Physiological demands and testing in table tennis

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Abstract: The purpose of this review was to support table tennis experts and scientists with up to date science research regarding physiological measurement of table tennis players. We have noticed that some authors use obsolete references when comparing data in their research.

Literature available all over the world has been consulted to unify the findings involving measurement of physiological characteristics among table tennis players. In the past ten years, we have encountered a lack of quantitative data regarding the evaluation of training intensity and physiological load capacity of table tennis players in training and competition. From this point of view the judgement on the quantity of sports load depended only on one's observation and experience, a situation which, unfortunately, lacked a scientific basis. In order to scientifically improve the training of table tennis players and support table tennis researchers with newer findings, it is necessary to put forward objective evaluation indices for the training intensity and physiological loads of table tennis players and to support scientists with the results of extant research.

Key words: table tennis, testing, physiology

1.0 INTRODUCTION

Table tennis is known around the world as the fastest ball game. With the development of table tennis equipment, rule changes and player techniques, ball speed and spin have increased greatly, which shortens the rallies for each point. This is not what table tennis was in the past. In order to increase the attractiveness of table tennis, the International Table Tennis Federation (ITTF) has carried out reforms, such as having different combination rubbers on each side of the racket, the co-existence of the white and yellow ball, regulations on service, a 40-mm ball, a shorter point system and lately the prohibition of glues containing harmful volatile compounds (VCs). This includes glues with organic and inorganic volatile compounds excluding water.

Table tennis has a major competitive aspect and is widely popular, especially in the Asian and some selected European areas; recently it has also become popular in Africa and America. But even though ITTF is one of the sport's greatest association (on November 2008 ITTF had exactly 205 members), this is not obvious in the scientific research about table tennis. Moreover, despite its popularity, little is known of the characteristics and competencies of high class table tennis. Because of its complex nature, it is not easy for scientists to provide measurements, e.g., at the World championships or the Continental championships, to collect the necessary data for presentation to coaches and athletes.

In talking with many coaches around the world, we see that there are few coaches who pay attention to the aerobic endurance factor. This is understandable, because most coaches think that table tennis training should be highly specific, and endurance is frequently not recognized as important in this sport. So the question is, why waste valuable training time if the result is not an improved performance which means achieving better results at table tennis competitions? But is this the truth? Table tennis, in common with other non-endurance sports activities, does indeed have an endurance, or aerobic, component. For example, if you do multi ball practice, you might fail to recognize the importance of cardiorespiratory endurance as part of a total training program. With a high aerobic endurance level, one can maintain stroke quality throughout the training session or the game and still remain fresh for the next game in the tournament. To improve endurance performance, the athlete must work specific muscles or organ systems at an increased resistance.

The same is true for the importance of including resistance training as part of the total table tennis training program: table tennis does not demand high levels of strength. Most coaches are afraid that strength would do damage to the basic motor movement – i.e. the sense for a good stroke. Yet, athletes in all sports do some resistance training to increase, or at least maintain basic strength levels. Winning the match in table tennis requires not only excellent technique, tactics and psychology, but great physical strength, as well.

A professional table tennis player requires high level physical capacity, technical skills and tactical competence. The purpose of a table tennis player's basic training is to reduce stress on the body imposed by exercise, so that any level of workouts can be carried out more comfortably and an increase in the maximum number of workouts can be achieved. The aim of this report is to give an overview of the characteristics and physiological demands of table tennis match-play from the physiological point of view. Most scientists all over the world agree that table tennis is an aerobic metabolism sport requiring great endurance, which often alternates with intense anaerobic metabolism over short periods.

Characteristics of the table tennis game

Demands of the game

During the match a table tennis player should exactly analyse changes in the tactics and techniques of the opponent. His cerebral cortex during play is in a tense state and his attention quite focused. He has only 0.2 to 0.4 seconds to analyse the approaching ball and to react. A world competition often lasts for a week, and a ranked player will attend many games. The load is heavy, and it always brings various effects such as a busy schedule, strong opponents, changes in diet and sleeping habits, a new environment and time difference [12]. It is therefore necessary for a player to be in good physical shape and mental condition. Still, however, skill is the decisive factor in a table tennis match.

Match characteristics of the table tennis game

During the last eight years, rules of table tennis have been changed enormously. Since the introduction of a bigger ball and a shorter point system, matches differ considerably from the physiological demands point of view from matches before the rules changes.

The old 38mm ball

On the basis of Weber's [26] conclusions, the energy during ball exchanges is supplied mainly by alactic anaerobic metabolism. It has to be pointed out that in his research real play lasted only 35.9% of total game time, - and games lasted on average 6:06 minutes - where the ball was in play for only 3.8 seconds. Epstein [9] reports 23.1% of total real play, and the ball was in play for 3.1 seconds, with 10.3 seconds of rest between single points. According to Yuza et al [21], a table tennis match (best of 3, 38mm ball, 21 points) lasts 28:40min. ± 7:35min.

The new 40mm ball

According to Katsikatedils et al [14] real play time at the Olympic Games in Athens in 2004 oscillated from 3:7 min. to 6:6 min. in total. The mean duration of games was increased at the development of organisation up to the quarterfinals. Men's pure play time ranged from 3:8 min. to 4:4 min. and women's from 3:7 min. to 6:6 min. Means of matches are 22:5 min. and 26:3 min. Djokić [7] analysed the differences between play with the 38mm ball till 21 points and the actual system and found that rally per point (without service) increased from 3:52 min. to 4:02 min.

Physiological characteristics

Mitchell et al [18] classified sports activities based on the static component, dynamic component and energy system involved, where table tennis falls into the low-moderate group of sports, together with baseball, softball, volleyball and tennis (doubles). From that point of view, table tennis requires significant energy from both the anaerobic and aerobic energy systems.

The most important ability for table tennis player is undoubtedly endurance. Top players usually have higher levels of endurance [27, 26]. Endurance is a term that describes two separate but related concepts: muscular endurance and cardiorespiratory endurance [24]. Each makes a unique contribution to the player's performance, so each differs in importance to different players. For a table tennis player, endurance is the quality that allows him to sustain a high speed over the couple of top spin strokes with high rotation of the ball. This quality is muscle endurance, the ability of the shoulder muscle group to sustain high-intensity, repetitive movement. The resulting fatigue is confined to a specific muscle group (the shoulder girdle), and the activity's duration is usually very short. Muscular endurance is highly related to muscular strength and anaerobic development [24].

On the other hand, cardiorespiratory endurance relates to the body as a whole. For a table tennis player, it means the ability to sustain prolonged activity in long table tennis competitions. Cardiorespiratory endurance is related to the development of the cardiovascular and respiratory systems and thus aerobic development. This is why the term aerobic endurance is used to represent cardiorespiratory endurance [24].

Most sports scientists regard VO_2max, representing aerobic power, as the best objective laboratory measure of maximal cardiorespiratory endurance capacity. VO_2max is defined as the highest rate of oxygen consumption attainable during maximal or exhaustive exercise. In table tennis these conditions arise only during training sessions and occasionally during long rallies – particularly when playing against a defensive player. DeVries [4] pointed out that measurement of maximal O_2 consumption has some serious problems. Although the measurement of VO_2 max has come to be the criterion against which all other PWC (physical working capacity) test procedures are evaluated, there are at least four grounds for criticism of those measurements. First, the subject must be taken to a

state of exhaustion; second, the results of the test vary considerably with test method and protocol; third, the results are couched in chemical terms, when the physical educator or coach is working with physical parameters of work and power, and fourth, the test requires an expensive laboratory and considerable testing time.

We can speak of three recognizable phases during the transition from low to maximal exercise level. The first phase of low intensity exercise mainly involves aerobic metabolism, characterized by small increases in ventilation and blood lactate levels similar to resting values (1-1.5 mmol). The second phase, or Aerobic Threshold (AerT – eg. [20]), is characterized by slight hyperventilation and increased lactate levels of approximately 2 mmol/l. As the level of exercise increases further, ventilation rises considerably, and there is a steady increase in blood lactate levels to approximately 4 mmol/l. This third phase is termed the Anaerobic Threshold (AnT).

Physiological testing

Djokic [6] pointed out that testing and measurement are the means of collecting information upon which subsequent performance evaluations and decisions are made. Effective functional diagnosis of athletes means success for the training program.

The battery of tests designed for the study by Melero Romero et al [17] included impedanciometry, sanguine analytic and field tests, with lactate determinations in capillary blood, and control of heart rate frequency. The data obtained from these tests reveal a better picture of the elite player's physical condition in relation to the other two groups of inferior sport category, and also a direct correlation among the variables considered, such as indicators of good physical condition, and the sport yield evidenced through the results of the field test.

In season 2002/2003 Djokić [5] reported increasing heart rates as the game unfolded. The average values of the heart rate during 6 official competition matches were from 162 to 172 beats.min^{-1}. During table tennis training the approximate value of the heart rate was 142 beats.min^{-1}. In purely tactical training when stress is placed on the precision of performing and returning the serve, the average values of the heart rate were 152-156 beats.min^{-1}. Weber reached the same conclusion [25] – the loud parameter heart rate in setback play becomes especially meaningful when the psychological factor in stress can be eliminated by the use of approved exercise and trainings. During interval training, the values vary from 98 to 115 beats.min^{-1} at the beginning and between 144 to 192 beats.min^{-1} at the end of an interval. In speed training (maximum intensity) where a series of 4-5 balls were projected rapidly followed by a short rest of 1-1.25 min, the heart rate at the beginning was 110-115 beats.min^{-1}, while at the end it was 168-192 beats.min^{-1}. Like many other authors [21, 26, 13], Djokić pointed out that heart rate depended on the type of training, but more demanding training yielded heart rates in excess of those found in competition.

Wang Xin [23] has put forward objective evaluation indices in fixed quantity for the training intensity and physiological load of adolescent table tennis players so as to scientifically improve the training of table tennis players. He measured 24 person-time experiments related to various sports loads on eight subjects. The data showed that the average heart rate was as follows: 27/10 seconds for heavy load, 24/10 seconds for medium load and 22/10 seconds for low load. So the heart rate can be considered as the main evaluation index for the training intensity of table tennis training.

The object of the study by Kasai et al [13] was to clarify cardiorespiratory response during practises and games and to obtain basic information on the best method for evaluating the cardiorespiratory function of a table tennis player. They measured oxygen consumption, ventilation, heart rate and blood lactate concentration during practices and games. Data showed that oxygen consumption, ventilation, heart rate and blood lactate during games are lower than during training. The main values in games were 30.7 ml/kg/min for ventilation, 142b/min mean for heart rate and 1.17mmol/l for blood lactate.

Using a 6 different practices and regular games, Watanabe et al [22] measured program of table tennis involving heart rate, blood lactate concentration and rating of perceived exertion (RPE) between Chinese national class players and Japanese university class players. All subjects performed a maximal exercise test, using a bicycle ergometer in the laboratory before the table tennis programme. As an expressed percentage of maximal O2, the exercise intensity of table tennis practice was 56-73% and 56-7% VO2max in the Chinese and Japans players, respectively. Chinese players showed lower exercise intensity than Japanese players in 5 practices out of 6. RPE showed a higher scale than physiological parameters. Throughout the program of table tennis, blood lactate had no changes in both groups.

Allen [2] reports on the physiological characteristics of elite Australian table tennis athletes and their responses to high level competition. A maximum oxygen uptake test using the Åstrand protocol on the treadmill and a Wingate test of anaerobic power were used for laboratory assessment, and at least four games were used for field evaluation where heart rate was measured and blood lactate levels were taken from each player. Values of maximum oxygen uptake vary from 2.55 l/min^{-1} in females to 4.13 l/min^{-1} in males. The anaerobic capacities recorded on the Wingate at peak power vary from 7.68

watts/kg^{-1} in females to 9.89 watts/kg^{-1} in males. It should be stressed that these measurements were carried out with the smaller ball.

In his experiment Ellwood [8] sought to establish whether VO_2 measured during a game of table tennis was consistent with the level predicted by a progressive sub-maximal treadmill test for equivalent heart rates. According to the results, it is suggested that a steady state treadmill test is not suitable for predicting oxygen uptake during table tennis games.

In order to compare some results with the previous smaller ball, here are the results from Weber's research [26]. In 30 minutes of competitive training, eight Bundesliga players had an average of 159 beats. min^{-1} in a 2 game match and for the rest of the time, 164 beats.min^{-1}. The lactate concentration in the arterialised blood was 1.99, (first game), 1.85 (second game) and 1.92 mmol (at the end of training). Preuß [19], too, tested the energy consumption during one typical "bundesliga" tennis training session and during one simulated training competition. During training, the concentration of lactate in the substance rose from 1.1±0,1mmol/l during rest to 2.6±1,0mmol/l after the load, while the rise during competition from 1.0±0,1mmol/l during rest to 2.0±0,7mmol/l after the load was not that high. Preuβ also compared this data to that from multiball training and found that there is significantly higher lactate present in blood – from 1.1±0,2mmol/l during rest to 4.3±1,9mmol/l during training. These obvious by increased values are probably based on the special load structure of the training form. Epstein [9] reports of 1.29mmol/l to 1.56±0,53mmol/l in training and 1.24mmol/l to 1.84mmol/l in competitive games where the heart rate gets over 190 beats.min^{-1}.

Lundin (in Preuβ [19]) reported in 1972 that during a single table tennis play the heart rate lies between 160-180 beats.min^{-1}. Because the rests between two games usually last a maximum of one minute, thi results in accumulated fatigue. At the constant pulse frequency of 160-180 beats.min^{-1}, this means that the player is constantly at the edge of preservation of anaerobic ability. Because of the high intensity, accumulation of lactic acid in blood is present. A top player should have a maximum oxygen uptake of at least 60ml/kg, and the anaerobic threshold should be 70-80% of this value. Research on the Swedish table tennis team between 1970-1972 showed that values for maximum oxygen consumption during the game were 65 ml.kg^{-1}.min.

For table tennis purposes (exercise prescription), we are really more interested in the level of performance that can be maintained without fatigue, rather than the aerobic power (VO_2max) available at the point of exhaustion.

The findings of Lu Yunxia (in Lin, [16]) indicate that China's coaches often attach great importance to skills and training tactics but pay scanty attention to training for physical strength, since they believe player achievement to be relatively unrelated to their physique.

Unfortunately, we do not have enough information about and access to the results of research by Chinese scientists that should lead us to better understanding of why Chinese players – especially women – are so superior in their games.

Physiological testing and players with disabilities

Abe et al [1] studied the fluctuation of salivary cortisol and urinary 17-ketosteroid of table tennis players during exercise. There was no increase in cortisol levels and no decrease in 17-ketosteroide levels in anyone's sample after 3-hours of table tennis exercise, which means that no one suffered from excessive stress during that time.

The present level of table tennis games in people with disabilities gives no more space for practice without physical training. It may be inconvenient for the individuals to have a disability, but this does not mean that they cannot improve their lives with high performance sports results.

Physiological testing and physical preparation as injury prevention in table tennis and health-related fitness

Furjan Mandić et al [10] reports on the possibility of implementing slide aerobics into the program of a table tennis player to avoid injury to the muscles of the lower extremities (e.c. abductor and adductor) and to strengthen leg muscles. On the other hand, since a slide aerobics programme is performed with music at an optimal tempo between 100 and 138 BPM, techniques specific to table tennis may be practised at a particular rhythm and a certain tempo, which means that we could also use a slide board for endurance testing of table tennis players. Nordic walking (Furjan- Mandić et al [11]) is another of the sports disciplines that can be implemented in fitness training for table tennis players. Nordic Walking is an effective method of walking with poles where the swing of the arms and the powerful placement of the pole influence the length of strides and requests from the player to activate the shoulder girdle muscles, which should be strengthened for better performance of spin strokes in table tennis.

Kobayashi et al [15] investigated the relationship of habitual physical activity to various components of health-related fitness as well as bone density in middle-aged women. Results of the measurements indicate that muscle activity during table tennis may not place sufficient stress on the bone to maintain a high level of bone mass. In addition, plasma HDL cholesterol

concentrations tended to be higher in table tennis groups than in sedentary groups. These results may indicate that habitual table tennis activity is beneficial to maintaining a high level of aerobic fitness as well as in reducing the risk of coronary heart disease.

2.0 CONCLUSIONS

We have discussed general trends in the adaptations that occur in response to training. However, we must always remember that we are talking about adaptations of individual table tennis players and that everyone does not respond in the same manner. Several factors that can affect player response to aerobic and anaerobic training must be considered. Based on a sample of international research, we can conclude that modern table tennis is a sport that requires both sub-maximal and maximal work and this puts pressure on both the anaerobic and aerobic systems.

Even though much work has been done, there is still a remarkable amount of information needed before comprehensive knowledge of table tennis can be claimed. In this paper we have focused only on the table tennis player's physiology.

Sport scientists have demonstrated the importance of endurance training for table tennis players. Nothing but great stamina enables players to bring their skills and tactics into full play. After competition table tennis players are often not only physically exhausted, but also highly tense in the mind, so great endurance performance is the most important factor in their success.

3.0 REFERENCES

[1] Abe, K., Kawakamii, Y., Ohuchii, M., Watanabe, Y., Shibataz, Y., & Takahashi-Abbe, S. (2002). Biochemical and physiological examination of intellectually disabled table tennis players. *International Journal of Table Tennis Sciences*, No.4&5. Pp. 61-67.

[2] Allen, G.D. (1991). Physiological characteristics of elite Australian table tennis athletes and their responses to high level competition. *Journal of Human Movement Studies* 20(3): 133-147.

[3] Baron, R., Petschnig, R., Bachl, N., Raberger, G., Smekal, G., & Kastner, P. (1992). Catecholamine excretion and heart rate as factors of psychophysical stress in table tennis. *International Journal of Sports Medicine*. 13(7):501-505.

[4] DeVries, H.A. (1986). *Physiology of Exercise*. Dobuque, Iowa: Wm. C. Brown Publisher

[5] Djokić, Z. (2004). Heart rate monitoring of table tennis players. In: Lees, A., Kahn, J.F. & Maynard, W.: Science and Racket Sports III. *The proceedings of the Eighth International Table Tennis Federation Sports Science Congress and The Third World Congress of Science and Racket Sports*. (p. 21-22). London and New York: Routledge.

[6] Djokić, Z. (2007). ITTF scored a goal (changes of rules in table tennis during 2000-2003). In: Kondrič, M., Furjan-Mandić, G. (ed). *Proceedings book. 10th International Table Tennis Sports Science Congress* (p. 168-174). Zagreb: Faculty of Kinesiology, CTTA, ITTF.

[7] Djokić, Z. (2007). ITTF scored a goal (changes of rules in table tennis during 2000-2003). In: Kondrič, M., Furjan-Mandić, G. (ed). *Proceedings book.10th International Table Tennis Sports Science Congress* (p. 336-341). Zagreb: Faculty of Kinesiology, CTTA, ITTF.

[8] Ellwood, J.D. (1992). Is the Sub-maximal Treadmill Test an Accurate Predictor of Oxygen Uptake in Table Tennis? *International Journal of Table Tennis Sciences*, 1:33-39.

[9] Epstein, S. (1992). Hämodynamische und metabolische Veränderungen im Tischtennis bei Weltklassespielern. [Haemodynamic and metabolic changes at the top players in table tennis]. Köln: DSHS.

[10] Furjan-Mandić, G., Kondrič, M., Rausavljević, N., & Metikoš, B. (2002). Slide aerobics in the physical preparation of table tennis players. *International Journal of Table Tennis Sciences*, No.4&5. Pp. 91-95.

[11] Furjan-Mandić, G. Kondrič, M., & Alikalfić, V. (2006). Nordic walking in the physical preparation of racket sports players = Nordic walking en la preparacíon física de los jugadores de deportes de raqueta. V: *[IV World congress of science and racket sports : 21-23 de Septiembre de 2006, Madrid]*, (Cultura, ciencia y deporte, Suplemento, Vol. 2,no. 4, ano 3). Guadalupe: Universidad católica San Antonio.

[12] Guan, Y. (1992). Functional Evaluation for Table Tennis Players. *International Journal of Table Tennis Sciences*, No.1. pp. 95-97..

[13] Kasai, J., Dal Monte, A., Faccini, P., & Rossi, D. (1994). Oxygen consumption during practice and game in table tennis. *International Journal of Table Tennis Sciences*, No.2, pp.120-121.

[14] Katsikadelis, M., Pilianidis, T. & Vasilogambrou, A. (2007). Real play time in table tennis matches in the XXVIII Olympic games «Athens 2004». In: Kondrič, M., Furjan-Mandić, G. (ed). Proceedings *book. 10th International Table Tennis Sports Science Congress* (p.94-98). Zagreb: Faculty of Kinesiology, CTTA, ITTF.

[15] Kobayashi, Y., Hososi, T., Takeuchi, T., & Okuda, N. (1996). Effects of long-term recreational table tennis on health related fitness, plasma lipids and bone density in middle-aged woman. *International Journal of Table Tennis Sciences*, 3:67-78.

[16] Lin, X.B. (2007). A feasibility study of interval hypoxic training of table tennis players. In: Zhang,

X.P., Xiao, D.D. & Dong, Y.: *The proceedings of the Ninth International Table Tennis Federation Sports Science Congress*. (p. 374-379). Beijing: People's Sports Publishing House in China.

[17] Melero Romero, C., Pradas de la Fuente, F., Sanchez Arjon, C., & Vargas Corzo, C. (2005). Physiological course to apply in table tennis. *MD revista científica en Medicina del Deporte.* p.p. 17-24.

[18] Mittchel, J.H., Haskell, W.L., & Raven, P.B. (1994). Classification of sports. Medicine and Science in Sports and Exercise 26(10-supplement), 242-245.

[19] Preuβ, A. (1988). Die Energiebereitstellung im Tischtennis in Wettkampf- und verschiedenen Trainingsbelastungen. [Supply of Energy at Table Tennis – during Competition Loads and during Different Training Loads] Diplomarbeit. Köln: Deutsche Sporthochschule.

[20] Skinner, J.S. & McLellan, T.H. (1980). Transition from aerobic to anaerobic metabolism. *Research Quarterly for Exercise and Sport (RQES)*, 51(1), 234 - 248.

[21] Yuza, N., Sasaoka, K., Nishioka, N., Matsui, Y., Yamanaka, N., Ogimura, I., Takashima, N., & Miyashita, M. (1992). Game Analysis of Table Tennis in Top Japanese Players of Different Playing Styles. *International Journal of Table Tennis Sciences*, No.1, pp. 79-89.

[22] Watanabe, M., Kitahara, T., Shu, J.Z., & Nagata, M. (1994). Exercise intensity of table tennis practice and games by heart rate, blood lactate concentration, and RPE. *International Journal of Table Tennis Sciences*, No.2, pp.121.

[23] Wang, X. (1994). The Evaluation of the Training Intensity and Physiological Load. *International Journal of Table Tennis Sciences*, No.2, pp.61 – 63.

[24] Willmore, J.H. & Costill, D.L. (2004). Physiology of sport and exercise. Champaign, Il:Human Kinetics.

[25] Weber, K. (1982). Analyse der körperlichen Beanspruchung in den verschiedenen Rückschlagspielen unter dem Aspekt der Präventiv- und Leistungsmedizin. In: Andersen/Hagedorn: Training im Sportspiel. 4. Int. Sportspielsymposium. Ahrensburg. Pp. 111-133.

[26] Weber, K. (1985). Reaktion und Adaptionen im Tennissport – eine sportmedizinische Analyse. [Reaction and adaptation in tennis – a sports medicine analysis]. Köln: DSHS.

[27] Weber, K. & Hollmann, W. (1984). Neue Methoden zur Diagnostik und Trainingssteuerung der tennisspezifischen Ausdauerleistungs-fähigkeit. [New methods on diagnostic and workout plan of tennis specific endurance abilities]. In: Gabler, H., Zein, B. (ed). Talentsuche und Talentförderung im Tennis. Ahrensberg: Czwalina. Pp. 186 – 209.