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INTELLIGENT DECISION MAKING TOOL FOR AIDING THE SETTING OF OPTIMAL INTENSITY IN AEROBIC ENDURANCE TRAINING

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ABSTRACT. Aerobic endurance training plays a significant part in the field of physical activity due to the fact that it has a medium intensity value and it depends primarily on aerobic energy generating processes. By engaging the cardiovascular and respiratory systems of the body this type of training is used to improve the overall endurance and fitness. The adaptation of these structures to the physical effort results in improving the performance output, by pushing the limits of cardiovascular and respiratory system's functions. In order to obtain the desired results it is necessary to ensure the operating points that are often hard to reach by classical training methods. The human heart rate variability with respect to the velocity of walking or running presents inherent nonlinearities that are required to be taken into account when designing computer integrated training aids. This paper implements a training aiding tool for setting the optimal intensity of the training, using an intelligent decision making system for the human cardiovascular fitness. This software application was tested and validated by using pre-recorded data from various subjects and was compared to the classical way of analysing the heart rate variability of a subject. The designed intelligent decision making tool ensures the optimal desired intensity profiles, finding its usefulness in supporting the training configuration process by specialized professionals.

Keywords: *intensity, aerobic endurance, training, intelligent system*

REZUMAT*. Instrument decizional inteligent pentru determinarea intensității optime în antrenamentul de rezistență aerobă.* Antrenamentul pentru rezistența aerobă poartă un rol important în aria activităților fizice datorită valorii medii ale intensității care activează, în principal, procesele aerobe energogene. Prin

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angrenarea sistemelor cardiovascular și respirator, acest tip de antrenament este utilizat pentru dezvoltarea anduranței generale. Adaptarea acestor sisteme la efortul fizic, care are ca rezultat creșterea performanței, este realizată prin continua forțare a funcțiilor sistemelor cardiovascular și respirator. Pentru a se obține rezultatele dorite este necesar să se asigure puncte operative obiective din punct de vedere fiziologic, lucru care este mai greu de realizat prin metodele de antrenament clasice. Variabilitatea frecvenței cardiace prezintă nonliniarități inerente, în ceea ce privește viteza mersului sau a alergării, care trebuie luate în considerare în conceperea instrumentelor pentru antrenamentele asistate de calculator. Această lucrare implementează un instrument decizional de asistare pentru setarea intensității optime a antrenamentului, utilizând un sistem inteligent de luare a deciziilor. Testarea și validarea acestei aplicații au fost realizate prin utilizarea unor date înregistrate anterior; totodată s-a efectuat și compararea acestui instrument cu metoda clasică de analiza a variabilității frecvenței cardiace. Instrumentul decizional inteligent asigură stabilirea profilelor optime dorite pentru intensitatea antrenamentelor, găsindu-și utilitatea în suportul acordat procesului de configurare a antrenamentului de către profesioniști.

Cuvinte cheie: *intensitate, rezistență aerobă, antrenament, sistem inteligent*

Introduction

The body undergoes multiple adaptations to the stress of an aerobic workout that allows optimal output of performance. The metabolic demands that appear as a result of muscle activity are one of the causes that generate an increased delivery of blood to working muscle groups and as a consequence an increased heart rate. One of the most common methods of improving the fitness of a person consists of maintaining their heart rate during the training at a set value that is unique for each individual. This set value is in close correlation with the previously settled intensity of the workout. The required heart rate is harder to be maintained by the subject if the intensity gets higher. The classic training methodologies for improving aerobic endurance work with in “off-line” way, meaning that the regulation of the intensity is made after the practice is over and the next practice will be arranged according to the information gathered during the previous one. This classical way of regulating the intensity of the training “off-line” can be improved by using applications to assist the trainer into taking a decision regarding the level of the next workout’s intensity. The stress of a workout on a subject’s body has a degree of subjectivity regarding the interpretation of the intensity’s actual level. The ability to include in an objective instrument this personal way of describing the intensity of a workout could prove to be invaluable to achieving the desired performance. These vague subjective values can be used in an intelligent decision making instrument using a type of logic that can incorporate non-crisp values, called fuzzy logic. (Passino, 1998, Willmore 1999)

The integration of abstract knowledge from physiology into a fuzzy logic controller has been done with great success. The controller proposed by the author consisted of 36 *if-then* rules that were applied on a model that had three sets of variables (Jacobs, 1997).

Human decision-making can be modelled using fuzzy logic set theory by including abstract notions like human drives and motives, though there is a gap in the literature describing the methodology of creating expert-driven fuzzy logic models. The authors proposed a 10 step method that allowed them to include variables like motivation and drives into the controller (Rudas, 2012).

Novatchkov and Baca proposed an evaluation of strength exercises using the fuzzy logic approach. They also considered that there is a lack of application of fuzzy logic control systems in the fields of sport and training (Novatchkov, 2013).

Measurement of the beat-to-beat interval of the heart clearly shows that heart rate is not constant but alters from beat to beat. This is known as heart rate variability (HRV). At rest this beat-to-beat interval fluctuates with the breathing cycle – it speeds up during inhalation and slows down during exhalation.

This variation is due to the attenuation of the parasympathetic activity to the heart during inhalation. Heart rate is regulated predominantly by the autonomic nervous system (ANS). The ANS describes the nerves that are concerned with regulation of bodily functions; these nerves function without consciousness or volition. The autonomic nerves comprise sympathetic and parasympathetic nerves; sympathetic nerves excite the heart, increasing heart rate and parasympathetic nerves reduce heart rate.

Measurement of HRV for use in monitoring training and recovery involves analysis of the beat-to-beat variation. By accurately measuring the time interval between heartbeats, the detected variation can be used to measure the psychological and physiological stress and fatigue on the body during training. Generally speaking the more relaxed and unloaded (free from fatigue) the body is the more variable the time between heartbeats.

HRV data can indicate the impact of fatigue due to prior exercise sessions, hydration levels, stress and even the degree of performance anxiety, nervousness or other external stressful influences. Studies have shown that it varies within individuals according to size of left ventricle (inherited trait), fitness level, exercise mode (endurance or static training) and skill (economy of exercise). Body position, temperature, humidity, altitude, state of mood, hormonal status, drugs and stimulants all have an effect on heart rate and HRV as do gender and age. (Aubert, 2003)

Overtraining is an imbalance between training/competition and recovery. Additional non-training stress factors and monotony of training may also contribute to overtraining syndrome. While short-term overtraining can be seen as a normal part of athletic training (HRV does not seem to be affected) long-term overtraining can lead to a state described as burnout or overtraining syndrome. (Earnest, 2004)

Well-timed rest is one of the most important factors of any training programme. The effects of training sessions can be negligible or even detrimental if insufficient rest and recovery is built in. HRV measurements demonstrate a significant and progressive decrease in parasympathetic activity during long-term heavy training, which is followed by an equally significant increase during rest. Sympathetic activity shows the opposite trend. (Lehmann, 1993)

HRV is a relatively simple, but effective, tool for regular checks of progress during endurance training programmes.

Heart rate variability monitors and associated software are powerful tools for athletes and coaches, providing useful information which can be used to adjust training programmes to best effect.

Objectives

1. Designing an intelligent decision making tool for aiding the aerobic endurance training
2. Testing the decision making tool
3. Comparing it with the classical analysis of heart rate variability

Materials and methods

We've used a Polar Wearlink heart rate monitor to record all the data for this study, and analysed it using Microsoft Office Excel software.

To design the decision making application that included both the human-computer interface and the actual intelligent instrument that will analyse all the data provided we've used the Matlab 2008 programming software.

The application requires the previous measurement of two variables: the R-R interval (heart rate variability) and the work heart rate that was used during the last two training sessions.

For each of the variables the operator needs to input two entries: the "Reference R-R Interval", the "R-R Interval Before Session", the Work Heart Rate before the last session and the Work Heart Rate of the last session. After the data is given to the application the "Calculate" button can be pressed. This results in the calculation of the "Recommended Training Intensity" by the application. This value of the intensity is presented in the form of a percentage that recommends how much the intensity for the next training should be changed. If the exit value is negative then the intensity should be lowered, and the opposite if the value is positive.

Subjects

For the testing and validation of the instrument we've recorded 4 subjects, all female, with the ages between 21 and 23 years old. We've recorded the subject's R-R intervals and also the heart rates of the training sessions during 13 days, because we need 10 entries to determine the Reference R-R Interval and the extra 3 were used in testing and comparing the application.

Results

After we collected the measured data for each of our subjects we analysed them using Excel. The first two subjects were the ones we've used our application on. The data from the other 2 subjects was used to see compare our application with the classical interpretation of the heart rate variability.

Table 1. Recordings of R-R Interval and the Reference Calculation

	Subject 1	Subject 2	Subject 3	Subject 4
Day 1	5.77	5.66	6.01	5.12
Day 2	6.05	5.40	5.89	5.15
Day 3	6.32	5.12	5.80	5.22
Day 4	6.67	5.90	5.99	5.30
Day 5	6.71	5.34	6.10	5.40
Day 6	6.65	5.70	6.15	5.39
Day 7	6.32	5.55	6.00	5.19
Day 8	6.10	5.41	6.14	5.64
Day 9	6.79	5.30	5.88	5.29
Day 10	6.13	5.10	5.94	5.25
Average	6.35	5.45	5.99	5.30
Standard deviation	0.34	0.26	0.12	0.15
Reference	6.01	5.19	5.87	5.14

Table 2. Recordings for the 11th, 12th and 13th day with Reference Calculation

	Subject 1	Subject 2	Subject 3	Subject 4
Day 11	6.44	5.21	6.12	5.14
Average	6.36	5.43	6.00	5.28
Standard deviation	0.33	0.25	0.12	0.15
Reference	6.03	5.17	5.88	5.13
Day 12	6.39	5.30	5.40	5.31
Average	6.36	5.42	5.95	5.28
Standard deviation	0.31	0.24	0.21	0.15
Reference	6.05	5.17	5.75	5.14
Day 13	6.50	5.19	5.80	5.27

Table 3. Evolution of R-R Interval and Reference

	Subject 1	Subject 2	Subject 3	Subject 4
Reference Before Day 11	6.01	5.19	5.87	5.14
Day 11	6.44	5.21	6.12	5.14
Reference Before Day 12	6.03	5.17	5.88	5.13
Day 12	6.39	5.30	5.40	5.31
Reference Before Day 13	6.05	5.17	5.75	5.14
Day 13	6.50	5.19	5.80	5.27

Table 4. The exit data for Subject 1 on the 3 evaluation days

	Subject 1		
WHR Two Sessions Ago	120.00	132.00	150.00
WHR Last Session	132.00	150.00	145.00
Recommended Intensity	4.50	3.20	12.00

Table 5. The exit data for Subject 2 on the 3 evaluation days

	Subject 2		
WHR Two Sessions Ago	120.00	124.00	136.00
WHR Last Session	124.00	136.00	140.00
Recommended Intensity	2.11	1.35	2.17

Discussion

The data we've collected after the analysis of the recorded variables allows us to show that using our application the optimal intensity can be adjusted according to individual needs. The evolution of the performance for the first two subjects reveals that the use of our software gives a more gradual and controlled way of setting the intensity of an aerobic training compared to the classical way of interpreting heart rate variability for the setting of the work load.

Conclusions

1. Out application uses well the information from the literature regarding the interpretation of the heart rate variability for setting the training's intensity
2. Out instrument allows a more gradual increase or decrease of the intensity
3. The integration of the previous training's work heart rates allows to better adjust the percentage with which to increase or decrease the intensity
4. This application opens the path to implement it into a larger control system for aerobic endurance training

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