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HIIT system programming and some practical problems of its application examined within the sample of selected Czech probands in Brno

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Abstract

High Intensity Interval Training is a training method based on a combination of periods in which high--intensity load alternate with low-intensity exercise or passive rest, the so-called rest interval or inactive phase. Nowadays it is gaining more popularity among the general population and is applied in modern fitness centers. The authors found that more than 95 % sports centers organizing group lessons in Brno offer some form of HIIT ("Tabata System", especially). Changing one of the HIIT components will affect the efficiency of the whole system. This effect is demonstrable on the aerobic and anaerobic performance and the composition of body tissues. Our goal within the broad research is to find out what effect changing one variable has on the most widely used HIIT program, and we wanted to examine whether the method is suitable for recreational athletes.

The authors have made the first step in the form of pilot research described in this article, trying to design the system and applying the components in it. The experiment involved twenty deliberately selected male probands. They were randomly divided into two intervention groups of ten probands. In both intervention groups, we observed: number of repetitions performed, subjective load assessment (on the Borg scale) and heart rate. The original design of the pilot study included three training units per week for two weeks (a total of six training units). Basic multiple articulated exercises (Burpees and Jump Squats) were selected for both sets in these protocols in order to achieve key intensity for HIIT. There were some limitations of the experiment described in the article.

The result of the first pilot study was essential concerning the adequacy of the cycle settings. The authors were forced to stop the piloting after the completion of the first week due to the acute overtraining of the probands. The reason to stop the experiment is attributed to an inadequate frequency of training units in individual weeks, which we reflected in the design of the following pilot study and reduced the number to two. The authors have kept the research questions and present the results of the modified piloting below.

It can be assumed that the prolongation of the rest interval has an impact on the ability to perform repeated exercises, heart rate and subjective perception of stress in selected exercises. These results of our pilot research are also related to people's desire to get as much as possible in as little (time) as possible. The HIIT method is (in many aspects) more effective than the continuous method. Its undeniable advantage is time saving, but efficiency is "redeemed" by intensity and demanding character (proved not just in the described experiments). Where is the line between benefit sport and health--threatening sport? What is the "correct" HIIT setting/programming and what causes a change in one of the key variables? Is less sometimes more or more demanding means more effective? Respecting people's demands and desires for performance, mental fitness and physical beauty, with regard to sustainability and health above all, we will seek answers to all these questions. The first step towards finding them is the study carried out.

INTRODUCTION

High Intensity Interval Training (abbreviated as HIIT) is a training method aimed at increasing the fitness of individuals. Based on the findings of many experts, especially after 2000, HIIT can

be defined more generally as a combination of periods in which high-intensity load (load interval = LI) alternate with low-intensity exercise or passive rest, the so-called rest interval (RI) or inactive phase (Gibala et al., 2006; Helgerud et al., 2007; Laursen et al.,2002). High intensity in the active phase is key to the effectiveness of the method and has been discussed by many experts. Bacon et al. (2013) or Danielse (2013) claim that intense exercise is one that exceeds seventy-five percent of maximum heart rate. According to Tabata et al. (1996), HIIT is any interval training with short pauses and maximum load. Perry et al. (2008) also include submaximal load training. Smith (2008) defines a measure of load intensity that exceeds seventy-five percent of VO_2max (the maximum amount of oxygen your body can utilize during exercise). All the criteria mentioned above determining the degree of intensity are in principle not in conflict and are accepted by the professional and lay public. Due to the maximum or submaximal intensity, the load duration is from a few seconds to 4 minutes (Smith et al., 2008). Therefore, the method belonging to the category of developing strength endurance also belongs to the group of intensive training with short to ultra-short intervals (Kuhn, 2005; Měkota & Cuberek, 2007).

HIIT method is not a completely new one and was used even in the last century by the runners like Hannes Kolehmainen or Emil Zátopek. They abandoned so-called master classes based on a large training volume (Billat, 2001). Nowadays, it is gaining more and more popularity among the general population and is being extended to all modern fitness centers. In the Czech Republic, this trend is apparent. We carried out a content analysis of the offer provided by some selected Brno gyms. We examined and compared training lessons offered on the websites *https://www.fitnessposilovna.cz/brno*. The results of this analysis display that more than 95 % of sports centers organizing group lessons provide some form of HIIT, of which the so-called "Tabata System" is dominantly represented.

One of the reasons for this preference can be the fact that this training corresponds to the trend of "fast time" and the effort to get as much as possible in a short time. Tabata System can provide a possibility for this approach and is very popular. Even the general motive is very topical. This kind of effort goes beyond the frame of sports training and becomes a topic of reflection across disciplines (sociology, psychology, or economy). Coming back to sports training, compared to classical endurance training, the exercise time is almost half (Laursen & Jenkins, 2002). We should take the apparent popularity of this kind of exercise set to the present day as a fact and, at the same time, a stimulus for more profound research, understanding, and subsequent streamlining of the method.

Speaking about one of the main reasons for the popularity of the HIIT method for recreational athletes in the commercial sphere, it should be added that the lower time requirement does not reduce the effectiveness of the method. In a number of recent studies, higher effectiveness of the HIIT method for the development of aerobic and anaerobic capacity compared to classical continuous loading has been demonstrated, and positive adaptation changes (especially a significant increase in VO_2 max) have been confirmed. For the purposes of our research, the conclusions of extensive meta-analyses of Milanovič et al. (2015) and Ramose et al. (2015) are the most suitable. They focus not only on the aspect of performance but also on the aspect of health, which must be taken into account in the field of recreational sports.

Ramos et al. (2015) proved the comparable or higher efficacy of the HIIT on vascular function in comparison with the continuous method. The monitored variables were blood pressure, insulin sensitivity, oxidative stress, body fat, or mitochondrial biogenesis (the critical factor is coactivator PGC-1a). In Milanovič's et al. (2015) meta-analysis focused on performance indicators (specifically aerobic performance), a significant positive effect on VO_2 max was demonstrated using an intensive and endurance program compared to the control group. The central goal of the analysis was to compare the effectiveness of both microcycles (HIIT versus Continuous Endurance Training). Higher efficiency was confirmed in the HIIT model. However, at the end

of the analysis, the authors refer to a more detailed examination of intensive training (variable components) for its accurate understanding. Some inconsistencies are pointed out, especially for the variables cycle length, work/rest ratio, and intensity.

The importance of variables for HIIT programming is discussed in more detail by Laursen and Buchheit (2013), both in the context of short-term stimulus and long-term cycle. For a short-term stimulus, the variables defined in particular are the length of the exercise interval and its intensity, the length of the rest interval, the number of intervals, the choice of exercises, and the form of the inactive phase (passive rest). From a long-term perspective, it is primarily the length of the training cycle and the frequency of training units. All components act interactively (training volume versus intensity, intensity versus frequency, frequency + intensity versus cycle duration, etc.). Their composition and final structure affect the requirements for aerobic and anaerobic energy coverage, post-exercise oxygen consumption (EPOC), hormone production, demands for regeneration, and some other attributes.

The problem of HIIT programming

In the following lines, we would like to present the results of some selected studies. They demonstrate the significance and impact of variables on the overall effectiveness of the program. It was found that the extension of the working interval while maintaining the length of the rest interval leads to an increase in the consumption of anaerobic glycolytic energy depending on the volume of work that is performed for a given section. Thus, increasing the duration of the load while maintaining the intensity causes an increase in the consumption of anaerobic glycolytic energy. In comparison to one minute of running with two minutes at VO_2 max at a work/rest ratio = 1, there was a significant increase in anaerobic glycolytic energy and O_2 deficiency (≈ 25 ± 2 vs. 21 ± 2 mL/kg, ES (effect size) +2.3).

Likewise, lactate values measured after completion of the stress section were significantly higher (8.8 ± 3.6 vs. 4.8 ± 1.1 mmol/L, ES +1.7) (Vuorimaa et al., 2000). However, even a seemingly slight difference in the load interval of 15% can lead to a substantial increase in glycolytic anaerobic system requirements and increase lactate production almost twofold. This is demonstrated by the findings of the Smith study in runners with a load at 100 % VO_2 max and different load intervals of 130 and 150 seconds (Smith et al., 2003). However, entitlements to an anaerobic system, and hence oxygen debt, may be different even if the same work and rest period ratio is maintained. The difference in oxygen debt compared to 1:1 and 2:2 is 23.8 ± 1.6 vs. 20.5 ± 1.9 mlO_2/kg (Vuorimaa et al., 2000).

It is notable that lactate production is not as sensitive as oxygen debt to the change in load/rest ratio. Its concentration is lower in the active form of rest at 60–70% of VO_2max than in passive rest (in the comparative study, active rest was 180 s longer (Belcastro & Bonen, 1975). Dupont's study confirmed the lower lactate concentration when active rest was included with active rest values ranging from 40–50% VO_2max (Dupont et al., 2004).

However, active rest may cause higher activation of the glycolytic system and lower muscle oxidation, which in turn may lead to higher lactate concentration (Dupont et al., 2003, 2004; Christmass et al., 1999). However, what is evident is the sensitivity to the change in intensity. Measured lactate values at load/rest at 90/80 % VO_2max, 100/70 % VO_2max, and 110/60 % VO_2max were 9.2 ± 1.3 mmol/, 9.8 ± 1.4 mmol/L and 11.3 ± 1.3 mmol/L (Billat, 2001).

The effect of time and intensity on the anaerobic system is also confirmed by Bisciotti's (2004) study, showing that anaerobic glycotic energy increases when the load is no longer than 30 s at 110 % VO_2 max. At 100 % VO_2max, there was a significant increase in lactate (La) concentration

at a load longer than 60 s (Bisciotti et al., 2004). However, even maintaining the same load/rest ratio, significant changes in the requirements for the glycotic system can be achieved through changes in the direction and selection of the surface on which the exercise is performed. The role is played primarily by the angle of change of direction and the surface characteristics (sand versus grass) (Dellal et al., 2010; Haydar et al., 2011; Binnie et al., 2013; Buchheit et al., 2012). Choosing exercises that significantly impact the intensity of training and energy system requirements is also essential. Claims vary considerably for kettlebell HIIT versus sprint interval cycling. (Williams, B. & Kraemer, R. 2015).

Laursen & Buchheit (2013) also cite the interesting finding that a similar load on the anaerobic system occurs at 30 with maximum load or runs at 300 m and repeated 4 with sprints on a non-motorized treadmill or repeated treadmill sprints of longer 6s separated by 17s pause.

The length of the rest period is of equal importance in terms of affecting the adaptation to the load. Increasing the rest period will allow for a repeat performance with at least partially supplemented acid bases and larger phosphocreatine stocks (PCr) which affects greater production of mechanical work and increases the use of the anaerobic system, hence the aerobic system and EPOC. This is demonstrated, for example, by an athlete study where lactate production was increased from 13.3 ± 2.2 to 15.1 ± 1.7 mmol/L (ES +0.9) due to an increase in rest period of 130 % (Buchheit et al., 2009). According to Rusk et al. (1993), rest periods for interval training should be longer than the 90s. The oxygen debt occurs at the beginning of the exercise, and the anaerobic system is fully loaded.

Summary of the problem and the aims of the research

The above findings mainly applied to physiological processes impacting performance and hence performance. However, the side effect of the HIIT method, which is the effect on body composition and the change in the ratio of active body mass to fat, cannot be ignored. Research on Tabata has shown a marked stress caloric output, which according to Olson (2013) and Talanian et al. (2007), is due to increased resting metabolism and EPOC (increased after stress oxygen consumption due to negative energy balance and intensive work in the anaerobic range). Increased resting metabolic rate due to both aerobic and anaerobic activity was also confirmed by Bastyan (2017) in his dissertation.

Other factors that occur in metabolic processes provoked by HIIT are: increased levels of fat metabolizing enzymes (Gillette et al., 1994), then increased fat utilization due to the maintenance of the necessary glycogen level (Rozenek, 2007), and adaptive changes in skeletal muscle, increasing fat oxidation in muscles and improving glucose tolerance (Boutcher, 2011). A number of studies have confirmed the effectiveness of the HIIT method for fat burning and increased efficiency over conventional continuous training (Stoppani, 2016; Konečný, 2014; Zhang et al., 2017).

Based on the above, we can argue that HIIT is a training method based on intensity and intervals' composition. It is very popular with recreational athletes. Changing one of the components will affect the efficiency of the whole system, and the effect of the method is demonstrable on the aerobic and anaerobic performance and the composition of body tissues. Our goal within the broad research is to find out what effect changing one variable has on the most widely used HIIT program in the commercial sphere and how it will affect aerobic and anaerobic performance and body composition. Considering the high intensity of the program, we want to prove, among other things, whether the method is suitable for recreational athletes and whether more intensive equals more efficient.

To achieve the stated objective, we have made the first step in the form of pilot research described in this article, which has given us an answer to the question of how to design the system. The data has indicated what results from we might expect.

METHODS

Tables 1 and 2 show a simplified schematic of the HIIT systems that will be compared within our further research. Therefore they have been applied in the pilot research. Table 1 shows that they are the so-called Tabata system with a change of variable RI (rest interval). The table is based on theoretical knowledge. In addition, what is expected after the extension of the RI is graphically expressed, and the suggested hypothesis, which we do not yet formulate in the pilotage, will be verified within our subsequent research.

Table 1. Training protocol 1

Intervention group 1 – Training protocol 1	
1st Set	
Period of load and rest/number of rounds	LI=20s, RI = *10s*/8 laps
Load intensity	Maximum
Selected Exercise	Jump Squat
2nd Set	
Period of load and rest/number of rounds	LI=20s, RI = *10s*/8 laps
Load intensity	Maximum
Selected Exercise	Burpee
Total amount of time performed 320s. There's a pause of 120s between sets.	

Source: processed by the authors

Table 2. Training protocol 2

Intervention group 2 – Training protocol 2	
1st Set	
Period of load and rest/number of rounds	LI=20s, RI = *20s*/8 laps
Load intensity	Maximum
Selected Exercise	Jump Squat
2nd Set	
Period of load and rest/number of rounds	LI=20s, RI = *20s*/8 laps
Load intensity	Maximum
Selected Exercise	Burpee
Total amount of time performed 320s. There's a pause of 120s between sets.	

Source: processed by the authors

Hypothetical thesis:

RI increase → NoR Increase → VO_2max reduction → Lower EPOC → Less fat loss

Figure. 1. The hypothetical thesis

Goals and research issues

The central objective of the planned broad research is to determine how and if a change in the rest period affects the performance of individuals, and consequently the composition of the body. In the pilot study, monitoring the performance aspect presented the secondary parameter, and the data obtained was weighted only intuitive in this respect. The primary was to verify that the system was set up due to intensity, exercise selection, and load frequency applicable over a multi-week cycle. We can anticipate what results we might expect after applying the cycle by comparing the data collected subjectively from the Borg scale data and objectively using the Polar M400 sporttester.

To help conclude, we have set out the following two research questions (RQ):

RQ1: Will the load (measured subjectively and objectively) and the RN (number of repetitions) implemented for Protocols 1 and 2 differ?

RQ2: Is the setting of the microcycle and its frequency adequate given the intensity?

Pilot research methods

The experiment involved twenty deliberately selected male probands (recreational athletes sporting up to 120min per week) aged 25–40 years. They were randomly divided into two intervention groups of ten probands. The average age of the participants in the first intervention group was 35 years, and the standard deviation was 4.1. In the second intervention group, the average age of participants was 34 years, and the standard deviation was 4.4. The participants' BMI (body mass index) ranged from 19 to 25. In this experimental mixed pre-research exercise, load and perception were assessed using the Borg scale (Table 3) and the sporttester Polar M400. In both intervention groups, following the application of Protocols 1 and 2, we observed the following variables: number of repetitions performed (RN), subjective load assessment on the Borg scale, and heart rate (HR). We then compared the data. The original design of the pilot study included three training units (TU) per week (Monday, Wednesday, and Friday) for two weeks (a total of six training units with a regeneration delay of 1–2 days). The start of the work intervals was preceded by a 15-minute warm-up focusing on activation of core and significant strained muscle parts, increased ventilation, and heart rate. A cool down and static stretching followed the finish. Basic multiple articulated exercises (Burpees and Jump Squats) were selected for both sets in these protocols in order to achieve key intensity for HIIT.

The main limitations of the experiment are the low number of probands for drawing more general conclusions. The measured heart rate does not depend on the actual HR max that we would obtain with a laboratory test but on the application of Polar. Also, BMI has some limitations, such as non-reflecting age, body composition (location or amount of body fat), or health (high value does not necessarily mean overweight or obesity). However, at this stage of the research and because of the following planned steps, we consider the data source and its value acceptable. The most significant risk was possible overtraining or injury due to the high workload and the inability of probands to continue the experiment.

Table 3 shows HR grades and perceived exertions. All probands were briefed on the scale and identification of each stage before the experiment began. The values were written on pre-prepared forms immediately after the load was completed.

Table 3. Heart rates and perceived extersions

Degrees	Heart rate (% of maximum)	Perceived effort
1.	60–70 %	very little effort
2.	70–72,5 %	little effort
3.	72,5–75 %	moderate effort
4.	75–80 %	greater effort
5.	80–85 %	great effort
6.	85–90 %	high effort
7.	90–94 %	very high effort
8.	94–97,5 %	extremely great effort
9.	97,5–100 %	near maximum effort
10.	100 %	exhaustion

Source: Čechovská, Dobrý (2008); (translated by the authors)

RESULTS

The result of the first pilot study was essential for us, despite the inevitability to discontinue the experiment, for further action. It gave us the answer to the key question related to the adequacy of the cycle settings.

We had to stop the piloting after the completion of the first week because of the acute overtraining of the probands. In the first intervention group, at the beginning of the second week, five probands reported an inability to continue the experiment, which is fifty percent of the sample. In the second intervention group, four probands were unable to continue. The reasons given were subjectively perceived insufficient time to regenerate between training units, back pain, and general exhaustion. Continuous readings on the Borg scale and the ability to perform in the active phase of repetitions for selected exercises also indicated a halt in piloting. In the first intervention group, the median on the Borg scale was level ten (two degrees higher than after the completion of the first training unit) after completing the third training session. The number of repetitions performed decreased by an average of twenty percent, even for the second intervention group, where the median was level eight on the Borg scale after completing the third training unit (two degrees higher than after the completion of the third first training unit). The heart rate ranged from submaximal to maximal, which is expected for this type of training, and did not fluctuate significantly.

The first experiment results within the pilot study did not give us an answer to RQ1 from which to draw a partial conclusion, but they did respond reliably to RQ2.

The reason for the need to stop the experiment is attributed to an inadequate frequency of training units in individual weeks, which we reflected in the design of the following pilot study and reduced the number to two (Monday and Thursday), extending the microcycle by a week so that the number of training units is the same as in the first experiment. So the piloting took three weeks. We have kept the research questions and presented the modified piloting results below.

Table 4 shows the median values in the repeat counts performed for the selected exercises, the assessment of subjectively perceived exertion after completion of the training according to

the Borg scale, the heart rate, percentage of maximal heart rate, and standard deviations (STD) for the first protocol. To determine the data given, the maxHR values for every proband were obtained from the formula 220-age=MaxHR.

Table 4. The median values for Training protocol 1

	Number of repetitions (NoR) Jump Squat/ Burpee	Evaluation on the Borg Scale	HR (measured)/% of maxHR
TU1	14/6	8	170/92
TU2	14/5	9	175/95
TU3	15/6	8	170/92
TU4	15/5	8	170/92
TU5	16/6	7	165/90
TU6	16/5	8	165/90
STD	0,89/0,54	0,63	3,76/1,83

Source: processed by the authors

Table 5 shows the median values in the repeat counts performed for the selected exercises, the assessment of subjectively perceived exertion after completing the Borg scale training, the heart rate, percentage of maximal heart rate, and standard deviations (STD) for the second protocol.

Table 5. The median values for Training protocol 2

	Number of repetitions (NoR) Jump Squat/ Burpee	Evaluation on the Borg Scale	HR (measured)/ % of max HR
TU1	18/8	6	155/84
TU2	18/8	7	160/87
TU3	19/8	6	155/84
TU4	20/8	6	160/87
TU5	21/9	5	150/82
TU6	20/9	6	150/82
STD	1,21/0,52	0,63	4,47/2,25

Source: processed by the authors

DISCUSSION

Based on the data obtained from the pilot study, several partial conclusions can be drawn, and the research questions identified can be answered. Although the experiment has some limitations, which we mention in the section on methodology, we consider the implementation and completion of the experiment beneficial or even necessary for the subsequent extended research. The findings of the pilot study and the answers to the research questions are as follows:

In the experiment and planned follow-up research, we examine if and to what extent a change in the selected variable (RI) affects the effectiveness of the microcycle. Based on the measured data following the application of Protocols 1 and 2, it can be assumed that efficacy will be affected. Differences are evident for all endpoints (number of repetitions performed, subjectively perceived load intensity, and HR). Changes in these, directly and indirectly, affect the energy coverage mode and the aerobic to anaerobic system involvement ratio, after EPOC oxygen stress consumption,

VO2 maximum, change in body composition, regeneration requirements, hormonal changes, and more mentioned in the theoretical part of the article. Efficacy differences in changes in aerobic and anaerobic capacity and changes in body composition will be further investigated in the framework of future research. For the time being, it can be assumed that the prolongation of the rest interval impacts the ability to perform repeated exercises, heart rate, and subjective perception of stress in selected exercises, thus also answering the first identified research question of secondary importance for the time being.

Although these assumptions will need to be confirmed or disputed in more extensive work, the data obtained indicate that the research intent set out by us is correct. After changing one of the variables, the differences in effectiveness will be confirmed with further consensus. However, the primary objective of the experiment was to verify that the application of the system is actual and that the research is feasible. We found that completing three training units per week is unsustainable for the general population. It appears adequate to use two training doses per week with a minimum of 48 hours to eliminate acute fatigue.

After reducing the training doses to two of the results, we conclude that completing the planned eight-week cycle is realistic. This position is also indicated by a tendency to decrease or stagnation in heart rate, subjectively perceived load, and the number of repetitions performed in the last week of the experiment, which may be due to partial load adjustment. Variables will have to be further monitored, results in follow-up research verified. However, based on piloting, it can be concluded that the application of training reports is possible at the frequency of two doses per week and risky or impossible at the frequency of three. This is also the answer to the crucial second research question. Due to the complexity of HIIT, we consider that a pilot study will be necessary, and we believe that the experiment conducted by us will serve other researchers.

CONCLUSIONS

Finally, we return to the initial claim of people's desire to get as much as possible in as little (time) as possible in an attempt to give it short shrift and answer the meaning of our investigation if it exists. The HIIT method is even more effective than the continuous method, as confirmed in many studies. Its undeniable advantage is time-saving, but efficiency is "redeemed" by the intensity and demanding character, as evidenced, among other things, by the results of our experiments. Where is the line between benefit sport and health-threatening sport? What is the "correct" HIIT setting/programming, and what causes a change in one of the key variables? Is less sometimes more or more demanding means more effective? Respecting people's demands and desires for performance, mental fitness, and physical beauty, concerning sustainability and health above all, we will seek answers to all these questions. The first step toward finding them is the study carried out.

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