Is there correlation between peak backward running velocity and performance variables in physically active men?

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Summary

Introduction: The aim of this study was to verify the correlations between peak backward running velocity (V_{peak_BR}) and peak forward running velocity (V_{peak_FR}), 5-km running performance, the agility T-test, 20-m sprint, and countermovement jump (CMJ) in physically active men.
Material and Method: Fifty-four physically active men (age: 27.7 ± 4.8 years) performed the following tests: Vpeak_FR, V_{peak_BR}, 5-km running performance, agility T-test, and 20-m sprint on the outdoor running track, and the CMJ test in the laboratory. Tests were performed at the same time of day with 48-hour intervals. Data normality was verified using the Shapiro-Wilk test and the Student's *t* test for dependent samples was used to compare variables. The correlation between the V_{peak_BR} and the other variables was performed using the Pearson correlation test (*r*), according to the following classification: 0.0 to 0.1 very low; 0.1 to 0.3 low; 0.3 to 0.5 moderate; 0.5 to 0.7 high; 0.7 to 0.9 very high; and 0.9 to 1.0 almost perfect. The significance level adopted was $P < 0.05$.
Results: There was a high correlation between the V_{peak_BR} and V_{peak_FR} (7.7 ± 0.1 km·h^{-1}; 13.0 ± 0.2 km·h^{-1}, respectively; $r = 0.58$); the V_{peak_BR} showed a moderate and negative correlation with 5-km running performance time (t-5km) (27.4 ± 0.5 min; $r = -0.46$). The V_{peak_BR} presented low or very low correlations with the other variables.
Conclusion: We concluded that there is a correlation between V_{peak_BR} and performance variables in physically active men, however this correlation is more expressive with the variables V_{peak_FR} and 5-km running performance.

Key words:
Training. Exercise test. Athletic performances.

¿Existe una correlación entre la velocidad máxima de carrera hacia atrás y las variables de rendimiento en hombres físicamente activos?

Resumen

Introducción: El objetivo de este estudio fue verificar las correlaciones entre la velocidad máxima de carrera hacia atrás (V_{peak_BR}) y la velocidad máxima de carrera hacia delante (V_{peak_FR}), el rendimiento en carrera de 5 km, la prueba T de agilidad, el sprint de 20 m y el salto en contramovimiento (CMJ) en hombres físicamente activos.
Material y Método: Cincuenta y cuatro hombres físicamente activos (edad: 27,7 ± 4,8 años) realizaron las siguientes pruebas: V_{peak_FR}, V_{peak_BR}, rendimiento en carrera de 5 km, prueba T de agilidad y sprint de 20 m en pista de carreras al aire libre, y la prueba CMJ en el laboratorio. Las pruebas se realizaron a la misma hora del día con intervalos de 48 horas. Se comprobó la normalidad de los datos mediante la prueba de Shapiro-Wilk y se utilizó la prueba *t* de Student para muestras dependientes para comparar las variables. La correlación entre V_{peak_BR} y las demás variables se realizó mediante la prueba de correlación de Pearson (*r*), según la siguiente clasificación 0,0 a 0,1 muy baja; 0,1 a 0,3 baja; 0,3 a 0,5 moderada; 0,5 a 0,7 alta; 0,7 a 0,9 muy alta; y 0,9 a 1,0 casi perfecta. El nivel de significación adoptado fue $p < 0,05$.
Resultados: Hubo una alta correlación entre V_{peak_BR} y V_{peak_FR} (7,7 ± 0,1 km·h^{-1}; 13,0 ± 0,2 km·h^{-1}, respectivamente; $r = 0,58$); V_{peak_BR} mostró una correlación moderada y negativa con el tiempo de rendimiento en carrera de 5 km (t-5km) (27,4 ± 0,5 min; $r = -0,46$). El V_{peak_BR} presentó correlaciones bajas o muy bajas con las demás variables.
Conclusión: Concluimos que existe una correlación entre V_{peak_BR} y variables de rendimiento en hombres físicamente activos, sin embargo, esta correlación es más expresiva con las variables V_{peak_FR} y rendimiento en carrera de 5 km.

Palabras clave:
Entrenamiento. Prueba de esfuerzo. Rendimiento atlético.

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Introduction

Forward and backward running are movements performed during the practice of several sports[1,2]. Compared to forward running (FR), backward running (BR) requires greater strength and muscle activation of the lower limbs, generates less mechanical stress in the knee, and requires a new visual perspective, contributing to the development of other sensory senses[3,4]. Additionally, BR has been associated with more concentric work and less eccentric work in the lower limbs[5], different from FR which demands more eccentric work[6,7].

Concerning the inclusion of BR in FR training programs, it is essential to have a sequence of volume and intensity progressions that allows the individual to adapt to the movement specificity[3]. For this, Kauffman-Tacada *et al.*[8] established a protocol to determine the peak backward running velocity (V_{peak_BR}) based on the variable peak velocity (V_{peak}), widely used for FR training prescription[9,10]. It is important to mention that V_{peak} is a performance variable associated with FR endurance performance[10,11], which represents the maximum velocity reached in an incremental running test, and used for the FR training prescription[9-11]..

In the study of Kauffman-Tacada *et al.*[8] the V_{peak_BR} was used to prescribe BR training and to establish the training intensities more precisely. The authors verified the effects of backward running training (BRT), forward running training (FRT), and combined backward/forward running training (BFRT), prescribed by V_{peak_BR} and peak velocity of forward running (V_{peak_FR}), on the performance of 33 men. After training, the participants presented improved in 5 km endurance race performance, FR ($P = 0.01$), V_{peak_FR} ($P < 0.01$) and the duration of the incremental test of BR ($P < 0.01$) increased significantly in all groups after training. V_{peak_BR} also increased significantly in groups that trained with BR. The authors suggest that greater control of BR training intensities is possible and necessary in order to optimize performance improvements.

Despite the positive effects of using the V_{peak_BR} for BR training prescription[8], and although previous studies have demonstrated the positive effects of BR training on FR aerobic performance, strength, power of the lower limbs, sprint, and agility[4,8,12-14], a study verified the correlation between V_{peak_BR} and other performance variables. Considering the importance of V_{peak_BR} for optimizing the prescription of BR training, it is important to demonstrate which performance variables best define the specific demands that characterize BR.

However, no studies have verified the correlation between V_{peak_BR} and other performance variables. Therefore, the aim of this study was to verify the correlations between V_{peak_BR} and V_{peak_FR}, 5-km running performance, the agility T-test, 20-m sprint, and countermovement jump (CMJ) in physically active men. The hypothesis of this study was that V_{peak_BR} will correlate with the V_{peak_FR}, 5-km running performance, agility T-test, 20-m sprint, and CMJ.

Material and method

Participants

Fifty-four recreationally active young men participated in the study (age 27.7 ± 4.8 years; body mass 79.7 ± 1.0 kg; height 177.0 ± 0.0 cm; body mass index 25.4 ± 0.3 kg·m^{-2}; body fat percentage 18.0 ± 0.7%; 5-km running performance: 27.4 ± 3.3 min). Prior to the measurements, all participants signed an informed consent form. The research was carried out with the consent of the local Ethics Committee, State University of Maringá (Ref. No.: #3.541.842/2019).

All procedures performed in the study were in accordance with the ethical standards of the institutional research committee and with the Helsinki declaration. The data associated with the paper are not publicly available but are available from the corresponding author on reasonable request.

Experimental design

The experimental protocol had a total duration of three weeks. After familiarization with the tests and anthropometric assessments, each participant performed five visits to the outdoor running track (400 m) to perform the following tests: 1st visit: V_{peak_BR}, 2nd visit: V_{peak_FR}, 3rd visit: 5-km running performance, 4th visit: agility T-test and 20-m sprint FR. In the 5th visit, in the laboratory, the participants performed the CMJ test. The tests were performed at the same time of the day under similar climatic conditions (temperature = 18 – 29°C and relative humidity = 56 – 72%) with an interval of at least 48 h between visits. For all tests, the participants were instructed to report for testing well rested, well hydrated, and wearing lightweight comfortable clothing, to avoid eating for 2 h before the maximal exercise tests, to abstain from caffeine and alcohol, and to refrain from strenuous exercise for 24 h before testing[10]. During the V_{peak_BR}, V_{peak_FR}, and 5-km running performance, the heart rate (HR) and rating of perceived exertion (RPE) were recorded. All participants were verbally encouraged throughout the tests.

Determination of V_{peak_BR}

The V_{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[8]. In the "V_{peak_BR} Determination section", after: "V_{peak_BR} was considered the maximum velocity reached by the subject during the test," please insert the following statement: "Participants were instructed to cross the line of cones with at least one foot simultaneously with the beep[15]." If the final stage was not completed, the V_{peak_BR} was calculated from its partial duration, following the equation proposed by Kuipers *et al.*[16]: $V_{peak\_BR} = Vc_{complete} + (t / T \times Inc)$; in which $V_{complete}$ is the running velocity of the final completed stage, Inc the velocity 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).

During the test, HR was verified continuously and recorded at the end of each stage (Polar®, RS800cx, Kempele, Finland), and HR_{max} was defined as the highest HR value recorded during the test. RPE was also monitored during the tests using a 6–20 Borg scale[19], and the highest RPE value was retained as the RPE_{max}. Blood samples (25 µl) were collected for the determination of lactate concentrations ([La]). Blood sampling was performed prior to starting the tests (La_{pre}), at the end of the tests

(La_{post}), and at the 3rd ($La_{3\text{-}min}$) and 5th ($La_{5\text{-}min}$) minutes after the end of the tests. The highest blood [La] observed post-test was considered the peak lactate concentration ([La_{peak}]).

Three secondary criteria were considered to verify if the subject reached the maximum effort in the incremental test: 1) [La_{peak}] (≥8 mmol·L^{-1})[17]; 2) HR_{max} ≥100% of HR predicted by age using the equation by Tanaka *et al.*[18] (HR_{max} = 207 [– 0.7 × age]); and 3) RPE_{max} ≥19 on the Borg 6-20 scale[19,20].

Determination of V_{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)[9,10]. The velocity during the test was controlled by sound signals and by cones distributed every 25-m on the outdoor running track. Participants were instructed to cross the line of cones with at least one foot simultaneously with the beep[15].

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. 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[15]. The V_{peak_FR} was the maximal running velocity reached during the incremental test and, if the final stage was not completed, the V_{peak_FR} was calculated using the equation proposed by Kuipers *et al.*[16]. The HR_{max} and RPE_{max} were recorded. [La] was determined following the aforementioned procedures (*i.e.,* determination of V_{peak_BR}).

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 (t-5km) was recorded using a stopwatch to determine the test duration. 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[21].

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[4,22]. The time of the test was recorded, considering the shortest time of three attempts.

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[23,24]. From a static standing start, the participants sprinted all-out, 20-m, five times. The recovery duration between subsequent sprints was 30 s. Was noted the participants fastest 20-m sprint time[25].

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[26,27].

Statistical analyses

The Statistical Package for the Social Sciences (SPSS® v22.0 for Windows, Inc., Chicago, IL, United States) was used to conduct the analysis. The normality assumption was verified using the Shapiro–Wilk test, and the results are presented as the mean and standard deviation (±SD). The Student's t-test for dependent samples was used to compare variables. The correlation between V_{peak_BR}, V_{peak_FR}, 5-km running performance, agility T-test, 20 m sprint and CMJ and was performed by Pearson correlation (r). The Pearson correlation (r) was classified as: 0.0 to 0.1 very low; 0.1 to 0.3 low; 0.3 to 0.5 moderate; 0.5 to 0.7 high; 0.7 to 0.9 very high; 0.9 to 1.0 almost perfect[28]. A significance level of P <0.05 was adopted.

Results

The results of the performance tests were: (mean ± SD): t-5km = 27.4 ± 0.5 min, agility T-test = 11.4 ± 0.2 s, 20-m sprint = 2.9 ± 0.5 s, and CMJ = 32.9 ± 0.9 cm.

Table 1 shows the results obtained during the tests to determine the V_{peak_BR} and V_{peak_FR}. Statistically significant differences were observed for all variables. These findings were already expected since the velocities reached during BR are lower than in FR.

In V_{peak_FR}, 78.0% (n = 42) of the participants reached the HR_{max} criterion, and 61.1% (n = 33) reached the RPE_{max} criterion. In V_{peak_BR} 56.0% (n = 30) of the participants reached the HR_{max} criterion and 27.8% (n = 15) reached the RPE_{max} criterion, demonstrating that the effort performed can be considered maximal in both cases.

Table 2 presents the results for the correlations between V_{peak_BR} with V_{peak_FR}, 5-km running performance, the agility T-test, 20 m sprint, and CMJ. There was a high correlation between V_{peak_BR} and V_{peak_FR}, demons-

Table 1. Variables determined during the V_{peak_FR} and V_{peak_BR} tests (n = 54).

	FR	BR
V_{peak} (km·h^{-1})	13.0 ± 0.2	7.7 ± 0.13*
Test duration (min)	21.0 ± 0.5	14.1 ± 0.4*
HR_{max} (bpm)	186 ± 1.4	180 ± 1.8*
RPE_{max} (6-20)	18.7 ± 0.3	16.0 ± 0.5*

V_{peak} : peak velocity; BR: backward running; FR: forward running; HR_{max}: maximal heart rate; RPE_{max} : maximal rating of perceived exertion.
*P <0.05 compared to FR.

Table 2. Correlations between V_{peak_BR} with V_{peak_FR}, 5-km running performance, agility T-test, 20-m sprint and CMJ (n = 54).

	V_{peak_BR}	
Variables	***r***	**Classification**
V_{peak_FR} (km·h^{-1})	0.58*	High
t-5km (min)	-0.46*	Moderate
Agility T-test (s)	-0.19	Low
20-m sprint (s)	-0.06	Very Low
CMJ (cm)	0.11	Low

V_{peak_BR}: peak velocity of backward running; V_{peak_FR}: peak velocity of forward running; t-5km: 5-km running performance time; CMJ: Countermovement jump. * = P <0.05

trating that both variables are associated and represent FR and BR. In addition, the V_{peak_BR} presented a moderate correlation with the t-5km. The other variables showed low or very low correlations with V_{peak_BR}.

Discussion

The aim of this study was to verify the correlations between V_{peak_BR} and V_{peak_FR}, 5-km running performance, the agility T-test, 20-m sprint, and CMJ in physically active men. The main findings were a high correlation between V_{peak_BR} and V_{peak_FR} and a moderate correlation between V_{peak_BR} and the t-5km. Furthermore, V_{peak_BR} was not correlated with the agility T-test, 20-m sprint, and CMJ. These findings only partially confirm the previously formulated hypothesis.

The present study found a statistically significant difference between V_{peak_BR} and V_{peak_FR}, in which the V_{peak_BR} was 59% lower than the V_{peak_FR}. This result was already expected, due to the biomechanical differences between running styles, which leads to the shorter stride length in the BR and lower intensities than the FR[29]. Weyand *et al.*[29] determined the maximal BR and FR velocities through a progressive and discontinuous test until exhaustion in 10 physically active participants (5 men and 5 women) and demonstrated that the maximal intensity achieved in BR is equivalent to 70% of the maximal velocity in FR because the foot-to-ground contact time is minimal.

The correlation between the V_{peak_BR} and V_{peak_FR}, was significant, high, and positive (r = 0.58), indicating that although the intensities were different, both variables present the same response during the incremental test. Although no studies have examined the relationship between V_{peak_BR} and V_{peak_FR}, previous studies verified the correlation of V_{peak_FR} values determined in different environments or conditions[10,11,30]. Manoel *et al.*[30] examined the association between V_{peak} determined on an outdoor running track (V_{peak_TF}) and on a laboratory treadmill (V_{peak_T}) in 20 male trained endurance runners, using a similar protocol to the present study, and found a very large correlation between the measures (r = 0.94), even though both V_{peak_TF} and V_{peak_T} presented differences in the maximal intensities.

Regarding V_{peak_BR}, the study by Kauffman *et al.*[31] was the first to determine this variable with the same protocol used in this study, and according to the authors, V_{peak_BR} can be used to prescribe BR training, as it resulted in an improvement in 3-km FR performance after five weeks of prescribed BR training with the variable V_{peak_BR}. However, no previous studies have investigated V_{peak_BR} and its correlation with other performance variables. Thus, just like V_{peak_FR}, V_{peak_BR} can be used to control training, as it is easily determined, without the need for sophisticated equipment for metabolic measurements or invasive techniques, in addition to being a good predictor of performance in endurance running[8,31].

Concerning the agility T-test, a low correlation was observed with V_{peak_BR} (r = -0.19). Although no studies were found in the literature that verified the correlation between these variables, it is important to mention that previous studies demonstrated that BR training improves agility performance[4,14]. Swati *et al.*[4], in 30 healthy university students (18 -25 years), compared three training groups during six weeks: group A (n =10) performed backward walking (4 km·h^{-1}), group B (n = 10) performed backward running (5.6 km·h^{-1}), both for 6 weeks (3 sessions per week), and group C (n = 10) was the control group. The training protocol used consisted of 3 to 5 minutes of lower extremity stretching and running in place, followed by 1 minute on a treadmill and 6 minutes of training; the backward walking group (group A) trained at 4 km·h^{-1} and the BR training group (group B) at 5.6 km·h^{-1}. The results demonstrated that BR training was effective in improving agility performance in a test with change of direction; the BR training group showed a greater reduction (Δ%: 0.475 ± 0.362%) compared to the control group (Δ%: 0.086 ± 0.196%). The effect of BR training on agility can be explained by the fact that BR provides more proprioceptive elements for body control and awareness (balance)[4,14].

For the 20-m sprint test, the present study found a very low correlation (r = -0.06) with the V_{peak_BR}. Although no previous studies have correlated these variables, Uthoff *et al.*[23] demonstrated that eight weeks of sprint BR training with intensities classified as slow, moderate, and fast (20-45, 50-75, and ≥95% of maximal effort, respectively), and velocities self-selected by the participants, resulted in improvements in 10-m and 20-m sprint performances in forty-three male adolescents (aged 13–15 years). These results from Uthoff *et al.*[23] likely occurred due to the specificity of training on performance.

Another important result was the low correlation between CMJ and V_{peak_BR}. This finding does not corroborate previous studies, that showed that BR training generates a better ability to produce muscle power and, consequently, greater height in the vertical jump[4,22]. Uthoff *et al.*[23] reported that adaptations related to BR training are transferable sprints tests and CMJ. The authors showed that the participants who performed the BR training presented improved CMJ performance in the BR group (%Δ = 9.88; ES = 0.83), when compared to the FR group (%Δ = -5, 03%; ES = -1.20). Swati *et al.*[4] found that both backward walking and BR improved quadriceps strength after six weeks of training, which could indicate an increase in CMJ height.

Finally, the significantly high and negative correlation between V_{peak_BR} and 5-km running performance is in agreement with the study by Kauffman *et al.*[31] who observed a significant high and negative correlation between V_{peak_BR} and 3-km running performance (r = –0.77), using the same protocol as the present study for V_{peak_BR} determination. However, the study of Kauffman *et al.*[31] was a pilot study, with a small sample number, which highlights the importance of our study with a large sample.

Despite the important findings, the current study had some limitations, such as the absence of strength tests. However, future studies could investigate the relationship of V_{peak_BR} with strength.

Conclusion

Therefore, we concluded that V_{peak_BR} was highly correlated with V_{peak_FR} and presented a moderate correlation with 5-km running performance in physically active men. In addition, the V_{peak_BR} was not associated with the other performance variables evaluated. The results of this study have important practical implications for the use of V_{peak_BR} in BR training prescription.

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Conflict of interest

The authors do not declare a conflict of interest.

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- **Balneoterapia e Hidroterapia** *(1)*
- **Desarrollos Avanzados de Oncología Personalizada Multidisciplinar** *(1)*
- **Enfermería de Salud Laboral** *(2)*
- **Enfermería de Urgencias, Emergencias y Cuidados Especiales** *(1)*
- **Fisioterapia en el Deporte** *(1)*
- **Geriatría y Gerontología: Atención a la dependencia** *(2)*
- **Gestión y Planificación de Servicios Sanitarios** *(2)*
- **Gestión Integral del Riesgo Cardiovascular** *(2)*
- **Ingeniería Biomédica** *(1)*
- **Investigación en Ciencias Sociosanitarias** *(2)*
- **Investigación en Educación Física y Salud** *(2)*
- **Neuro-Rehabilitación** *(1)*
- **Nutrición Clínica** *(1)*
- **Nutrición y Seguridad Alimentaria** *(2)*
- **Nutrición en la Actividad Física y Deporte** *(1)*
- **Osteopatía y Terapia Manual** *(2)*
- **Patología Molecular Humana** *(2)*
- **Psicología General Sanitaria** *(1)*

(1) Presencial *(2) Semipresencial*

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