

High-Intensity Interval Training with Cycling and Calisthenics: Effects on Aerobic Endurance, Critical Power, Sprint and Maximal Strength Performance in Sedentary Males

Entrenamiento Interválico de Alta Intensidad con Ciclismo y Calistenia: Efectos sobre la Resistencia Aeróbica, la Potencia Crítica, el Sprint y el Rendimiento de Fuerza Máxima en Hombres Sedentarios

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Abstract. TABATA protocol is considered to be one of the most effective strategies among high-intensity interval training (HIIT) methods. A limited number of studies have compared the chronic effects of cycling-based and calisthenic HIIT in TABATA-type. The aim of this study was to compare the chronic effects of a 8-week TABATA-type calisthenic high-intensity interval and high-intensity interval in cycling on aerobic endurance, sprint and maximal strength performance in sedentary men. 17 sedentary males participated in our study. Participants were randomly divided into calisthenic HIIT (n=9) and cycling HIIT (n=8) groups. Training groups were given 3-sessions of exercise per week on non-consecutive days for 8 weeks. Before and after the 8-week training, the body mass, body mass index, fat percentage, 30-m sprint, 1-repetition maximal strength, aerobic power and critical power levels of the participants were determined. No statistically significant different was observed in body mass ($p=0.917$), body mass index ($p=0.928$), and body fat ratio ($p=0.980$) in both training groups. However, both training groups achieved statistically significant improvements in peak power output ($p=0.017$), maximal oxygen consumption ($p=0.040$) and critical power ($p=0.048$), and there was no significant difference in the level of improvement between the groups ($p>0.05$). There was no statistically significant difference in 1 repetition maximal strength and sprint values of both training groups ($p<0.05$). TABATA type HIIT performed calisthenic provides chronic effects similar to that of interval cycling form.

Keywords: Aerobic capacity, calisthenic, critical power, high-intensity interval, TABATA.

Resumen. El protocolo TABATA se considera una de las estrategias más efectivas entre los métodos de entrenamiento de intervalos de alta intensidad (HIIT). Un número limitado de estudios ha comparado los efectos crónicos del HIIT calisténico y basado en ciclismo en el tipo TABATA. El objetivo de este estudio fue comparar los efectos crónicos de un intervalo calisténico de alta intensidad tipo TABATA de 8 semanas y un intervalo de alta intensidad en ciclismo sobre la resistencia aeróbica, el sprint y el rendimiento de fuerza máxima en hombres sedentarios. 17 hombres sedentarios participaron en nuestro estudio. Los participantes se dividieron aleatoriamente en grupos de HIIT de calistenia (n=9) y HIIT de ciclismo (n=8). Los grupos de entrenamiento recibieron 3 sesiones de ejercicio por semana en días no consecutivos durante 8 semanas. Antes y después del entrenamiento de 8 semanas, se determinaron los niveles de masa corporal, índice de masa corporal, porcentaje de grasa, sprint de 30 m, fuerza máxima de 1 repetición, potencia aeróbica y potencia crítica de los participantes. No se observaron diferencias estadísticamente significativas en la masa corporal ($p=0,917$), el índice de masa corporal ($p=0,928$) y el índice de grasa corporal ($p=0,980$) en ambos grupos de entrenamiento. Sin embargo, ambos grupos de entrenamiento lograron mejoras estadísticamente significativas en la producción de potencia máxima ($p=0,017$), el consumo máximo de oxígeno ($p=0,040$) y la potencia crítica ($p=0,048$), y no hubo diferencias significativas en el nivel de mejora entre los grupos. ($p>0,05$). No hubo diferencias estadísticamente significativas en los valores de fuerza máxima y sprint de 1 repetición de ambos grupos de entrenamiento ($p<0.05$). El HIIT tipo TABATA realizado calisténico proporciona efectos crónicos similares a los de la forma de ciclismo por intervalos.

Palabras clave: Capacidad aeróbica, calistenia, potencia crítica, intervalo de alta intensidad, TABATA.

Introduction

Regular physical activity and exercise are necessary to prevent cardiovascular diseases caused by a sedentary lifestyle and to increase comfort of life (Fealy et al., 2018). Regardless of age, gender, socioeconomic status

or ethnicity, it is observed that the most common obstacle against participation in regular exercise a lack of time (Korkiakangas et al., 2009). High-intensity interval training is utilized as an effective exercise strategy that can provide rapid development in cardiovascular fitness levels. High-intensity interval training is a training model that is applied with brief recovery intervals between sets of maximal or supramaximal intensity (Suarez-

Manzano et al., 2021). Although it is commonly used by performance athletes, its use among sedentary and recreationally active individuals has also been becoming widespread as it provides effective development in a short period of time. There are strong findings indicating that high-intensity interval training, which has been attracting significant interest from researchers in recent years, provides similar and even more effective cardiovascular and metabolic adaptation gain compared to the long-lasting, traditional constant-load training method (Gist et al., 2014).

Tabata et al. (1996) revealed that a HIIT exercise with 10-second rest intervals between 20 seconds of pedaling with maximal effort provided higher gains in terms of both aerobic and anaerobic power compared to the traditional constant-load training method (60 minutes, 70% of the VO_{2max} intensity). Compared to the traditional constant-load endurance training method, which lasts approximately 40-60 minutes, HIIT can be regarded as an important factor for participation in exercise in terms of providing time efficiency. The TABATA protocol is regarded as one of the most effective strategies among HIIT methods. Despite involving higher-intensity effort compared to other HIIT methods, this method stands out among similar HIIT approaches in terms of time efficiency. The method involves 10-second rest intervals between 8 high-intensity sets lasting 20 seconds. Although the TABATA protocol originally focused on cycling, it was later adapted to different types of exercises such as running and rowing, as well (Buckley et al., 2015).

Although the TABATA protocol, which has been in use since 1996, can be easily applied to calisthenics exercises, it has been attracting attention as a study subject only in the last ten years. Calisthenics high-intensity interval training consists of various calisthenic movements and exercises applied with high intensity (Haddock et al., 2016). Among the important advantages of this type of training is that it requires no to minimal equipment, and can be performed in a narrow space regardless of location (Gist et al., 2015). Therefore, with the COVID-19 pandemic, high-intensity interval training performed with one's own body weight has been attracting attention. While high-intensity interval training provides adaptations related to the aerobic system, the TABATA calisthenics high-intensity interval training is beneficial in terms of the adaptations provided by both aerobic and endurance training (Feito et al., 2018).

The TABATA calisthenics high-intensity interval training is known to provide similar levels of aerobic endurance development with traditional endurance

exercise, with an added benefit on muscular performance (Buckley et al., 2015; McRae et al., 2012). In the study conducted by McRae et al., comparing TABATA calisthenics high-intensity interval training (4 minutes of calisthenics training, 4 sessions per week) with moderate-intensity continuous running (treadmill exercise for 30 minutes, 4 sessions per week) over 4 weeks, similar improvements were observed in maximal oxygen consumption levels. In addition, improvement was achieved on muscular endurance in the TABATA calisthenics high-intensity interval training group. Comparing TABATA HIIT (involving running) and calisthenics HIIT programs in moderately trained individuals, Menz et al. (2020) reported that both training methods improved maximal oxygen consumption and muscular performance at similar levels.

As far as known, there are only two studies in the literature comparing the chronic effects of traditional HIIT and calisthenics HIIT. Therefore, the present study will contribute to the literature in this respect. The present study aims to compare the effects of an 8-week TABATA high-intensity interval training with cycling and calisthenics on aerobic endurance, sprint and maximal strength performance in sedentary males.

Material and method

Participants

Participants in the study were contacted via online advertisement. Because sedentary behavior was defined as a MET <2.0 (e.g. equivalent to sitting or lying down) (Salmon et al., 2003), participants with a daily energy expenditure of less than 2.0 MET were accepted into the study. After the participants were informed verbally regarding the experimental phases and risks of the present study, written informed voluntary consent forms were distributed. The participants signing this form were included in the study. The present study was approved by xxx University Ethics Committee and carried out in accordance with the Declaration of Helsinki. 23 sedentary males participated in the study. As 4 participants contacted COVID-19 patients and 2 others had reservations due to the pandemic, the study was completed with 17 individuals. Participants were asked not to participate in any exercise during the study. Also, none of the participants were taking any medications or nutritional supplements.

Data Collection Tools

Cycling tests and exercises were applied using an Emotion Fitness (Motion Cycle 600 Med Emotion Fitness GmbH, Hochspeyer, Germany) electromagnetic-

resistance bicycle ergometer. Respiratory responses during the tests were monitored using a PNOE (ENDO Medical, Palo Alto, CA) respiratory gas analyzer and heart rates were monitored using a Polar (Polar RS 400, Polar Electro Oy, Kempele, Finland) telemetric heart rate monitor device. The participants' one-repetition maximum strength values for different muscle groups were measured using isolation fitness machines and free weights (Ergoline Fitness, Turkey). Anthropometric measurements were performed using a Tanita body composition monitor (Tanita SC-240) and times of finishing 30 meters were determined using a laser timing gate system (Smart Speed, PT, Fusion Sport, Germany).

Experimental Design

The present study was designed as a randomized-controlled training study involving two different training groups (cycling and calisthenics) and two measurement times (initial and post-training). The participants were instructed to abstain from heavy exercise and alcohol 24 hours prior to the initial and post-training measurements, and to be fully hydrated on test days. The participants were randomly divided into two groups as Cycling High-Intensity Interval Training (C-HIIT) (n=8) and Calisthenics High-Intensity Interval Training (CS-HIIT) (n=9). Both high-intensity interval training programs were designed using a model involving 10-second rest intervals between 8 sets of high-intensity exercise for 20 seconds. 3 sessions of exercise per week were applied to the training groups on non-consecutive days for 8 weeks (Monday, Wednesday and Friday). The participants performed one of the two interval models with 2 sets in the first 4 weeks and 3 sets in the last 4 weeks. One-minute breaks were given between sets. The 30m sprint, one-repetition maximum strength, aerobic power and critical power levels of the participants before and after the 8-week training program were determined. Following the anthropometric measurements of the participants, 30-meter sprint tests were performed on the first test day and leg extension, leg curl, bench press and half squat one-repetition maximum values were recorded on the second test day. On the third test day, a test with gradually increasing workload was applied. The highest oxygen consumption value in the said test and the corresponding power output were obtained. On the fourth and fifth test days, at 85%, 95%, 100% and 110% of the peak power output (PPO) obtained from the incremental test, the participants were subjected to exhausting tests with constant workload with two tests per day. The tests applied on these five days were also applied before and after the 8-week program. The data obtained from these tests were fitted to a non-linear

2-parameter model, and critical power levels were obtained.

Training Groups

Cycling High-Intensity Interval Training (C-HIIT)

In our research, unpublished pilot studies revealed that the highest exercise intensity should be approximately 120% of PPO to be able to pedal 8 times for 20 seconds with 10 seconds of rest. Therefore, exercise intensity corresponding to 170% of the PPO used in the original publication (Tabata et al., 1996) was not used in our study. TABATA high-intensity interval training with 10-second rest intervals between 8 sets of high-intensity exercise for 20 seconds at 120% of the PPO on the bicycle ergometer was applied to the participants for 8 weeks. During the high-intensity periods, the participants were asked to keep the cycling cadence (rpm) at 90 ± 5 . Passive recovery was applied between the high-intensity periods. The C-HIIT sets were performed with 1-minute intervals. In order to monitor the potential improvements at the end of the 4th week of the training period and optimize C-HIIT intensity, the PPO was re-determined using the progressive test.

Calisthenics High-Intensity Interval Training (CS-HIIT)

In this interval model, the participants performed each movement consisting of 4 different body weights (squat, burpee, mountain climber and glute bridge, respectively) 2 times consecutively, and completed 8 sets of 20-second exercise at maximum effort with 10-second rest intervals. Since the other participant group pedaled on the bicycle ergometer based on the tabata model, it was paid attention that the calisthenic exercises were aimed at the large muscle groups in the lower extremities. Passive recovery was applied between the high-intensity periods. The CS-HIIT sets were performed with 1-minute intervals.

Measurements

Anthropometric Measurements

The body mass and body fat index of the participants were determined using a laboratory-type body composition monitor (Tanita SC-240).

Sprint Tests

30-meter sprint measurements were performed with 2 repetitions and 2-minutes rest intervals in between (Cin et al., 2021). The faster repetition between the two was accepted as the participant's 30-meter sprint performance. The sprint tests were performed in an indoor hall

and 30m sprint times were determined using a laser timing gate system.

Maximum Strength Measurements

The participants were subjected to one-repetition maximum (RM) strength tests for a total of four movements involving leg extension, leg curl, bench press and half squat. While the 1 RM strength for both right and left leg extension and curl was measured using an isolation fitness machine, the 1 RM strength for bench press and half squat was measured using free weights.

After the participants performed their routine warm-up exercises, they completed the warm-up with 5-10 sets of light weights. The weights that the participants were able to lift for 2-3 sets were prepared, and the participants were asked to lift them. The application was continued after the participants could not lift a load of 1 RM anymore (Haff & Triplett, 2016). 2-minute rest intervals were given between each set.

Peak Power Output Obtained from the Incremental Test

The peak oxygen consumption levels of the participants and the corresponding power output levels (watts) were determined using the test in which the workload was increased until voluntary muscle exhaustion was reached. The progressive test consisted of gradual periods of 2 minutes. The first level was initiated at a workload of 50 watts and the workload of each level was increased by 25 watts until the participants were exhausted. Therefore, the workload reached in the last level was regarded as the peak power output (PPO).

Determination of Critical Power

The time of fatigue and power output data obtained from the exhausting tests applied at 85%, 95%, 100% and 110% of the PPO were fitted to a non-linear 2-parameter model and critical power values were obtained. The equation of the non-linear 2-parameter model is shown below.

(1) Non-linear 2-parameter model

$$Time = W / (Power - CP) \quad (\text{Moritani et al., 1981})$$

Determination of the Individual O_{2max} Values of the Participants

The highest 30-second mean VO_2 value obtained for the incremental test and at 85%, 95%, 100% and 110% of the PPO of each participant was recorded. Then, the arithmetic mean of the highest O_2 values obtained from the tests performed the incremental test and at 85%, 95%, 100% and 110% of the PPO of each participant was regarded as O_{2max} . The highest 30-second mean value of VO_2 obtained from the ramp incremental test was recorded.

Statistical Analysis

In order to determine whether the data are normally distributed, the Shapiro-Wilk normality test was performed. The significant differences between the 2 groups were evaluated using 2×2 repeated measures ANOVA. A significance level of ≤ 0.05 was regarded as the level of statistical significance. All statistical analyses were performed using a statistical package program (SPSS version 16.0; SPSS, Chicago, III., USA).

Results

Tables 1, 2 and 3 show the findings of the present study in order and detail. When Table 1 is examined, it is observed that at the end of 8 weeks, no statistically significant change occurred compared to the pre-tests in either training group in terms of body mass ($p=0.917$), body mass index ($p=0.928$) and body fat index ($p=0.980$).

Table 1:

Body mass, body mass index and body fat index pre-test and post-test data for both training groups

| Variable | Pre-test | Post-test |
|------------------------|-------------|-------------|
| <i>Body Mass (kg)</i> | | |
| Calisthenics | 79.93±13.48 | 79.27±12.35 |
| TABATA | 85.35±16.12 | 84.96±16.09 |
| <i>Body Mass Index</i> | | |
| Calisthenics | 25.77±4.93 | 25.56±4.45 |
| TABATA | 27.90±6.40 | 27.74±6.40 |
| <i>Body Fat Index</i> | | |
| Calisthenics | 21.77±9.0 | 21.67±8.94 |
| TABATA | 23.17±7.40 | 23.11±7.37 |

* Within-group statistically significant difference ($p<0.05$)

** Between-groups statistically significant difference ($p<0.05$)

According to Table 2, both training groups achieved statistically significant improvements in PPO ($p=0.017$), maximal oxygen consumption ($p=0.040$) and critical power ($p=0.048$) values, and no significant difference was observed between the groups in terms of the level of improvement ($p>0.05$) (Table 2).

Table 2:

Peak power output, maximal oxygen consumption and sprint pre-test and post-test data for both training groups

| Variable | Pre-test | Post-test |
|--|------------|---------------|
| <i>Peak Power Output (watts)</i> | | |
| Calisthenics | 194.4±34.8 | 216.7±33.0* |
| TABATA | 203.13±16 | 212±16.0* |
| <i>Maximal Oxygen Consumption (mL·dk⁻¹·kg⁻¹)</i> | | |
| Calisthenics | 39.60±8.67 | 45.45±7.51* |
| TABATA | 39.36±8.81 | 46.02±8.99* |
| <i>Critical Power (watts)</i> | | |
| Calisthenics | 134.6±30.9 | 147.66±30.8* |
| TABATA | 148.8±10.7 | 168.12±10.99* |
| <i>30m sprint time (sec)</i> | | |
| Calisthenics | 4.81±0.45 | 4.75±0.44 |
| TABATA | 5.07±0.71 | 4.97±0.74 |

* Within-group statistically significant difference ($p<0.05$)

** Between-groups statistically significant difference ($p<0.05$)

Table 3 shows that no statistically significant difference was observed compared to the pre-tests in the one-repetition maximum strength and sprint values in either training group at the end of 8 weeks ($p>0.05$).

Table 3:
One-repetition maximum strength pre-test and post-test data for both training groups

| Variable | Pre-test | Post-test |
|----------------------------|------------|------------|
| <i>Leg Extension Left</i> | | |
| Calisthenics | 64.28±13.9 | 68.57±13.4 |
| TABATA | 61.87±19.2 | 66.25±19.2 |
| <i>Leg Extension Right</i> | | |
| Calisthenics | 61.42±12.8 | 65.12±12.9 |
| TABATA | 65.6±19.3 | 70.6±18.21 |
| <i>Leg Curl Left</i> | | |
| Calisthenics | 42.14±9.51 | 44.3±11.7 |
| TABATA | 49.37±9.42 | 53.7±10.9 |
| <i>Leg Curl Right</i> | | |
| Calisthenics | 42.85±9.94 | 45±11.9 |
| TABATA | 50.62±8.63 | 54.3±10.5 |
| <i>Squat</i> | | |
| Calisthenics | 105.8±24.8 | 1133±26.77 |
| TABATA | 101.2±23.6 | 113.1±26.4 |
| <i>Bench Press</i> | | |
| Calisthenics | 68.3±20.1 | 70.8±19.8 |
| TABATA | 65.3±19.3 | 67.5±22.4 |

* Within-group statistically significant difference ($p<0.05$)

** Between-groups statistically significant difference ($p<0.05$)

Discussion

The present study aims to compare 8-week High-Intensity Interval Training programs in the form of TABATA Calisthenics and Cycling in terms of their effects on body composition, maximal oxygen consumption, critical power, sprint and maximal strength performance in sedentary males. In contrast with the findings reported in the literature on body composition (Gremeaux et al., 2012; Walker et al., 2011), no statistically significant change compared to the pre-tests was observed in either training group in terms of body mass ($p=0.917$), body mass index ($p=0.928$) and body fat index ($p=0.980$) at the end of 8 weeks. Although TABATA calisthenics and cycling HIIT exercises have positive effects on body composition, there are other studies reporting similar findings with the present study (Fealy et al., 2018). Fealy et al. (2018) applied calisthenics HIIT to 13 overweight sedentary males for 6 weeks (3 days/week) and reported no impact on body fat index and body mass index. Similarly, in the study conducted by Menz et al. (2020), in study groups performing treadmill HIIT and calisthenics HIIT for 4 weeks, no change was observed in body composition. As a result of the meta-analysis conducted by Batacan et al., it was reported that high-intensity interval training exercises performed for less than 12 weeks improved VO_{2max} but had no effect on body composition (Batacan et al., 2017). Therefore, the reason

why no change was observed in the body composition of the participants in the present study could be that is that they did not achieve a negative calorie balance as a result of only following a 4-minute TABATA interval training program and also as a result of maintaining their current diet. Achieving a negative calorie balance is critical for weight loss (McCarty, 1995). In our study, weekly exercise duration ranged from 24 minutes to 36 minutes. In our study, although the exercise intensity was high for both TABATA models, the weekly exercise durations in our study may not have provided sufficient stimulus to achieve a negative calorie balance.

Using a methodology similar to the present study, in a previous study comparing TABATA calisthenics and running HIIT programs, it was reported that the running-based TABATA model provided an improvement of 12% in VO_{2max} while the calisthenics-based TABATA model provided an improvement of 10% (Menz et al., 2020). Similarly, in the present study, the calisthenics-based TABATA model provided an improvement of 13.5% in the VO_{2max} level while the cycling-based TABATA model provided an improvement of 14.5%. The general findings in the literature indicate that high-intensity interval training programs applied over 2 weeks in the form of calisthenics, cycling and running provide gains in terms of VO_{2max} development (Talanian et al., 2007).

Critical power levels, which are regarded as the maximum power output at which VO_2 can be kept stable without reaching VO_{2max} , significant improvements were observed in both training groups at the end of 8 weeks. The rate of this improvement was recorded as 9.5% in the calisthenics-based TABATA model and as 11.5% in the cycling-based TABATA model. Indeed, calisthenic exercises produce less environmental fatigue compared to cycling (Fitzsimmonset al., 1993), which may result in lower glycogen depletion and this may affect outcomes in power output (Hulston et al., 2010). However, no statistically significant difference was found between the critical power values of both training groups used in our study. These improvements observed in VO_{2max} and critical power values show that the application of both high-intensity interval training models for 8 weeks is adequate.

Although the number of studies investigating the effects of the calisthenics-based TABATA model on one-repetition maximum is limited, the general findings indicate that the model improves one-repetition maximum (Brian Kliszczewicz et al., 2019; Florian et al., 2019). In the findings of the present study, although an improvement of 4-8% was observed in the one-repetition maximum strength values of both training groups, this was not at a significant level. In this respect,

the findings of the present study differ from others (Brian Kliszczewicz et al., 2019; Florian et al., 2019).

The impact of HIIT applied in the form of calisthenics and cycling based on the TABATA interval protocol on anaerobic power was evaluated with the peak power output value in the wingate anaerobic test. The use of 30m-sprint time as the form of anaerobic power test is different from similar studies in this regard (Brian et al., 2019; Murawska-Cialowicz et al., 2020). Calisthenics high-intensity interval training exercises performed for 4 weeks provided an improvement of 6% in the peak power output of the wingate anaerobic test (Brian et al., 2019). In another study, the TABATA protocol applied in the form of calisthenics provided an improvement of 0.5% in the peak power output values of sedentary males from the wingate power test and an improvement of 3.5% in the participant group (Murawska-Cialowicz et al., 2020). In a cycling-based TABATA protocol applied to recreationally active individuals for 2 weeks, an improvement of 5% was achieved in peak power outputs (Moghaddam et al., 2021). In the present study, the calisthenics training group completed the 30m sprint anaerobic power test in 1.25% shorter time while this rate was 2% for the cycling group ($p>0.05$). The lower effect compared to other studies may be due to the fact that the form of training applied is not running-based.

Conclusion and suggestions

While both HIIT models applied in the form of cycling and calisthenics exercises were unable to provide improvement in body mass, body mass index, body fat index, maximal strength and sprint at the end of 8 weeks, they provided high gains in terms of peak power output, maximal oxygen consumption and critical power. The calisthenics-based TABATA model provides chronic effects similar to the cycling-based model.

In conclusion, calisthenics-based TABATA HIIT has positive effects similar to those of cycling-based HIIT. As a result of the present study, it was revealed that both training methods provided positive effects on only aerobic capacity and power. In addition, periods longer than 8 weeks may be preferred in order to have an positive effect on body weight, body mass index and body fat index. The HIIT model applied with calisthenics exercises can be preferred by sedentary individuals as a motivating alternative training method for the development of cardiovascular endurance since it requires little to no equipment and can be performed at home or at work. This training method is suggested as it is more encouraging compared to other approaches, particularly under the conditions of the pandemic.

Ethics statement

The study was carried out in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Bayburt University.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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