EFFECT OF EQUATED CONTINUOUS AND INTERVAL RUNNING PROGRAMS ON ENDURANCE PERFORMANCE AND JUMP CAPACITY

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ABSTRACT

Tuimil, JL, Boullosa, DA, Fernández-del-Olmo, MA, and Rodríguez, FA. Effect of equated continuous and interval running programs on endurance performance and jump capacity. *J Strength Cond Res* 25(8): 2205–2211, 2011–We evaluated the effect of 2 different interval and continuous training programs on the maximal aerobic speed (MAS), time limit at MAS (T_{lim}), and on the countermovement jump (CMJ). Twenty-two physically active men were randomly distributed in an interval training group (ITG), continuous training group (CTG), and control group. The CTG and ITG performed 2 different training programs (65–70 and 90–100% of the MAS for CTG and ITG, respectively) that consisted of 3 sessions per week during a period of 8 weeks with an identical external workload (% MAS × duration in minutes). The MAS, the T_{lim} and the CMJ were recorded before and after the running training programs. The data analysis showed a significant and similar improvement ($p < 0.01$) of the MAS for both the ITG (5.8%) and CTG (8.3%). The T_{lim} and CMJ did not change significantly for either group after the training period. Our results indicate that 8 weeks of continuous or interval running programs with externally equated load led to similar improvements in the MAS without changing T_{lim} and CMJ performance in moderately trained nonrunners.

KEY WORDS University of Montreal Track Test, maximum aerobic speed, time limit at maximum aerobic speed, countermovement jump

INTRODUCTION

Continuous and interval running regimens are the most common methods for endurance training. Each method can be described by 2 main parameters: training intensity and volume. When the programmed intensity is moderate (e.g., 50–80% $\dot{V}O_2$max), exercise is maintained without difficulty, and, therefore, it can be performed in a continuous way. On the other hand, during high-intensity exercise (e.g., 90–120% $\dot{V}O_2$max), it is necessary to fractionate the distance (i.e., interval training) so that a sufficient training volume can be performed (18).

Previously, various studies (1,6,11,17,21,22,31) have been carried out to determine the influence that both continuous and interval training methods have on endurance performance limiting factors. In most studies, no significant differences were observed between both methods in $\dot{V}O_2$max, ventilatory threshold, lactate threshold, maximal work capacity, performance, and O_2 kinetics. However, some studies found significant increases in $\dot{V}O_2$max, ventilatory threshold, O_2 kinetics, and lactate removal ability after a period of interval training compared to the continuous method (4,14,19,21,33,37). Regarding these contradictory findings, it may be suggested that the exercising intensity and the subjects' training background influence subsequent endurance training adaptations (25,27), although some of these studies were performed without matching workloads for appropriate comparisons. Therefore, the confounding results obtained generate doubts for the application of these findings to the running training on the field. Nowadays, it is very common that physically active subjects start to take part in recreational running programs. In this regard, it may be interesting to know the effectiveness of different running programs because it is very common for these recreational runners to have few sessions for training per week. Therefore, it could be important to know the different effects of these 2 training modes for preparing for activities requiring good levels of aerobic power on active individuals who are not experienced in running training on the field.

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With regard to field running performance, the maximum aerobic speed (MAS), defined as the minimum speed at which $\dot{V}O_2$max is obtained (8), is one of the most relevant parameters for both determining aerobic power and prescribing training programs for individuals of different level and training background (8,15,23,26,30). This parameter is correlated to performance in endurance running (8,26,30), because other parameters such as $\dot{V}O_2$max, running economy, or anaerobic threshold seem to influence it (10,23,26). Another related parameter is the exhaustion time at maximal aerobic speed (MAS, T_{lim}) (9). T_{lim} is useful for predicting performance in endurance tests (5,9,24) and can also be related to an improvement in the lactic anaerobic capacity (7). Consequently, these 2 parameters (MAS and T_{lim} at MAS) could be considered appropriate for the evaluation and prescription of endurance running training on the field.

Besides, those studies describing the physiological adaptations after endurance training programs did not provide any information regarding power performance. Indeed, the "interference phenomenon" between endurance and strength training has been well documented (16), meaning that the adaptations (e.g., fiber type recruitment) derived from strength or endurance regimens are antagonistic. Hence, a detrimental effect of endurance training on power performance, such as the vertical jump, could be expected (32). Although some studies reported a maintenance or an improvement of jump capacity when endurance and strength training were performed simultaneously (20,38), there are no studies to our knowledge that reported the effect of an endurance training program on jump capacity in physically active subjects. Consequently, it is necessary to study the effect on jump capacity of both continuous and interval endurance training regimes because the impact of aerobic training on muscular characteristics is also dependent upon exercising intensity (16,27).

Thus, this study was designed to investigate changes in MAS, T_{lim} at MAS, and jump capacity after 8 weeks of equated continuous and interval running programs in physically active subjects. We hypothesized a similar effect of both training methods on running (MAS and T_{lim} at MAS) and jump performance (countermovement jump [CMJ]).

METHODS

Experimental Approach to the Problem

A group of physically active subjects were randomly assigned into 3 groups: control group (CG), continuous training group (CTG), and interval training group (ITG). The experiment consisted of 2 different endurance running programs (continuous vs. interval) with the same external workload (% MAS × duration) during an 8-week period. Before, in the middle, and after this 8-week period, the subjects were evaluated in running performance (University de Montréal Track test and time limit at MAS) with assessment of jump capacity only in the pre and postevaluations. The changes in endurance (MAS and T_{lim} at MAS) and jump performance (CMJ) parameters (dependent variables) were evaluated for every group considered (independent variables).

Subjects

We recruited 22 male physical education students (age 20 ± 1 years; weight: 71 ± 6 kg; height: 174 ± 6 cm; body fat: 9.2 ± 1%) for participating in this study. We asked subjects to report their current level of physical activity on a scale of 0–10 (0 indicating no physical activity and 10 indicating vigorous exercise daily for at least 60 minutes), and all the subjects reported physical activity between 7 and 10 points. None of them had previous experience in endurance running. Also, the experimental groups did not take part in other training programs during the course of the experiment, whereas controls were advised to maintain their habitual physical activity. They were also advised not to change their nutritional or hydration habits. The Local Ethics Committee approved of this study design, and all the subjects gave their informed written consent before participation.

Procedures

The experiment was conducted during the months of April and May (i.e., Spring). The subjects took part in 3 testing sessions: a first session (S1) before starting the training program; a second session (S2) half way through the training program; and a third session (S3) after the completion of the training program. In each session, the subjects performed first the Université de Montréal Track Test (UMTT), and 24 hours later the time limit at the MAS determined during the UMTT. In S1 and S3, the CMJ test was also performed. All the testing and training sessions were performed at the same hour of the day to avoid any influence of circadian rhythms.

Université de Montréal Track Test

The UMTT (28) is a progressive test developed in an athletic track (400 m). The initial velocity is 7 $km \cdot h^{-1}$with increments of 1 $km \cdot h^{-1}$ every 2 minutes until the subject cannot maintain the velocity of a follow-up cyclist with a calibrated speedometer (MT200, Cateye, Osaka, Japan) (13). The velocity reached and maintained in the last complete 2-minute period is the one considered as the MAS with recording of the total final time (T_{UMTT}). The MAS obtained with the UMTT has been previously reported to be valid and reproducible on different populations (8). The test was taken simultaneously by a group of 5 runners each time. Every runner was supervised by one research assistant with a chronometer. The cyclist was informed about the accumulated distance at intervals of 1 minute in order to confirm rhythm and the progression indicated by the protocol. All subjects were encouraged to reach their maximal level of effort during the test.

Time limit at Maximal Aerobic Speed

The time limit at the minimum speed that elicited $\dot{V}O_2$max (T_{lim}) can be performed on a treadmill (7,9,10,24) or on a track with a follow-up cyclist (13) with high values reported for validity and reproducibility (8). In our study, the following

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Table 1. Summary of the running training program for the interval group.*†

Week	Monday	Wednesday	Friday
1	4 × 2 min (1:1) (100: 50% MAS)	3 × 3 min (1:1) (95: 45% MAS)	2 × 4 min (1:1) (90: 40% MAS)
2	5 × 2 min (1:1) (100: 50% MAS)	3 × 3 min (1:1) (95: 45% MAS)	3 × 4 min (1:1) (90: 40% MAS)
3	5 × 2 min (1:1) (100: 50% MAS)	4 × 3 min (1:1) (95: 45% MAS)	4 × 4 min (1:1) (90: 40% MAS)
4	4 × 2 min (1:1) (100: 50% MAS)	3 × 3 min (1:1) (95: 45% MAS)	2 × 4 min (1:1) (90: 40% MAS)
5	5 × 2 min (1:1) (100: 50% MAS)	4 × 3 min (1:1) (95: 45% MAS)	4 × 4 min (1:1) (90: 40% MAS)
6	6 × 2 min (1:1) (100: 50% MAS)	5 × 3 min (1:1) (95: 45% MAS)	4 × 4 min (1:1) (90: 40% MAS)
7	7 × 2 min (1:1) (100: 50% MAS)	5 × 3 min (1:1) (95: 45% MAS)	5 × 4 min (1:1) (90: 40% MAS)
8	5 × 2 min (1:1) (100: 50% MAS)	3 × 3 min (1:1) (95: 45% MAS)	3 × 4 min (1:1) (90: 40% MAS)

*MAS = maximal aerobic speed.

†For example, the session on the Monday of the first week means: The 4 × 2 minutes indicates 4 bouts of 2 minutes of training running plus 2 minutes of recovery running; the 1:1 index indicates equal duration for the training and recovery running bouts and 100:50% MAS the intensity for the training and recovery running bouts, respectively.

protocol was applied: The subject waited at a specific spot of the track while the cyclist performed a warm-up lap (400 m) to gather the individual speed corresponding to the MAS previously obtained by the subject in the UMTT. When the cyclist reached the subject, the subject started to follow the cyclist. At that moment, the speedometer was started, and, when the runner could not maintain the required speed, it was stopped. Besides the direct reading of the speedometer, the distance cycled was controlled at intervals of 1 minute, in the same way as for the MAS. For each subject, there was a researcher who measured the time to exhaustion of their individual MAS.

Countermovement Jump

The CMJ is a common and valid method for measuring the performance in explosive actions (12). Subjects were instructed to start the CMJ in an upright position with their arms akimbo. The angular displacement of the knee was standardized so that the subjects were required to bend their knees to approximately 90°. Jump height was recorded on a capacitative platform (12) connected to a digital timer with an accuracy of +0.001 seconds (Ergojump, Psion XP, MA.GI.CA., Rome, Italy).

Training Programs

After the S1 session, the subjects were randomly assigned to 1 of the 3 training groups: ITG ($n = 7$), CTG ($n = 7$), and CG ($n = 8$). During the time of the experiment, only 2 subjects of the CTG dropped out because of injuries not related to the study. The training programs for the ITG and CTG groups consisted of 24 sessions distributed over 8 weeks (3 sessions per week). The CG only participated in the testing sessions. The CTG group performed a single running bout in each training session, whereas the ITG group performed several bouts in accordance with the training program.

These training programs were designed based on the classical recommendations of Åstrand and Rodahl (3). The external load of both methods was the same for each training session and for all weeks, keeping the same criteria for the 2 methods in terms of gradual increase in effort and supercompensation. Tables 1 and 2 show the load evolution throughout the 2 mesocycles making up the 8-week training

Table 2. Summary of the running training program for the continuous group.*

Week	Monday	Wednesday	Friday
1	16 min (75% MAS)	18 min (70% MAS)	16 min (65% MAS)
2	20 min (75% MAS)	18 min (70% MAS)	24 min (65% MAS)
3	20 min (75% MAS)	24 min (70% MAS)	32 min (65% MAS)
4	16 min (75% MAS)	18 min (70% MAS)	16 min (65% MAS)
5	20 min (75% MAS)	24 min (70% MAS)	32 min (65% MAS)
6	24 min (75% MAS)	30 min (70% MAS	32 min (65% MAS)
7	28 min (75% MAS)	30 min (70% MAS)	40 min (65% MAS)
8	20 min (75% MAS)	18 min (70% MAS)	24 min (65% MAS)

*MAS = maximal aerobic speed.

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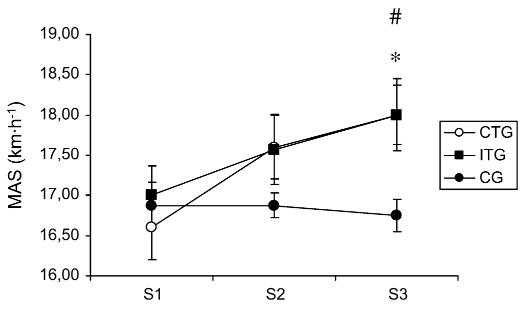

# $p<0.01$ (ITG vs CG)

* $p<0.05$ (CTG vs CG)

Figure 1. Mean and *SEM* for the MAS across the sessions test for each group. The analysis showed a significant main effect for the Group factor ($F = 28.1$, $p < 0.01$) and the interaction Group × Test session ($F = 9.35$, $p < 0.01$). Post hoc analysis shows significant differences between CG vs. ITG and CG vs. CTG for S3 session ($t = 3.71$, $p < 0.01$ and $t = 2.62$, $p < 0.05$, respectively).

period. The load rate was obtained by multiplying volume (time in minutes) by intensity (%MAS) based on the previous proposal by Overend et al. (31), who stated that the workload of an interval session could be equated to that of a continuous session if the work-to-rest ratio is 1:1. Thus, the mean intensity of an interval session is equal to the sum of both work and active recovery intensities divided by 2. Subsequently, the product of the volume and the intensity of an interval session should be equated to the product of the volume and the intensity of a continuous session.

Statistical Analyses

Repeated-measure analysis of variance (ANOVA) over the MAS was performed with an intrasubject main factor of *Test session* (S1, S2, and S3) and an intersubject factor of *Group* (ITG, CTG, and CG). To know the changes in the MAS in each training group across the test sessions, a separate repeated-measures ANOVA was performed with only Test session as main factor. Post hoc *t*-tests were computed using a Bonferroni correction. *T*-tests were carried out for the T_{lim} and CMJ. None of the data violated the normality assumption necessary to conduct parametric statistical tests. Cohen's *D* was calculated for the assessment of the effect size when appropriate.

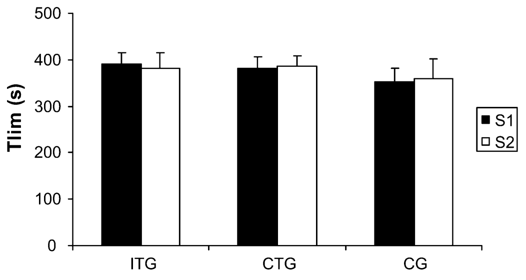

Figure 2. Mean and *SEM* for the T_{lim} for each group before and after the training program. No significant differences were found between groups nor between sessions.

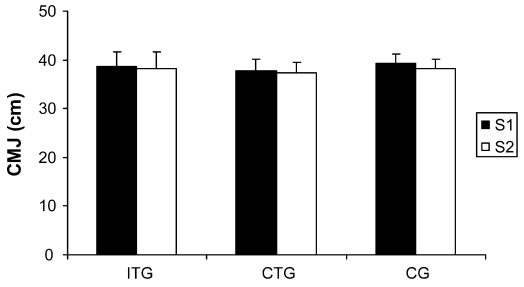

Figure 3. Mean and *SEM* for the countermovement jump (CMJ) for each group before and after the training program. No significant differences were found between groups nor between sessions.

RESULTS

The ANOVA for the MAS (Figure 1) showed a significant effect for the *Test session* ($F = 28.1$, $p < 0.01$) and significant interaction *Test session* × *Group* ($F = 9.35$, $p < 0.01$). Post hoc analysis showed no significant differences between groups for S1 and S2; and differences for S3 between ITG vs. CG ($t = 3.71$, $p < 0.01$) and CTG vs. CG ($t = 2.62$, $p < 0.05$). No differences were found between ITG vs. CTG in any testing session.

The repeated-measures ANOVA showed a significant main effect for the *Test session* for ITG ($F = 12.06$, $p < 0.01$) and CTG ($F = 47.97$, $p < 0.01$). Post hoc analysis showed that the MAS in the ITG group increased significantly between S1 and S2 ($t = 2.93$, $p < 0.05$); S1 and S3 ($t = 4.26$, $p < 0.01$); and S2 and S3 ($t = 2.38$, $p < 0.05$). Similar results were found for

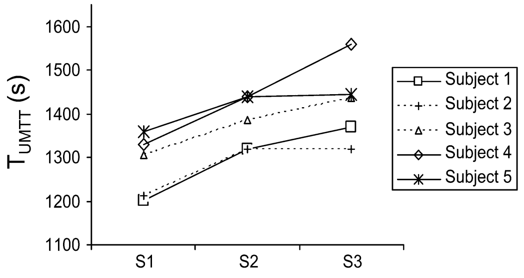

Figure 4. Individual responses for the continuous training group (CTG) before and after the training period. T_{UMTT} = final time in the Université de Montréal Track Test. Note that 1,200 seconds correspond to a maximum aerobic speed (MAS) of 16 km·h^{-1}. Every 120 seconds completed the MAS is 1 km·h^{-1} higher. All the subjects improved their MAS.

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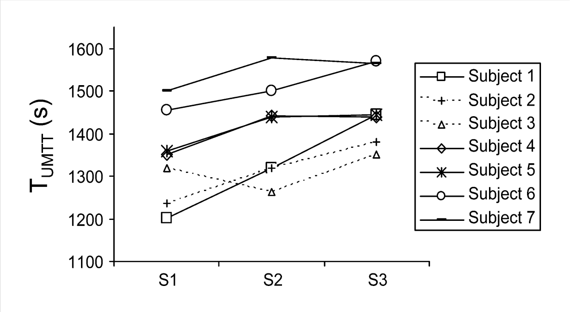

Figure 5. Individual responses for the interval training group (ITG) before and after the training period. T_{UMTT} = final time in the Université de Montréal Track Test. Note that 1,200 seconds correspond to a maximum aerobic speed (MAS) of 16 km·h^{-1}. Every 120 seconds completed the MAS is 1 km·h^{-1} higher. Only subject 3 did not experience any improvement in MAS after the training regimen.

the CTG group: S1–S2 ($t = 14.68, p < 0.01$); S1–S3 ($t = 7.89, p < 0.01$); and S2–S3 ($t = 9.65, p < 0.05$).

No changes were found for the T_{lim} between groups before or after the training program nor between S1 and S2 (Figure 2). Regarding the vertical jump, no change between groups or between S1 and S2 was found (Figure 3).

Individual T_{UMTT} records for CTG (Figure 4) and ITG (Figure 5) are also shown for a detailed analysis after both training regimens.

DISCUSSION

The main results in our study show that during the period of 8 weeks of endurance training, both interval and continuous training regimes were equally effective in improving the MAS. Also, posttraining, T_{lim} at MAS was similar to pretraining T_{lim}, regardless of the training method employed. In addition, these 2 running programs led to a maintenance of the jump capacity. Consequently, the 2 equated training programs showed a similar influence on endurance and jump performances.

The improvement of the MAS reported in our study was not significantly different ($p > 0.05$) for both continuous (8.3%) and interval methods (5.8%). These results are in agreement with those of previous studies with similar samples and training protocols (6,22) but in contrast with other studies (4,11,19,21,33,35,37), which have shown better results in favor of 1 method. However, it is difficult to compare our results with others because different methodologies were used. For example, Gorostiaga et al. (21) only found significant increases in the $\dot{V}O_2$max and in the maximal work capacity after the interval method, but the low intensity (50% of the maximal work capacity) used for the continuous group in this study could explain the discrepancy with our results. Another recent study (19) described a higher increment of MAS after the interval compared to the continuous training method (15.1% vs. 10.3%), but the subjects of this study trained 6 d·wk^{-1} during a period of 6 weeks, which is fairly beyond the absolute workload of this study. Further, the initial MAS of the subjects of this previous study (19) was lower than our subjects' MAS (15.2 vs. 16.8 km·h^{-1}), demonstrating a lower absolute postraining MAS (17 vs. 18 km·h^{-1}). This consideration is interesting given that the training background of the subjects could be another influencing factor. Comparing this and the previous study (17), it may be suggested that the lower effectiveness of the previous training regime in less fit subjects may be reflecting an overreaching that induced a lowered response to training in the subjects of the study. Consequently, although comparisons among studies seem difficult because they could be systematically biased by different factors like training background or the absolute workload of every training regimen employed, it may be suggested that a similar mean improvement in MAS could be expected for both methods when the external workload is equated in physically active nonrunners. Thus, these findings could be interesting for those recreational athletes that decide to start a running program for the first time, with only 3 sessions per week.

Interestingly, the continuous method was more effective in this study for MAS improvement in S2 if compared with interval method (6 vs. 3.3%), although this difference did not achieve statistical significance ($p > 0.05$; Cohen's $D = 1.12$). This consideration may be important for those active individuals who need a rapid improvement in endurance running performance within a 4-week period (e.g., team sports preseason) (38). Thus, it may be suggested that 3 d·wk^{-1} during 4 weeks (12 sessions) seems to be a sufficient stimulus for a fast improvement (6%) in MAS for active individuals. Furthermore, if we have a look at individual responses of both regimes (Figures 4 and 5), it seems that the continuous method is more effective considering that some subjects had lower or absence of MAS improvement (subject 3) in the interval group. This observation may be interesting regarding the specificity of the training regimes in the sense that, paradoxically, the submaximal workload seemed more effective from a dose–response perspective than the more specific interval series performed at $\dot{V}O_2$max levels. In this regard, the low running experience of our subjects could be an important factor, suggesting a lower tolerance for higher intensities in those subjects of a similar level or training background. Further studies are needed for comparison of the current training regimes in higher trained athletes for testing the influence of the level in MAS improvements in the subjects of the study.

Regarding the physiological impact of the current training regimes, some characteristics of the interval running workload, such as intensity and interval duration, may be relevant because they could influence oxygen kinetics and, hence, the time spent at $\dot{V}O_2$max, which has been proposed as an important factor for the effectiveness of the interval method (29). Although we matched the workload of both training methods by the external parameters (i.e., velocity and duration), further studies are needed to assess the influence of the internal workload (e.g., oxygen kinetics) on

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running bouts and subsequent performance. Previously, Eddy et al. (17) and Overend et al. (31) reported that when the external load is equivalent between methods, their effect over the MAS is similar, whereas others reported differences between methods for cycling exercising when load was matched by mechanical work (14,21). Consequently, one may speculate about a different physiological impact of externally equated workloads depending upon exercising mode (cycloergometer vs. running). It should be pointed out that although we did not measure $\dot{V}O_2$max, MAS is the most important parameter to evaluate running performance (8,10). Moreover, because the MAS is influenced by other factors such as running economy and anaerobic threshold (7,8,26), it could be considered that an increase in the MAS could not be accompanied solely by an increase in the $\dot{V}O_2$max. Indeed, although the same training effect on MAS was observed after both training regimens, it may be speculated that the improvements recorded on this parameter could have a different physiological origin for either training method. Consequently, future studies using the present training protocols must be carried out to explore the physiological impact (e.g., $\dot{V}O_2$max, running economy) of both training methods. Further, if we consider the achievement of different physiological adaptations throughout every training method, but with the same influence on performance, the mixture of both methods may be taken into account in future studies when looking for the sum of the potentially different benefits of every training regime (e.g., 2 sessions of the continuous method interspersed with 1 session of interval training per week).

Regarding the T_{lim} at the new MAS, no changes were reported between the 2 experimental groups or between sessions although it may be considered that the same T_{lim} performance at an enhanced MAS means that the subjects were able to run longer in the same time. The absence of significant differences between both methods is surprising because we would expect a better capacity of maintaining the MAS for the interval group based on the greater dependence of the T_{lim} on the anaerobic capacity (9,22). To our knowledge, there is no previous information about the effects of training on the T_{lim} at MAS, but based on our results, it seems that this parameter has low trainability. Another explanation is related to the intensities selected for the interval training since other studies reported significant improvements on anaerobic capacity after higher training intensities (34,36). More studies must be carried out to know this interesting parameter in more detail, taking into account the influence on T_{lim} of higher running intensities during interval training. Nevertheless, because the same T_{lim} performance but with a higher new MAS allows subjects to cover more distance in the same time, it may be suggested that there is a positive effect of both training regimes in subsequent running performance.

Another interesting finding was the maintenance of vertical jump performance after both training programs. This finding suggests that these endurance training regimes did not interfere with the vertical jump capacity of physically active nonrunners regardless of training intensity (16). Previously, Glowacki et al. (20) reported no changes in the vertical jump after 12 weeks of continuous running training (65–80% heart rate reserve) in untrained men. Although in our study the subjects did not demonstrate any change in body composition, the subjects of the study of Glowacki et al. (20) experienced a significant body weight loss after training (−1.2%) that could counteract a jump capacity loss. Therefore, it may be suggested that the current regimes are equally effective for the improvement of endurance performance without changes in power capacity for active subjects. Indeed, considering the pronounced negative effect of interval training intensities for the "interference phenomenon" between strength and endurance training (16), it may be considered that the continuous training regime could be most appropriate method for concurrent jump and endurance performance improvements. Consequently, when the maintenance of jump capacity could be interesting depending upon the initial level of the subjects and their future physical requirements, it may be suggested that both methods could be appropriate.

In summary, our results show that 8 weeks of continuous or interval training methods with equated external workload result in similar improvement in the MAS without affecting the time in which the new aerobic velocity is maintained nor the capacity to perform vertical jump.

PRACTICAL APPLICATIONS

From the current results, it may be suggested that 3 $\text{d}\cdot\text{wk}^{-1}$ of a continuous and an interval running programs with similar external workload are equally effective to improve MAS with the maintenance of the T_{lim} and jump capacity in physically active nonrunners . Thus, the described training programs are interchangeable if coaches would like to focus primarily on MAS improvements during an 8-week period although a trend for a better response in the CTG could suggest a better tolerance of this workload on this population. These findings could be useful for those novice recreational athletes who decide to prepare for a short race with limited amount of time for training.

When a rapid improvement is needed during a shorter training period (e.g., 4 weeks), it seems that the continuous mode is more effective, pointing out that only 3 sessions per week are a sufficient stimulus for such an improvement. Regarding the T_{lim} at MAS, a similar performance after the training period may be expected but with a new higher MAS, allowing athletes to cover more distance in the same time. Subsequently, it may be suggested that this approach is more appropriate for those athletes that require similar $\dot{V}O_2$max levels (2), specifically in a short period of time (38).

Regarding the absence of changes in vertical jump performance, it may be suggested that there are benefits of a concurrent power training program in those athletes needing the enhancement of both capacities because the

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expected negative influence of endurance training on explosiveness was not observed in our study. Specifically, taking into consideration a previously proposed model (16) for the "interference phenomenon" observed between concurrent strength and endurance training that stated a pronounced negative influence for intensities near to $\dot{V}O_2$max levels if compared with submaximal workloads, it would be suggested that there is a higher benefit when continuous and power training regimens are performed.

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