INDIVIDUALISATION OF THE TRAINING PROCESS OF TENNIS PLAYERS USING THE HEART RATE MONITOR

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Abstract. *This study aims to demonstrate the efficiency and necessity of heart rate monitoring and especially individualising workouts depending on each athlete's response to the effort provided in both training and everyday life. The study included a group of 6 female tennis players aged 13-14, with 6-7 years of tennis experience. The methods used to conduct this study were the following: bibliographic documentation, direct and indirect observation, testing and measurement, graphical method. In this research, the Polar M400 Heart Rate Monitor was used during the 14 weeks of training. Each girl athlete has her own device (watch and chest belt) and own Polar Flow account where data are transferred from the watch. The software allowed us to record data during the physical training and tennis training of athletes, as well as their daily activity expressed as a percentage. The assessments of tested parameters highlighted the following: the 50-minutes run at a pace of 150 beats per minute (bpm) recorded an average increase of 1.3 km, with a percentage increase of 19.78%; basal heart rate recorded an average decrease of 14.3 bpm, with a percentage increase of 18.14%; VO₂ max recorded an average increase of 6 ml/kg/min, with a percentage increase of 10.81%. Differences between the initial and final tests indicate progress for each athlete, which means that the methodology of teaching training lessons has been efficient and therefore the performance of athletes has increased.*

Keywords: heart rate monitor, methodology, tennis players, training.

Introduction

It is well known that the evolution and level of development of any society are conditioned by the quality of education and organisation of the young generation in physical, mental, moral, aesthetic, professional terms but not only. Unfortunately, contemporary society is marked by modern technology and the virtual world, and currently many children “practise” different branches of sport on the computer, which represents a real and dangerous social phenomenon. This reality should alarm all the actors involved in the education of the young generation.

Sport as a cultural fact reflects the characteristics of the society in which it is immersed but at the same time is an instrument with which to act on the system, a vehicle of social change able to generate attitudes and behaviours (Delgado & Gómez, 2011). When talking about education in sport, we refer to ambition, courage, emulation, distributed attention, determination, perseverance, calm, modesty, honesty, multiple traits of will and character. Formal and informal education benefits from the values transmitted through sports, such as information accumulation, motivation, skills, willingness to make personal efforts, as well as social qualities such as teamwork, solidarity, volunteering, tolerance and fair play, all in a multicultural context (Dragnea & Teodorescu, 2002).

This paper highlights the theoretical information that athletes acquire during the instructive-educational process. By introducing heart rate monitors in the training of athletes, they will gain knowledge about the reactions of their own bodies to different types of effort. Heart rate monitors are mainly used to determine exercise intensity during a training session or race. Compared to other indicators of exercise intensity, heart rate is easy to monitor, is relatively cheap and can be used in most situations (Achten & Jeukendrup, 2003; Goodie et al., 2000).

Heart rate provides a lot of information but reliable data are needed to correctly interpret it. Accurate data allow the assessment of responses, adaptations and energy expenditure (Benson & Connolly, 2011). The individualisation of training programmes involves understanding the mechanisms of body function and adaptation according to the characteristics of each athlete.

Early adolescence, which starts around the age of 11-12 years in girls and lasts until 13-14 years, is the transition period between childhood and adolescence, the quantitative gains during the process of growth, development and maturation of the body culminating with the emergence of a qualitative leap (Himes, 2006).

They experience a unique state at each stage of their development, showing different physiological abilities in each growth period. Physical and physiological changes, which sometimes occur suddenly during each stage, are accompanied by dramatic behavioural changes.

The issue of monitoring exercise heart rate is a common topic addressed all over the world for different sports such as football, volleyball, swimming, athletic endurance events, as well as for young or adult sedentary people and even people with health problems. Research over time shows that using heart rate monitors is a common method of assessing athletes (Akenhead & Nassis, 2016; Thorpe et al., 2017). The increased number of commercial and software products for recording and analysing heart rate has helped to make the sports training process more efficient (Naranjo et al., 2015; Perrotta et al., 2017; Plews et al., 2017; Schneider et al., 2018).

Jeukendrup and Van Diemen (1998) studied the need to monitor exercise intensity during training in cyclists to obtain optimal training effects and avoid overtraining. Given that speed is not an accurate indicator of exercise intensity in this sport, the authors had to find alternatives to monitor exercise intensity during training and competition.

According to Li (2014), Polar Heart Rate Monitor is an important tool for football coaches to design a scientific and rational training programme.

Morgans et al. (1987) monitored the heart rates of players during singles and doubles tennis competitions, and then compared the two values obtained.

Other studies examined the influence of different types of exercise training on heart rate variability in young athletes (Aubert et al., 2003).

Heart rate was related to the intensity of training, the rate of injuries and the overtraining syndrome in young elite gymnasts (Sartor et al., 2013).

Doyle-Baker (2015) recorded the heart rates of elite alpine skiers because “in sport, fatigue is not only the demise of the athlete’s ability to reach peak performance but it also can increase the risk for serious injury” (p. 1).

The aforementioned studies provided important information but none of them addressed exercise heart rate at relatively young ages even though their authors related heart rate to the overtraining syndrome and the high risk of injury.

A paediatric study (Franklin & Weiss, 2012) states that children significantly differ from adults, the former being more susceptible to injury. The authors claim that recognition, proper rest and attention to mechanics may assist in decreasing the incidence and severity of injuries.

We believe that an important issue in injury prevention at this age involves limiting the intensity of exercises and gradually introducing them into the young athlete's programme. We consider it imperative to compensate each time for high-intensity training through aerobic and stretching exercises. We also think it is very important for athletes to be educated to know their bodies, their own limits and own progress, as well as the importance of certain training lessons but also some parts of it such as warm-up before starting exercise and recovery after exercise.

Through this methodology (using the Polar M400 device in training sessions), athletes will measure their progress in relation to themselves, not to others, by comparing their current results with previous ones. Thus, they will be able to assess their personal value in an objective and less frustrating way.

The novelty of this paper is represented by the implementation of modern technology in the training of competitive tennis players aged between 13 and 14 years. This will facilitate the learning and understanding of training lessons, recovery measures and a healthy lifestyle from an early age.

A heart rate monitor is a device that takes a sample of heartbeats and computes the beats per minute so that the information can easily track heart condition. Human's heart pumps oxygen-rich blood to muscles and carries cell waste products away from tissues. Heart rate can vary according to the muscle demand to absorb oxygen and excrete carbon dioxide changes, such as during exercise or sleep. It also varies significantly between individuals based on fitness, age and genetics. This means heart must beat faster to deliver more oxygen-rich blood. During exercise routines, heart rate gives a strong indication of how effective that routine is in improving health. (Rahman et al., 2012). Normal heart rate for a resting child over 12 years old is about 55 beats per minute (bpm) to 85 bpm.

Comprehensive heart rate monitoring is crucial for understanding an athlete's individual responses to training in order to optimise the scheduling of training and recovery strategies (Schneider et al., 2018).

Training load monitoring is important to both determine whether an athlete is adapting to the training programme and minimise "the risk of developing non-functional overreaching, illness and/or injury" (Halsen, 2014, p. 139).

Research purpose

This study aims to demonstrate the efficiency and necessity of heart rate monitoring and especially individualising workouts depending on each athlete's response to the effort provided in both training and everyday life. The current paper tries to make a theoretical contribution to enriching the sports teaching methodology by implementing technology in the training of young athletes.

Research questions

Is it possible to increase training efficiency in young tennis players by using the heart rate monitor? Will this help athletes better understand the importance of individualisation and of using certain effort zones in their training plans to correlate tennis with physical training?

Methodology

Participants

The study included a group of 6 female tennis players aged 13-14 years, members of the CSS 6, “Mircea Eliade” Sports Club and “AS Politehnica” Sports Club in Bucharest.

Methods

The methods used in this study were: bibliographic documentation, direct and indirect observation, testing and measurement, mathematical and statistical method, graphical method.

Instruments

Athlete monitoring was performed using the following instruments: M400 GPS sports watches produced in Kempele, Finland, by the POLAR Company and chest belts with built-in Polar H7 sensor. These instruments helped to determine the data for the following indicators: 50-minute run at a pace of 150 beats per minute, basal heart rate value and VO₂ max value.

Procedure

The research was conducted between 16.09.2019 and 17.12.2019 on the athletic track of the “Lia Manoliu” Sports Complex, at the “Voinicelu” Tennis Club and the “AS Politehnica” Tennis Club in Bucharest.

The study design involves the following steps:

- Stage I - on 16.09.2019, initial testing;
- Stage II - between 17.09.2019 and 16.12.2019, athlete monitoring;
- Stage III - on 17.12.2019, final testing.

The monitored athletes had 6-7 years of tennis experience. Their tennis training took place 5-6 times per week, and a session lasted 90 minutes on average; they also performed physical training 3-4 times a week, which could last between 70 and 120 minutes, depending on the training objective and period.

During the 14 weeks, the experimental group performed 9 workouts per week, 6 tennis sessions and 3 physical sessions. Athletes performed 5 workouts per week in the aerobic zone

(150 bpm), 1 workout in the anaerobic threshold zone (160-170 bpm), 1 workout in the lactate threshold zone (over 170 bpm) and 2 workouts in the speed-agility zone (ATP-CP).

It should be noted that all tennis players included in the study work with the same physical trainer but have different tennis coaches. Their competition calendar is quite busy (because international tournaments become a challenge at this age) but flexible, in the sense that some competitions are common while certain tournaments are played depending on the national or international individual ranking as well as the time and financial resources of the athlete. At the beginning of the study, participants were explained the testing characteristics and the assessment techniques used. They expressed their agreement and consent was obtained by signatures from their parents. All ethical and medical conditions related to research involving human subjects were respected.

Methodology for implementing the heart rate monitor

Each girl athlete has her own device (watch and chest belt) and own Polar Flow account where data are transferred from the watch. The watch stores a limited number of workouts, which is why data are transferred to the Polar Flow account. All downloaded information about the athlete's activity is stored in this account, which represents very important data for both athletes and coaches.

Tennis players were explained how to use the watch, how to record workouts and how to transfer data to their accounts. Coaches have access to their Polar Flow accounts all the time (even if the athlete is training or competing in another city or country) and thus can see their reactions to scheduled workouts, can see other workouts (physical or tennis training) but also other daily activities. Depending on these data, they can modify/individualise future workouts.

Athletes' activity

The software allowed us to record data during the physical training and tennis training of athletes, as well as their daily activity expressed as a percentage. The figures below show the daily activity charts as follows: Figure 1, their daily activity during a week, and Figure 2, their daily activity during a month. These charts provide us with a lot of information on their activity.

Figure 1 shows data on the athlete A.W.M., who recorded an average activity of 254% (8 hours 37 min); the distance travelled averaged 17.06 km per day, with an average energy consumption of 3004 kcal. The graphs illustrate in colour the five levels of activity intensity, the darkest colour corresponding to the most intense activity, and the lightest colour, to the lowest-intensity activity. The athlete recorded during a week: 2 days and 4 hours - idle activity, 10 hours and 2 minutes - rest activity, 1 day 21 hours - sitting activity, 1 day 10 hours - light activity, 17 hours 36 minutes - moderate activity, 8 hours 16 minutes - intense activity.

Figure 1. Daily activity

Figure 2. Monthly activity

Aerobic capacity

Heart rate monitoring is an indicator that helps us check whether the planned means of training really serve to develop the aerobic/anaerobic effort zone, whether they develop or compensate for a specific type of effort. In standardised physical training, athletes can see their own progress as shown in Figure 3 and Figure 4, which reveal an improvement in running pace and implicitly performance at the same energy expenditure.

Between 20 September and 16 December 2019, the athlete G.I. makes progress in the 50-minute run, the distance travelled being improved from 6.39 to 7.51 km, and thus the average speed decreasing from 7 min 50 sec per 1000 m to 6 min 40 sec per 1000 m. Average heart rate is 1 bpm lower, maximum heart rate is 4 bpm lower, minimum heart rate is 20 bpm lower, average cadence improves by 2 steps per minute and maximum cadence improves by 20 steps per minute, with caloric intake remaining the same.

Figure 3. 50-minute run, September

Figure 4. 50-minute run, December

Training intensity

Training intensity is critical to an athlete's performance. A training programme that lacks high-intensity training will not improve aerobic fitness, but a too high-intensity programme may cause illness and overtraining. Therefore, a practical means of monitoring training intensity is important to a coach or athlete (Gilman, 1996).

Training, whether it is tennis or physical training, should start at the level at which the athlete finds it easy to maintain. Changes in training intensity should be gradual to avoid muscle pain and injury (Crespo & Miley, 1998).

Because the border between fatigue and overtraining is very thin, athletes need to start getting used to intensity. If there are many minutes accumulated in the first intensity zones during tennis training, then the scheduled physical training sessions will have to compensate for that effort or will not penetrate the surrounding effort zones.

Regarding changes in the training plan, most of them were made during physical training, the development of technical skills being a priority in the tennis game played at this age.

Figure 5 gives an example of high-intensity tennis training, and Figure 6, an example of physical training aimed to “un-fatigue”, regenerate the body.

In tennis training that is focused on the technical/tactical component and whose intensity is negligible, intensity workouts will be scheduled in physical training lessons.

Figure 5. Tennis training

Figure 6. Physical training

Maximum oxygen uptake

The heart is a muscle and responds like any other muscle becoming bigger and stronger as athletes train. After a training session, the heart continues to pump blood into the muscles to feed their repair and recovery. Therefore, heart rate can indirectly inform about the state of recovery of athletes' muscles. If they have microtears or are replacing fuel, their metabolism will be increased, and heart rate will also be slightly higher.

Athletes transmit their minimum pulse rates every morning, and if there are increases of more than 6-7 pulse beats, light physical activities will be scheduled or athletes will be allowed more rest time, the main goal being their optimal health status.

Another function of the Polar device is the Fitness Test (Figure 7), which indicates the value of VO_2 max (maximum oxygen uptake). This test was performed mainly in the morning, under basal metabolism.

The Polar Fitness Test is easy and it takes between 3 and 5 minutes to complete. During this time, the Polar Heart Watch measures 255 heartbeats. At the end of the test, the watch displays a value that predicts VO_2 max as an index. This non-exercise test measures aerobic (cardiovascular) fitness, assessing maximum oxygen uptake (VO_2 max) in ml/kg/min. It tracks the value of resting heart rate and heart rate variability in athletes and combines this information with their background (gender, age, height, body weight) and an assessment of their physical activity over the past six months, as shown in Figure 8.

December, 2019		0 Sessions
Fitness Test 08:41	74 ELITE
Fitness Test 11:26	74
Fitness Test 11:59	74
Fitness Test 07:38	73

Figure 7. Values of VO_2 max

Elite		>62 74 VO_2 max
Very good		57 - 62
Good		51 - 56
Moderate		44 - 50
Fair		38 - 43
Low		32 - 37
Very low		<32

Figure 8. Fitness Test

Results and Discussion

Tables 1, 2 and 3 show the initial and final results obtained by athletes in the 50-minute run, basal heart rate and VO_2 max tests, the values achieved in the initial test (IT) and final test (FT), the difference between the two tests and the rate of the progress expressed as a percentage.

Table 1. *Initial and final test results for the 50-minute run*

Athlete	IT	50-minute run		
		FT	Difference	Percentage %
A.W.M.	7.0	8.38	1.38	16.46
I.G.	6.39	7.51	1.12	14.91
A.A.	6.28	7.75	1.47	18.96
A.D.	6.5	7.9	1.4	17.72
C.O.	7.2	8.3	1.1	13.25
S.T.	6.1	7.4	1.3	17.65

Table 2. *Initial and final test results for basal heart rate*

Athlete	Basal heart rate		Difference	Percentage %
	IT	FT		
A.W.M.	82	63	19	23.17
I.G.	80	65	15	18.75
A.A.	79	68	11	13.92
A.D.	73	59	14	19.17
C.O.	74	60	14	18.91
S.T.	85	72	13	15.29

Table 3. *Initial and final test results for VO₂ max*

Athlete	VO ₂ max		Difference	Percentage %
	IT	FT		
A.W.M.	68	74	6	8.10
I.G.	56	64	8	10
A.A.	48	55	7	12.7
A.D.	51	55	4	7.27
C.O.	50	55	5	9.09
S.T.	60	65	5	7.69

We chose to test the 50-minute run at a pace of 150 bpm (Table 1) because we considered that this type of effort would bring a lot of benefits to athletes. The purpose of training is to increase aerobic capacity by using a large volume of continuous workout at a uniform pace (Bompa & Carrera, 2006). This type of training increases the concentration of haemoglobin and VO₂ max, improves the intake of oxygen and nutrients, and decreases submaximal heart rate, submaximal respiratory rate and resting blood pressure (Bompa & Haff, 2014). During this training, the number of capillaries increases, allowing the exercising muscle to perform more efficiently (Reuter, 2012).

The biggest problem for us was to educate athletes to keep their heartbeats at a low-intensity pace. At this age, the desire to compete is very strong, which is why they had to perform this type of training individually while being asked to respect the running pace no matter how slow it seemed to them.

The values of the 50-minute run at a pace of 150 bpm were measured for 6 athletes in the initial and final tests (Figure 9). All athletes made progress, the best result measuring a difference of 1.47 km, and the poorest, a difference of 1.1 km. Therefore, the rate of progress increased by 18.96% for the best value and 13.25% for the lowest value (Table 1).

Figure 9. Results of the 50-minute run obtained by athletes in the initial and final tests

When measuring heart rate under basal conditions, we want to know the athlete's reaction to the training programme on the previous day. Basal heart rate is heart rate measured in the morning, before starting any activity, and illustrates the physiological state and reaction to the training programme.

Under normal conditions, basal heart rate should not fluctuate too much. However, it varies depending on the training phase and the athlete's adaptation to the training programme. Heart rate will decrease as the athlete adapts to the training programme: the better the adaptation, the lower the pulse. In basal metabolism, a heart rate increase of 6-8 bpm compared to the previous day means that the athlete does not tolerate the training programme well, or the athlete has not met the recovery measures, or daily activities require the athlete to provide additional effort. Whatever the cause, the training programme must be changed until the pulse returns to its previous value (Bompa, 2008).

In the current study, the recording was made without excessive noise. Athletes put their heart rate monitors next to their beds before going to sleep in order to minimise any disturbance. They recorded their heartbeats for 3 to 5 minutes and noted the lowest constant value.

Basal heart rate values were measured for 6 athletes in the initial and final tests (Figure 10). All athletes made progress, the best result measuring a difference of 19 bpm, and the poorest, a difference of 11 bpm. Therefore, the rate of progress increased by 23.17% for the best value and 13.92% for the lowest value (Table 2).

Figure 10. Basal heart rate results obtained by athletes in the initial and final tests

$\dot{V}O_2$ max represents the highest rate at which oxygen can be taken up and used by the body during severe exercise. It is one of the main variables in the field of exercise physiology and is often used to indicate the cardiorespiratory fitness of an individual. In the scientific literature, an increase in $\dot{V}O_2$ max is the most common method of demonstrating a training effect (Bassett & Howley, 2000).

The values of $\dot{V}O_2$ max were measured for 6 athletes in the initial and final tests (Figure 11). All athletes made progress, the best result measuring a difference of 8 ml/kg/min, and the poorest result, a difference of 11 ml/kg/min. Therefore, the rate of progress increased by 12.7% for the best value and 7.27% for the lowest value (Table 3).

Figure 11. $\dot{V}O_2$ max results obtained by athletes in the initial and final tests

Conclusion

Differences between the initial and final tests indicate progress for each athlete, which leads to the conclusion that including the heart rate monitor in the methodology of teaching training lessons has been efficient. The investigated athletes learnt to know their bodies, their

reactions to fatigue but also to increase, decrease or maintain the pace indicated by coaches. They were able to see some physiological effects of their efforts, which raised their awareness during both training sessions and everyday life.

The assessments of tested parameters highlighted the following:

- the 50-minute run at a pace of 150 bpm recorded an average increase of 1.3 km, with a percentage increase of 19.78%;
- basal heart rate recorded an average decrease of 14.3 bpm, with a percentage increase of 18.14%;
- VO₂ max recorded an average increase of 6 ml/kg/min, with a percentage increase of 10.81%.

Due to the use of the Polar M400 device, we managed to obtain important data on the sports activity and daily activity of the research athletes, which gave us the opportunity to individualise each athlete's programme. This technology allowed coaches to correlate tennis training with physical training and modify the lesson plan (weekly, monthly) depending on the athletes' progress/stagnation or regression during their workouts.

Some training exercises could be standardised and measured so that athletes learn to objectively assess their own improvements, get more involved and raise their awareness in the training process.

Even if athletes fall into the same age range and have appropriate values in terms of tennis ranking, physiological differences do exist, which means that they have their own "recipes" for achieving sports performance.

The data obtained from this research can be used by coaches, who can implement heart rate technology in their own training plans. This is a continuous method of verification, diagnosis, assessment and control in finding the key to the correct alternation of exercise volume and intensity, which is one of the keys to sports performance and success.

Authors' Contributions

All authors have equally contributed to this study and should be considered as main authors.

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