Comparison between backward, forward, and combined running training on performance of recreationally active young men

Comparação entre treinamento de corrida para trás, para frente e combinada no desempenho de jovens recreativamente ativos

Comparación entre el entrenamiento de carrera hacia atrás, hacia adelante y combinado sobre el rendimiento de hombres jóvenes recreativamente activos

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ABSTRACT
The study verified the effects of backward running training (BRT), forward running training (FRT), and combined backward/forward running training (BFRT), prescribed by $V_{\text{peak}}$, on performance in 5-km running, countermovement jump,
20-m sprint, and the agility T-test, in thirty-three recreationally active young men. Thirty-three men (age 27.7 ± 4.8 years) were randomly assigned to one of three training groups (BRT; FRT; BFRT) and performed the following tests: 5-km running, vertical jump, 20-m sprint, agility performance, pre- and post-five weeks of running training. The normality of the data was verified by the Shapiro-Wilk test and the comparisons between groups and moments were performed by mixed ANOVA for repeated measures, followed by Bonferroni’s post hoc; the percentage of variation and the effect size (ES) were calculated. A significance level of $P < 0.05$ was adopted. All groups improved 5-km ($P = 0.01$) performance at post-training. The $V_{peak}$ ($P < 0.01$) and duration of the incremental test ($P < 0.01$) increased significantly in all groups after training. The $V_{peak, BR}$ increased significantly in the BRT and BFRT groups. CMJ jump height increased significantly for the FRT ($P < 0.01$) and BFRT ($P < 0.05$) groups. In the agility T-test there was a significant moment effect ($P < 0.01$) on the performance time. In conclusion, the inclusion of BRT sessions into FRT, prescribed based on $V_{peak, BR}$ and $V_{peak, FR}$, leads to improvements in 5-km endurance running performance in recreationally active young men. Thus, it is suggested that BRT prescribed by $V_{peak, BR}$ could be more widely incorporated into FRT as a training method to obtain the same results in endurance performance as FRT alone.

**Keywords:** athletic performance, endurance training, physical activity.

**RESUMO**

O estudo verificou os efeitos do treinamento de corrida para trás (BRT), treinamento de corrida para frente (FRT) e treinamento combinado de corrida para frente e para trás (BFRT), prescritos pelo $V_{peak}$, no desempenho em corrida de 5 km, salto com contramovimento, sprint de 20 m e o teste T de agilidade, em trinta e três jovens recreativamente ativos. Trinta e três homens (idade 27,7 ± 4,8 anos) foram distribuídos aleatoriamente em um dos três grupos de treinamento (BRT; FRT; BFRT) e realizaram os seguintes testes: corrida de 5 km, salto vertical, sprint de 20 m, desempenho de agilidade, pré-treinamento. e após cinco semanas de treinamento de corrida. A normalidade dos dados foi verificada pelo teste de Shapiro-Wilk e as comparações entre grupos e momentos foram realizadas por ANOVA mista para medidas repetidas, seguida de post hoc de Bonferroni; foram calculados o percentual de variação e o tamanho do efeito (TE). Foi adotado nível de significância de $P < 0.05$. Todos os grupos melhoraram o desempenho nos 5 km ($P = 0.01$) no pós-treinamento. A $V_{pico}$ ($P < 0.01$) e a duração do teste incremental ($P < 0.01$) aumentaram significativamente em todos os grupos após o treinamento. O $V_{peak, BR}$ aumentou significativamente nos grupos BRT e BFRT. A altura do salto no CMJ aumentou significativamente para os grupos FRT ($P < 0.01$) e BFRT ($P < 0.05$). No teste T de agilidade houve efeito significativo do momento ($P < 0.01$) no tempo de execução. Concluindo, a inclusão de sessões de BRT no FRT, prescritas com base em $V_{peak, BR}$ e $V_{peak, FR}$, leva a melhorias no desempenho da corrida de resistência de 5 km em jovens recreativamente ativos. Assim, sugere-se que o BRT prescrito pelo $V_{peak, BR}$ poderia ser mais
amplamente incorporado ao FRT como método de treinamento para obter os mesmos resultados no desempenho de resistência que o FRT sozinho.

**Palavras-chave:** desempenho atlético, treinamento de resistência, atividade física.

**RESUMEN**

El estudio verificó los efectos del entrenamiento de carrera hacia atrás (BRT), el entrenamiento de carrera hacia adelante (FRT) y el entrenamiento combinado de carrera hacia atrás/adelante (BFRT), prescritos por Vpeak, sobre el rendimiento en carrera de 5 km, salto con contramovimiento y sprint de 20 m. y la prueba T de agilidad, en treinta y tres hombres jóvenes recreativamente activos. Treinta y tres hombres (edad 27,7 ± 4,8 años) fueron asignados aleatoriamente a uno de tres grupos de entrenamiento (BRT; FRT; BFRT) y realizaron las siguientes pruebas: carrera de 5 km, salto vertical, sprint de 20 m, rendimiento de agilidad, pre - y después de cinco semanas de entrenamiento de carrera. La normalidad de los datos se verificó mediante la prueba de Shapiro-Wilk y las comparaciones entre grupos y momentos se realizaron mediante ANOVA mixto para medidas repetidas, seguido del post hoc de Bonferroni; Se calculó el porcentaje de variación y el tamaño del efecto (TE). Se adoptó un nivel de significancia de P <0,05. Todos los grupos mejoraron el rendimiento de 5 km (P = 0,01) después del entrenamiento. La Vpico (P < 0,01) y la duración de la prueba incremental (P < 0,01) aumentaron significativamente en todos los grupos después del entrenamiento. El Vpeak_BR aumentó significativamente en los grupos BRT y BFRT. La altura del salto CMJ aumentó significativamente para los grupos FRT (P <0,01) y BFRT (P <0,05). En la prueba T de agilidad hubo un efecto de momento significativo (P <0,01) en el tiempo de ejecución. En conclusión, la inclusión de sesiones de BRT en FRT, prescritas en función de Vpeak_BR y Vpeak_FR, conduce a mejoras en el rendimiento de carrera de resistencia de 5 km en hombres jóvenes recreativamente activos. Por lo tanto, se sugiere que el BRT prescrito por Vpeak_BR podría incorporarse más ampliamente al FRT como método de entrenamiento para obtener los mismos resultados en el rendimiento de resistencia que el FRT solo.

**Palabras clave:** rendimiento deportivo, entrenamiento de resistencia, actividad física.

**1 INTRODUCTION**

Different training strategies and prescription methods have been investigated with the aim of optimizing performance of runners (UTHOFF et al., 2018a; MACHADO et al., 2013). Recently, backward running (BR) has been used as a strategy to reduce the risk of injuries and improve forward running (FR)
performance (UTHOFF et al., 2018a; CAVAGNA et al., 2012). For instance, due to its biomechanical characteristics, compressive forces on the patellofemoral joint in BR is lower compared to FR (FLYNN, SOUTAS-LITTLE, 1995), causing less joint impact at the same running velocities (UTHOFF et al., 2018b; MEHDIZADEH et al., 2015). For this reason, BR is used as part of rehabilitation process of recently knee injured athletes as a way to maintain cardiovascular fitness (UTHOFF et al., 2018b; FLYNN, SOUTAS-LITTLE, 1995).

Adesola and Azeez (2009) reported higher metabolic cost and cardiopulmonary responses during BR at the same intensity and duration when compared to FR. In addition, although VO_{2max} values were similar for the two running modes, the peak minute ventilation and respiratory exchange ratio were higher in BR, and such results may at least partly explain associated running performance improvements.

Of note, BR training has also shown positive results on lower limb muscle strength and power (UTHOFF et al., 2019; UTHOFF et al., 2018b; SWATI et al., 2012), sprint performance (UTHOFF et al., 2018a), and agility (UTHOFF et al., 2018b; SWATI et al., 2012; TERBLANCHE; VENTER, 2009) in trained individuals. These neuromuscular effects are probably regarded to higher forces produced in isometric and concentric actions (FLYNN, SOUTAS-LITTLE, 1995) during BR, leading to muscle action-specific strength improvements that might positively affect athletic movements that rely primarily on concentric movements (NEGRA et al., 2022).

Training prescription and monitoring using physiological and performance milestones are already well established in FR programs (NUUTTLA et al., 2022; MANOEL et al., 2017). For example, the use of ventilatory and lactate thresholds as physiological markers for the prescription of endurance training leads to improvement in the lactate threshold and the VO_{2max} after a few weeks of training (GAESSER; POOLE, 1986). Concerning BR prescription, most studies relied on short-duration sprints, with the speed being self-selected by participants (UTHOFF et al., 2019; UTHOFF et al., 2018b), without training intensity individualization. This means that no meticulous control of the training intensities
was adopted (UTHOFF et al., 2018b; ORDWAY et al., 2016; TERBLANCHE et al., 2005), which can lead to under or overestimation of the adequate intensities.

In this sense, a recent pilot study by Kauffman et al. (2021) proposed a field shuttle protocol for determining peak velocity in BR ($V_{\text{peak_BR}}$). Briefly, the protocol consists of an incremental BR test, starting with a warm-up at 4 km·h$^{-1}$ for three minutes. The first stage is set at 5 km·h$^{-1}$, with successive increments of 1 km·h$^{-1}$ every three minutes until participants reach exhaustion. The test is performed at a distance of 20-m in which the individual perform shuttle runs according to the intensity determined by sound beeps (adapted from LEGER and LAMBERT, 1982). Such short distance and low initial velocity help participants to keep the required pace under limited visual field (HOOGKAMER et al., 2014). The $V_{\text{peak_BR}}$ was subsequently used to prescribe the BR training and individualize training intensities. It was found that five weeks of training with two weekly sessions of BR training improved 3-km FR and $V_{\text{peak_BR}}$, suggesting that the $V_{\text{peak_BR}}$ determined according to the proposed protocol and at the intensities used by the pilot study can be adopted to prescribe BR training. However, since the referred study did not compare BR with other training strategies, further investigations are necessary to determine whether BR in isolation or in combination with FR will induce optimal performance adaptation.

Thus, the aim of this study was to compare the effects of backward running training (BRT), forward running training (FRT), and combined backward/forward training (BFRT) prescribed by the respective $V_{\text{peak}}$ on performance in 5-km FR running, countermovement jump (CMJ), 20-m sprint, and agility T-test. The hypothesis was that a combined BFRT would promote greater changes in performance during a 5-km time-trial, in CMJ, 20-m sprint, and agility T-test, compared to BRT and FRT alone.

2 MATERIALS AND METHODS

2.1 PARTICIPANTS

Thirty-three recreationally active young men participated in the study (age 27.7 ± 4.8 years; body mass 78.7 ± 7.6 kg; height 175 ± 0.1 cm; body mass index
25.5 ± 2.4 kg·m⁻²; body fat percentage 18.7 ± 5.5%). Before participating, the participants underwent previous clinical examinations with a cardiologist to verify their cardiological condition, in addition to aptitude assessment and receiving authorization to carry out the evaluations relevant to the study. The participants provided written informed consent and the procedures performed in this study followed the regulations required by the Declaration of Helsinki and were approved by the local Ethics Committee.

2.2 EXPERIMENTAL DESIGN

The experimental training protocol had a total duration of eight weeks. Participants were randomized into three experimental groups: a group that performed the BRT, a group that performed the FRT, and a group that performed BFRT.

After familiarization with the testing procedures, each subject underwent five visits to the outdoor track (400 m) to perform the following tests: 1st visit: 5-km FR performance, 2nd visit: FR peak velocity (\(V_{\text{peak.FR}}\)), 3rd visit: \(V_{\text{peak.BR}}\), 4th visit: time limit (\(t_{\text{lim}}\)) at \(V_{\text{peak.FR}}\), 5th visit: 20-m sprint FR and agility T-test. The 6th visit took place at the laboratory, where participants performed the CMJ test. The tests were performed at the same time of the day under similar weather conditions (temperature = 18–29°C and relative humidity = 56–72%), with an interval of at least 48h between visits. For all tests, the participants were instructed to avoid eating for 2h before the maximal exercise tests, to abstain from caffeine and alcohol and refrain from strenuous exercise for 24h before testing (MACHADO et al., 2013).

2.3 5-KM RUNNING PERFORMANCE TEST

The 5-km running performance test was preceded by a self-selected moderate-intensity run warm-up of 10-min. The 5-km running performance time was recorded using a stopwatch to determine the test duration, allowing the calculation of mean velocity. No information on the elapsed time was provided for
the participants and they were instructed and encouraged to attain their best time in the time-trial, being able to freely choose their pacing strategy during the test.

2.4 DETERMINATION OF $V_{\text{peak FR}}$

After a 3-min warm-up walking at 6 km·h$^{-1}$, the protocol started with an initial velocity of 8 km·h$^{-1}$, followed by an increase of 1 km·h$^{-1}$ every 3-min until volitional exhaustion (i.e., when participants were unable to continue running) (MANOEL et al., 2017; MACHADO et al., 2013). The velocity during the test was controlled by sound signals and by cones distributed every 25-m on the outdoor track. Participants were instructed to cross the line of cones with at least one foot simultaneously with the beep (LÉGER; BOUCHER et al., 1982).

The interval between the beeps at each stage decreased every 3-min, and the higher beep tone indicated that a new stage was starting, so the participant could increase their running velocity. $V_{\text{peak}}$ was considered the maximum velocity reached by the subject during the test. If the final stage was not completed, the $V_{\text{peak}}$ was calculated from its partial duration, following the equation proposed by Kuipers et al. (2003): $V_{\text{peak}} = V_{\text{complete}} + (t/ T \times \text{Inc})$; where $V_{\text{complete}}$ is the running velocity of the final completed stage, Inc the speed increment (i.e., 1 km·h$^{-1}$), t the number of seconds sustained during the incomplete stage, and T is the duration of a complete stage (i.e., 180s). The test was ended due to exhaustion or when the assessor identified that the runner failed to cross the cone line with at least one foot twice in a row (LÉGER; BOUCHER, et al., 1982). In addition to the participants having to perform the test until voluntary exhaustion (i.e., the participant was unable to continue running), they should have met at least two of the following criteria to have been considered a successful test: [1] peak blood lactate concentration ([LA$_{\text{peak}}$]) ≥ 8 mmol·L$^{-1}$ (MACHADO et al., 2013), [2] maximum heart rate (HR$_{\text{max}}$) ≥ 95% of HR predicted by age using the equation by Tanaka et al. (2001) (207 [-0.7 × age]); and [3] maximal rating of perceived exertion (RPE$_{\text{max}}$) ≥ 18 in the 6–20 Borg scale (HOWLEY et al., 1995; BORG, 1982).
2.5 DETERMINATION OF $V_{\text{peak_BR}}$

The $V_{\text{peak_BR}}$ test consisted of BR on a 20-m course, demarcated by two cones, at progressively increasing velocities, controlled by sound signals. The protocol consisted of 3-min warm-up backward walking at 4 km·h$^{-1}$, followed by BR at 5 km·h$^{-1}$ and an increase of 1 km·h$^{-1}$ every 3-min until volitional exhaustion or until the subject failed to place at least one foot over the cone line twice in a row (KAUFFMAN et al., 2021). The $V_{\text{peak_BR}}$ was the maximal running velocity reached during the incremental test and, if the final stage was not completed, the $V_{\text{peak_BR}}$ was calculated using the equation proposed by Kuipers et al. (2003). The HR$_{\text{max}}$ and RPE$_{\text{max}}$ were recorded. [La] was determined following the aforementioned procedures (i.e., Determination of $V_{\text{peak_FR}}$).

2.6 COUNTERMOVEMENT JUMP (CMJ)

The vertical height of the CMJ was used to assess lower limb muscle power. The Jump System Pro (Cefise®, Nova Odessa–SP, Brazil) jumping mat was used to quantify jump height. The test was performed three times, with a 10-s recovery interval between trials. The best performance for the jump height parameter was retained for analyses (MARKOVIC et al., 2004).

2.7 20-M Sprint Test

To determine repeated sprint performance, a 20-m sprint FR test was performed, during which the subject covered the distance in the shortest time possible. Five attempts were given to the participants and the shortest time across attempts was considered (UTHOFF et al., 2018b). From a static standing start, the participants sprinted all-out, a distance of 20-m, five times. The recovery duration between subsequent sprints was 30-s. The best sprint time was retained for analysis.

2.8 AGILITY T-TEST

The agility T-test was used to determine the velocity of directional changes, such as FR, sideway running, and BR. Three cones were separated by
4.57 meters in a straight line. A fourth cone was placed 9.14 meters of the middle cone so that the cones form a T. Three cones were placed in a straight line 4.57 meters apart; a fourth cone was positioned 9.14 meters towards the middle cone, forming the letter T. The test followed the protocol previously used (SWATI, et al., 2012). The time of the test was recorded, considering the shortest time of three attempts.

2.9 BR AND FR TRAINING PROGRAMS

All training sessions were carried out on a 400-m outdoor track field. The sessions were monitored using the session RPE through the CR-10 scale (FOSTER et al., 2001) applied 30 minutes after the end of the session. The three groups performed two types of training, continuous and interval, with intensities and durations that are shown in Table 1.

Table 1. Continuous and interval training sessions prescribed for FRT, BRT, and BFRT groups.

<table>
<thead>
<tr>
<th>Week 1</th>
<th>FRT</th>
<th>BRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Training</td>
<td>30 ± 2.5 min at 75 ± 4% of $V_{peak}$</td>
<td>15 ± 2.5 min at 80 ± 4% of $V_{peak, BR}^a$</td>
</tr>
<tr>
<td>Interval Training</td>
<td>X$^n$ series at 100 ± 2% of $V_{peak}$ with duration 60% their respective $t_{lim}$ and intervals (passive) with duration 60% of $t_{lim}$.</td>
<td>15 ± 2.5 min of X$^*$ series of 50 meters at 165 ± 2% of $V_{peak, BR}$ with effort ratio and break (1:1).</td>
</tr>
<tr>
<td>Week 2, 3, 4 and 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous Training</td>
<td>FRT</td>
<td>BRT</td>
</tr>
<tr>
<td></td>
<td>40 ± 2.5 min at 75 ± 4% of $V_{peak}$</td>
<td>20 ± 2.5 min at 80 ± 4% of $V_{peak, BR}$ (5-min increase each week).</td>
</tr>
<tr>
<td>Interval Training</td>
<td>X$^n$ series at 100 ± 2% of $V_{peak}$ with duration 60% their respective $t_{lim}$ and intervals (passive) with duration 60% of $t_{lim}$.</td>
<td>20 ± 2.5 of X$^*$ series of 50 meters at 165 ± 2% of $V_{peak, BR}$ with effort ratio and break (1:1).</td>
</tr>
</tbody>
</table>

$^a$The number of sets performed by each participant was adjusted so that the total duration of the interval training session was 30 ± 2.5 minutes.

$^*$The number of sets performed by each participant was adjusted so that the total duration of the interval training session was 15 or 20 ± 2.5 minutes.

$^a$Based on current evidence and from both BR, as intensidades e duração das sessões de BR são diferentes das estabelecidas em programas de FR. These programming guidelines have also been found to lead to positive adaptations after BR (Uthoff et al., 2019; Uthoff et al., 2018b).

Training was based on studies Manoel et al., (2017); Machado et al., (2013); Kauffman et al., (2021); Uthoff et al., (2018b).

Source: Prepared by the author, 2024.
2.10 STATISTICAL ANALYSES

All statistical analyses were performed using the software Statistical Package for the Social Sciences (SPSS® v.20, Inc., Chicago, IL, USA). Data normality was verified by the Shapiro-Wilk test. The variables are presented as mean ± standard deviation (SD). Comparisons between the three experimental groups and between the pre- and post-training moments were performed by the mixed analysis of variance (ANOVA) for repeated measures, followed by the Bonferroni post hoc for multiple comparisons. The sphericity was verified by the Mauchly test and, when violated, the Greenhouse–Geisser correction was used. The percentage value (%) of variation ([post-moment value - pre-moment value] ÷ pre-moment value * 100) was also calculated for each variable. The effect sizes (ES) were determined as follows: (M1–M2)/(SD1+DP2/2), where M1 and M2 are the means of the conditions, and DP1 and DP2 are the standard deviations of the respective means (COHEN, 1988). The ES was classified as: ≤ 0.20 (trivial), 0.21–0.50 (small), 0.51–0.80 (moderate), and > 0.80 (large) (HOPKINS et al., 2009). The significance level adopted for all analyses was $P < 0.05$.

3 RESULTS

Concerning the intensities of the training programs evaluated by the RPE, there were no significant intergroup differences in mean weekly RPE: BRT group ($1^{st}$ week = 7.3 ± 1.5 AU; $2^{nd}$ week = 7.1 ± 1.6 AU; $3^{rd}$ week = 6.7 ± 2.0 AU; $4^{th}$ week = 6.5 ± 2.1 AU; $5^{th}$ week = 6.4 ± 1.8 AU), FRT group ($1^{st}$ week = 6.8 ± 2.2 AU; $2^{nd}$ week = 7.0 ± 2.3 AU; $3^{rd}$ week = 6.6 ± 2.2 AU; $4^{th}$ week = 6.8 ± 2.2 AU; $5^{th}$ week = 6.8 ± 2.4 AU), and BFRT group ($1^{st}$ week = 6.7 ± 1.7 AU; $2^{nd}$ week = 7.2 ± 2.2 AU; $3^{rd}$ week = 7.8 ± 2.0 AU; $4^{th}$ week = 7.0 ± 2.3 AU; $5^{th}$ week = 6.8 ± 2.8 AU).

Performances in the 5-km FR (T5km) at pre- and post-training for the three groups are presented in figure 1. There was a significant moment effect on the T5km ($P = 0.01$), in which all groups improved performance post-training (BRT = 26.7 ± 3.4 vs. 25.6 ± 2.7 min; FRT = 27.3 ± 2.3 vs. 25.5 ± 3.1 min; BFRT = 27.6 ± 2.6 vs. 26.0 ± 2.7 min). No significant group effect ($P = 0.883$) or group ×
moment interaction was observed ($P = 0.325$). In addition, reductions of -3.9%, -6.8%, and -5.6% were found in the T5km for BRT, FRT, and BFRT groups, respectively.

Figure 1. Time to complete the 5-km FR performance at pre- and post-training (mean ± SD) for FRT, BRT, and BFRT groups.

* $P < 0.05$ in relation to pre-training.

5-km Performance

Source: Prepared by the author, 2024.

The results obtained during the tests to determine the $V_{\text{peak, FR}}$ and $V_{\text{peak, BR}}$, as well as the analysis of the magnitude of changes (i.e., ES and Diff.%) pre- and post- the 5-week training protocol are shown in table 2. A significant moment effect was found for $V_{\text{peak}}$ ($P < 0.01$) and duration of the incremental test ($P < 0.01$), in which both variables increased significantly in all groups in response to training. There was no significant group effect ($P = 0.942$; $P = 0.940$) or group × time interaction ($P = 0.289$; $P = 0.231$) for the same variables. Concerning peak values of BR test, a significant moment effect ($P < 0.01$) and a significant group × moment interaction were observed for the variables $V_{\text{peak, BR}}$ and duration of $V_{\text{peak, BR}}$ ($P = 0.027$; $P = 0.035$, respectively). The $V_{\text{peak, BR}}$ increased significantly in the BRT and BFRT groups, presenting a moderate ES between pre- and post-
training. There was no significant group effect for the same variables ($P = 0.511$; $P = 0.619$, respectively). For the other variables ($\text{HR}_{\text{max}}$, $\text{RPE}_{\text{max}}$, $[\text{La}_{\text{peak}}]$), there were no statistical differences between the pre- and post-training moments, intra and intergroup, and the ES values ranged between trivial and small.
Table 2. Variables obtained from the incremental protocols to determine the $V_{\text{peak}}$ forward running (FR) and backward running (BR) for the training groups BRT, FRT, and BFRT.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Test</th>
<th>BRT (n = 10)</th>
<th>FRT (n = 13)</th>
<th>BFRT (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Diff.%</td>
</tr>
<tr>
<td>$V_{\text{peak}}$ (km·h$^{-1}$)</td>
<td>FR</td>
<td>13.0 ± 1.2</td>
<td>13.3 ± 1.2*</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>BR</td>
<td>7.8 ± 0.7</td>
<td>8.4 ± 0.8*</td>
<td>7.5</td>
</tr>
<tr>
<td>Duration (min)</td>
<td>FR</td>
<td>21.1 ± 3.6</td>
<td>22.0 ± 3.6*</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td>BR</td>
<td>14.4 ± 2.5</td>
<td>16.1 ± 2.5*</td>
<td>11.8</td>
</tr>
<tr>
<td>$HR_{\text{max}}$ (bpm)</td>
<td>FR</td>
<td>184 ± 8.5</td>
<td>187 ± 9.8</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>BR</td>
<td>179 ± 9.5</td>
<td>186 ± 11.9</td>
<td>3.8</td>
</tr>
<tr>
<td>$RPE_{\text{max}}$ (UA)</td>
<td>FR</td>
<td>19.1 ± 1.6</td>
<td>19.3 ± 1.6</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>BR</td>
<td>15.7 ± 3.4</td>
<td>17.3 ± 3.7</td>
<td>10.2</td>
</tr>
<tr>
<td>$[La_{\text{peak}}]$ (mmol·L$^{-1}$)</td>
<td>FR</td>
<td>12.2 ± 3.8</td>
<td>11.6 ± 3.3</td>
<td>-4.1</td>
</tr>
<tr>
<td></td>
<td>BR</td>
<td>10.4 ± 3.4</td>
<td>11.3 ± 2.7</td>
<td>8.5</td>
</tr>
</tbody>
</table>

Note: BR, backward running training group; FR, forward running training group; BFR, backward + forward combined running training group; $V_{\text{peak}}$, peak run speed; FR, forward running; BR, backward running; $HR_{\text{max}}$, maximum heart rate; bpm, beats per minute; $RPE_{\text{max}}$, maximum perceived exertion; $[La_{\text{peak}}]$, peak lactate concentration. *$P < 0.05$ in relation to pre-training moment intragroup. Source: Prepared by the author, 2024.
Table 3 presents the results for the CMJ, 20-m sprint, and agility T-test pre- and post-training, as well as the analysis of the magnitude of change (i.e., ES and Diff.%). Concerning the CMJ, a significant moment effect was observed, but there was no significant group effect ($P = 0.350$) or group × moment interaction ($P = 0.440; P = 0.368; P = 0.224$, respectively). The CMJ jump height increased significantly in the FRT ($P < 0.01$) and BFRT ($P < 0.05$) groups.

In the 20-meter sprint test, no significant differences were observed between groups and between pre- and post-training moments. In the agility T-test, there was a significant moment effect ($P < 0.01$) on the performance time, but no significant group effect ($P = 0.843$), or group × moment interaction ($P = 0.309$). Only the BRT group showed a significant improvement in performance of the agility T-test ($P = 0.004$), with a reduction of -7.2% and a small ES (0.4).
Table 3. CMJ, 20-m sprint, and agility T-test pre- and post-training for the BRT, FRT, and BFRT training groups.

<table>
<thead>
<tr>
<th>Variables</th>
<th>BRT (n = 10)</th>
<th>FRT (n = 13)</th>
<th>BFRT (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Diff.%</td>
</tr>
<tr>
<td>CMJ (cm)</td>
<td>34.7 ± 7.9</td>
<td>35.7 ± 8.1</td>
<td>2.9</td>
</tr>
<tr>
<td>20-m sprint (s)</td>
<td>3.0 ± 3.0</td>
<td>3.0 ± 3.0</td>
<td>-0.7</td>
</tr>
<tr>
<td>T-test (s)</td>
<td>11.7 ± 2.0</td>
<td>10.9 ± 1.6*</td>
<td>-7.2</td>
</tr>
</tbody>
</table>

Note: BR, backward running training group; FR, forward running training group; BFR, backward + forward combined running training group; CMJ, Countermovement jump; cm, centimeter; s, seconds; Diff.%, percentage difference; ES, effect size.

*P < 0.05 in relation to pre-training moment intragroup.

Source: Prepared by the author, 2024.
4 DISCUSSION

The aim of this study was to compare the effects of BRT, FRT, and BFRT prescribed by $V_{\text{peak}}$ on 5-km running performance, CMJ, 20-m sprint, and the agility T-test. The main finding was that 5-km performance improved in all groups after the 5-week training period. Although there was not interaction effect, greater improvements were displayed by the FRT and BFRT groups (moderate ES) compared to the BRT group (small ES). Furthermore, a significant increase in the CMJ was found for the FRT and BFRT groups after the training program and the agility T-test significantly improved in the BRT group. These findings only partially confirm the previously formulated hypothesis.

Concerning the 5-km running performance, improvements were observed for the three experimental groups with a decrease in $T_{5\text{km}}$ (BRT: -3.9%; FRT: -6.8%; BFRT: -5.6%); however, greater magnitudes of changes were demonstrated for the FRT and BFRT groups compared to the BRT group. These results can be explained by the fact that the proposed FRT has been shown to be positive in promoting adaptations in aerobic parameters (MANOEL et al., 2017; MACHADO et al., 2013), while studies with BRT predominantly demonstrate improvement in other physical parameters, such as lower limb strength and agility (UTHOFF et al., 2019; UTHOFF et al., 2018b; SWATI et al., 2012).

Although the BRT group showed a lower percentage of improvement in $T_{5\text{km}}$ when compared to the other groups, the $T_{5\text{km}}$ improved significantly. Our findings were similar to those found by Kauffman et al. (2021) with eight young men who performed five weeks of BRT prescribed by $V_{\text{peak, BR}}$. In that study the participants improved their 3-km performance by 5.0%. This improvement may be associated with the increase in cardiorespiratory fitness after the BRT program, as shown by other studies which found that aerobic fitness can be improved with BRT as the cardiopulmonary demands are relatively higher than during FR (UTHOFF et al., 2018a; ORDWAY et al., 2016; TERBLANCHE et al., 2005). It is likely that the lower increase in $T_{5\text{km}}$ can be explained by the lower
Specificity of BR in terms of muscle recruitment patterns and coordination (UTHOFF et al., 2018a; FLYNN, SOUTAS-LITTLE, 1995).

Specifically, for the group that performed only FRT sessions, our findings are similar to previous studies (MANOEL et al., 2022; PESERICO et al., 2019) which confirmed that training intensities prescribed by $V_{\text{peak}_{\text{FR}}}$ and its respective $t_{\text{lim}}$ lead to positive improvements in performance in medium and long-distance races. For example, Manoel et al. (2022) found a significant reduction in the time to perform the 10-km (pre: $41.3 \pm 2.4$ vs. post: $39.9 \pm 2.7$ min) after four weeks with 20 training sessions prescribed by $V_{\text{peak}_{\text{FR}}}$, in moderately trained men.

Regarding the $V_{\text{peak}_{\text{BR}}}$, only the groups with BR in their training (i.e., BRT and BFRT) showed significant improvements in this variable after five weeks of training. This result was already expected, as the BRT and BFRT groups required specific sensorial and coordination adaptations for BR (MEHDIZADEH et al., 2015; HOOGKAMER et al., 2014). It is important to emphasize that the results of the present study confirm again the importance of the training specificity, in which the groups with BRT included in their routines showed changes in the BR incremental test, unlike the FRT group (TUBINO; MOREIRA, 2003).

Based on the aforementioned studies and ours, the $V_{\text{peak}_{\text{FR}}}$ (PESERICO et al., 2019; MANOEL et al., 2017), as well as the $V_{\text{peak}_{\text{BR}}}$ (KAUFFMAN et al., 2021), can be used for the prescription of running training, to control the intensity of moderate to high-intensity exercises, regardless of the individual’s sex or training level (MANOEL et al., 2022; KAUFFMAN et al., 2021;). In addition, $V_{\text{peak}}$ is sensitive enough to gauge the changes generated throughout a training program, showing a high correlation with endurance running performance (MANOEL et al., 2022; PESERICO et al., 2019).

Other important findings reported in our study were related to performances in the CMJ, 20-m sprint, and T-test agility. The muscle power of the lower limbs, evaluated by the CMJ test, was significantly increased after the training period in the FRT and BFRT groups, but no significant improvement was detected in the BRT group. This finding was different from the study by Uthoff et al. (2018b), in which the authors found a greater change in CMJ height for the
athletic group that trained BR sprints (pre: 53.2 ± 8.2 cm vs. post: 58.5 ± 8.4 cm; Δ%: 9.8%) compared to the group that trained FR (pre: 54.1 ± 5.8 cm vs. post: 55.5 ± 5.5 cm; Δ%: 2.8%). These differences can be explained by the fact that the training proposed by Uthoff et al. (2018b) is sprint-based, which leads to improvement in stretch-shortening cycle function as well as muscle power. This means that not only the type of locomotion drives adaptations to training, but intensity also matters.

On the other hand, the present study corroborates the results of Terblanche and Venter (2009), who found a higher performance in the CMJ test for the FRT group (moderate effect) compared to the BRT group (trivial effect) in young female netball athletes. However, it is important to mention that most previous studies (UTHOFF et al., 2018b; SWATI et al., 2012; TERBLANCHE et al., 2005) disagree with our findings, as improvements were reported in vertical jump height in BRT groups.

The responses related to the 20-m sprint test did not reveal pre- and post-training changes in any of the groups. This finding is different from the results reported by Uthoff et al. (2018b). They found a greater magnitude of performance changes in the 20-m sprint test for the BRT group (pre: 3.4 ± 0.3 s vs. post: 3.2 ± 0.2 s; Δ%: -5.1%) compared to the FRT (pre: 3.4 ± 0.2 s vs. post: 3.2 ± 0.2 s; Δ%: -3.7%) and control groups (pre: 3.4 ± 0.2 s vs. post: 4.4 ± 0.2 s; Δ%: 1.6%), in young male athletes. The authors explain these findings by the specificity of training performed by the participants, which consisted of a sprint-training program of 10 to 20 meters with progressive intensities, either using BR or FR.

Finally, in the present study, the performance in the agility T-test significantly improved only in the BRT group. This result is similar to those reported by Swati et al. (2012), who evaluated 30 young university students (18-25 years) and identified that BRT was effective in improving agility T-test performance, in which the BRT group showed a greater time reduction (Δ%: 0.5 ± 0.4%) compared to the control group (Δ%: 0.1 ± 0.2%). These results were also observed in the study of Terblanche and Venter (2009), with the inclusion of BRT
in specific training of female netball players, in which the experimental group with BRT showed a significant improvement in the T-test.

The effect of BRT on agility can be explained, according to Swati et al. (2012), by the fact that BR provides more proprioceptive elements for control and body awareness (balance). Balance is one of the components of agility training, in conjunction with strength, reaction time, starting speed and acceleration, flexibility, and change of direction (Uthoff et al., 2018a). According to Uthoff et al. (2018a), improvements in the agility test indicate that BR is not only a concentric contractile stimulus but can also promote positive adaptations in the rapid stretch-shortening cycle through a movement that has a large eccentric component.

Concerning future studies, evaluation of the effects of combined BFRT should be performed in individuals (men and women) with different levels of running training, as well as in training programs for team sports. In addition, other tests could be carried out, such as (isometric and concentric) strength tests, considering the muscular stimulus provided by BR.

5 PRACTICAL APPLICATIONS

The results of this study have important practical implications for coaches, practitioners and endurance runners in terms of inserting BRT sessions into FRT as a way to vary the training stimulus and still achieve similar results in endurance performance as with FRT alone. The present study approaches in a deeper way issues related to the prescription of BRT, presenting and testing the \( V_{\text{peak, BR}} \) as a parameter to set training intensities. Finally, BRT was proven to be effective for improving agility performance, representing a possible training method for modalities that require this ability.

6 CONCLUSIONS

In conclusion, it was demonstrated that FR is the main training stimulus to improve 5-km endurance. Furthermore, the inclusion of BRT sessions into FRT, prescribed based on \( V_{\text{peak, BR}} \) and \( V_{\text{peak, FR}} \), leads to improvements in endurance
running performance with similar magnitude to the FRT alone, in recreationally active young men. It is also possible to conclude that BRT alone promotes positive changes in $V_{\text{peak, BR}}$ and agility T-test speed, thus demonstrating the importance of training specificity.
REFERENCES


