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Abstract

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Keywords

aerobic capacity, anaerobic capacity, performance improvement, team sports

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Article

Interval training using a slide board is superior to cycloergometer regarding aerobic capacity and specific fitness in elite ice hockey players

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Abstract: Introduction: Ice hockey is a physically demanding sport that requires a combination of aerobic and anaerobic capacities, as well as specific on-ice skills. This study aimed to compare the effectiveness of individualized interval training on a slide board with training on a cyclo-ergometer, focusing on aerobic capacity and specific fitness in elite ice hockey players. Materials and Methods: Thirty players were randomly divided into an experimental (slide board) and a control (cyclo-ergometer) group. Both groups underwent a 6-week training program with the same intensity and volume. Results: The results showed that both forms of training led to significant improvements in aerobic capacity, as indicated by VO_{2max} and VO_2 lactate thresholds. The slide board training group demonstrated higher effect sizes (d = 1.49, 1.62) than the cyclo-ergometer one (0.76, 0.43). Specific on-ice performance tests showed that slide board training resulted in faster skating times ($p = 0.0002$), suggesting a greater transfer of training effects to on-ice skills. Conclusions: This study highlights the benefits of incorporating slide board interval training into the off-season training regimen of elite ice hockey players. Slide board training improves specific on-ice skills, which are crucial for high-level hockey performance. These findings provide valuable insights for coaches and strength and conditioning specialists working with elite ice hockey players.

Keywords: aerobic capacity, anaerobic capacity, performance improvement, team sports.

1. Introduction

Ice hockey is one of the most challenging and impressive sports. Modern ice hockey is constantly developing into a game of increasing intensity and dynamics, which causes the effort of the ice hockey player to increase. The activities are intermittent, depending on the number of formations available, usually consisting of 45-second bouts of high energy output separated by about 2 minutes of rest in the box.

In every sport, there are certain values that must be taken into account in terms of the variables that determine the athlete's level of performance, one of which is aerobic metabolism. This guarantees the possibility of optimal implementation of training objectives and effective repetitive work at maximum intensity with severely limited recovery time. Previous reports indicate that VO_{2max} values should be at least above 50 [ml/min/kg]. According to many authors conducting studies on ice hockey, the effort during a match is based on approximately 69% anaerobic metabolism, during which the ice hockey player incurs an oxygen debt to levels of 8.5–9.6l and there is a significant increase in lactate concentration above 8 mmol/l [1–9]. Thus, the dominant energy source of the hockey player is anaerobic metabolism.

Relying solely on a high level of anaerobic capacity would lead a hockey player to a state of overreaching in a very short period of time. Anaerobic metabolism does not provide full energy conservation of the effort undertaken by hockey players during an on-ice bout. Athletes' extremely high ability to undertake repeated efforts of maximum intensity is, in fact, determined by the speed of restitution. The speed of restitution determines the rate of utilization of glycogen breakdown. Therefore, a low level of VO_{2max} can lead to a limitation of the athlete's ability to recover quickly during the match [10–12].

Therefore, the off-season, during which coaches must increase aerobic capacity, anaerobic capacity and specific on-ice fitness to the highest possible level in the shortest possible time, is an important stage of training. This leads to methodological problems of how to optimize training for so many different variables in a short off-season period.

The supreme solution seems to be the use of interval training, which has been studied by many researchers. Although many publications have demonstrated the effectiveness of interval training [13–15], it is rare to compare the effectiveness of different types of interval training. The research presented in this paper aimed to compare the effectiveness of 6 weeks of individualized interval training on a slide board with interval training on a cycloergometer, while maintaining the same intensity and training volume.

2. Materials and methods

The study involved 30 players who were participating in the preparation for the top tier ice hockey league season. The hockey players were randomly divided into two groups: experimental and control. The experimental group (N = 15; height 185.69±6.33 cm; body weight 86.69 ±6.25 kg; body fat 14.64±3.43%) performed an interval training program using a slide board. The control group (N = 15; height 183.19 ±6.39 cm; weight 84.61 ±5.31 kg; body fat 13.76 ±2.39%) performed interval training on a bicycle cycloergometer. Each participant had undergone a medical examination that allowed them to participate in sports, including maximal intensity exercise. The project was approved by the Bioethics Committee for Scientific Research of the Jerzy Kukuczka Academy of Physical Education in Katowice.

2.1. Study design

The experimental protocol included two sets of tests before and after the application of individualized interval training. Ice hockey players in both the control and experimental groups underwent a 6-week training program of the same intensity and volume. One factor that differentiated the training protocols of the study groups was the device used for training (Ketler Giro GT cycloergometer vs. slide board).

2.2. Evaluations

The tests were spread over 2 days. The first day started with height measurement. This was followed by the weight and body composition measurements using the InBody 220. A person trained and certified by MEDfitness performed the measurements. The weight was measured between 9 and 10 am, 2 hours after breakfast. Subjects did not exercise or take any medication or ergogenic supplements prior to the measurement. The study was conducted at 21°C. Following this, anaerobic capacity was assessed. After 48 hours of rest, an aerobic capacity test was performed.

2.3. VO_{2max} measurement

Exercise testing consisted of a progressive exercise test on a bicycle ergometer (Excalibure Sport, Lode) to determine VO_{2max} and anaerobic threshold. The exercise test commenced with a load of 40W and included a increment of 40W every 3 minutes. The test continued until the subject refused or was unable to maintain a minimum cadence of 60 rpm. During the test, a cadence range of 60–80 rpm was recommended. Heart rate (HR), minute ventilation (VE), breath frequency (BF), oxygen uptake (VO_2), and expired carbon dioxide (VCO_2) were continuously recorded at rest (3 minutes before the test) and during the test using a MetaLyzer 3B–2R high-speed gas analyzer (Cortex). All variables were analyzed during each breath (breath-by-breath method) and presented in averaged 15-second intervals. The criterion used for the evaluation of VO_{2max} was when the respiratory exchange rate (RER) value was >1.1.

2.4. Lactate measurement

At the end of each exercise (stage lasts 15s), capillary blood samples were taken from the fingertip to determine lactate concentration. The data obtained were used to analyze the kinetics of the concentration of this metabolite in the blood. Blood lactate concentrations were determined using a Biosen C-line Clinic analyzer (EKF-diagnostic GmbH, Germany). Based on the lactate curve obtained from the VO_{2max} test and the heart rate curve, Lt thresholds were determined for the athletes, and then based on Cogan's algorithm, individual training load zones were determined for the athletes, including the "improving Lt" zone, on the basis of which interval training was then performed.

2.4. 30m and 5m skating time

On day 2 of the study, the athletes' specific fitness was measured on the ice. Both acceleration and absolute speed tests were measured by photocells (Microgate Italy, Bolzano, Italia) during a measured acceleration of forward sprint skating. The photocells first recorded the start of the sprint, then the finish of the 4 m sprint, and finally the finish of the 30 m and 4m sprint on a straight sprint track marked diagonally across the ice hockey rink [16]. The starting photocell sensor was placed 15 cm above the ice, and the two finish-line sensors were placed 108 cm above the ice.

2.5. 6 × 54m skating time

The 6 × 54m shuttle run was selected as the anaerobic capacity on-ice test [12]. The players were studied during an all-out exercise with sticks on a European standard ice rink. Photocell setting was similar to skating speed testing.

2.6. Training program

Both groups followed the same training programs on ice and in the gym, supplemented with 6 weeks of interval training (3 times a week), which was the subject of the study, based on an individualized training load zone based on the Lt threshold. The only factor that differentiated the training programs of each research group was the training device: in the experimental group it was a slide board, while in the control group it was a bicycle cycloergometer. Each training session consisted of a 15-minute warm-up, followed by 8 repetitions of 5-minute effort at the heart rate obtained from Cogan's algorithm for the LT threshold zone, with a 4-minute rest interval after each repetition. The interval training was followed by a 15-minute cool-down. The intensity during the session was individually adjusted for each participant based on the heart rate obtained for the individual's designated LT threshold zone. During the first week, the hockey players trained at a heart rate between the lower limit of the LT threshold zone and the LT threshold (the middle of the range). In subsequent weeks, the hockey players trained at a heart rate from the LT threshold to the upper limit of the LT threshold. The experimental group trained on a slide board. The slide board was constructed from a 61 × 185 cm (width x length) piece of polyethylene and featured adjustable beveled end plates with an 8° "toe-out" angle [17]. The slide board was placed on a flat floor to prevent any movement of the device during the exercise. Subjects wore dirt-free nylon socks over their athletic shoes, and a silicone lubricant was applied prior to each trial [18]. The cadence on both the cycloergometer and the slide board was selected by the athlete during the exercise so that his or her heart rate was within the individualized "LT threshold" zone during the exercise; the cadence during the trial could not be less than 60 rpm on the cycloergometer and 40 spm on the slide board.

2.7. Statistical methods

The results were presented as arithmetic means (x) with standard deviations (SD) and confidence intervals (95%CI). The normality of the distributions of the variables analyzed was tested using the Shapiro-Wilk test, homogeneity of variance using the Levene test, and sphericity assumptions using the Mauchley test. The analysis of variance with repeated measures was used to test the significance of the differences between the variables. The strength of the effect was calculated using the coefficient η^2. The strength of the effect was classified as weak if η^2 ranged from 0.01–0.059, medium 0.06–0.137, and large > 0.137. When significant differences were found in the analysis of variance, Tuckey's post hoc multiple comparison tests for equal numbers were used to verify between which groups there were significant differences. For pairwise comparisons, effect sizes were determined by Cohen's d which was characterized as large (d > 0.8), moderate (d between 0.8 and 0.5), small (d between 0.49 and 0.20) and trivial (d < 0.05). Statistical significance was set at $p < 0.05$.

3. Results

The analysis of the results started with the calculation of basic descriptive statistics for the study groups on the basis of the time of measurement.

Table 1. Basic descriptive statistics for analyzed variables and confidence intervals for means.

	Experimental group		**Control group**	
	Pre	Post	Pre	Post
	M±SD (-95%CI;95%CI)	M±SD (-95%CI;95%CI)	M±SD (-95%CI;95%CI)	M±SD (-95%CI;95%CI)
VO_{2max} [ml/kg/min]	50.65±3.60 (48.65; 52.64)	55.93±3.43 (54.03; 57.83)	53.43±3.72 (51.37; 55.49)	56.29±3.83 (54.17; 58.41)
VO_{2LT} [ml/kg/min]	39.67±2.63 (38.21; 41.12)	43.57±1.99 (42.47; 44.67)	41.57±4.18 (39.25; 43.88)	43.79±4.28 (41.42; 46.16)
4m [s]	0.93±0.08 (0.89; 0.98)	0.86±0.06 (0.83; 0.89)	0.93±0.08 (0.88; 0.97)	0.90±0.08 (0.86; 0.94)
30m [s]	4.68±0.18 (4.59; 4.78)	4.37±0.15 (4.29; 4.45)	4.69±0.21 (4.58; 4.81)	4.53±0.20 (4.42; 4.64)
6×54m [s]	58.27±2.58 (56.84; 59.70)	52.58±1.28 (51.87; 53.29)	58.55±2.60 (57.11; 59.99)	55.66±2.33 (54.37; 56.95)

In subsequent stages, analysis of variance with repeated measures was applied to the considered variables. The description of the results of the study began with the VO_{2max} variable.

Analysis of the results showed no significant differences for the main effect group F = 1.57; $p = 0.22$. Significant differences were found for the main effect × pre-post F = 82.25; $p < 0.0001$; $\eta^2 = 0.75$ and for the interaction group × pre-post F = 7.59; $p = 0.01$; $\eta^2 = 0.21$. Tuckey's post hoc multiple comparison test was used to determine significant differences between groups. A statistically significant increase in mean VO_{2max} after the applied interval training was found for both the control group mean pre = 53.43 vs. mean post = 56.29; $p = 0.0006$; d = 0.76 and the experimental group mean pre = 50.65 vs. mean post = 55.93; $p = 0.0002$; d = 1.49. These results are presented in Figure 1.

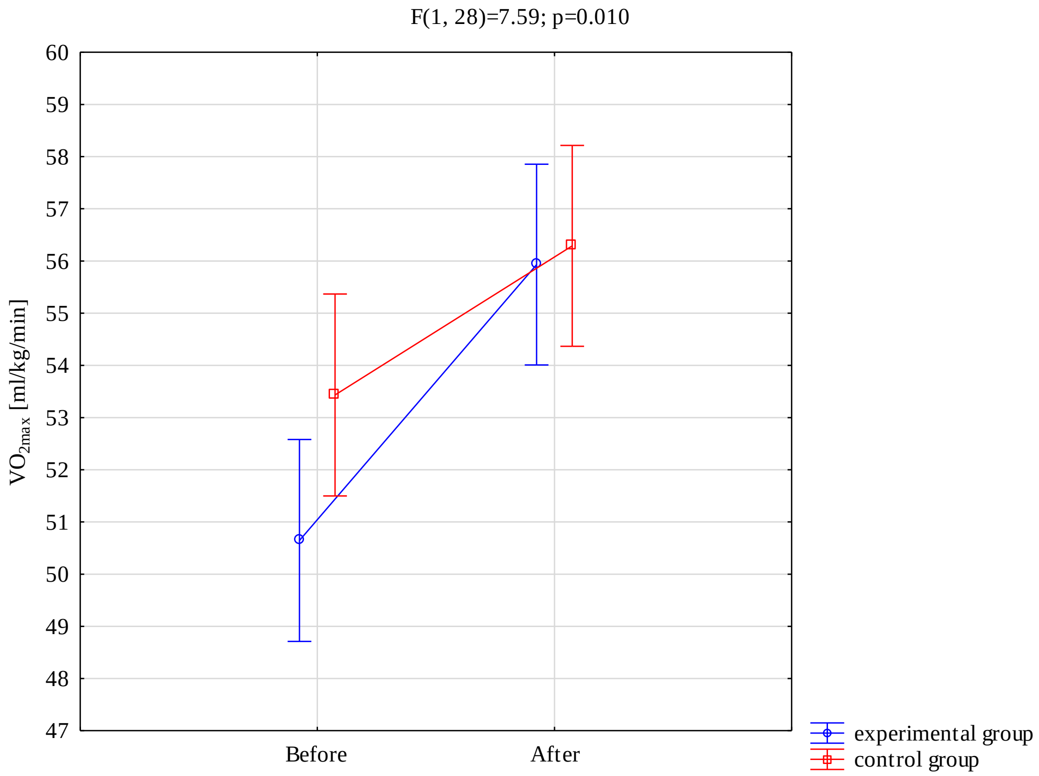

Figure 2. VO_{2max} changes after the training intervention in the experimental and control groups

Similar analyses were performed for the VO_{2LT} variable. Analysis of the results revealed no significant differences for the main effect group F = 0.76; $p = 0.39$. Significant differences were found for the main effect × pre-post F = 120.199; $p < 0.0001$; $\eta^2 = 0.81$ and for the interaction group × pre-post F = 9.081; $p = 0.0054$; $\eta^2 = 0.25$. A statistically significant increase in mean VO2LT values after the applied interval training was found for both the control group mean pre = 41.57 vs. mean post = 43.79; $p = 0.0002$; d = 0.43 and the experimental group mean pre = 39.67 vs. mean post = 43.57; $p = 0.0002$; d = 1.62. These results are presented in Figure 2.

Further analyses were performed for the 4m [s] variable. Analysis of the results revealed no significant differences for the main effect group F = 0.39; $p = 0.54$. Significant differences were found for the main effect × pre-post F = 81.99; $p < 0.0001$; $\eta^2 = 0.74$ and for the interaction group × pre-post F = 17.66; $p = 0.00024$; $\eta^2 = 0.39$. A statistically significant improvement in the 4m [s] mean values after the applied interval training was found for both the control group mean pre = 0.928 vs. mean post = 0.90; $p = 0.010$; d = 0.38 and the experimental group mean pre = 0.935 vs. mean post = 0.86; $p = 0.0002$; d = 0.96. These results are presented in Figure 3.

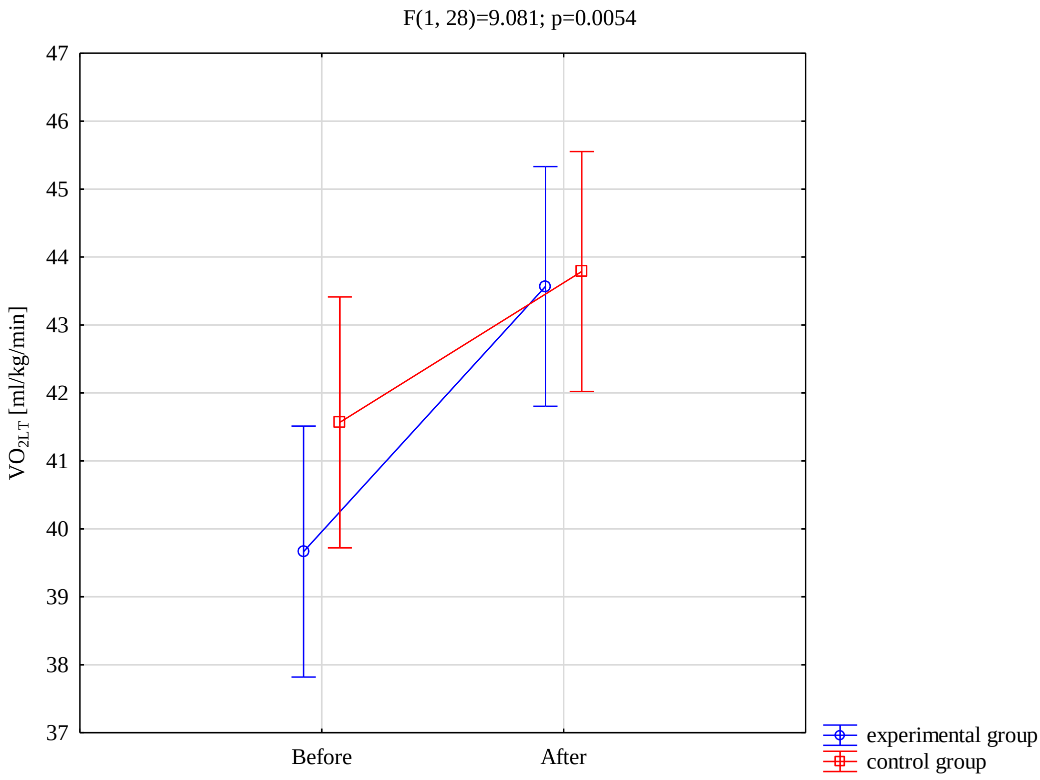

Figure 2. VO_{2LT} changes after the training intervention in the experimental and control groups

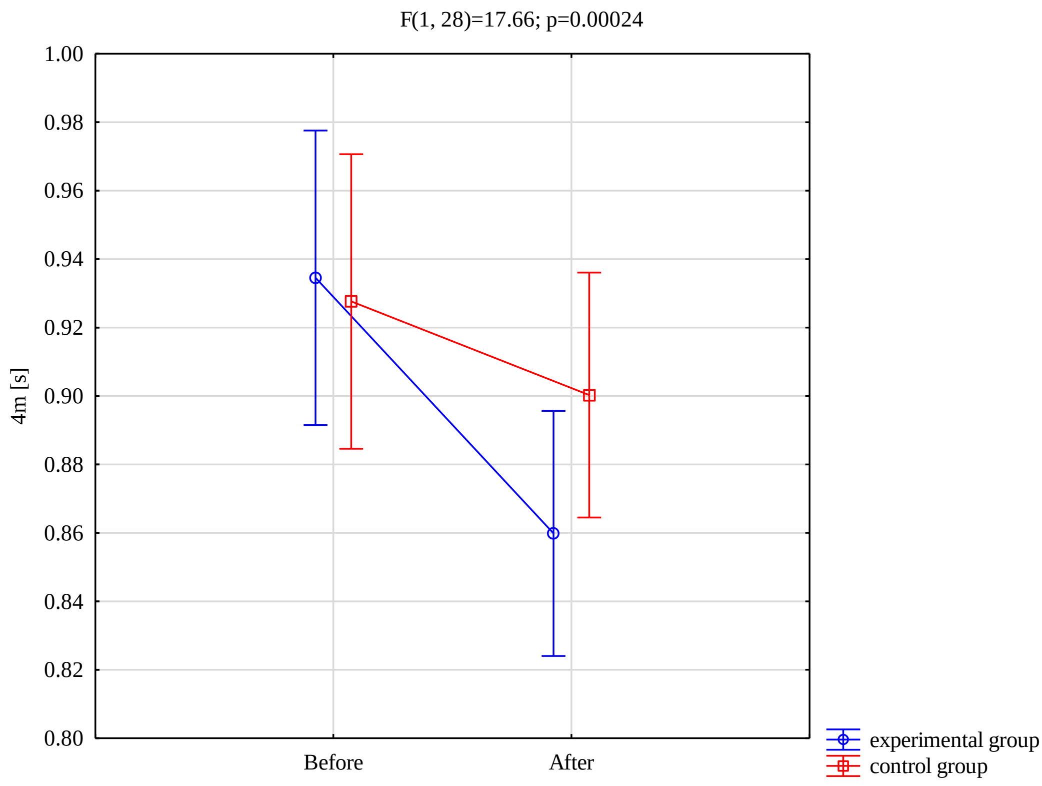

Figure 3. 4m [s] changes after the training intervention in the experimental and control groups

The following analyses were performed for the 30m [s] variable. Analysis of the results showed no significant differences for the main effect group F = 1.71; $p = 0.20$. Significant differences were found for the main effect × pre-post F = 288.71; $p < 0.0001$; $\eta^2 = 0.91$ and for the interaction group × pre-post F = 30.16; $p < 0.0001$; $\eta^2 = 0.52$. A statistically significant improvement in the mean 30m [s] values after the applied interval training was found for both the control group mean pre = 4.69 vs. mean post = 4.53; $p = 0.0002$; d = 0.78 and the experimental group mean pre = 4.68 vs. mean po = 4.37; $p = 0.0002$; d= 1.83. These results are presented in Figure 4.

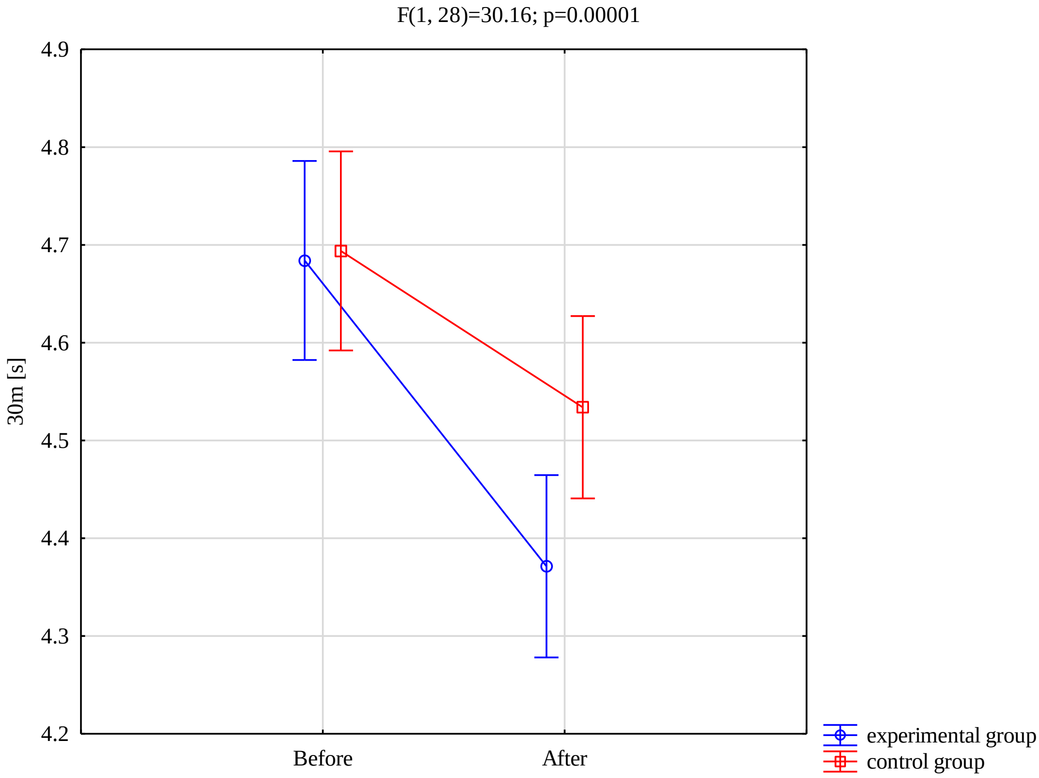

Figure 4. 30m [s] changes after training intervention in the experimental and control groups

Following the above, analyses were performed for the 6 × 54m [s] variable. The analysis of the results showed significant differences for main effects between groups F = 4.81; $p = 0.037$; $\eta^2 = 0.15$ between pre-post F = 189.99; $p < 0.0001$; $\eta^2 = 0.87$ and for interaction group × pre-post F = 20.29; $p < 0.0001$; $\eta^2 = 0.42$. A statistically significant improvement in the mean values of 6x54m [s] after the applied interval training was found both for the control group mean pre = 58.55 vs. mean post = 55.66; $p = 0.0002$; d = 0,11 and for the experimental group mean pre = 58.27 vs. mean post = 52.58; $p = 0.0002$; d = 0,78. These results are presented in Figure 5. A significantly better result was also found for the experimental group after training mean EG pre = 52.59 compared to the result of the control group after training mean CG post = 55.66; $p = 0.0002$; d = 1,88. These results are depicted in Figure 5.

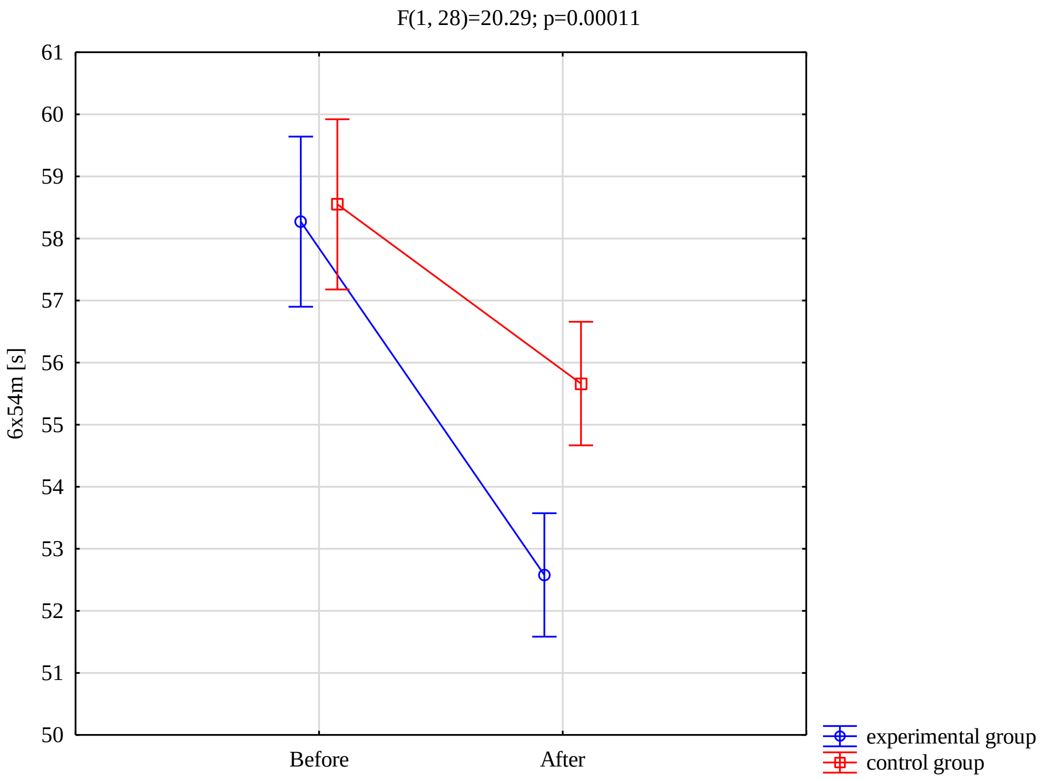

Figure 5. 6 × 54m [s] changes after training intervention in the experimental and control groups

4. Discussion

The main aim of the study was to compare the effectiveness of individualized 6-week interval training performed on a slide board to interval training performed on a bicycle cycloergometer, while maintaining the same intensity and training volume. Taking into account the fact that any training of a hockey player is supposed to ultimately translate into specific fitness on ice in the form of fast skating, choosing the right exercise that gives an activation stimulus not only in the direction of increasing aerobic or anaerobic capacity, glycolytic capacity, but also faster skating, seems to be crucial in the off-season. In Poland, interval training is most often implemented on the basis of training on a cycloergometer or running training.

This paper presents an unique proposal for a type of interval training that gives a stimulus not only towards performance, but also towards strengthening the specific skills of the athlete while skating on ice with the help of a slide board. Skating performance is one of the basic skills of a top-class hockey player [19]. It requires the acceleration of alarge body mass and the ability to repeatedly develop high power outputs [20]. Correlation of on-ice skating performance to off-ice measures is important for both the hockey coach and the strength and conditioning specialist to properly design and monitor training during the off-season.

The analysis of the results included in the paper allowed us to conclude that in the case of both types of interval training, both cycloergometric and slide board training, the selected variables of aerobic capacity VO_{2max} and VO_{2LT} improved statistically significantly. Differences emerged with respect to special fitness tests on ice at distances of 4m and 30m where times also improved significantly for both trainings, and there were no significant differences between post-training results in the two groups, although Cohen's d effect size for interval training on the slide board were much higher than for cycloergometric training. The analysis of the 6x54m test also allowed for a statistically significant improvement in performance for both types of training, but significant differences were also found between the results of the distance run time after the training sessions in favor of the group training on the slide board, which ran this distance after 6 weeks of training significantly faster than the group performing cycloergometric training.

The presented research also confirms the study of Farlinger and Fowles [21], who proved that the improvement in on-ice skating sprint performance when supplemental training progressed in specificity supports this principle of training and promotes transfer to a complex sporting movement such as skating [21]. Taking into account the fact that slide board exercise is a multifaceted, closed kinetic chain, weight-bearing activity that imparts low-impact forces to the lower extremities and is used to enhance muscular strength, endurance, proprioception, agility, balance, body composition, and cardiorespiratory fitness [18]. The SB was originally designed as a sport-specific, off-ice training device for speed skaters. Slide board training is increasingly popular with figure skaters and hockey players. Slide board training is performed in a frontal plane rather than the sagittal plane that is characteristic of traditional aerobic exercise training. The sliding motion is divided into 3 phases – push-off, glide, and landing – and recruits muscles form the entire body for balance and power, but emphasizes a lower body workout. Classified as a closed-chain exercise, sliding induces concentric, eccentric, and isometric contractions at the foot, ankle, knee, and hip joints [18]. The results presented by Pies et al. [18] confirmed that the slide board can be an optimal training tool for hockey players. The authors stated that strength and conditioning programs containing slide board training may optimize on-ice fitness, are cost effective, can improve the skaters' physiological condition, and may ultimately improve performance. The results also seem to confirm the work of Naimo et al. [15], in which the researchers demonstrated that high-intensity interval training has a positive effect on skating performance.

Taking into account the fact that during the 12–14 week preparatory period, the first training emphasis of the presented study was a stimulus aimed at a rapid increase in VO_{2max}, VO_{2LT} and, also a stimulus that directly correlates with specific work during ice skating, we also agree with the results of the specific on-ice performance based on long intervals, and we fully agree with the reports of other authors [13], who demonstrated that multiple (30-second work sessions) induced a greater improvement in on-ice endurance skating performance in well-trained adolescent ice hockey players than longer intervals (5-minute work sessions). Thus, practitioners seeking to improve on-ice skating performance in ice hockey players should consider implementing multiple short interval training sessions in their off-ice training.

However, interval training was performed on bicycle cycloergometers, which was a limitation of this study. Any training must be well directed and aimed at providing the right adaptive stimuli at the right time. Numerous other modern training methods have been presented in studies carried out around the world to rapidly improve aerobic capacity variables [23], but they require specific training facilities. This paper presents the first part of the experiment, which includes 1 mesocycle in the preparatory period, in which the maximum emphasis was placed on the restoration of aerobic capacity parameters, and for this reason, in 1 mesocycle, 5-minute intervals were used with a simultaneous adaptive stimulus specific to ice skating (training on a slide board), which gave better results in specific fitness tests already at this stage of the pre-season than training of the same intensity and volume on a cycloergometer.

The better results in the 6 × 54m test and the higher effect forces in the 4m and 30m tests for the interval training on the slide board could also be due to the similarity of the work on the slide board to that of the players on ice, which was well described by Novak et al. [24], who stated that the movements on ice are highly specific to the use of skates and motor tasks based on a slide with push-off, which does not occur in any conventional off-ice movement (running, cycling), but does occur during slide boarding. This is also supported by a close relationship between on-ice and off-ice agility, which exist in running change of direction skills [25].

5. Conclusions

The results of this study lead to the conclusion that off-ice interval training, which mimics the specific conditions of a hockey player on the ice using a slide board, produces similar results in improving aerobic fitness variables as interval training using a cycloergometer, but is more effective in improving the results of specific fitness tests on ice.

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