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Effects of sprint interval training on sloping surfaces on aerobic and anaerobic power

I. Ethem Hindistan[1], Emel Cetin Ozdogan[2], Gürkan Bilgin[3], Omer Halil Colak[4], Y. Gul Ozkaya[2]

[1] Department of Coaching Education, Faculty of Sports Sciences, Akdeniz University, Antalya, Turkey; [2] Department of Sport and Health Sciences, Faculty of Sports Sciences, Akdeniz University, Antalya, Turkey; [3] Vocational School of Technical Sciences, Mehmet Akif Ersoy University, Burdur, Turkey; [4] Department of Electrical and Electronics Engineering, Faculty of Engineering, Akdeniz University, Antalya, Turkey

Summary

Study aim: Several sprint interval training applications with different slope angles in the literature mostly focused on sprint running time and kinematic and dynamic properties of running. There is a lack of comparative studies investigating aerobic and anaerobic power. Therefore, this study aimed to examine the effects of sprint interval training on sloping surfaces on anaerobic and aerobic power.

Material and methods: A total of 34 male recreationally active men aged 20.26 ± 1.68 years and having a BMI of 21.77 ± 1.74 were assigned to one of the five groups as control (*CON*), uphill training (EXP_1), downhill training (EXP_2), uphill + downhill training (EXP_3) and horizontal running training (EXP_4) groups. Gradually increased sprint interval training was performed on horizontal and sloping surfaces with an angle of 4°. The training period continued for three days a week for eight weeks. The initial and the final aerobic power was measured by an oxygen analyser and anaerobic power was calculated from the results of the Margaria-Kalamen staircase test.

Results: Following the training programme, an increase in aerobic power was found in all training groups (EXP_1 = 20.79%, EXP_2 = 14.95%, EXP_3 = 26.85%, $p < 0.01$) and EXP_4 = 20.46%) ($p < 0.05$) in comparison with the *CON* group (0.12%), but there were no differences among the training groups. However, significant increases in anaerobic power were found in uphill training (4.91%) and uphill + downhill training (8.35%) groups ($p < 0.05$).

Conclusion: This study showed that all sprint interval studies on horizontal and sloping surfaces have a positive effect on aerobic power, and uphill and combined training are the most effective methods for the improvement of anaerobic power.

Keywords: Oxygen consumption – Anaerobic power – Uphill running – Sloping surface – Combined training

Introduction

Coaches and training scientists are constantly looking for new training methods to improve sport performance. In this context, several training methods have been reported to improve aerobic and anaerobic power [21]. It is well known that regular endurance training improves the sport performance largely due to increased utilization of oxygen and metabolic substrates by the working muscles. On the other hand, high-intensity, short-duration type training has been reported to improve both anaerobic and aerobic power [21] and, in practice, high-intensity, short-duration type training is often used to improve performance by endurance athletes [23].

In the light of previous studies, there is a general trend showing that the effects of the anaerobic short-term high-intensity training programme on aerobic and anaerobic power are similar to those obtained with continuous aerobic training programmes in terms of circulatory, respiratory and metabolic adaptations. It is also demonstrated that sprint interval training methods have resulted in more improvements in several parameters of aerobic power [1, 5, 6, 16, 22, 23, 27, 29, 40, 41]. Also, a number of previous studies showed that sprint interval training has a positive effect on anaerobic power [8, 29, 32, 34]. However, the results of studies investigating the effects of sprint interval training on aerobic and/or anaerobic power are mostly concentrated on the training methods on horizontal surfaces. Relatively few studies have been reported

Author's address I. Ethem Hindistan, Department of Coaching Education, Faculty of Sports Sciences, Akdeniz University, Dumlupınar Boulevard, Campus, 07058, Konyaaltı-Antalya, Turkey ehindistan@akdeniz.edu.tr

on the results of the training methods on a sloping surface [37, 39].

In the literature, the results of studies examining the effects of sprint interval training on sloping surfaces are mainly focused on the effects of sprint running time, kinematic and dynamic properties of running and electromyographic activity of muscles during sprint running and anaerobic power. [7, 37, 39, 43]. However, there are a limited number of comprehensive studies examining the effects of sprint running on sloping surfaces on aerobic power. It is conceivable to propose that the mechanical and neuromuscular factors with training on sloping surfaces in a comparison with the horizontal surface may have differential effects on muscle energetics and running performance.

This study was aimed to examine the effect of sprint interval training on different sloping surfaces on aerobic and anaerobic power. For this purpose, we compared the results of the sprint interval training on the uphill, downhill, horizontal and combined (uphill + downhill) surfaces with the same workload. Sprint interval training was performed by recreationally active men on a platform with an angle of 4° for all training groups on sloping surfaces or 0° for the horizontal training group.

Material and methods

Participants

The study was carried out with the participation of recreationally active individuals who are healthy, not using any drugs and not smoking. Before the study started, each participant was informed about the content of the study and voluntarily participated after reading, understanding and signing the Informed Consent Form in accordance with the Helsinki Declaration. The study conforms with the Code of Ethics of the World Medical Association (Declaration of Helsinki) and was approved by the Ethical Committee of Clinical Research of the Faculty of Medicine, Akdeniz University (approval number: 21.12.2010/220).

Fifty male students from Akdeniz University voluntarily participated in the study. Thirteen of the participants were withdrawn for a variety of reasons such as time insufficiency and not being willing to continue, three of the participants were excluded due to disability and the study was completed with a total of 34 participants. The demographic characteristics of the participants who completed the study are presented in Table 1. Height was measured using an ultrasonic height measure (Soehnle-Waagen GmbH & Co. KG). Body weight, percentage body fat, fat-free mass (FFM) and total body water were measured with a Body Composition Analyzer (Model TBF-300 TANITA, Tokyo, Japan). The body mass index (BMI) was calculated for each subject [24].

Participants were randomly allocated to five groups as one control group and four (experimental) sprint interval training groups. Groups are shown as follows:
CON (n = 7): Control group,
EXP_1 (n = 7): Uphill training group,
EXP_2 (n = 7): Downhill training group,
EXP_3 (n = 6): Combined (uphill + downhill) training group,
EXP_4 (n = 7): Horizontal running group.

General strength training programme

The persons participating in the study performed 15 minutes of dynamic warm-up and stretching before all the training sessions during the study.

Two weeks of general strength training and running technique workouts were performed before the sprint training programme started to protect the individuals from injuries. The maximum force values of each participant were determined by a widely used method of estimating

Table 1. Body composition characteristics of the study groups

	CON	EXP_1	EXP_2	EXP_3	EXP_4
Age [Year]	20.57 ± 1.13	19.29 ± 1.11	20.14 ± 2.03	20.83 ± 1.47	19.57 ± 1.51
Height [cm]	177.85 ± 4.34	171.85 ± 5.18	175.29 ± 10.37	177.5 ± 6.63	174.85 ± 4.26
Body Mass [kg]	69.27 ± 6.71	61.8 ± 5.54	68.99 ± 6.72	67.25 ± 7.13	67.49 ± 6.37
BMI [(kg · m^{-2}]	21.96 ± 1.89	20.94 ± 1.05	22.50 ± 1.94	21.35 ± 1.92	22.04 ± 1.69
% Fat	11.98 ± 2.02	9.59 ± 1.60	11.75 ± 2.28	10.87 ± 4.21	11.50 ± 2.76
Fat Mass [kg]	8.4 ± 3.04	6.00 ± 1.29	8.16 ± 2.07	7.33 ± 2.87	7.91 ± 2.52
LBM [kg]	60.87 ± 1.94	55.94 ± 4.69	60.83 ± 5.61	59.91 ± 6.74	59.57 ± 4.21

BMI: Body Mass Index; LBM: Lean Body Mass; *CON*: Control group; EXP_1: Uphill training group; EXP_2: Downhill training group; EXP_3: Combined training group; EXP_4: Horizontal training group.

1RM [17] and the intensity of personal loading was determined before starting the strength training.

A total of three sets of exercises as a station workout by using the machines (Matrix Fitness System USA) were applied with eight to ten repetitions with weights ranging between 75 and 80% of their one-repetition maximum (1RM), and three and a half minute active rests were given among the sets. In the stations, participants performed squat, abdominal crunch, leg extension, core extension, and leg flexion exercises. The participants performed the exercises accompanied by a metronome to ensure that the movements were applied with the same tempo. Since the stations are arranged for different muscle groups, no rest was given among the stations and sufficient time required for the station change was given.

A high knee pull and steady high knee practices were included among the strength stations to improve and correct the running technique. Additionally, one drill was added to improve the arm and leg coordination and arm and leg workout. This drill was applied three times for 10 seconds with two and a half minute rest periods in between.

In the cool-down period, participants performed an active cool down by ergo cycling for three minutes followed by jogging and stretching. The total cooling down duration was ten minutes. The strength training programme was performed by all participants three days a week for two weeks.

Assessments

After two weeks of general strength training, initial measurements of the aerobic power and anaerobic power of the groups were made. The measurements were carried out two days after the last training session and on different days. The aerobic and anaerobic test measurements were repeated after all of the sprint training programmes had been finalized.

Aerobic power measurement

The Bruce test protocol was used to determine aerobic power. The test was performed on a motor-driven treadmill (LE 200 CE model, VIASYS, US) and oxygen consumption was analysed by an oxygen analyser. Participants were told that they should not perform high-intensity exercise 48 hours before the test.

Before the test participants were given a two-minute period for warm-up. The Bruce test is a widely used protocol to determine aerobic power, and the stages, the speed of the treadmill and the slope are gradually increased every three minutes until the individual becomes tired [3, 4, 42]. The test was continued until the participant was observed to be unable to continue, or the participant declared "OK" [19, 25, 35].

Expired gases were analysed during all tests using an automated on-line metabolic analysis system (Sensor Medics, CA), in the breath-by-breath mode. The analyser was calibrated before and after each test using two precision reference gases of known concentrations. The VO_2max values as an index of aerobic power are expressed in $ml \cdot kg^{-1} \cdot min^{-1}$.

Anaerobic power measurement

The Margaria-Kalamen staircase test protocol was applied for this measurement. The test was chosen due to the motion mechanics in the test being in accordance with the sprint running. The test was performed on a special platform. The participants were given two or three trials to get accustomed to the platform before the test. Participants were initially kept 6 m away from the first step and with the start command, they were asked to climb the stairs at the highest speed they could reach. The photocells placed on the third and ninth steps recorded the duration with the precision of 1/100 seconds. In this test, New Test 2000 model (Bosco, FIN) test photocells were used for time measurement. After several trials, the test was repeated three times with a three-four minute rest between tests. The best score was used to determine the anaerobic power. The anaerobic power was calculated by applying the following formula [31]

$$P = (W \times D) \times 9.81 \div t,$$

where P = power (watts), W = body weight [kg], D = vertical distance between the third and ninth steps [m], t = time between the third and ninth steps [s].

Training Design

During the study, EXP_1, EXP_2, and EXP_3 groups performed their training programme on a platform coated with tartan with an angle of 4°. The EXP_4 group performed their training programme on a flat surface on an athletics track. The measurements and photographs of the platforms are presented in Figures 1 and 2. In the training programmes, the criterion of "1 min rest for each 10 m running" was used to calculate the resting time [18].

Training programmes of the experimental groups are presented in Table 2.

Participants in EXP_1, EXP_2, and EXP_4 groups performed a 4-set training programme, with each set consisting of 4 repeats. One additional repeat was added to the 1st and 3rd sets at the 5th and 6th weeks of training based on the principle of increasing the load in the training programme. At the 7th and 8th weeks, 1 additional repeat was added to the 2nd and 4th sets and the participants performed 5 repetitions in each set until the end of the study. In the EXP_3 group, on the other hand, participants performed a 2-set training programme with longer distance as stated in detail below, with each set consisting of 4 repeats. In this group, an additional repeat was inserted into the 1st set in the 5th and 6th weeks of the training. At the 7th and 8th weeks, 1

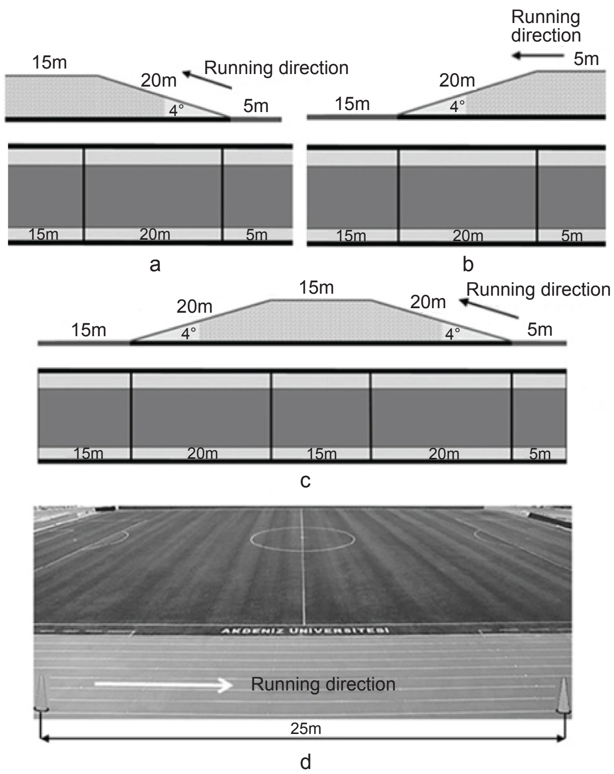

Fig. 1. Training areas and distances of working groups. a – uphill training group (EXP_1), b – downhill training group (EXP_2), c – combined training group (EXP_3), d – horizontal training group (EXP_4)

Fig. 2. Photograph of the training field used by EXP_1, EXP_2 and EXP_3 groups

repeat was added to the 2nd set and both sets were applied for totally 5 repeats again.

Uphill training (EXP_1) group. Participants in this group performed a total of 4 sets with 4 repeats of each set of running exercises (16 × 20 m) on the track with a 4° slope. This group ran a total distance of 40 m which consisted of the following sections: 5 m acceleration run (horizontal) +20 m maximal sprint (uphill) +15 m finish with a smooth run. Since the active sprint running was performed in 25 m of the 40 m distance, active rest was given for 2.5 minutes between sprint repetitions, and 5 minutes between sets.

Downhill training (EXP_2) group. Participants in this group performed a total of 4 sets with 4 repeats of each set of running exercises (16 × 20m) on the tartan track with a 4° slope. This group ran a 40 m distance which consisted of the following parts: 5 m acceleration run (horizontal run) +20 m maximal sprint (downhill) +15 m finish with a smooth run. Since the active sprint running was performed in 25 m of the 40 m distance, active rest was given for 2.5 minutes between sprint repetitions, and 5 minutes between sets.

Combined training (EXP_3) group. Participants in this group performed a total of 2 sets with each set consisting of 4 repeats of combined (uphill + downhill) work out on the tartan track with a 4° slope. This group ran 75 m in each repeat which consisted of the following parts: 15 m acceleration running (horizontal) +20 m maximally sprint (uphill) running +15 m plain running (horizontal +20 m max sprint running (downhill)+15m plain running (horizontal). Since the sprint running was applied at 50 m of the 75 m distance, active rest was given for 5 minutes between sprint repeats and 7 minutes between sets.

Horizontal training (EXP_4) group. This group ran on the horizontal surface with 4 sets of training which consisted of 4 repeats. Each repeat of running was performed for the 25 m distance and an active rest of 2.5 minutes was given between the repetitions, and 5 minutes between the sets.

Control (*CON*) group. Participants in the *CON* group participated only in the initial and final test measurements without performing any training programme.

Statistical analysis

The results are presented as the mean + standard deviation (SD). In the statistical analysis of the results, the Shapiro-Wilk method was used to determine the normal distribution of the data. The Kruskal-Wallis test was used to analyse the differences among the groups and the Mann-Whitney U test was used to determine the differences between initial and final measurements. The significance level was accepted as $p < 0.05$ for comparisons within groups and $p < 0.01$ due to the Bonferroni correction in the comparisons among groups. For initial and final measurements of the aerobic power and anaerobic power, confidence interval (95%CI) values were presented, and effect size (ES) was calculated as the mean difference between the initial and final measurement divided by SD of the baseline measurement for each group. ES values of

Table 2. Daily training programs of the experimental groups (sprint × reps × sets)

Weeks	EXP_1	EXP_2	EXP_3	EXP_4
Weeks 1–4 (3. d.wk^{-1})	20m uphill sprint ×4 = 1 set (×4 sets)	20m downhill sprint ×4 = 1 set (×4 sets)	Combined sprint ×4 = 1 sets (×2 sets) 15 m horizontal sprint +20-m uphill sprint +10-m horizontal fluently running +5 m horizontal sprint +20-m downhill sprint +15 m fluently running	25m horizontal sprint ×4 = 1 sets (×4 sets)
Weeks 5–6 (3. d.wk^{-1})	20m uphill sprint ×5 = 1st set 20m uphill sprint ×4 = 2nd set 20m uphill sprint ×5 = 3rd set 20m uphill sprint ×4 = 4th set	20m downhill sprint ×5 = 1st set 20m downhill sprint ×4 = 2nd set 20m downhill sprint ×5 = 3rd set 20m downhill sprint ×4 = 4th set	Combined sprint ×5 = 1st set Combined sprint ×4 = 2nd set	25m horizontal sprint ×5 = 1st set 25m horizontal sprint ×4 = 2nd set 25m horizontal sprint ×5 = 3rd set 25m horizontal sprint ×4 = 4th set
Weeks 7– 8 (3. d.wk^{-1})	20m uphill sprint ×5 = 1st set 20m uphill sprint ×5 = 2nd set 20m uphill sprint ×5 = 3rd set 20m uphill sprint ×5 = 4th set	20m downhill sprint ×5 = 1st set 20m downhill sprint ×5 = 2nd set 20m downhill sprint ×5 = 3rd set 20m downhill sprint ×5 = 4th set	Combined sprint ×5 = 1st set Combined sprint ×5 = 2nd set	25m horizontal sprint ×5 = 1st set 25m horizontal sprint ×5 = 2nd set 25m horizontal sprint ×5 = 3rd set 25m horizontal sprint ×5 = 4th set

EXP_1: Uphill training group; EXP_2: Downhill training group; EXP_3: Combined training group; EXP_4: Horizontal training group.

0.01 to 0.19 were considered as very small, 0.2 to 0.49 as small, 0.5 to 0.79 as moderate and >0.80 as large.

Results

The results of the measurements of aerobic power and anaerobic power of the groups are given below:

Aerobic power

Tables 3 shows the comparisons of aerobic power results among the groups at the initial and final phases of the study. In the final measurements, increases in aerobic power in a comparison with the initial measurements were found as 20.79%, 14.95%, 26.85%, $p < 0.01$ for EXP_1, EXP_2 and EXP_3, respectively and 20.46%, $p < 0.05$ for EXP_4. The ES between initial and final measurements of groups were found to be 0.707, 0.880 and 0.796 in EXP_1, EXP_2, and EXP_3 groups, respectively. The ES between initial and final measurement of the EXP_4 group was found to be 0.705.

At the initial measurements, there were no statistically significant differences among the training groups, but statistically significant differences were found between the *CON* group and the training groups ($p < 0.01$ for EXP_1, EXP_2, EXP_3 groups). After 8 weeks of the training period, aerobic power was also found to be increased in all training groups ($p < 0.01$) in comparison with the *CON* group. The ES values at the initial measurements between the *CON* and training groups were 0.690, 0.837, 0.758 and 0.663 for EXP_1, EXP_2, EXP_3 and EXP_4 groups, respectively. At the final measurements, there were also statistically significant differences between the EXP_1, EXP_2, and EXP_3 groups in comparison with the final measurement of the *CON* group ($p < 0.01$, ES: 0.914 for EXP_1 group, 0.936 for EXP_2 group, and 0.932 for EXP_3 group). The ES for the final measurement of EXP_4 and *CON* groups was found to be 0.663. The aerobic power in the final measurement of the EXP_3 group was also found to be higher in comparison with the EXP_2 group ($p < 0.01$, ES: 0.793).

Table 3. Comparison between initial and final measurements in aerobic power of the study groups

	Aerobic power (ml · kg^{-1} · min^{-1})			
	Initial		Final	
Groups	Mean ± SD	CI%95	Mean ± SD	CI%95
CON	41.34 ± 3.03	38.54–44.12	41.39 ± 3.9	37.76–45.02
EXP_1	46.75 ± 6.33	45.35–57.05	56.47 ± 8.45**	57.32–72.95
EXP_2	48.16 ± 4.33	44.16–52.16	55.36 ± 4.71**	51.10–59.72
EXP_3	53.48 ± 5.79	47.40–59.55	67.83 ± 8.59**	58.82–76.85
EXP_4	49.26 ± 9.13	39.80–58.72	59.34 ± 13.54*	45.14–73.55

* – $p < 0.05$. ** – $p < 0.01$ difference from initial measurement of groups. *CON*: Control group; EXP_1: Uphill training group; EXP_2: Downhill training group; EXP_3: Combined training group; EXP_4: Horizontal training group.

Table 4. Comparison between initial and final measurements in anerobic power of the study groups

	Anaerobic power [Watts]			
Groups	Initial		Final	
	Mean ± SD	CI%95	Mean ± SD	CI%95
CON	1449.52 ± 170.77	1231.81–1529.36	1451.27 ± 162.55	1238.71–1536.56
EXP_1	1297.21 ± 172.75	1112.99–1513.11	1360.72 ± 182.23*	1233.03–1536.44
EXP_2	1494.06 ± 122.49	1354.45–1670.56	1533.41 ± 143.51	1457.23–1702.03
EXP_3	1314.83 ± 188.84	1080.36–1549.31	1424.67 ± 155.59*	1231.48–1617.87
EXP_4	1543.46 ± 183.18	1395.72–1826.08	1568.96 ± 200.81	1405.61–1880.11

* – $p < 0.05$ difference from initial measurements. *CON*: Control group; EXP_1: Uphill training group; EXP_2: Downhill training group; EXP_3: Combined training group; EXP_4: Horizontal training group.

Anaerobic power

The results of the anaerobic power test performed at the start and end of the 8-week training period are presented in Table 4. There were no statistically significant differences among the groups at the initial measurements. At the final measurements, EXP_1 and EXP_3 groups showed an improvement in anaerobic power results in comparison with the initial measurements ($p < 0.05$, ES: 0.508 and 0.711 for EXP_1 and EXP_3 groups, respectively). The observed rates of improvement in anaerobic power were found to be 8.35% in EXP_3 and 4.91% in EXP_1 groups.

Discussion

In the present study, we aimed to investigate the effects of the different sprint interval running training programmes with sloping surfaces (4°) and horizontal surface (0°) on aerobic power and anaerobic power in recreationally active men. All participants in the training groups carried out the training programme with uphill, downhill, combined or horizontal surfaces for 8 weeks. Our results suggested that the sprint training programme for 8 weeks results in an increase in aerobic power in all sloping and horizontal conditions, but the most prominent improvement occurs following combined training. We also found that uphill and combined sprint training result in an increase in anaerobic power. Our results point out the differences in aerobic and anaerobic metabolism following sprint training programmes on sloping surfaces.

Training on a sloping surface is one of the most popular training methods among athletes to improve the sprint running performance. Downhill running training has been shown to increase the step length or step frequency, and increase the supramaximal running speed by shortening the contact time of the foot [20, 46].

In sloping conditions, the grade of slope used is important in terms of sprint performance. In the literature, several results of sprint performance by using a 2–6.9° slope to increase sprint performance have been presented [2, 7, 11, 12]. Kunz and Kaufmann have shown that sprint training applied on a 3° surface reduces the sprint time by 5.4% and the horizontal running speed by $0.5 \text{ m} \cdot \text{s}^{-1}$ [28]. Paradisis et al. showed that the running speed increased by 4.7% and the step frequency increased by 4.8% in the athletes with 8-week combined training using the downhill slope with an angle of 3° [38]. On the other hand, Ebben et al. used the 0-6.9° slope to evaluate the acceleration, running speed and running time of the sloping surfaces at 10° (91.44 m) and 40 yards (3.4°, 4°, 4.8°, and 5.8° slopes) (365.8 m) and showed a statistically significant shortening of the sprint time, with optimal performance occurring on sloping surfaces to increase sprint performance at a slope of 5.8° [11]. In the present study, we used a sloping surface with an angle of 4° for uphill and downhill training, and 0° for horizontal running. Several methods including running with vests, resistance cords, or parachutes are also shown to improve running duration [30, 47]. To our knowledge, there is no study in the literature showing the effects of training on a sloping surface with an angle of 4°.

In this study, we did not find any differences among the groups in demographic characteristics. However, we found significant differences in initial measurements of aerobic power results in EXP_1, EXP_2 and EXP_3 groups in comparison with the *CON* group. The differences in the initial measurements between the *CON* group and the above-mentioned groups are due to the assignment of the groups by randomization of demographic characteristics of the participants.

Studies that have examined the effects of high-intensity sprint running on aerobic power have recently been numerically increased [14, 26, 44]. Many studies have been conducted to determine the effects of high-intensity exercise training which has been applied for several weeks on aerobic metabolism determinants such as activities of mitochondrial enzymes as well as VO_2max [21]. It seems that a consensus has been provided in previous studies starting with the first published study by Astrand et al. (1960) that sprint interval training improves aerobic performance and the oxidative capacity of the skeletal muscle. The results of the previous reports showing an increase in VO_2max following sprint interval training were found to range from 4 to 18% [10, 13, 14, 18, 32, 44, 45]. Although our study shows similarities with previous work in terms of training variables such as intensity, duration and frequency of training, it differs from previous studies in terms of the fact that the training programme in the present study was applied on sloping surfaces.

The results in the aerobic power of the present study groups, after the application of the 8 weeks of sprint training, showed that higher values of VO_2max were obtained in comparison with the averages obtained in previous studies in the literature. The percentage of development in VO_2max reported in the literature ranged from 4 to 18% as mentioned above, while it ranged from 14.95% to 26.85% in our experimental groups. The significant increases in the VO_2max in the training groups were found to be 14.95% in EXP_2, 20.46% in EXP_4, 20.79% in EXP_1, and 26.85% in EXP_3 groups in a comparison with the initial measurements. No significant improvement in the *CON* group was observed.

The increase in VO_2max in the EXP_3 group, which used both positive and negative resistances during training applications, is higher than the other groups, suggesting that loads with both positive and negative resistances are a significant influence on aerobic power development. However, when the results of the experimental groups with positive and negative resistances (EXP_1 and EXP_2) were compared separately, it was observed that the sprint training with positive resistance (EXP_1) had a greater effect than the sprint training with negative resistance (EXP_2).

The above-mentioned results clearly showed that the sprint training on sloping surfaces as an example of training with positive and negative resistance positively affects aerobic power. To elucidate this differential effect of resistance exercise, the features and amounts of resistance and also the triggering factors contributing to the aerobic metabolism in skeletal muscles should be determined with further studies. Additionally, one of the proposed physiological mechanisms during resistance exercise is the possibility of additional stress on the skeletal muscles and/or cardiovascular system, which we did not consider or measure. Also, several muscular, biochemical, circulatory and neural adaptation mechanisms, complex cellular interactions and individual differences concerning exercise participation [33] should be elucidated in further studies to clarify the exact mechanism of the connection between resistance training and aerobic power.

In this study, uphill and combined sprint training on the surface with 4° resulted in an increase in anaerobic power in comparison with the initial measurements. The significant increases in anaerobic power were 4.91% and 8.35%, in EXP_1 and EXP_3 groups, respectively. In a previous study using a training programme on a sloping surface with 3°, Paradisis (2009) reported that no statistically significant changes occur in anaerobic power output after the 6 weeks of training [37]. Also Padulo et al. (2016) previously showed that the blood lactate and oxygen consumption levels are increased during acute exercise on a sloping surface [36]. Several previous studies in the literature reported that sprint training results in an increase in anaerobic power [9, 15, 34] ranging from 8 to 28.6%. One of the possible explanations of this variability of the previous results might be due to the different profiles of the participants, and/or the anaerobic power measurement methods used. The small differences in anaerobic power in the present study could be regarded as a negative result. However, it should be kept in mind that, in practice, anaerobic power-based activities could lead to significant motor performance increases due to their nature. One of the most convincing explanations for the increase in anaerobic power following the combined and uphill running training as demonstrated in the study is the metabolic adaptation response of the skeletal muscles to an increase in metabolic demand during the training on the sloping surface. Further studies require clarification of the physiological interactions between mechanical loading and metabolic response following repeated bouts of sprint running training.

Several limitations of the present study should be mentioned. First of all, the training programme applied in the present study lasted eight weeks, which is known to be sufficient to elucidate alterations in anaerobic and aerobic power. Secondly, we neglected the individual differences in the participation in the training programme, which may be one of the causal factors for the drop out of the study. The study design should be replicated in further studies with longer training periods and also in professional athletes, which may decrease the study dropout rates.

In conclusion, the results of the study clearly showed that the sprint interval running training groups (uphill, downhill, combined and horizontal) on 4° sloped surfaces for 8 weeks results in an increase in aerobic power. However, only uphill and combined training increase anaerobic power. In considering the practical applications for training experts, or coaches, our results clearly showed that the combined resistance training programme provides the largest improvement in aerobic and anaerobic power in recreationally active men.

Practical applications

The results of this study clearly demonstrated that sprint interval training on a sloping surface with an angle of 4° and training on a horizontal surface for 8 weeks increase the aerobic and anaerobic power. These results suggest that the application of sprint interval studies on sloping surfaces may be more effective in the development of aerobic power in athletes with a training background instead of aerobic power studies with long-term aerobic character. This will give an advantage to the coaches in the preparation of the annual training programme. Also, training programmes applied in EXP_1 and EXP_3 groups may be used as alternative methods by the coaches for the improvement of anaerobic power.

Conflict of interest: Authors state no conflict of interest.

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