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Can the high intensity interval running in slope affect concurrently explosive strength performance?

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ABSTRACT
Background: Physical exercise programs are typically composed of activities directed to the development of different physical abilities, usually stimulated in the same session. **Objective:** The aim of the study was to determine the effect of one session of aerobic exercise at high intensity to 1% and 10% gradient on the height (HJump) and kinematics of the depth jump (PExc - eccentric, concentric phase PCon, and contact time – CT). **Methods:** Twenty-five moderately trained men (VO2Max 53.2 ± 4.3 mL.kg-1.min-1) attended five visits in the laboratory. Familiarity with the procedures in depth jump, VO2Max measures and their velocity associated (VVO2Max), and time to exhaustion performance (TLim) were performed at two initial visits. **Results:** On the three subsequent visits, the volunteers were subjected to three maximum depth jumps before and 10 min after the following conditions: (1) running intervals at high intensity of 10% gradient (R10%), (2) at 1% gradient (R1%), and control condition (CON). The order of conditions was determined randomly. A running condition did not induce significant changes from HJump (R1% 1.1% vs 1.0% R10%) when expressed as percentage difference from the CON condition. The PExc, PCon, and CT also did not change after running sessions (P> 0.05). None of the intervals running strategies were able to generate significant change in height and kinematics of the vertical depth jump. **Conclusion:** The prescription of the running at VVO2Max in 1% or 10% gradient does not seem to lead to concurrent effect, is suggested to ensure the concomitant development of maximal aerobic power and explosive strength.
Keywords: Aerobic exercise; Heart rate; Muscle fatigue; Vertical jump.

BACKGROUND

Physical exercise programs are typically composed of activities directed to the development of different physical abilities, usually stimulated in the same session. When long-term aerobic activities precede isokinetic, isotonic, or explosive strength exercises, deleterious effects on performance seem to be observed(1-3). According to aerobic modality characteristics, for example the long-term activities (> 2 h), damages can still last for hours and even for several days after their accomplishment(4).

These short-term and long-term changes in muscle strength and power would be directly associated with repetitive eccentric loads observed in long-term running(5). Prolonged exposure to these mechanical loads would attenuate reflex responses to stretch by reducing the sensitivity of intrafusal fibers(1), contributing to decrease the performance of the stretch-shortening cycle (SSC)(6,7). Thus, for athletes who need to adjust their training to a multiple-stimuli model in the same session, strategies are necessary to ensure the optimal development of cardiorespiratory fitness without short- and long-term damage to the development of strength and power.

In line with this, it is evident that the intensification of aerobic training through interval stimuli is the fastest and most efficient way to develop aerobic performance and VO_{2max} (8-10). With this strategy, gradual increases in inclination were inversely associated with a proportional reduction in eccentric loads during running(11), which result in less muscle damage to intra and extrafusal fibers(12). The increase in ground slope would then seems as an optional way to neutralize concurrence between strength or power performance(13). Given this scenario, we can argue that intermittent interval exercise and lower eccentric muscle contraction request during running in slope (11,14) reduce the period of exposure to the mechanical loads imposed on the locomotor system, which compromise the SSC, and therefore, the deleterious effect on the explosive strength performance. Although consistent, this aspect has not yet been investigated.

Thus, this study aimed to determine the effect of a high intensity interval session with 1% and 10% slope over the height of the jump in depth (H_{Jump}). The kinematic variables, concentric phase (P_{Con}), eccentric (P_{Exc}) and contact time (CT) were compared after the running session in both slope conditions in order to explain possible changes in jump performance. We have theorized that the lower eccentric overload in the running at 10% inclination would attenuate the concurrent effects on the performance of explosive force.

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METHODS

The present study used as reference the assumptions described by the International Committee of Medical Journal Editors (ICMJE) and respected all the items proposed in the guideline "Consolidated Standards of Reporting Trials" (CONSORT). All procedures were performed according to the Declaration of Helsinki and included in the clinical trial registration database of the U.S. National Institutes of Health (ClinicalTrials.gov; NCT02498730).

Sample

Twenty-five university students, physically active, and familiar with aerobic exercise on treadmill were invited to the experiment. All were characterized as low risk according to the risk stratification for coronary artery disease (CAD)[15] , and were instructed to do not eat in the three hours prior the experiment and do not perform physical activities in the 24 hours prior to the visits. The sample size was calculated considering an ⍰ error of 5%, and a statistical power of 80%. The lowest significant effect expected (4 cm for jump height) [16](Arteaga *et al.*, 2000) resulted in a "N" of 25 participants (Medcalc v.7.3.0.1, Medcalc Software, Mariakerke, Belgium). The sample characteristics are presented in Table 1.

Table 1. Sample characterization.

Variables	Mean ± SD
Age (years)	26.2 ± 3.4
Fat Mass (%)	13.3 ± 4.2
Body Mass (kg)	81.6 ± 10.1
Height (cm)	172.1 ± 7.3
$VO_{2Máx}$ (mL.kg.$^{-1}$min^{-1})	53.2 ± 4.3
T_{Lim} Performance (min)	6.4 ± 1.6

***Note:** TLim Performance – performance from TLim to exhaustion until speed associated with VO2max.

Ethical Aspects

All procedures were duly approved by the Research Ethics Committee of Gama Filho University (# 047,2010). All the participants signed the informed consent form accepting the participation, in which they informed all the procedures to be performed.

Experimental Procedures

The investigation consisted of five visits with interval among their of three to ten days. In the initial visit, the risk stratification procedures for CAD were performed, followed by familiarization with the vertical jump in depth, and immediately after, the determination of the VO_{2max} values and its associated velocity (V_{VO2max}). On the second visit, a new familiarization was made for the vertical jump followed immediately by the determination of TLim performance in ($V_{VO2Máx}$). During the familiarization, two jumps were performed at each of the three chosen heights (20, 30 and 40 cm), being used in the experimental sessions and in the control only the height associated with the higher performance. All jumping attempts had periods of 1 min. of interval among their.

In the following visits (i.e., third to fifth), participants performed three maximum jumps before and approximately 5 min after the following conditions: (1) high intensity interval running at 10% slope ($C_{10\%}$), (2) high intensity interval running at 1% slope ($C_{1\%}$) and (3) control condition (CON). In the control session, participants remained seated for 10 min between the sequences of jumps. The order of visits was randomly determined. All procedures were performed in the same period of the day standardized for each participant with controlled temperature (21 to 23º). Figure 1 shows the experimental design of the study.

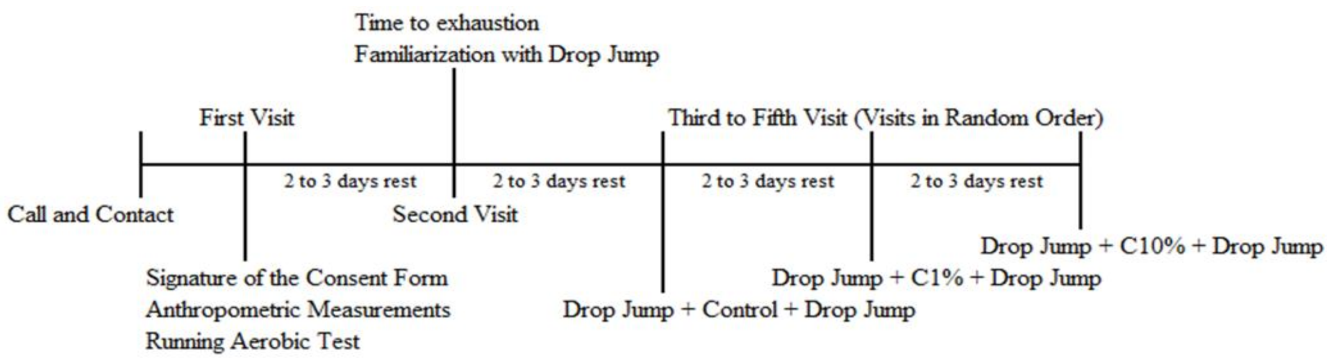

Figure 1. Experimental design

Anthropometry

All measurements were determined as suggested by the International Society for the Advancement of Kinanthropometry (ISAK). The anthropometric measures obtained were body mass, height (Filizola Scale, São Paulo, Brazil), and skinfolds (Slim Guide, Rosscraft, Surrey, Canada). We estimated the percentage of body fat through the equations suggested by Jackson & Pollock's equation(17).

Vertical Jumping

After the familiarization sessions, the participants underwent procedures that involved the identification and marking of three anatomical points (major trochanter, knee joint - lateral collateral ligament at the central point of intersection in the knee between the femur and the tibial plateau, and lateral malleolus) at the beginning of each visit. Then, the participants performed three to five jumps without any prior or preparatory activity. Instructions on the jumping technique was given in the initial and always remembered visits at the beginning of each experimental session. Participants should jump with their hands at their waist and encouraged to reach the maximum height, with no restrictions on knee flexion degrees or contact time at the moment of the eccentric phase during contact with the ground. The jumps were registered by a digital camera (Samsung ES17, Samsung Electric Co. Ltd., California, USA), with a sampling frequency of 30 Hz, located in a sagital plane 200 cm from the jump box and 60 cm perpendicular to the ground. VirtualDub software (Version 1.9.6, Free Software Foundation, Cambridge, USA) was defined from frame to frame inspection, the frames corresponding to the initial position (static - Figure 2A) and the final position (maximum jumping displacement - Figure 2B).

A template of known height (50 cm - Figure 2C) was used at each visit to establish proportionality between the figures and to define the actual H_{Jump} value. All frames were imported into CorelDRAW® graphics software (Graphics Suite X4, Corel Corporation 2008, USA) and analyzed from the vertical dimension tool. The kinematics of the jump in depth was defined by the analysis of the P_{Exc} frames (difference between the moment of entry into the ground and the beginning of the extension of the knee and ankle), P_{Con} (difference between the highest degree of knee flexion and loss of contact with ground) and TC (time contact with ground) (Figure 3). For greater sensitivity in obtaining kinematic data, the mean between two frames was used to increase the accuracy of the measurement of the jumping phases. For the comparative data analysis obtained before and after the running protocols, the highest performance jumping was used within the three trials. The internal consistency and stability of the vertical jumping in depth variables (P_{Con}, P_{Exc}, CT, H_{Jump}) were established based on the control visit and the subsequent experimental visit after the subjects' familiarization (Table 2).

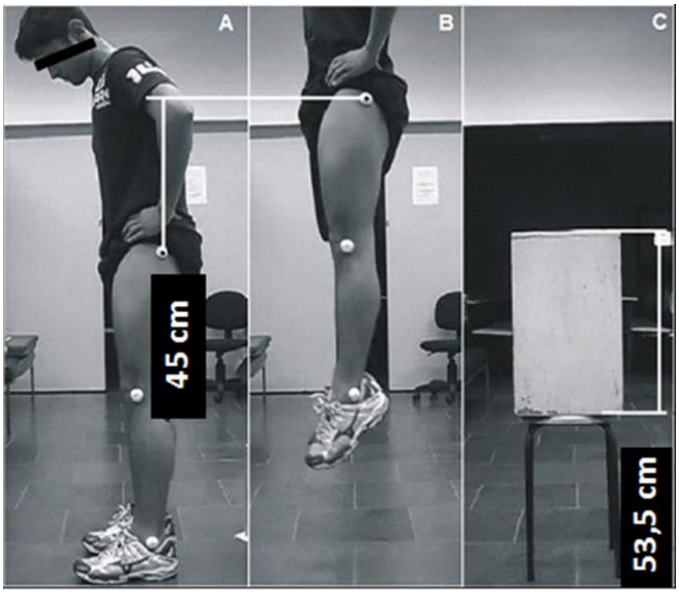

Figure 2. Definition of the heel height from the vertical dimension tool, (A) final position, (B) position of maximum height after displacement of the crate and the eccentric moment and (C) results from vertical height = 50cm.

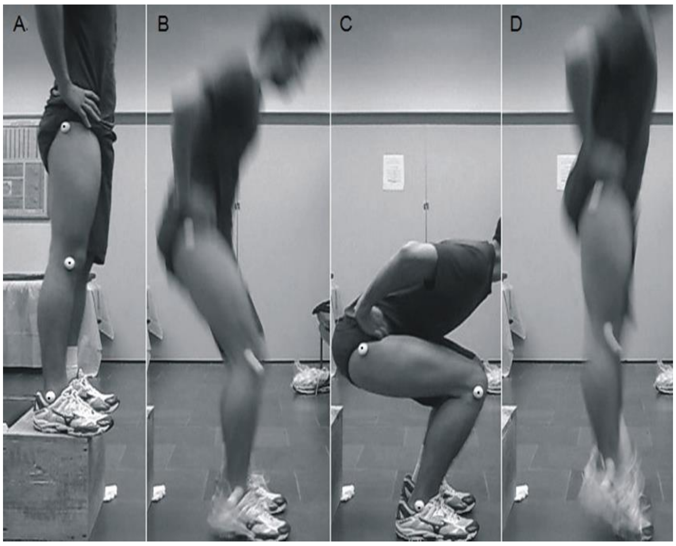

Figure 3. Stages of the vertical jump, PExc - difference between the moment of entry into the ground (A) and the beginning of the extension of the knee or ankle (B), PCon - difference between the greater degree of knee flexion (C) and contact loss with soil (D), CT - accumulated time between the initial contact (B) and the ground output (D).

Table 2. Reliability of kinematic measures and height of vertical jump in depth.

	P_{Exc}		P_{Con}		CT		H_{Jump}	
	IC	S	IC	S	IC	S	IC	S
ICC	0.84	0.80	0.91	0.91	0.90	0.92	0.90	0.92
P Value	0.001	0.001	0.001	0,001	0.001	0.001	0.001	0.001
TME (Absolute)	25.9	31.5	21.4	21,8	43.7	45.0	1.2	1.4
TME (Relative)	9%	9%	6%	7%	7%	7%	3%	3%

***Note:** ICC – intraclass correlation coefficient, P_{Con} - concentric phase, P_{Exc} - eccentric phase, CT – Contact time, H_{Jump} – Jump height, ms - milliseconds, cm - centimeters; IC = Internal Consistency; S = Stability; P Value = ICC Statistical Significance Level; TME = Typical Measurement Error;

Cardiorespiratory Test

Before the familiarization procedure with the vertical jump, the resting heart rate (Vantage, Polar Electro Oy, Kempele, Finland) was obtained in 6 to 10 min in the supine position. Participants started walking on the treadmill at 5 $km.h^{-1}$ and 1% incline. The speed was increased by 1.0 km/h per minute up to 65% of the reserve heart rate (HR_{Res}), when the velocity was then stabilized for a period of 6 min. HR and effort perception (RPE) were recorded every minute. Then, further increases in velocity (1.0 $km.h^{-1}$ per minute) were administered until participants were unable to continue running, when actual peak heart rate (HR_{maxR}) and V_{Peak} were recorded. Participants received verbal encouragement to achieve maximum performance. The VO_{2max} and V_{VO2max} were predicted from the race equations proposed by the ACSM[15], and from the reservation method proposed by Swain[18].

The use of the reserve method to estimate VO_{2max} is based on the assumption of previously validated equations[19]. The predictive validity of this approach was extremely satisfactory (r ≥ 0.90)[20], even when compared to direct VO_{2max} measurement methods[21].The concurrent validity, in a study not yet published by our group, resulted in a standard error of the estimate of 5.3 $mL.kg^{-1}.min^{-1}$. In addition, the reliability of the method using exercise as a mode of exercise provided a typical measurement error of 2.4 $mL^{-1}.kg^{-1}.min^{-1}$ (4.9%) and an intra-class correlation coefficient of 0.864[20].

Time Limit (T_{Lim})

After the familiarization, the procedures with the vertical jumping occurred at the second visit, with 6 to 60% heating of the V_{VO2max} being performed, followed by a 3-minutes interval. The treadmill was set at 1% slope in V_{VO2max}, where T_{Lim} performance was initiated. The volunteers were verbally encouraged to remain running for the longest time tolerated. The criterion for completing the test was maximal voluntary exhaustion.

Aerobic Exercise Protocol

A 6 min warm-up was performed at 60% intensity of V_{VO2max}. Then, V_{VO2max} stimuli with 50% T_{Lim} duration were provided in both stimulus and recovery (i.e., 1:1 ratio). The metabolic demand between the 1% and 10% slope race protocols was matched from the ACSM[15], metabolic running equation. The conclusion of six stimuli or maximal voluntary exhaustion were considered as the limit of the end of activity.

Statistical analysis

The descriptive analysis of the volunteers was presented in mean and standard deviation. A paired t-test compared total exercise time (T_{Time}) between the two strategies (C1% and C10%). A two-way ANOVA with repeated measurements for the time and group factor determined the difference among averages of vertical jumping in depth (P_{Exc}, P_{Con}, CT and H_{Jump}). A Tukey Post Hoc test was used to identify differences between groups, and the magnitude of the differences were established by the effect size calculation (ES). All assumptions were previously tested and analyzes were performed on GraphPad Prism (v. 5.01, GraphPad Software Inc., San Diego California, USA) with adjusted significance level at p=0.05.

RESULTS

The T_{Time} of the running activity at 1% inclination was statistically higher than the time referring to 10% slope (34.6 ± 8.4 min, 18.5 ± 3.8 min, respectively for $C_{1\%}$ and $C_{10\%}$; p<0.001). An average of 5.0 ± 1.3 and 2.6 ± 0.7 stimuli for $C_{1\%}$ and $C_{10\%}$, respectively, were concluded.

The P_{Exc}, P_{Con}, CT and H_{Jump} variables did not show significant differences before and after the ramp intervention at 1 and 10% slope. All the results were described with their respective levels of significance in Table 3. The ES observed for all dependent variables showed results with a range of 0.03 to 0.19. In conjunction with the results found, ES conferred a trivial effect for intervention, suggesting little or no effect of short running interval on vertical jumping performance.

Table 3. Mean and standard deviation of kinematic variables and vertical jump performance in the three interval running conditions.

	$C_{1\%}$			$C_{10\%}$			Control		
	Pre	Post	*p*	Pre	Post	*p*	Pre	Post	*P*
P_{Exc} (ms)	294.4 (47.8)	302.1 (59.4)	0.512	283.0 (54.9)	285.7 (56.2)	0.180	289.0 (48.6)	287.5 (52.2)	0.101
P_{Con} (ms)	334.8 (48.6)	333.6 (43.5)	0.080	333.0 (55.4)	324.8 (57.7)	0.554	330.1 (56.9)	337.0 (49.0)	0.469
CT (ms)	628.8 (85.6)	635.4 (84.0)	0.249	615.6 (101)	610.2 (100)	0.204	622.9 (97.4)	624.0 (87.8)	0.060
H_{Jump} (cm)	41.97 (4.6)	42.29 (5.3)	0.251	41.40 (4.3)	42.24 (3.8)	0.353	41.82 (4.3)	40.72 (4.0)	0.866

***Note:** P_{Con} – concentric time, P_{Exc} - eccentric time, CT – contact time, H_{Jump} – Jump height, ms - milliseconds, cm – centimeters.

DISCUSSION

The present study is pioneer in examining the effect of high intensity interval running with and without slope on performance and kinematics of vertical jumping in depth. The relevance of this study is in line with the possibility of administering stimuli of interval running without a deleterious influence on the subsequent performance of explosive force. Interventions with high intensity running intervals for both $C_{1\%}$ and $C_{10\%}$ groups did not present immediate concurrent effects on the power variables investigated.

The results observed by the present study diverge from some evidence in the literature[1-3]. The loss of isoinertial, isokinetic or power strength after performing an aerobic activity has been reported mainly in long-term running[2,3,6], but also on protocols of interval exercise [22,23],or in submaximal vertical jumps until exhaustion[4].In these studies, the main mechanisms responsible for the reduction in strength and power immediately after aerobic exercise appear to be related to metabolic production and / or to repeated eccentric loads influencing the SSC mechanisms, or even generating structural damages[4,12]. This phenomenon does not seem to have been reproduced in our study.

Interestingly, the present study did not demonstrate any deleterious effect as a result of exposure to run at 1 and 10% slope. The T_{Time} of aerobic exercise could be a factor influencing the subsequent performance of strength and power[2]. It is possible that a longer aerobic activity, with repeated eccentric loads, could induce the reduction of muscle spindle sensitivity with the concomitant reduction of SSC capacity[1]. It is observed, therefore, that the activity time adopted in the present study ranged from four to five times less than the T_{Time} of exercise reported by authors who showed a significant reduction in strength or power[2,3,6], (34.6 min and 18.5 min, respectively for $C_{1\%}$ and $C_{10\%}$). It is possible that the time of activity administered was insufficient, explaining the absence of competing effects between the activities.

However, this statement seems not be supported[24], where strength losses were reported in maximal voluntary contraction (15.1%) in leg press exercise and 20 m sprint velocity (16.3%) after a short test of 5 km until exhaustion (16 min and 58 s ± 1 min and 12 s). Despite these results, the methods used [24], were different from the protocols used in our study, which could explain such divergences between results. In this sense, concurrent or even potentiated effects on the explosive strength performance seem tenuous and dependent on the type of protocol[25,26], contraction[27], among other characteristics like T_{Time}, modality, type of training and training status[2,22].

The interval trajectory characteristic of the reduced T_{Time} of exercise may be the key to the different response found in the performance and kinematics of the vertical jump in depth, perhaps due to a lower metabolic influence, being this one of the mechanisms able to contribute to the reduction of strength [4]. In addition, the SSC overload pattern during high-intensity interval running was probably not able to generate significant muscle damage as seen in vertical jumping protocols until exhaustion[28].

It should also be noted that the T_{Time} difference between 1% and 10% slope runs is an important finding suggesting that T_{Lim} performance may be limited in large slope percentages (10%), possibly due to higher metabolic activity[29] and muscular recruitment[30] . In addition, T_{Lim} performance differences may have been maximized by the indirectly provided metabolic equivalence from the ACSM running equation [15].This strategy is therefore inadequate for setting up a training intervention at different slopes. Regardless of this finding, the ES between the magnitude of the differences in vertical jump performance in depth between conditions $C_{1\%}$ and $C_{10\%}$ proved to be trivial and, therefore, of no substantial relevance.

Analyzing the method used, variables such as CT did not comply with the values observed in the literature for similar heights (300 to 600 ms versus 200 to 250 ms for the present study and the literature, respectively)[16]. The observed CT pattern can be attributed to the angle of knee flexion assumed during the eccentric phase, which remained free between the subjects for the greater development of H_{Jump}. Already the means and standard deviation of H_{Jump} in our study were higher than those reported[16] , (41.9 ± 4.0 cm vs. 34.6 ± 6.1 cm, respectively) and lower than the mean in recreationally trained subjects (52.6 ± 2.5 cm)[31] .

This difference can be attributed mainly to different levels of training, experience in the execution of the task and technique/orientation of the jump. This distinction between results does not seem to be related to the indirect method of determining vertical jump, kinematics or data variability, since the values presented satisfactory reliability (Table 3), in addition to using the same procedures before and after interval training sessions.

Finally, the difference between the T_{Time} and the number of stimuli in conditions $C_{1\%}$ and $C_{10\%}$ can be highlighted as a finding that could have limited our intervention. Only T_{Lim} at 1% slope was measured and considered for the training configuration at 10% slope. Possible differences seem to exist between the performance of T_{Lim} in V_{VO2max} at 1% and 10% slope, which probably led to different training impacts, and early fatigue at 10% slope. Regardless, the lowest T_{Time} to $C_{10\%}$ did not affect the final results, not influencing the conclusion.

CONCLUSION

Interval strategies of 1% and 10% slope races were not able to generate significant changes in height and kinematics of vertical jump in depth. The prescription of the interval race in V_{VO2max} at 1% or 10% of inclination does not seem to have concurrent effects since performed in a volume similar to the one used here, and are suggested to guarantee the concomitant development of maximum aerobic power and explosive force.

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