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Original

Effectiveness of a power-training block with two cluster set configurations in recreationally trained young adults on sprint performance

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ABSTRACT

Objective: The purpose of the present study was to evaluate the effectiveness of a three-week power-training block with two different cluster set configurations using pneumatic equipment on sprint performance.
Method: Thirty recreationally active subjects participated in this study (18 female and 12 male). The subjects were distributed randomly into Control (CG), Cluster 1 (CL1) and Cluster 2 (CL2) groups. The experimental procedure involved a three-week training period; at the pre- and post-training time points, a 20-meter sprint tests were applied.
Results: There was an intergroup significant difference for the CL2 versus the CG for time, acceleration and velocity in the first 10-meter sprint test. The alpha value used was $p < 0.05$. For total time, total velocity, time and velocity in the first 10-meter sprint test: significant differences were observed for both CL1 and CL2 at the post-test. The total acceleration and acceleration in the first 10-meter sprint test was significantly different for the CL2 at the post-training. There were no significant differences in time, velocity and acceleration in the final 10-meter sprint test between groups.
Conclusion: These results suggest that interventions with intra-set intervals (specifically CL2) using pneumatic equipment allow for positive adaptations in velocity and acceleration after three-week training.
Keywords: Intra-set rest; Resistance training; Sports performance; Plyometric training.

Eficacia del entrenamiento de potencia en bloque utilizando dos configuraciones de conglomerados en jóvenes adultos aficionados entrenados, sobre el rendimiento en el Sprint

RESUMEN

Objetivo: evaluar la eficacia de tres semanas de un entrenamiento de potencia en bloque utilizando dos configuraciones diferentes de conglomerados con equipo neumático sobre el desempeño en el *Sprint*.
Método: treinta individuos recreacionales activos participaron en este estudio (18 mujeres y 12 hombres). Los sujetos fueron distribuidos aleatoriamente en los grupos Control (GC), *Cluster* 1 (CL1) y *Cluster* 2 (CL2). El procedimiento experimental implicó un período de entrenamiento de tres semanas; en los momentos pre y post-entrenamiento se aplicaron pruebas de *Sprint* de 20 metros.
Resultados: hubo una diferencia significativa intergrupos para el CL2 versus CG en el tiempo, aceleración y velocidad en los primeros 10 metros de *Sprint*. El valor alfa utilizado fue $p < 0.05$. Para el tiempo total, velocidad total, tiempo y velocidad en los primeros 10 metros del *Sprint*: se observaron diferencias significativas para CL1 y CL2 en el post-test. La aceleración total y aceleración en los primeros 10 metros del *Sprint* presentó diferencias significativas para el CL2 en el post-entrenamiento. No hubo diferencias significativas en el tiempo, velocidad y aceleración en los 10 metros finales del *Sprint* entre los grupos.
Conclusión: estos resultados sugieren que las intervenciones con intervalos intra-series (específicamente CL2) utilizando equipo neumático permiten adaptaciones positivas a la velocidad y la aceleración después de tres semanas de entrenamiento.
Palabras clave: Intervalo intra-serie; Entrenamiento de fuerza; Rendimiento deportivo; Entrenamiento pliométrico.

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Eficácia do treinamento de potência em bloco utilizando duas configurações de cluster set em jovens adultos recreacionalmente treinados sobre desempenho de Sprint.

RESUMO

Objetivo: avaliar a eficácia de três semanas de um treinamento de potência em bloco utilizando duas configurações diferentes de *cluster set* com equipamento pneumático sobre o desempenho de *Sprint*.

Método: Trinta indivíduos recreacionalmente ativos participaram deste estudo (18 mulheres e 12 homens). Os sujeitos foram distribuídos aleatoriamente nos grupos Controle (GC), *Cluster* 1 (CL1) e *Cluster* 2 (CL2). O procedimento experimental envolveu um período de treinamento de três semanas; nos momentos pré e pós-treinamento foram aplicados testes de *Sprint* de 20 metros.

Resultados: Houve uma diferença significativa intergrupos para o CL2 versus CG no tempo, aceleração e velocidade nos primeiros 10 metros de *Sprint*. O valor alfa utilizado foi p <0.05. Para o tempo total, velocidade total, tempo e velocidade nos primeiros 10 metros do *Sprint*: diferenças significativas foram observadas para CL1 e CL2 no pós-teste. A aceleração total e aceleração nos primeiros 10 metros do *Sprint* apresentou diferenças significativas para o CL2 no pós-treinamento. Não houve diferenças significativas no tempo, velocidade e aceleração nos 10 metros finais do *Sprint* entre os grupos.

Conclusão: Estes resultados sugerem que intervenções com intervalos intraséries (especificamente CL2) utilizando equipamento pneumático permitem adaptações positivas na velocidade e aceleração após três semanas de treinamento.

Palavras-chave: Intervalo intra-série; Treinamento de força; Desempenho esportivo; Treinamento pliométrico.

Introduction

Development of velocity and acceleration are essential characteristics for successful performance in both team and individual sports that require single or repeated maximal sprints.[1,2] A linear sprint can be divided into three phases, including acceleration, maximum velocity, and deceleration. In the first acceleration phase, greater force and power is required to generate high movement velocity. In the maximum velocity phase, it is important to increase the rate of force and power production as well as the efficiency of movement for better propulsion.[3]

During the first sprint acceleration phase, the main muscle groups involved are the hip, knee and ankle extensors.[3] However, the training effectiveness for such a specific characteristic can be enhanced by adhering to the highest possible movement specificity.[4] With sprinting being the fastest form of human displacement without external assistance,[5] the expression of strength at a very high rate that results in high power outputs is preferred.[6]

Muscle power is one of the trainable characteristics that can be improved through resistance training (RT).[7] The power-training benefits go beyond the sport scope. The American College of Sports Medicine[7] points out as neuromuscular contributions to maximum power-training: the maximum rate of strength development, strength production with slow and fast contraction velocities, stretching-shortening cycle performance and movement pattern coordination and can also be used in injury rehabilitation and prevention programs through improved functional performance.[8] To optimize power development, cluster set configurations have been advocated to maintain consistency in repetition force and power output, allowing greater availability of phosphocreatine (PC) and resynthesis of adenosine triphosphate (ATP).[9] Cluster set configurations involve incorporation of relatively short intra-set rest intervals (RI) with a set divided into repetition clusters.[10]

There is a large literature on comparisons between traditional versus cluster-set structures,[11-13] which characterizes a comparison between a stimulus that uses the traditional glycolytic energy system and another that uses the ATP-PC (cluster set) system. However, there is a gap in the literature regarding the comparison of two-cluster set structures organized to use the glycolytic system versus ATP-PC, aiming at improving performance of long-term training for sprint performance. Therefore, scientific evidence regarding the use of two cluster set structures, applying specific training for high-intensity muscle power, and knowing which cluster set structure can improve muscle function and movement speed, increasing functional performance[8,14] can assist physical education professionals by providing new possibilities for planning and organizing individualized training programs, optimizing velocity and acceleration, and consequently improving the functional performance of young adults recreationally trained.

Thus, the purpose of the present study was to evaluate the effectiveness of a three-week power-training with two different cluster set configurations using pneumatic equipment on sprint performance. We hypothesized that cluster training using a smaller number of repetitions would elicit superior adaptations in sprint performance.

Methods

Subjects

The sample size (*n*) was determined using the G * Power 3.1.9.2 (G * Power 3 for Mac) software[15,16] using a repeated measures ANOVA between factors, 80% test power, number of groups to be tested: 3, probabilistic error: 0.05 and f = 0.5. Being F = 3.35413, the sample calculation was estimated for 30 subjects. The study consisted of 30 subjects (18 female and 12 male); all were recreationally active in different team and individual sports, although non-athletes. The inclusion criteria were experience with RT but without regular practice over the past six months, and who had never performed any specific power-training. The exclusion criteria were: subjects who (a) had some osteomyoarticular injuries, (b) women who used contraceptives and (c) used some ergogenic aids that could influence the results of the study. The anthropometric measures of the subjects are shown in Table 1.

Table 1. Anthropometric Measures of the subjects.

	Control	Cluster 1	Cluster 2
Age (years)	25.66 ± 1.8	24.90 ± 1.0	23.68 ± 0.40
Body Mass (kg)	72.21 ± 3.13	69.89 ± 3.87	65.60 ± 4.00
Height (m)	1.68 ± 0.01	1.71 ± 0.03	1.66 ± 0.02
IMC (kg/cm^2)	25.38 ± 0.94	23.82 ± 0.88	23.59 ± 0.80
Experience with RT (months)	20.60 ± 2.17	17.20 ± 1.08	19.90 ± 0.9

BMI: Body mass index; RT: Resistance Training.

Thus, the present study consisted of 10 participants in the control group (CG) composed of five women and five men, of which four practiced jiu-jistu, two practiced swimming, two practiced handball and two practiced running. The Cluster 1 group (CL1) had 10 participants, six women and four men, of which five practiced jiu-jistu, three practiced running and two did not have a regular activity but practiced running and soccer on sporadic days a week. The Cluster 2 group (CL2) had 10 participants, six women and four men, of which one practiced soccer, two practiced handball, two practiced jiu-jitsu, one practiced basketball, two practiced running, and two did not have a regular activity but practiced running and soccer on sporadic days a week. Although the practitioners were already performing an activity, they had a maximum of two sessions per week, and none of the participants performed power-training, so their modalities had no influence on the results of the present study.

Given that previous studies[12,17,18] used participants who already performed regular activities and only inserted an intervention into their daily routine, the present study also chose to preserve the participants' daily activities routine, provided that no new activity was initiated after the study started, and that they did not interrupt the activities that were already being performed, so that there was a standardized comparative parameter of the study from the beginning to end of training.

Experimental Procedure

During the first visit, subjects signed the informed consent form (TCLE) before participating in the study in accordance with the Declaration of Helsinki and resolution 466/2012 of the National Health Council for research on human beings. This study was analyzed and approved by the Research Ethics Committee of the Rio de Janeiro Federal University under the protocol CAAE: 92731418.0.0000.5257.

This study was designed to compare the effects of two different cluster set configuration on sprint performance after three weeks of a pneumatic apparatus (Keiser® Sports Trainer - Keiser® Sports Health Equipment, Inc., Fresno, CA, USA). All the tests were carried out before and after the training period, including anthropometric measures (body mass and height) and 20-meter Sprint test.

Body mass (kg) and height (cm) were measured on a mechanical scale model 31 Filizola (São Paulo, SP, Brazil). Body mass index (BMI) was calculated by mass divided by height squared [BMI = body mass (kilograms) / height^2 (centimeters)].

Before the training period, the participants were familiarized with the exercises countermovement jump (CMJ) and countermovement sprint (CMS) where the movement started with the feet in parallel, the participant took a step back and then carried out a 1-meter sprint. A Muscle power test (MPT) was conducted on the pneumatic apparatus, after 72 hours of familiarization, for the CMJ and CMS. The MPT was used only to perform the overload adjustment. The third visit was performed 48 hours following the MPT, during which the 20-meter sprint test (S20) was performed. After another 48 hours, the training program was initiated on the pneumatic equipment, and subjects were distributed randomly into CG, CL1 and CL2 groups. The experimental procedure consisted of a three-week training period, and the MPT was conducted only pre-training and S20 test was conducted pre-and post-training.

Muscle Power Test (MPT)

The MPT was performed on the pneumatic apparatus for the CMJ and CMS. Participants underwent a warm-up, consisting of two sets of 15 squat repetitions with body weight, with a one-minute rest interval between sets. Following the warm-up, a high overload was used on the pneumatic and participants were instructed to perform the largest number of repetitions to failure in both the CMJ and CMS exercises. The overload was considered high when in the accomplishment of the repetitions were less than 20. If the subjects performed more than 20 repetitions, a 5-minute rest interval was granted, the overload was increased and a new attempt was performed. A five-minute rest interval was granted between exercises.[19] The value of one maximum repetition (1MR) was estimated through the Brzycki equation, where 1MR = (overload) / 1.0278 - 0.0278 * number of repetitions performed.[20] The 1MR value of the MPT was used to define the progression of the intensities used in the training period (80%, 85% and 90% of 1MR).

20-meter Sprint test (S20)

The S20 was conducted on an outdoor court. The markers were positioned at baseline and every 10 meters of distance. In addition, a marker was positioned five meters apart after the 20 meters cone to avoid deceleration at the end of the sprint. The subjects were positioned behind the baseline, and upon an audio signal, they ran as fast as possible through the 20-meter course. Each subject had three attempts with a three-minute rest interval to allow full recovery between S20 attempts. The shortest time of the three trials was used for analysis.[21]

A digital video camera (GoPro, Hero 3+ black, GoPro Inc, San Mateo, California, USA) with 240Hz[22] and resolution of 1080p = 1920x1080 pixels (16:9) was positioned perpendicular to the sprint path in the sagittal plane at 10-meter mark, directed at a distance of 9.15 meters to cover the entire 20-meter course. The participant's sacrum were marked to allow clear identification of the time point when they passed through the start, 10-meter, and 20-meter.[23] With this feature, it was possible to calculate velocity and acceleration of the total course and every 10-meter through video analysis software (Kinovea 0.8.15).

Training Sessions

Each group was composed of 10 participants. After pre-testing, the experimental procedure was started consisting of a three-week training period. The CG did not perform training, attending sessions only for the pre- and post-testing. The CL1 group performed two sets of 15 repetitions [2 x (3x5)] with 20-second intra-set rest intervals (between three clusters of five repetitions), and with a 50-second inter-set rest interval. The CL2 group performed 15 sets of two repetitions [3 x (5x2)] with 10-second intra-set rest intervals (between five clusters of two repetitions), and with 20-second inter-set rest intervals. In previous studies analyzing power[24,25], cluster configurations with two repetitions presented better results in movement velocity, greater power and muscular strength development. Therefore, both cluster groups performed 30 repetitions. The exercises performed on the Keiser® pneumatic equipment were the CMJ and CMS. Each session lasted 25 minutes.

Before each training session, a warm-up of two sets of 15 squat repetitions were performed using body weight, with a one-minute rest interval between sets and then two minutes before the first training exercise. The subjects performed two weekly sessions, with an overload progression each week calculated through the MPT (Week 1 - 80% of 1MR of the MPT, Week 2 - 85% of 1MR of the MPT, Week 3 - 90% of 1MR of the MPT) being the fourth week destined exclusively to the post-training test.

Statistical Analyses

Values are expressed as mean and standard deviation. The Shapiro-Wilk test showed that the variables presented normal distribution ($p>0.05$). A two-way ANOVA of repeated measures was applied to analyze the differences between the different time points (pre- and post-training) within and between groups. If there was significant interaction, the multiple comparisons were made through Bonferroni post hoc. The alpha value used for all stages of experimental analysis was $p < 0.05$. The effect size (ES) statistic was used to evaluate the difference between the pre- and post-training time points, where values less than 0.35 were considered *trivial*; from 0.35 to 0.8 considered *small*; 0.8 to 1.50 considered *moderate*; and values greater than 1.50 considered *large* for recreationally trained individuals.[26] Version 22.0 of SPSS software for Mac (SPSS Inc., Chicago, IL, USA) was applied in all statistical analyses.

Results

The effect size of the time, velocity and acceleration for all groups are presented in table 2. Regarding the total time, no intergroup differences were observed ($F = 2.878$; $p = 0.074$). There was a significant intragroup difference ($F = 10.786$; $p = 0.003$). For velocity at 20-meters, no intergroup differences were

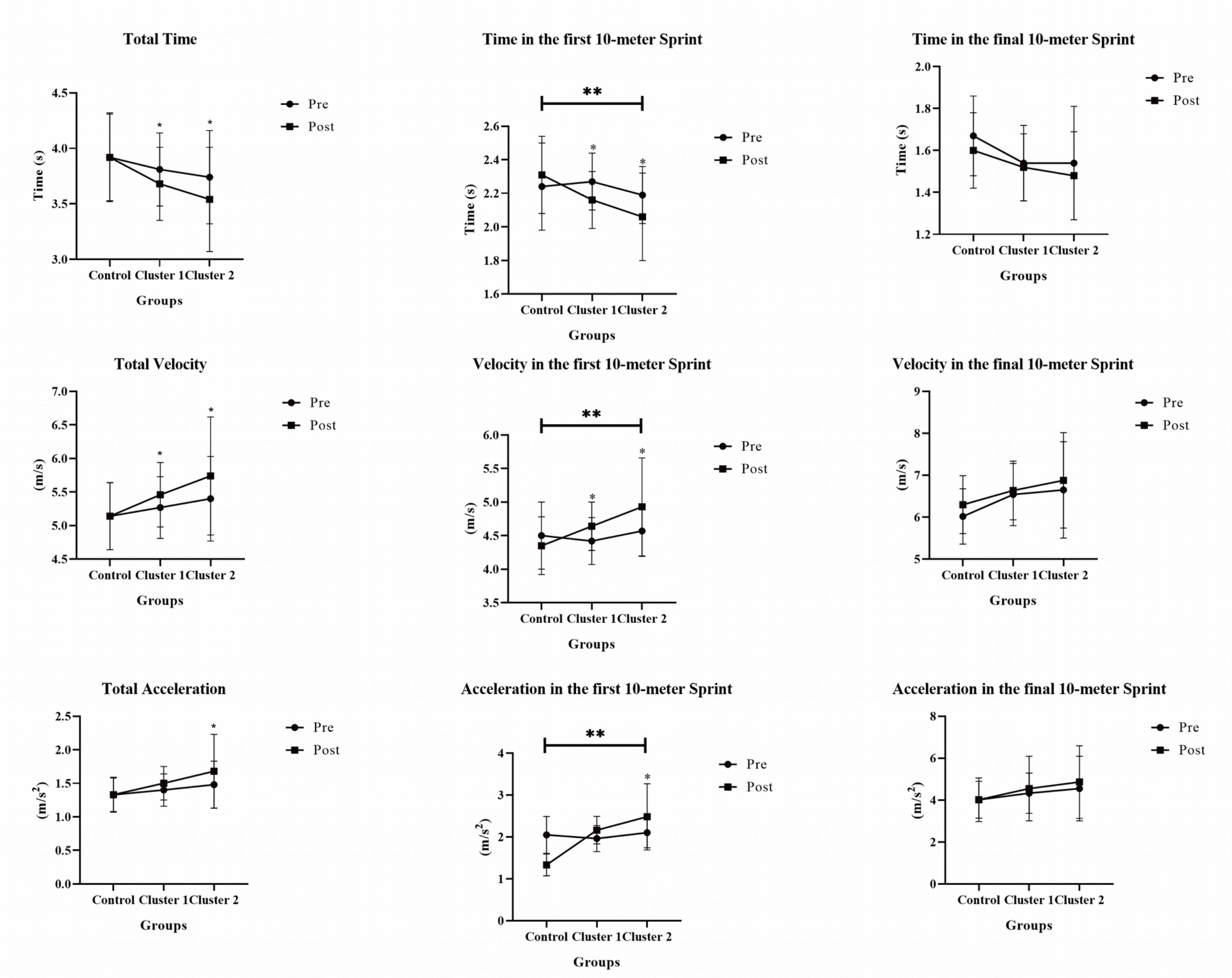

Figure 1. Time, Velocity and Acceleration in the 20-meter sprint pre and pos-training.*Significant intragroup differences in relation to the pre-training period; **Significant intergroup differences in relation to the control group.

observed (F = 2.972; p = 0.068), but there were significant intragroup differences (F = 10.149; p = 0.004). No intergroup differences were observed in total acceleration (F = 2.667; p = 0.088), but there were significant intragroup differences (F = 8.450; p = 0.007) (Figure 1).

For the time in the first 10 meters, an intergroup significance was observed (F = 4.758; p = 0.029). There was a significant intragroup difference (F = 15.354; p < 0.001). Regarding the velocity in the first 10 meters of the sprint, significant intergroup differences were observed (F = 5.541, p < 0.001). There was a significant intragroup difference (F = 19.461; p < 0.001). For acceleration in the first 10-meters of the sprint, there were significant intergroup differences (F = 5.763; p = 0.032). There was a significant intragroup difference (F = 20.802; p < 0.001) (Figure 1).

Table 2. Effect size of the time, velocity and acceleration on 20-meter Sprint.

	Control	Cluster 1	Cluster 2
	ES	ES	ES
T_T (seconds)	Trivial (0.24)	Small (0.39)	Small (0.46)
T_0	Trivial (0.27)	Small (0.60)	Small (0.75)
T_{10F}	Trivial (0.05)	Trivial (0.14)	Trivial (0.22)
Vel_T (m/s)	Trivial (0.26)	Small (0.41)	Small (0.52)
Vel_0	Trivial (0.30)	Small (0.62)	Moderate (0.91)
Vel_{10F}	Trivial (0.016)	Trivial (0.13)	Trivial (0.19)
$Accel_T$ (m/s^2)	Trivial (0.27)	Small (0.42)	Small (0.57)
$Accel_0$	Trivial (0.31)	Small (0.42)	Moderate (1.01)
$Accel_{10F}$	Trivial (0.00)	Trivial (0.13)	Trivial (0.19)

TT: Total time; T0: Time in the first 10-meter; T10F: Time in the final 10-meter; VelT: Total velocity; Vel0: Velocity in the first 10-meter; Vel10F: Velocity in the final 10-meter; AccelT: Total acceletation; Accel0: acceleration in the first 10-meter; Accel10F: Acceleration in the final 10-meter; ES: Effect Size.

In relation to the final 10-meters of the sprint, there were no intergroup (F = 0.307; p = 0.738) and intragroup differences (F = 4.141; p = 0.322), intergroup (F = 0.297, p = 0.745) and intragroup (F = 4.294, p = 0.745) for velocity; and intergroup (F = 0.281, p = 0.757) and intragroup (F = 4.119, p = 0.274) for acceleration (Figure 1).

Discussion

The aim of the present study was to evaluate the effectiveness of three weeks of training using two different cluster set configurations on sprint performance. There was a significant difference between CG and CL2 groups for the time, velocity and acceleration in the first 10 meters of the 20-meter sprint test. Furthermore, improvements were demonstrated in total time, total velocity, first 10-meters time and velocity for both the CL1 and CL2 groups, as well as improvements in total acceleration and first 10-meters acceleration in the CL2 group after four weeks of training on Keiser® pneumatic equipment. These results demonstrate the importance of specific power-training for improving sprint performance.

The training exercises employed in the current study involved vertical force production (CMJ) as well as horizontal force production (CMS), with the CMS being a key kinetic variable in sprint performance[6]. In contrast to the present study Arazi et al.[11] sought to determine the impact of 8-weeks resistance training with different set configurations on anthropometrics, power output, strength and hormonal adaptations. There were improvements in strength and vertical jump performance. However, it was not observed differences in sprint performance in either group after eight weeks of training. This divergence of results may be related to the fact that the aforementioned study did not use exercises that simulated the sprint movement pattern, minimizing neuromuscular specificity for this skill.

Corroborating with the present study, Asadi & Ramírez-Campillo[12] applied six weeks of plyometric training using traditional versus cluster set training on jump ability, sprint and agility performance. The authors concluded that both traditional and cluster training equally improved jump, agility, and sprint performance. It is worth mentioning that the aforementioned study was 6-weeks long, while the present study was 3-weeks long. Furthermore, the training sessions performed in the present study lasted 25 minutes, practically half of the time taken per session in the Asadi & Ramirez-Campillo[12] study; yet significant improvements were demonstrated in sprint performance with very little time commitment using both cluster set configurations.

In the present study, significant differences were observed in the total velocity and in the velocity for the first 10-meters for both the CL1 and CL2 groups, and total acceleration and acceleration for the first 10-meters for the CL2. Moreno et al.[25] found that two-repetition cluster configuration allowed for greater maintenance of power, take-off velocity and jump height versus the Traditional 2x10 protocol when performing a squat with body weight. Morales-Artacho et al.[24] concluded that the inclusion of 30-second rest intervals between every two-repetition clusters of the jump squat resulted in greater acute movement velocity. In both of the aforementioned studies, the authors used cluster set configurations with two repetitions. Moreno et al.[25] used a 10-second intra-set rest interval as the present study and Morales-Artacho et al.[24] used a 30-second intra-set rest interval. Independent of the differing methodology, both authors found greater ground reaction force implementing cluster set configurations, increasing not only movement velocity but also the power of the lower limbs. In this way, we might infer that cluster set configurations using two repetitions promote shorter ground contact times, increasing horizontal ground reaction force in the acceleration phase of a sprint (first 10 meters).

As performance in the Sprint test is highly dependent on myosin ATPase activity rate in skeletal muscle fibers and ATP-PC activation rate[28]. Another possible explanation for the improvement in speed from three weeks of CL2 training is the fact of that CL2 had more inertia outputs (15 inertia outputs, compared to CL1 that performed six outputs), increasing the myosin ATPase and consequently promoting the conversion of muscle myosin from its slower forms to the faster ones[27, 28].

Moreover, in the final 10-meters of the sprint test in the present study (also known as the maximum-velocity phase); there were no significant differences in time, velocity, and acceleration between groups. These findings can be explained by the fact that in this phase, the hamstrings muscles present greater isometric action[29], and since the exercises proposed in the training were predominantly dynamic, minimizing the specificity of the muscular action, it was not possible to observe better results in this phase of the test.

The present study also had some limitations such as the non-control of the sports activities performed by the participants during the training weeks, however, the participants were instructed not to start activities beyond those they were performing during the study period, as well as to remain in the activities that they were performing when the study was started, so that there was a standardization of their daily routine during the 3-week training. Participants were also instructed not to perform moderate to vigorous activities 48 hours before the tests. Thus, there was verbal feedback from participants regarding the maintenance of their physical activity routines.

Future investigations be carried out with other configurations of cluster sets, as well as the need for chronic studies with a longer exposure time to the cluster sets method using pneumatic equipment in populations of different training levels.

Cluster set configurations that involved intra-set intervals have as main goal to reduce fatigue and maintain force, velocity, and power output. The present study showed that the cluster configurations, especially structures that use the ATP-PC system (CL2) improved performance in relation to the pre-test measures after three weeks of training with pneumatic equipment. The observed results suggest that the interventions with intra-set intervals using pneumatic equipment may allow for positive adaptations in velocity and acceleration in a short time frame. This would be useful for athletes to institute during different phases of a training cycle to coincide with the competition schedule to result in peak performance at the right time.

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