max}$ using a portable gas analyzer K4b2 Cosmed®, Rome, Italy), and the $\dot{V}O_{2max}$ was considered as the maximal value obtained during the test, measured at an average of 15 s intervals. The $v\dot{V}O_{2max}$ was the minimum velocity at which the participants were running when $\dot{V}O_{2max}$ occurred[13].

V_{peak_BR} determination

The V_{peak_BR} test consisted of BR in a 20 m course at progressively increasing speeds controlled by audio. The protocol adapted from Machado et al.[9], consisted of 3 min warm-up backwards walking at 4 km/h, followed by BR at 5 km/h and an increase of 1 km/h every 3 min until volitional exhaustion or until the participant failed twice in a row to overtake with one foot in the cone line. The V_{peak_BR} was the maximal running speed reached during the incremental test and if the last stage was not completed the V_{peak_BR} was calculated from the equation proposed by Kuipers et al[14]:

$$V_{peak} = V_{complete} + \left(\frac{t}{T} \times \mathrm{Inc}\right)$$

where $V_{complete}$ is the running velocity of the last complete stage, Inc the speed increment (*i.e.*, 1 km/h), t the number of seconds sustained during the incomplete stage and T is the number of seconds required to complete a stage (*i.e.*, 180 s).

3 km FR performance

A track field test was performed to determine the time to complete the 3 km FR performance. The participants had a self-determined 10 min warm-up.

[Lac], HR, and RPE determination

During the tests, the peak blood lactate concentration ([Lac_{peak}]), maximal heart rate (HR_{max}), and maximal rating of perceived exertion (RPE_{max}), variables were monitored following the protocols below[8,10].

Earlobe capillary blood samples (25 µL) were collected into a capillary tube at the start and end of the tests (time zero of recovery) and at the third and fifth minutes of passive recovery, while participants were sitting in a comfortable chair. From these samples, [Lac] was subsequently determined by electroenzymatic methods using an automated analyzer (YSI 2300 STAT®, Yellow Springs, Ohio, USA). [Lac_{peak}] was defined for each participant as the highest post-exercise [Lac] value. HR was monitored during all tests, in the 3 km test the HR was monitored every 400 m, while in the $\dot{V}O_{2max}$ and V_{peak_BR} tests the

HR was monitored at the end of each stage (Polar® RS800sd; Kempele, Finland) and HR_{max} was defined as the highest HR value recorded during the test. RPE was also monitored during all tests by using a 6-20 Borg scale[15], and the highest RPE value was adopted as the RPE_{max}.

BR training program

The 5 weeks BR training program was performed twice a week with two types of BR sessions: continuous moderate-intensity and high-intensity interval training. All training sessions were held on a 400 m outdoor track field, between 5:00 and 9:00 pm, under the supervision and guidance of the researchers. Continuous BR training was performed out around the official track field and interval training for BR was performed in a straight line, with a distance of 50 m demarcated by two cones. The total duration of the training session and the intensities are described in Table 1. Sessions were preceded by 10 min free warm-up, and after the main part of the session, it was a free cool-down of self-selected low-intensity running and stretching. A stopwatch and track measurements were used to control the running velocity of each participant.

Statistical analyses

Data are presented as mean ± standard deviation (SD) and were analyzed using the Statistical Package for the Social Sciences Software (SPSS® version 22.0). The normality was verified using Shapiro-Wilk test and lead to parametric statistics. The student's t-test for dependent samples was used to compare variables between pre- and post-training. The association between 3 km FR performance and V_{peak_BR} was performed by Pearson correlation (r). Percentage changes and effect size (ES)[16] were calculated to assess the magnitude of changes between pre- and post-training. The ES were classified as: < 0.2 (trivial), 0.2-0.6 (small), 0.6-1.2 (moderate), ≥ 1.2 (large)[17]. A significance level of $P < 0.05$ was adopted.

Table 1 - Continuous and interval training of BR.

	Week 1 - Familiarization
Continuous training	15 ± 2.5 min at 80 ± 4% of V_{peak_BR}.
	Weeks 2, 3, 4 and 5 - Training Protocol
Continuous training	20 ± 2.5 min (5 min increase each week) at 80 ± 4% of V_{peak_BR}
Interval training	X[#] sprints 50 m at 165 ± 2% of V_{peak_BR} with effort ratio and break (1:1)

[#]The number of series performed by each participant was adjusted so that the total duration of interval training session corresponded to 15 ± 2.5 min.

Results

Table 2 demonstrated that there were significant differences between pre- and post-training for V_{peak_BR} and test duration (P = 0.001). The ES values were moderate, except for the HR_{max} that showed small ES.

Table 3 showed that there were no significant differences between pre- and post-training for all variables obtained during the $\dot{V}O_{2max}$ test. ES values were small and trivial for all the comparisons, except for the $[Lac_{peak}]$ that showed a moderate ES.

Figure 1 demonstrate that the time to complete the 3 km FR performance was significant different between pre- and post-training [14.2 ± 1.2 *vs.* 13.5 ± 1.0 min, respectively; P = 0.005; ES = −0.64 (moderate); %change = −4.6 ± 3.9]. Significant difference was also observed for the $[Lac_{peak}]$ between pre- and post-training (8.1 ± 1.8 *vs.* 11.3 ± 1.8 $mmol \cdot L^{-1}$, P = 0.046). HR_{max} and RPE_{max} were not different between moments (P = 0.38; P = 0.12, respectively).

The correlation between V_{peak_BR} and 3 km FR performance at post-training was high and negative (r = −0.77; P = 0.03).

Discussion

This study aimed to evaluate the effects of a BR training program prescribed by the V_{peak_BR} on physiological variables and a 3 km FR performance. The main findings were that there was a significant improvement in the V_{peak_BR} and the 3 km FR performance after the train-

Table 2 - Physiological and performance variables obtained during the incremental test for V_{peak_BR} determination at pre- and post-training (mean ± SD) (n = 8).

Variables	Pre-training	Post-training	% change	ES
V_{peak_BR} ($km \cdot h^{-1}$)	8.0 ± 0.8	8.5 ± 0.5*	7.4 ± 6.3%	0.75 (moderate)
Test duration (min)	15.0 ± 2.4	16.5 ± 1.5*	11.7 ± 11.5%	0.75 (moderate)
HR_{max} (bpm)	180 ± 11.0	183 ± 7.4	1.7 ± 7.3%	0.26 (small)
$[Lac_{peak}]$ ($mmol \cdot L^{-1}$)	8.9 ± 1.7	8.2 ± 1.4	−5.6 ± 17.7%	0.62 (moderate)
RPE_{max} (AU)	15.2 ± 3.6	18.0 ± 3.0	21.5 ± 22.7%	0.84 (moderate)

Note: V_{peak_BR}: backward peak velocity running; HR_{max}: maximal heart rate; $[Lac_{peak}]$: peak lactate blood concentrations; RPE_{max}: maximal rating of perceived exertion; AU: arbitrary unit; ES: effect size.
*$P < 0.05$ in relation to pre-training.

Table 3 - Physiological and performance variables obtained during the incremental test for $\dot{V}O_{2max}$ determination at pre- and post-training (mean ± SD) (n = 8).

Variables	Pre-training	Post-training	% change	ES
$\dot{V}O_{2max}$ (mL·kg^{-1}·min^{-1})	41.2 ± 2.3	42.7 ± 3.1	3.9 ± 10.4	0.56 (small)
v$\dot{V}O_{2max}$ (km·h^{-1})	12.8 ± 1.3	13.1 ± 1.1	2.6 ± 10.0	0.25 (small)
Duration (min)	22.4 ± 3.3	22.7 ± 3.5	1.5 ± 4.1	0.09 (trivial)
HR_{max} (bpm)	192 ± 9.7	190 ± 7.6	−0.6 ± 2.7	−0.16 (trivial)
[Lac_{peak}] (mmol·L^{-1})	8.1 ± 1.8	9.5 ± 1.6	24.9 ± 42.2	0.82 (moderate)
RPE_{max} (AU)	18.8 ± 2.4	19.3 ± 0.9	4.8 ± 20.1	−0.30 (small)

Note: $\dot{V}O_{2max}$: maximal oxygen uptake; v$\dot{V}O_{2max}$: speed associated with the occurrence of $\dot{V}O_{2max}$; HR_{max}: maximal heart rate; [Lac_{peak}]: peak lactate blood concentrations; RPE_{max}: maximal rating of perceived exertion; AU: arbitrary unit; ES: effect size.

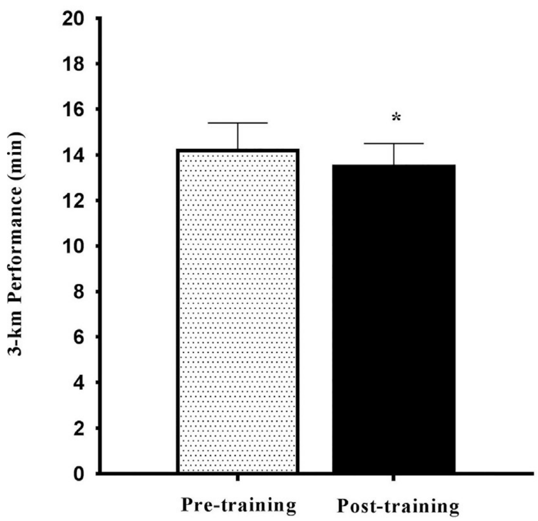

Figure 1 - Time to complete the 3 km FR performance (min) at pre-and post-training (mean ± SD). *$P < 0.05$ in relation to pre-training.

ing period. A high correlation was found between the V_{peak_BR} and the 3 km FR performance.

The significant improvement found in the V_{peak_BR} after 5 weeks of BR training is like other studies that used the V_{peak} for the prescription of FR[8,18]. It is important to mention that V_{peak} is a performance variable in FR and that it is sensitive to changes stemming from training; further, it may be used to evaluate, prescribe, and monitor the training of runners.

These results are important because an appropriate training prescription requires the use of variables that can control and monitor effort intensities and possible physiological adaptations resulting from the practice[8,9,11].

In contrast to the V_{peak_BR}, the pre-and post- training $\dot{V}O_{2max}$ was not significantly different. This outcome is also aligned with studies that observed the positive effects of FR endurance training on other physiological and performance variables, but not in the $\dot{V}O_{2max}$[8,18]. It is suggested that $\dot{V}O_{2max}$ is not a sensitive variable capable of detecting the effects of training; thus, the use of other variables such as V_{peak} may be necessary[18].

The improvement observed in the 3 km FR performance in the present study conformed to the reports of previous studies that verified the effects of FR training prescribed for endurance running performance according to the V_{peak}[8,18].

Finally, the significantly high and negative correlation between the V_{peak_BR} and the 3 km FR performance at the post-training testing resulted from the efficient application of the choice of the V_{peak_BR} for the prescription of BR training. This correlation is similar to the findings of studies that verified the correlation between the V_{peak} and the FR endurance performance at different distances[8,9].

Despite the important findings, this study must acknowledge certain limitations, such as the low number of participants and the absence of a control group comprising solely of FR training. It is suggested that future studies should investigate the insertion of BR based on the V_{peak_BR} into an FR training program to verify whether BR training can enhance FR performance.

Conclusions

The BR training program undertaken for this study effectively enhanced the V_{peak_BR} and 3 km FR performance of the participants. Therefore, coaches and runners aiming to optimize athletic performance should consider the following advantages of implementing BR training for FR athletes. First, BR training is recommended as an effective training method that could be included in FR training programs to improve the 3 km FR running performance of runners. Second, the V_{peak_BR} determined according to the 3 km protocol used in this study may effectively be used for the prescription of BR training. Finally, BR training can be implemented in the FR training program, to provide different stimuli to avoid training monotony and improve performance.

References

1. Terblanche E, Page C, Kroff J, Venter RE. The effect of backward locomotion training on the body composition and cardiorespiratory fitness of young women. Int J Sports Med. 2005; 26:214-9.

2. Uthoff A, Oliver J, Cronin J, Harrison C, Winwood P. Sprint-specific training in youth: backward running vs. forward running training on speed and power measures in adolescent male athletes. J Strength Cond Res. 2018;34 (4):1113-22.
3. Flynn TW, Soutas-Little RW. Mechanical power and muscle action during forward and backward running. J Orthop Sports Phys Ther. 1993;17(2):108-12.
4. Adesola AM, Azeez OM. Comparison of cardio-pulmonary responses to forward and backward walking and running. Afr J Biomed Res. 2009;12:95-100.
5. Roos PE, Barton N, Van Deursen RWM. Patellofemoral joint compression forces in backward and forward running. Journal of Biomechanics. 2012;45:1656-60.
6. Ordway JD, Laubach LL, Vanderburgh PM, Jackson KJ. The effects of backwards running training on forward running economy in trained males. J Strength Cond Res. 2017;30(3):763-7.
7. Flynn TW, Connery SM, Smutok MA, Zeballos RJ, Weisman IM. Comparison of cardiopulmonary responses to forward and backward walking and running. Med Sci Sports Exerc. 1994;26:89-94.
8. Da Silva DF, Simões HG, Machado FA. v$\dot{V}$O2max versus Vpeak, what is the best predictor of running performances in middle-aged recreationally-trained runners? Sci Sports. 2015;30(4):e85-e92.
9. Machado FA, Kravchychyn ACP, Peserico CS, Da Silva DF, Mezzaroba PV. Incremental test design, peak 'aerobic' running speed and endurance performance in runners. J Sci Med Sport. 2013;16(6):577-82.
10. Peserico CS, Zagatto AM, Machado FA. Evaluation of the Best-designed Graded Exercise Test to Assess Peak Treadmill Speed. Int J Sports Med. 2015;36(9):729-34.
11. Manoel FA, Da Silva DF, De Lima JRP, Machado FA. Peak velocity and its time limit are as good as the velocity associated with $\dot{V}$O2max for training prescription in runners. Sports Med Int Open. 2017;1(1):E8-E15.
12. Jones AM, Doust JH. A 1% treadmill grade most accurately reflects the energetic cost of outdoor running. J Sports Sci. 1996;14:321-7.
13. Billat V, Beillot J, Jan J, Rochcongar P, Carre F. Gender effect on the relationship of time limit at 100% VO2max with other bioenergetic characteristics. Med Sci Sports Exerc. 1996;28(8):1049-55.
14. Kuipers H, Rietjens G, Verstappen F. Effects of stage duration in incremental running tests on physiological variables. Int J Sports Med. 2003;24(07):486-91.
15. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982;14:377-81.
16. Cohen J. Statistical power analysis for the behavioral sciences. Hillsdale, NJ: Lawrence Erlbaum. 1988.
17. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc. 2009;41(1):3-12.
18. Da Silva DF, Ferraro ZM, Adamo KB, Machado FA. Endurance running training individually-guided by HRV in untrained women. J Strength Cond Res. 2019;33(3):736-46.

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Manuscript received on September 1, 2020
Manuscript accepted on May 12, 2021