ANALYSIS OF DIFFERENCES IN THE DESIGN OF INTERVAL AND CONTINUOUS AEROBIC TRAINING OF ELITE TEAM HANDBALL PLAYERS

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Abstract
The purpose of this paper is to evaluate the efficiency of High-Intensity Continuous Training (HICT) of an aerobic training program on elite handball teams. The study included the participation of 16 handball players, members of first league teams of Iceland. The participants trained five times a week over the course of four weeks using the HICT. The intensity of the training work was programmed individually for each participant according to the amount of oxygen they consumed. A statistically significant (p<.001) improvement was obtained from all measurable indicators of aerobic capacity (maximal consumed oxygen, maximal relative consumption of oxygen, speed of running at which maximal amount of oxygen is consumed) when comparing the pre and post-tests, as well as a great positive effect (ES reaching from 1.17 to 1.28). Using the method of mathematical simulation, a comparison was made between the tested method of programming aerobic training and several influential High-Intensity Interval Training (HIIT) models. The results of the analyses demonstrate that HICT has numerous positive features compared to HIIT, which is why further research into its application in training practices is recommended.

Key words*: aerobic training, High-Intensity Continuous Training, High-Intensity Interval Training, VO_2max, handball.*

Introduction

Aerobic capacity is one of the basic requirements for general movement, including sports movement, and as a prerequisite for achieving high sports results. Aerobic training programs systematically influence the state of all organic and metabolic systems which are using oxygen to create the energy necessary for body movement. Several models exist upon which aerobic training is designed, which can be divided into continued and discontinued (interval) types of design.

The differences in design include, firstly, the duration of the action and, consequentially, the division of the training load, hence distinguishing them as Low-Intensity Interval Training (LCT) and High-Intensity Interval Training (HIIT). Care must be taken to distinguish between the intensity of the action whilst comparing the two types of designs (continuous and discontinuous), while in practice differing names appear, which should not be confused. The continuous training, amongst other things, improves capillarization and the oxidative capacity of muscles, while interval training especially promotes the capacity of the heart muscles and through various intensities, increasing circulation, delivers oxygen to muscles, which is needed for creating energy for movement (Klisuras, 2013). Regardless of how it is designed, the ultimate objective of this activity is to, by influencing the organic and metabolic systems, come to an increase in aerobic capacity, whose maximum oxygen intake is (VO_2max). Due to its well-documented efficiency (Ravier, Dugué, Grappe, Rouillon, 2009) HIIT is currently favored in sports practice.

Among the interval methods, the Hoff-Helgerud model (HIIT1) (Helgerud, Engen, Wisloff, Hoff, 2001), the Billat model (HIIT2) (Billat, 2001) and the Dello Iacono model (HIIT3) (Dello Iacono, Eliakim, Meckel, 2015; Dello Iacono, Karcher, Michalsik, 2018) are used the most. HIIT1 anticipates the creation of training sessions that consist of 4 running intervals of 4 minutes, with an intensity of 90-95% maximal heartbeat value (Ravier, et al., 2009). Between these intervals, 3 minutes of running at 50-60%, the running speed for which VO_2max occurs (vVO_2max), are inserted. HIIT2 and HIIT3 are slightly different, and are designed for training sessions that use vVO_2max. Both models utilize long and short intervals in training. For handball, the most interesting is the short aerobic interval high intensity training. After numerous experimentations, Bilatt came up with the idea of switching up repeated intervals of running 30-30 seconds in order to prolong the amount of time spent at maximal aerobic capacity (Billat, 2001). The first 30-second interval is run at 100% vVO_2max, and the second at 50% vVO_2max. Elite competitors can run this way between 18 and 20 minutes. According to HIIT3, long and short training intervals also exist, whereby the speed at which the maximal oxygen spent varies in range between 85% and 105% VO_2max (Dello Iacono, et al., 2015, 2018). In this model, pauses can be passive and active. HIIT3 for handball recommends 10 to 30 intervals of running that last from 15 to 20 seconds of 96% to 100% VO_2max intensity, including pauses between running lasting 15 to 20 seconds with 40% to 50% VO_2max intensity (Dello Iacono, et al., 2015, 2018).

In both cases, there is a high intensity of action which causes glycolytic activity (Billat, 2001; Dello Iacono, et al., 2015, 2018). Output sizes for both types of training included the distance run. All three described models allowed for the individualization of training sessions (Billat, 2001; Dello Iacono, et al., 2015, 2018; Helgerud, et al., 2001). For the first model, the control is realized according to pulse (Helgerud, et al., 2001), while the latter two via the speed of running (Billat, 2001; Dello Iacono, et al., 2015, 2018).

As a result of many years of research into aerobic training (Blagojevic, Milosevic, Mudric, Dopsaj, 2003; Milosevic, Milosevic, 2010a, 2013b; Milosevic, Džoljić, Milošević, Yourkesh , Behm , 2014a) Milošević et al. (Milošević, Nemec, Nemec, Milošević , 2017; Milošević, Nemec, Nemec, Milošević, 2018) recommend a model in which both types of design (interval and continuous) of aerobic training, are combined, that is, High-Intensity Continuous Training (HICT). Care must be taken once again when it comes to the name High-Intensity Continuous Training, which is already known in sports science and practice, but also for the recommended model (Milošević, et al., 2017, 2018) which, due to its intensity, differs significantly from it, and is by virtue more similar to HIIT, which is why it has been decided to provide the well-known name with a more precise meaning. Namely, the intensity of the work is designed individually for each participants (Milošević, et al., 2017, 2018) so it can be found between the minimal group of anaerobic threshold and the VO_2max of each athlete (Astrand, Rodahl, Dahl, Strømme, 2003; Kenney, Wilmore, Kostill, 2015; Bouchard, Sarzynski, Rice, Kraus, Church, Sung, Rao, Rankinen 2011; Milošević, et al., 2017, 2018; Tucker, Collins, 2012; Wilmore, Costill, 2008).

This model assumes that the individualization of the aerobic training is designed directly according to the amount of oxygen consumed (VO_2) (Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018). The control and analysis of the training effects and changes is carried out according to VO_2max and maximum relative oxygen uptake (VO_2rel), Cooper's 12-minute running test (K), vVO_2max, distance run (∑DT), energy spent (∑kcal), speed of running and consumption of oxygen at anaerobic threshold, estimated genetic capacity $VO_2max_{(GC)}$, $VO_2rel_{(GC)}$ and $vVO_2max_{(GC)}$ (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2014a; Milošević, et al., 2017, 2018). Such a model offers greater control when planning and programming the training work and effects, a more precise level of individualization of the work which enables greater cardiovascular adaptation, great oxidation capacity of the skeletal muscles, the biogenesis of mitochondria and other physical adaptations of the participants, when compared with the interval models. The efficiency of the models has so far been validated essentially on samples of members of the police and armed forces (Milosevic, Milosevic, 2013b), as well as in the preparation of elite athletes of martial arts (Milosevic, Milosevic, 2013b; Blagojevic, et al., 2003). Still, the question is posed as to the application of this model on members of elite handball teams which currently find themselves competing. It is particularly questionable whether the levels of aerobic capacity among athletes and teams that have already achieved high levels of aerobic capacities through many years of training designed according to interval models, can be raised at all.

The goal of this paper is to evaluate the efficiency of anaerobic training programs designed according to the HICT model on one elite handball team, that is, to examine the effects of carrying out such a program, as well as to analyze differences in the design and realization when compared with aerobic interval high-intensity training programs according to models HIIT 1, 2, and 3. It is assumed that HICT will lead to significant improvement in aerobic capacities for elite handball teams who have already reached a "competitive shape" , and will enable more time and space for resting and practicing tactical-technical elements when compared with interval models. The results of this study will lay the foundation for further research into the issue of efficiency of the model of creating aerobic training programs, as well as for furthering the practice of training.

Materials and methods

Participants

Sixteen professional handball players playing for first league handball teams in Iceland participated in the study. Their average age was 23.8 ± 3.6, height 188.2 ± 6.3 cm, weight 92.4 ± 10.2 kg, and body mass index 26.4 ± 2.8. At the beginning of the study, the team was already in the process of competing, which explains the finding that all participants were fully in shape, while their aerobic capacity was, on average, 20% over peak genetic capacity. The sample size was determined after power analysis. For one tail t tests, two dependent means with $\alpha=0.05$, power $1-\beta=0.90$ and large effect size ($dz=0.80$) (Faul, Erdfelder, Lang, Buchner, 2007), the sample size should include at least 15 subjects.

All the participants gave informed consent to the procedures of the study. The conditions of the study were approved by the university's ethics committee.

Measures

For the purposes of calculating, designing, and controlling the training effects and changes, age, height, weight, and Cooper's 12 minute running test were used for the handball players. From this day, the anaerobic threshold ($L \cdot min^{-1}$) was calculated, as were other aerobic parameters (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018).

Maximum relative oxygen uptake was calculated according to the following equation (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018):

$VO_2rel = 3.134304 \cdot 10^{-7} \cdot K^2 + 0.02077344 \cdot K - 9.03125$

where VO_2rel – is the maximum relative oxygen uptake expressed in millimeters per kilogram of body weight in one minute (ml . kg^{-1}. min^{-1}), and K – the value of the Cooper's 12-minute running test expressed in meters (m).

Maximum oxygen uptake is calculated according to the following equation (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018):

$VO_2max = [(3.134304 \cdot 10^{-7} \cdot K^2 + 0.02077344 \cdot K - 9.03125) \cdot BW] \cdot 1000^{-1}$

where VO_2max – is the maximum oxygen uptake expressed in liters per minute (L . min^{-1}), K – the value of the Cooper's 12-minute running test expressed in meters (m), and BW – body weight expressed in kilograms (kg).

The running speed for which maximum oxygen uptake occurs is calculated according to the following equation (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018):

$vVO_2max = 0.0014 \cdot K + 0.1786$

where vVO_2max – is the running speed for which VO_2max occurs expressed in meters per second (ms^{-1}), K – the value of Cooper's 12-minute running test expressed in meters (m).

The value of the genetic capacity in relative oxygen uptake is calculated according to the following equation (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018):

$VO_2rel_{(GC)} = VO_2rel_{(I)} + 105 \cdot e[(^{-.02803419 - .00040123 \cdot AGE) \cdot VO2rel (I) + 0.0000003134304 \cdot AGE}]$

where $VO_2rel_{(GC)}$ – is the genetic value of maximum oxygen uptake expressed in millimeters per kilogram of weight in one minute (ml . kg^{-1}. min^{-1}), $VO_2rel_{(I)}$ - the initial value of maximum oxygen uptake expressed in millimeters per kilogram of body weight in one minute (ml . kg^{-1}. min^{-1}), AGE – age.

The value of the genetic capacity in the maximum oxygen uptake is calculated according to the following equation (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018):

$VO_2max_{(GC)} = \{VO_2rel_{(I)} + 105 \cdot e[(^{-.02803419 - .00040123 \cdot AGE) \cdot VO2rel (I)) + 0.0000003134304 \cdot AGE}] \cdot BH\} \cdot 1000^{-1}$

where $VO_2max_{(GC)}$ – is the maximum oxygen uptake expressed in liters per minute (L . min^{-1}), $VO_2rel_{(I)}$ - the initial value of the maximum relative oxygen uptake expressed in milliliters per kilogram of body weight per minute (ml . kg^{-1}. min^{-1}), AGE – age, and BW – body weight expressed in kilograms (kg).

The value of the genetic capacity for the Cooper's 12-minute running test is calculated according to the following equation (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018):

$K_{(GC)} = \{VO_2rel_{(I)} + 105 \cdot e[(^{-.02803419 - .00040123 \cdot AGE) \cdot VO2rel (I)) + 0.0000003134304 \cdot AGE}] + 9.1976\} \cdot 0.027^{-1}$

where $K_{(GC)}$ – is the genetic value of the crossed distance in 12 minutes during Cooper's test expressed in meters (m), $VO_2rel_{(I)}$ - the initial value of the maximum relative oxygen uptake expressed in millimeters per kilogram of weight per minute (ml . kg^{-1}. min^{-1}), AGE – age.

The capacity value of the speed of running at maximal oxygen consumption is calculated according to the equation (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018):

$vVO_2max_{(GC)} = 0.0014 \cdot K_{(GC)} + 0.1786$

where $vVO_2max_{(GC)}$ – the capacity value of running with VO_2max expressed in meters per second \ (ms^{-1}), $K_{(GC)}$ – capacity value of Cooper's 12-minute running test expressed in meters (m). The lower limit of load was the lowest value of the anaerobic threshold (3.22 L . min^{-1} or 75% of VO_2max) of handball players (Blagojevic, et al., 2003; Klisuras, 2013). It served to determined the lower limits of the range in which the monthly load of all handball players would be distributed (Blagojevic, et al., 2003; Klisuras, 2013). The upper limit of the load of each handball player would always be measured according to the maximum oxygen consumed and the speed at which it was consumed. This type of load fits handball, as it is an anaerobic aerobic sport (Astrand, et al., 2003; Bouchard, et al., 2011; Kenney, et al., 2015; Milošević, et al., 2018; Wilmore, Costill, 2008).

Next, we determined the amount of oxygen that the participant will consume during one month of training (one of the goals of training) in accordance with the training effects, changes, and capacities, according to the following equation (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018):

$VO_2 = 1176.683 + 78.885 (Month) + 2.277 (Month)^2$

where VO_2 – is the overall oxygen uptake expressed in liters per minute (L . min^{-1}), Week – the number of weeks of treatment.

Experimental Design

The study is designed according to a pre and post-test plan with one experimental group. Between the initial and final measurements, the participants carried out HICT and other usually planned activities. Apart from different aerobic training with the team, there was no difference from their usual type of training. HICT (Tables 1 and 2). started at 7 or 8 o'clock. According to the plan, training sessions were to be held on Monday, Tuesday, Wednesday, Friday, and Saturday. Thursday and Sunday were rest days. Uninterrupted continuous training time was 20 minutes with a previously programmed load.

Tables 1 and 2 provide the first and last week of training for one handball player. The load was defined by the distance covered and the amount of oxygen and energy consumed.

Table 1. First Week of Aerobic Training.

Day	Date (ddmmyy)	Distance (m)	Time (min)	Oxygen (liter)	Energy (kcal)
Monday	03.08.20	4253	20	82.79	413.95
Tuesday	04.08. 20	3503	20	69.15	345.57
Wednesday	05.08. 20	4003	20	77.92	389.60
Thursday	06.08. 20	Pause			
Friday	07.08. 20	4764	20	92.53	462.65
Saturday	08.08. 20	3763	20	73.05	365.25
Sunday	09.08. 20	Pause			
	SUM	20286	100	395.44	1977.20

Legend: training days, distance crossed for each day, running time, oxygen consumed at crossed distance, and energy consumed at crossed distance.

Prior to each training session, all participants warmed up for five minutes, while after each session they would cool down for ten minutes of light running, relaxation, and stretching. Each time, the training session was programmed to last four weeks or one month. The duration of the training, the training resources, methods, training objectives, intentional influence, intensity, volume, daily and multi-day load distribution, were individually determined and designed for each participant in accordance with his capacities as demonstrated in the initial measurement of Cooper's 12-minute running test, $VO_2max_{(I)}$ and $VO_2rel_{(I)}$, $vVO_2max_{(I)}$, $VO_2max_{(GC)}$, $VO_2rel_{(GC)}$, $vVO_2max_{(GC)}$, and $K_{(GC)}$ (Table 3), and the demands of the matches by using the VAC Bioengineering hardware-software system (Astrand, et al., 2003; Blagojevic, et al., 2003; Kenney, et al., 2015; Milošević, et al., 2017, 2018; Milosevic, Nemec, Zivotic, Milosevic, Rajevic, 2014b). The calculations of VO_2max as a change that induces a programmed training that includes increasing VO_2max, VO_2rel, vVO_2max, and distance covered in Cooper's test is carried out according to mathematical functions described in the subchapter on measures. In addition to the equations from this study, the software is based on complex mathematical models for the acquisition and processing of day, programming, realization, and control of the training (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2018).

Table 2. Fourth Week of Aerobic Training.

Day	Date (ddmmyy)	Distance (m)	Time (min)	Oxygen (liter)	Energy (kcal)
Monday	24.08.20	4003	20	77.92	389.60
Tuesday	25.08.20	3763	20	73.05	365.25
Wednesday	26.08.20	5004	20	97.40	487.00
Thursday	27.08.20	Pause			
Friday	28.08.20	3763	20	73.05	365.25
Saturday	29.08.20	4003	20	77.92	389.60
Sunday	30.08. 20	Pause			
	SUM	20536	100	399.34	1996.70

Legend: training days, distance crossed for each day, running time, oxygen consumed at crossed distance, and energy consumed at crossed distance.

Exercise Protocol

When the amount of oxygen which will be consumed for one month is determined (equation 8), then in accordance with the anticipated effects and changes, the amount of oxygen which will be consumed in one week (Tables 1 and 2) is distributed (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018). Once the consumption of VO_2 is determined for each day of the week, unique for each handball player, the speed is determined (equation 3) according to which that amount of VO_2 is spent (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018). The appropriate percentage of such a determined speed is run in each training session.

The training session is designed individually, which is why the form of the computer printouts for training is the same (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018). The only differences are the distances run, the consumed VO_2 and energy (kcal) among the participants (Tables 1 and 2). In order to not repeat the printouts for each handball player, we shall show how training programs are made (Tables 1, 2) for only the average results of one participant, and only for the first and last week (Tables 1 and 2). His average age was 23.8, height 188.2 cm, weight 92.4 kg, VO_2max 4.85 L . min^{-1}, 52.70 ml . kg^{-1}. min^{-1} and vVO_2max 4.17 ms^{-1}. Each week in a month includes one peak (95% VO_2max), in the second, two peaks (96% VO_2max), in the third three peaks (98% VO_2max), and in the fourth, one again (100% VO_2max) (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018).

The consumption of oxygen on other days varies each week over a span of 75% to 93% VO_2max (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018).

The training session lasts 20 minutes. By multiplying the speed of running with twenty minutes, a length of the distance run from each training session is obtained (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018).

Multiplying the estimated % of VO_2max by 20 the amount of consumed VO_2 for the entire duration of each individual training is obtained (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018). After a month, the designed program will not render the planned effect and changes, thus the procedure of testing and designing the training is repeated.

Data Analysis
The impact HICT has on the development of aerobic capacity on elite handball players will be determined according to the procedures of the primary processing of data. Comparing the training effects and training changes obtained through the consecutive successive measuring at various time points, under the influence of continuous aerobic training work, a t-statistic will be carried out on small, dependent samples, while the effect size is calculated using Cohen's formula. For all procedures, a level of significance of $p \leq 0.001$ was chosen. All results of the measurement were analyzed with the help of the SPSS version 22.0 software package.

Results

The effects and changes induced by HICT training programs on elite handball teams represents the basic result of this study, while the aerobic genetic capacities of handball players and their use in designing training programs will be covered in the discussion.

Training Effects and Changes
Table 3 presents the descriptive indicators of variables : maximal oxygen consumption, initial and final ($VO_2max_{(I)}$ and $VO_2max_{(F)}$) are expressed in liters per minute ($L \cdot min^{-1}$), maximum relative consumption of oxygen, initial and final ($VO_2rel_{(I)}$ and $VO_2rel_{(F)}$) expressed in milliliters per kilogram of body weight per minute ($ml.kg^{-1}.min^{-1}$), the speed of running in which the maximum amount of oxygen is consumed, initial and final ($vVO_2max_{(I)}$ and $vVO_2max_{(F)}$) expressed in meters per (ms^{-1}), and Cooper's 12-minute running test, initial and final ($K_{(I)}$ and $K_{(F)}$ expressed in meters (m). Finally, the same table presents the t-statistics values, their statistical significance, and the size of the effect.

Table 3. Descriptive Statistics of the Variables of Aerobic Status of the a Pre and Post-test Measurements, T-Statistics and Effect Sizes.

	Minimum	Maximum	Mean	Mean Std. Err.	Std. Dev.	t	ES
$VO_2max_{(I)}$	4.03	5.83	4.85	.12	.48	16.42*	1.17
$VO_2max_{(F)}$	4.55	6.44	5.40	.12	.46		
$VO_2rel_{(I)}$	42.06	57.33	52.70	1.21	4.84	15.91*	1.26
$VO_2rel_{(F)}$	48.20	63.97	58.73	1.17	4.70		
$vVO_2max_{(I)}$	3.49	4.47	4.17	.08	.31	15.73*	1.28
$vVO_2max_{(F)}$	3.88	4.90	4.56	.07	.30		
$K_{(I)}$	2362	3066	2852.06	55.75	223	15.90*	1.27
$K_{(F)}$	2645	3372	3130.19	54.15	216.60		

Legend: $VO_2max_{(I)}$ et $VO_2max_{(F)}$ – initial and final value of maximum rate of oxygen consumption expressed ($L \cdot min^{-1}$), $VO_2rel_{(I)}$ et $VO_2rel_{(F)}$ – initial and final and transitive value of the maximum relative oxygen consumption expressed ($ml.kg^{-1}.min^{-1}$), $vVO_2max_{(I)}$ et), $vVO_2max_{(F)}$ - initial and final value of the maximum oxygen uptake in meters (m), $K_{(I)}$ et $K_{(F)}$ - initial and final values in Cooper's 12-minute run test, t - T-Statistics, df=15, *p<.001, ES - Cohen's d effect size.

The results of the t-statistics for small dependent samples (Table 3) speak to the existence of statistically significant differences in degree $p<.001$ in all variables that describe aerobic changes. Handball players (Table 3) began their four-week training with VO_2max (equation 2) which came out from 4.03 $L \cdot min^{-1}$ to 5.83 $L \cdot min^{-1}$, then VO_2rel (equation 1) from 42.06 $ml.kg^{-1}.min^{-1}$ to 57.33 $ml.kg^{-1}.min^{-1}$, Cooper's test from 2362 m to 3066 m and vVO2max (equation 3) from 3.49 ms^{-1} to 4.47 ms^{-1}. The results (Table 3) demonstrate that, after four weeks, handball players significantly ($p<.001$; $p<.001$; $p<.001$; $p<.001$) improved their VO_2max from 4.55 $L \cdot min^{-1}$ to 6.44 $L \cdot min^{-1}$ which comes out from 10 % to 12%. For VO_2rel from 48.20 $ml.kg^{-1}.min^{-1}$ to 63.97 $ml.kg^{-1}.min^{-1}$ which is an improvement from 11% to 13%. In Cooper's test (K), they improved from 2645 m to 3372 m which comes out from 10% to 11% and vVO2max from 3.88 ms^{-1} to 4.90 ms^{-1} which comes out from 10% to 11% (Dello Iacono, et al., 2015, 2018; Milošević, et al., 2017, 2018). To achieve these results (Table 4), over four weeks training (20 training sessions in total) the handball players had to consume from 1358.00 to 1964.70 liters of oxygen (ΣVO_2), to run a distance (Σ DT) from 70567.80 m to 90383.40 m and to spend energy from 6790.5 to 9823.50 kilocalories (Σ

kcal) (Dello Iacono, et al., 2015, 2018; Klisuras, 2013; Milošević, et al., 2017, 2018). The smallest aerobic strength with which they ran in the period of four weeks came out 3.02 L . min^{-1} that is, 15.11 kcal, while the greatest aerobic strength came out to 5.83 L . min^{-1} that is 29.15 kcal.

Genetic Capacities

Table 4 represents the descriptive indicators of genetic capacities : $_{(GC)}$ – value of genetic capacity of maximal consumed oxygen expressed in liters per (L . min^{-1}), $VO_2rel_{(GC)}$ – value of genetic capacity of maximal relative oxygen spent expressed in milliliters per kilogram of body weight per minute ($ml.kg^{-1}.min^{-1}$), $vVO_2max_{(GC)}$ – value of genetic capacity of the speed at which the maximal consumption of oxygen is expressed in meters per second (ms^{-1}) and $K_{(GC)}$) – the value of Cooper's 12-minute running test expressed in meters (m). In the same table (Table 4), the variables describing the training sessions are displayed. ∑ DT – total distance run over four weeks of training expressed in (m), ∑ VO_2 – total of consumed VO_2 when running over four weeks of training expressed in liters per minute (L . min^{-1}) and ∑ kcal – total consumed energy over four weeks of training.

Among all variables in the first and second measurements, an estimation error of the average value in the sample is exceptionally low for the entire sample (Tables 3, 4). That means that the confidence interval is exceptionally narrow, that is, that the average values in the sample are practically the same as they are among the sample of elite handball players.

Table 4. Descriptive Statistics for Genetic Capacity Variables and Descriptive Training Variables.

	Minimum	Maximum	Mean	Mean Std. Err.	Std. Dev.
$VO_2max_{(GC)}$	5.22	7.24	6.14	.15	.61
$VO_2rel_{(GC)}$	61.06	71.12	67.35	.57	2.28
$vVO_2max_{(GC)}$	4.71	5.36	5.12	.037	.15
$K_{(GC)}$	3238.00	3652.00	3524.31	25.07	100.29
∑ DT	70567.80	90383.40	84338.14	1576.00	6304.01
∑ VO_2	1358.00	1964.70	1645.56	44.11	176.45
∑ kcal	6790.50	9823.50	8227.88	220.60	882.41

Legend: $VO_2max_{(GC)}$ – maximum rate of oxygen consumption measured during incremental exercise in liters per minute (L . min^{-1}), $VO_2rel_{(GC)}$ – the value of the genetic capacity of the maximum relative oxygen uptake in milliliters per kilogram of body weight per minute ($ml.kg^{-1}.min^{-1}$), $vVO_2max_{(GC)}$ – the maximum oxygen uptake in meters (m), ∑ DT – the total distance travelled in 4 weeks in meters (m), ∑ VO_2 – total consumed VO_2 in running during 4 weeks in liters (L), ∑ kcal – the total consumed energy during 4 weeks of training.

Discussion

The obtained results, particularly the difference between the initial and final measures, t statistics, and size of the effect (Tables 3 and 4), speak undoubtedly in favor of the hypothesis that HICT led to the improvement of the state of aerobic capacities for elite handball teams who had already reached high capacity levels prior to the study's beginning. Even so, to further understand, that is, evaluate the model itself, a comparative analysis is needed in the introduction of the demonstrated models (Billat, 2001; Dello Iacono, et al., 2015, 2018; Helgerud, et al., 2001; Milošević, et al., 2017, 2018), as well as for comparing the obtained results with those from similar studies.

Comparative Analysis

With the goal of comparing the various models, it is possible for the average results of one handball player (age 23.8 years old, height 188.2 cm, weight 92.4 kg, VO_2max 4.85 L . min^{-1} , 52.70 $ml.kg^{-1}.min^{-1}$ and vVO_2max 4.17 ms^{-1}) to be transformed into the training goals and activities with the help of algorithms according to which each training session of the given model sis created.

HIIT1 consists of 4 series of running according to an intensity of 90 – 95% maximal heartbeat value (Helgerud, et al., 2001). These running intervals are divided into periods of 3 minutes of running at 50 % of vVO_2max. The observed handball players consume 62 liters of VO_2 in 16 minutes according to HIIT1. If the VO_2 spent in three pauses of three minutes (11.64 liters VO_2) is added to that, then the observed handball player 72.64 liters of oxygen in one training session.

His speed of generating energy comes out to 14.53 kcal . min^{-1}. The handball player runs the intervals and pauses in 25 minutes. During that time period, the distance run (intervals + pauses) comes out to 4328.46 m. If we were to observe only 20 minutes of HIIT1 the handball player covers a distance of 3462.77 m and consumes 58.11 liters of VO_2. HIIT2 estimates the shifting of repeated running at 30 second intervals at 100% vVO_2max with 30 seconds at 50% vVO_2max in order to extend the amount of time spent at maximal aerobic capacity (Billat, 2001). In HIIT2, the observed handball player consumes 48.5 liters VO_2 in 10 minutes during one training session. To that is added the VO_2 which he consumes in 10 active pauses lasting 30 seconds each.

In the first 15 seconds, half the pause spends the maximal amount of VO_2 which comes out to 24.25 liters VO_2 in five minutes. In the second half of the pause, half the amount of VO_2 is spent in five minutes 12.12 liters. When added up, one observed handball player consumes 85.12 liters of VO_2 in one training session. The speed of generating energy in this model comes out to 21.28 kcal . min^{-1}. The handball player covers the intervals and pauses in 20 minutes. During that time, he runs a distance (intervals + pauses) of (intervals + pauses) 3753.00 m and consumes 85.12 liters of VO_2.

HIIT3 for handball players estimates 10 to 30 intervals lasting 15 to 20 seconds of intensity from 95% to 100% VO_2max, with pauses between running from 15 to 20 seconds, whose intensity is from 40 to 50% VO_2max (Dello Iacono, et al., 2015, 2018). The most intensive HIIT3 in the shorter version, 30 intervals lasting 20 seconds with 100% intensity and 30 active pauses lasting 20 seconds at 50% intensity. Through HIIT3, in one training session the observed handball player consumes 48.5 liters VO_2 for 30 intervals lasting 20s. He runs the pauses at 50% intensity and during that time spends 24.5 liters of VO_2. When adding up the consumed VO_2 while the handball player runs intervals with consumed VO_2, while when running during pauses he gains 72.75 liters VO_2. The speed of generating energy in this model comes out to 18.19 kcal . min^{-1}. The handball player runs 20 minutes in intervals and pauses. During that time, he covers a distance (intervals + pauses) of 4230.00 m, consuming 72.75 liters VO_2.

When observing the least intensive HICT (Milošević, et al., 2017, 2018) (intensity 75% VO_2max), the following results are obtained. For running distances of 20 minutes, the handball player consumes 68.7 liters VO_2. The distance he ran in 20 minutes came out to 3753 m. The speed of generating energy at this intensity comes out to 18.19 kcal . min^{-1}. When observing the most intensive training (intensity 100% VO_2max), this models provides us with the following results. For running at distances of 20 minutes, the handball player consumes 97.4 liters VO_2. The distance he ran came out to je 5004 m. The speed of generating energy at this intensity came out to 24.25 kcal . min^{-1}.

All other results of running twenty minutes from lowest to greatest intensity are found between them, and are greater than the results described in the three HIIT (Billat, 2001; Dello Iacono, et al., 2015, 2018; Helgerud, et al., 2001). That can be seen from the monthly distribution of the model's load. The load distribution (Tables 1, 2) in HICT over the course of one month is the following: 40% total training time drops in intensity from 95% to 100% VO_2max. In intensity from 80% to 93% VO_2max 35% drops, and in intensity from 75% to 80% VO_2max, 25% of the total training time drops.

In each training session where the intensity is above 80% VO_2max consumption, the VO_2 , distance run, speed of generating energy are greater than in the three described models.

The demonstrated HIIT (Billat, 2001; Dello Iacono, et al., 2015, 2018; Helgerud, et al., 2001) did not develop the methodology according to which the genetic aerobic capacities of handball players are determined (equations 4, 5, 6, 7), the initial percentage from which handball players start in relation to genetic capacity, percentage, and potential of aerobic improvement in relation to genetic capacities, as opposed to HICT (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018). The sample of handball players is estimated (Table 4) to have a minimal value $K_{(GC)}$ 3238.00 m, average value 3524.31 m and maximal value 3652.00 m. Then, the minimal value $VO_2max_{(GC)}$ 5.22 L . min^{-1}, average value 6.14 L . min^{-1}, and maximal value 7.24 L . min^{-1}. The minimal value $VO_2rel_{(GC)}$ 61.06 $ml.kg^{-1}.min^{-1}$, average value 67.35 $ml.kg^{-1}.min^{-1}$ and maximal value 71.12 $ml.kg^{-1}.min^{-1}$. Finally, the minimal value vVO_2max ($_{GC}$) achieved at 4.71 $m.s^{-1}$, average value at speed 5.12 $m.s^{-1}$ and maximal value at speed 5.36 $m.s^{-1}$. Minimal value of the speed of generating energy in this sample came out to 26.1 kcal . min^{-1}, average value 30.7 kcal . min^{-1}, and maximal value 36.2 kcal . min^{-1}.

When the handball players started training (Tables 3 and 4), they were on average at 79% of their genetic capacity of their VO_2max, 78% of VO_2rel and 81% capacity of vVO_2max. After four weeks of training (Tables 3, 4), all handball players significantly improved in all variables ($p<.001$).

VO_2max on average was found at 90% genetic capacity, VO_2rel on average was at 89% genetic capacity, and vVO_2max on average was at 89% genetic projected capacity. The results of similar earlier studies (Blagojevic, et al., 2003; Bouchard, et al., 2011; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018; Tucker, Collins, 2012) attest to the fact that, over the following month, and according to the newly designed training program, all observed handball players could reach values of up to 96% capacity.

If comparing the training effects obtained through simulating running for twenty minutes with the same data of the followed handball players for all four models (Billat, 2001; Dello Iacono, et al., 2015, 2018; Helgerud, et al., 2001; Milosevic, Milosevic, 2010a, 2013b) , what can be determined is that, over the same period of time, HICT 39.20 more liters of VO_2 than does HIIT1, 12.28 liters VO_2 more than HIIT2 and 24.65 liters more than HIIT3.

The speed of generating energy is greater for HICT by 9.72 kcal . min^{-1} than HIIT1, 3.00 kcal . min^{-1} than HIIT2 and 6.06 kcal . min^{-1} than in HIIT3. Through CT, the handball player ran 1551 m more in 20 minutes than he ran during that same time according to HIIT1, ran 1251 m more than by HIIT2 and 774 m than by HIIT3 over the same time. Given that the training lasted the same amount of time in all the models, and that it has been designed for the same participant, these results indicate that the HICT programs are more intensive. It is hence logical to assume that HICT causes more intensive aerobic adaptations from the participant (Astrand, et al., 2003; Costill, 2008; Kenney, et al., 2015; Wilmore, Bouchard, et al., 2011). Since HICT demonstrates, for the same time period, a greater consumption of VO_2, distance run, and speed of energy generation, that means that said intensity will lead to a higher cardiac output, as well a greater number of active mitochondria in myocites, and an increase grow in the amount of aerobic metabolism enzymes, leading to the increased capacity in creating ATP (Astrand, et al., 2003; Costill, 2008; Kenney, et al., 2015; Wilmore, et al., 2011). It then influences the increased capacity for the oxidation of carbohydrates, through which great amounts of pyruvates are metabolized aerobically (Astrand, et al., 2003; Costill, 2008; Kenney, et al., 2015; Wilmore, et al., 2011). During that same time, through HICT the participant ran from 774 m to 1551.26 m more than in all three HIIT (Billat, 2001; Dello Iacono, et al., 2015, 2018; Helgerud, et al., 2001) which places the participants in the position so that his leg extensors created a greater force on the surface (RFD) and include motor units more quickly in order to extend the length and frequency of their steps (Milošević, et al., 2014a, 2014b.

Analysis of the Effects

The obtained results (Tables 3 and 4) are in line with the results from earlier studies in which the efficiency of HICT was validated on various samples (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018). Still, for the purposes of accomplishing this research goal, the obtained results and effects must be compared with the results of similar studies done on elite handball players. This will allow the validity of the conclusions of the comparative analysis to be re-examined. Through HICT, over the course of four weeks handball players ran an average distance (∑ DT) of 84338.14 m, consumed an average of 1645.56 liters of oxygen (∑ VO_2) and 8227.88 kilocalories (∑ kcal). During that time, they significantly ($p<.001$; $p<.001$; $p<.001$; $p<.001$) improved their VO_2max from 4.55 L . min^{-1} to 6.44 L . min^{-1} which comes out to 10 % to 12%. In VO_2rel from 48.20 ml.kg^{-1}.min^{-1} to 63.97 ml.kg^{-1}.min^{-1} which is an improvement from 11% to 13%. The values of elite handball players (world champions) (Klisuras, 2013) were approximately 60 ml . kg^{-1}. min^{-1} while for Boraczyński and Urniaża (Boraczyński, Urniaż,. 2008) when discussing elite handball players that level is significantly lower, and comes out to 45.4 ml . kg^{-1}. min^{-1}. The initial result of VO_2rel in his sample was 42.3 ml . kg^{-1}. min^{-1} , which reached 45.4 ml . kg^{-1}. Min^{-1} after four weeks, which is an improvement of about 7%. Boraczyński I Urniaża (Boraczyński, Urniaż, 2008) believe that the handball players improved significantly. Their participants started from a much lower initial level than the participants of this study had (52.70 ml . kg^{-1}. min^{-1}) and improved much less over four weeks of training, which attests to the strength of HICT. For Cooper's Test (K) they improved from 2645 m to 3372 m, which comes out from 10% to 11%, and for vVO2max from 3.88 ms^{-1} to 4.90 ms^{-1} which comes from 10% to 11% (Blagojevic, et al., 2003; Milosevic, Milosevic, 2010a, 2013b; Milošević, et al., 2017, 2018). They started out training at 79% genetic capacity of VO_2max and after a month improved from 11% to 13% ($p<.001$), that is, they reached 90% of their VO_2max genetic capacity.

This monthly load contributes to the described response on the bodies of handball players, and causes permanent adaptations in all organic and metabolic systems that participate in the transport of oxygen and its usage for the creation of energy needed for work (Astrand, et al., 2003; Bouchard, et al., 2011; Kenney, et al., 2015; Wilmore, Costill, 2008). Given the limited number of studies focusing on the effects of aerobic training on handball players, the obtained results must be compared with similar studies with our sports samples. If the obtained results (Table 3) are compared with the effects of HIIT on increasing VO_2max noted among elite karate practitioners (ES=0.93) (Ravier, et al., 2009), National-level soccer team players with 8 weeks of treatment (ES=0.97) (Belegišanin, 2017) , elite junior soccer players with also 8 weeks of treatment (ES=0.2) (Helgerud, et al., 2001), elite judo practitioners with 12 weeks program (no significant change) (Bonato, Rampichini, Ferrara, Benedini S, Sbriccoli, Merati, Franchini, La Torre, 2015), and even among recreational athletes (mean ES=0.63) (Sloth, Sloth, Overgaard, Dalgas, 2014) the effects of HICT are significantly greater.

Conclusion

Based on all the analyses that were carried out, the conclusion is that the goal of this study has been realized. The experiment took place with elite handball teams from Iceland, consisting of 16 competitors over the course of four weeks' training. The intensity of the work was programmed individually for each participant according to the HICT method. This program led to significant improvement in the aerobic capacities of elite athletes who, prior to the study's beginning, already had a highly developed capacity. Results of the comparative analysis demonstrated that, when obtained results are compared from the simulations on the same data of the handball players of all four analyzed models, the conclusion is that HICT has the superior features compared with HIIT, which is why its further research is recommended, as is its application in training practices.

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