PHYSIOLOGICAL ANAEROBIC CHARACTERISTICS OF SLOVENIAN ELITE TABLE TENNIS PLAYERS

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The aim of this research was to analyze the anaerobic characteristics of Slovenian elite table tennis male and female players. A total of 8 subjects were divided into two groups. The first group consisted of the four best Slovenian female players while the second group consisted of the four best Slovenian male players. For measurements we used Wingate test (WAnT). WAnT requires pedaling for 30 s at maximal speed against a constant force setting to yield the highest mean and peak power. We used the original recommended equation for force settings (0.075 kp·kg^{-1} bw, a force equivalent to a level of mechanical work of 4.41 J rev.$^{-1}$ kilogram^{-1} bw) on the Monark 634 ergo meter. To estimate the lactate concentration in the blood and muscles, we collected 20 µL blood samples from the participants' heparinzed earlobes, before and immediately after finishing the test and also, respectively, 3, 5 and 7 minutes after the test for lactate analysis. The data were processed by the statistical software SPSS 8.0 for Windows and the software for WAnT. The anaerobic capacities of the subjects as measured by the WAnT 30 second test indicated that the male group developed a mean power of 7.95 watts·kg^{-1} with a peak power of 9.60 watts·kg^{-1}, and that power output declined by 33.08% over 30 seconds. For the female group the corresponding values were a mean power of 6.55 watts·kg^{-1} with a peak power of 8.03 watts·kg^{-1}, and that power output declined by 31.83% over 30 seconds. The peak power calculated in this study ranged from 8.7 watts·kg^{-1} to 10.4 watts·kg^{-1} in the male group and 7.0 watts·kg^{-1} to 8.8 watts·kg^{-1} in the female group. Based on the established sensitivity of the WAnT to detect changes brought about by the basic physical preparation of table tennis players, our research addresses the problem of training effects on anaerobic performance.

Keywords: Table tennis, motor tests, anaerobic ability, Wingate anaerobic test.

INTRODUCTION

The modern table tennis game demands very good motor abilities such as: speed, strength, endurance, agility, balance and good reflexes and sense of touch. The majority of world top players prefer to concentrate on an attacking or counter attacking game. Many young players have sound backhand plays but very few are able to match their forehand power capabilities.

Numerous table tennis trainers have focused on maximal aerobic capacity, completely ignoring such items as peak muscle power and local muscle endurance, even though these fitness components are important for various situations in the table tennis game. For example, there are many events where it is essential to develop high intensity power instantaneously or within a few seconds. Intermediate term anaerobic performance capacity is defined as the total work output during a maximal exercise repetition lasting for about 30 s. This can be considered as being equivalent to the Wingate test in terms of intensity and duration (MacDougall, Wenger, & Green, 1991).

Tests of anaerobic ability involve very high intensity exercise lasting between a fraction of a second and several minutes (Skinner & Morgan, 1985). The anaerobic capacity is set by an accumulation of lactic acid within the active muscles during the training or testing. During the effort, production of lactate continues for about 40 to 50 seconds, but usually exercise is halted when a blood lactate concentration of 10 to 15 mmol per liter has been reached, although intramuscular concentrations may be then be as high as 30 mmol per liter (Shephard, 1987). Gladden (2004) reports that lactate can no longer be considered the usual suspect for metabolic "crimes", but is instead a central player in cellular, regional and whole body metabolism. Very few scientific studies in table tennis have been conducted on anaerobic performance as a component of fitness. Even today, many coaches, fitness appraisers, health professionals and others consider fitness and physical working capacity to be synonymous with aerobic fitness (deVries, 1986).

Performance in table tennis and also in any sporting event is the result of a number of factors, which include the amount and structure of training performed, the body's predisposition and adaptation to the training, motivation level, facilities, social-cultural background, etc. Therefore, physiological parameters only account for a portion of any performance, and so the role of any exercise physiologist is also similarly limited. Through fitness testing, the factors involving physiological processes, over which there is some control, can be measured and ultimately improved upon. Competition is the ultimate test of performance capability, and is therefore the best indication of training success. Nevertheless, when trying to maximize performance, it is important to determine the player's ability in individual aspects of performance. Fitness testing attempts to measure individual components of performance, with the ultimate aim of studying and maximizing the player's ability in each component (Kondrič & Furjan-Mandić, 2002).

Benefits of fitness testing in table tennis are necessarily for the exact planning of training. First of all we can identify and establish the weaknesses and strengths of the player. This can be done by comparing test results to those of other athletes in the same training group or a similar population group. Previous test results of large groups are often published as normative tables. In the case of the smaller nations there is a problem of how to assure enough subjects in order to set standards, which are to be declared as norms for table tennis players.

Fitness testing is primarily used for help in designing the most appropriate athletic training programme for the achieving of better results in the table tennis game. Training at the anaerobic level is, for the table tennis player, just as important as training at the aerobic level. Table tennis is a unique game requiring instant explosive power and endurance at the same time; both tempered with the fine motor control utilized during the overall match. In modern table tennis most international competitors favor an aggressive and powerful game in which anaerobic performance is of great importance. The aim of our research was to find out what are the physiological anaerobic characteristics of Slovenian elite table tennis players.

METHODS

Subjects

A total of 8 subjects were divided into two groups. The first group consisted of the four best Slovenian female players while the second group consisted of the four best Slovenian male players. All of them are members of the Slovenian national table tennis team. These players were highly ranked in the national ranking list and had taken part in the last two World and European Championships.

Description of the test and test lay-out

The Wingate anaerobic test (WAnT) has been accepted in laboratories around the world to assess muscle power, muscle endurance and fatigability (Bouchard, Taylor, Simoneau, & Dulac, 1991; Inbar, Bar-Or, & Skinner, 1996; Bar-Or, 1987). The Wingate anaerobic test (WAnT) is a state of the art review of the most widely used anaerobic performance test in the world. The test has been chosen because numerous laboratories have confirmed its very high reliability as well as its validity as a test that can yield information on peak mechanical power and on local muscle endurance. Peak power is the highest mechanical power elicited from the test taken as the average power over any 5 s period. Mean power is the average power maintained throughout the six 5 s segments. The fatigue index is the amount of the decline in power during the test expressed as a percentage of peak power (Inbar, Bar-Or, & Skinner, 1996). For a long period of time it has been considered that the 30 s maximal test does not tax maximally lactic anaerobic capacity (Jacobs et al., 1982) but the latest study on energetics of WAnT (Beneke, Pollmann, Bleif, Leithäuser, & Hütler 2002) clearly underlined the fact that WAnT metabolism is highly anaerobic, and showed that 80% of the energy turnover during test is derived from anaerobic alactic and lactic acid metabolism dominated by glycolysis. According to the published data, we can support the hypothesis that the maximal ATP generation rate from the ATP-PC system is insufficient for the generation of energy necessary for the production of peak power (Weicker & Strobel, 1994), so that energy from anaerobic lactic acid metabolism can be assumed to contribute to power output even within the initial 5 s of the WAnT (Bangsbo et al., 1990; Boobis, Williams, & Wooton, 1982; Jones et al., 1985; Jacobs et al., 1982, 1983). Kavanagh and Jacobs (1988) investigated oxygen consumption during the Wingate test after noting conflicting data that reported aerobic contributions ranging from 13 to 44% during the 30 s test. Based on an assumed mechanical efficiency of 25% for cycle exercise, they estimated the aerobic contribution to be 18.5%. Other studies (Smith & Hill, 1991) using similar procedures, estimated the aerobic contribution to be 16%. In contrast to these rather low estimates, 5 studies that used the accumulated oxygen deficit to quantify energy supply reported values between 23 to 33% for 30 s of maximal, exhaustive exercise (Withers, Sherman, & Clark, 1991; Gastin & Lawson, 1994; Calbet, Chavarren, & Dorado, 1997; O'Brien, Payne, & Gastin, 1997). The peak oxygen deficit was determined by the method developed by Hermansen and Medbø (1984). Peak oxygen deficit was calculated as the difference between the total oxygen uptake (liters) and the estimated total energy required during the supramaximal bout of exercise. The total energy required was calculated as the product of the rate of energy expenditure and the exercise duration. In line with these estimates, Bogdanis et al. (1996) using direct muscle measures, reported a 29% aerobic contribution.

The WAnT requires pedaling for 30 s at maximal speed against a constant force setting to yield the highest mean and peak power. We used the original recommended equation for force settings (0.075 $kpkg^{-1}$ bw, a force equivalent to mechanical work of 4.41 J per pedal revolution per kilogram body weight) on the Monark 634 ergometer (Bar-Or, 1987). A sampling period of 1 s was obtained by using the special sensor and data acquisition software (SMI, USA). Warm-ups were done on a cycle ergometer to promote more specific physiological and motor adaptations. The subjects pedal as fast as possible against a low resistance to overcome the inertial and frictional resistance of the flywheel and to shorten the acceleration phase. After a few seconds the full load is then applied to start the 30 s test. The subject needs to pedal as fast as possible from the beginning and to maintain maximal speed throughout the 30 s period.

To estimate lactate concentration in the blood and muscles, we collected 20 μL blood samples from their heparinized earlobes, before and immediately after they finished the test and also, respectively, 3, 5 and 7 minutes after the test for lactate analysis. Blood samples were stored in special plastic containers with EDTA (Eppendorf, Germany) and sent for immediate biochemical analysis by an Eppendorf Ebio+ lactate analyzer. The lactate analysis was carried out within one hour after the test.

To prevent dizziness and syncope following the exertion of the WAnT, each subject pedalled for 2–3 minutes against a light resistance immediately after the test to cool down.

Statistics

Data were processed by the statistical software SPSS 8.0 for Windows and the software for WAnT. The results, unless otherwise specified, are in median values with standard deviations. A oneway analysis of variance (ANOVA) was used to test all variables for significant differences among two groups (Petz, 1981). When the result of the ANOVA was significant ($p < 0.05$), canonical discriminant analysis was done for significant effects between the two groups.

RESULTS

The results of both groups are presented in TABLE 1 and TABLE 2. In TABLE 3 are the results of ANOVA and in TABLE 4 the results of canonical discriminant analyses.

TABLE 1
Anaerobic capacities of selected male table tennis players

Group A

Player	Ppeak	Pmean	Pmin	F-Index	La rest	La max	La 3	La 5	La 7	Work	Rel Work
	W/kg	W/kg	W/kg	%	mmol/L	mmol/L	mmol/L	mmol/L	mmol/L	Joules	J/kg
M1	9.2	7.5	5.80	37.50	1.8	3.4	7.5	8.2	8.2	15 449	224.0
M2	8.7	7	5.60	35.40	1.8	5.2	9.6	11.1	11.2	16 170	210.0
M3	10.1	9	7.70	23.80	1.7	3.4	8.2	9.4	10.2	20 853	271.0
M4	10.4	8.3	6.70	35.60	1.9	7	10.1	11.5	11.4	18 653	249.0

No cases	4	4	4	4	4	4	4	4	4	4	4
Min	8.70	7	5.60	23.80	1.70	3.4	7.50	8.20	8.20	15 449.00	210.00
Med	9.65	7.9	6.25	35.50	1.80	4.3	8.90	10.25	10.70	17 411.50	236.50
Max	10.40	9	7.70	37.50	1.90	7	10.10	11.50	11.40	20 853.00	271.00
Average	**9.60**	**7.95**	**6.45**	**33.08**	**1.80**	**4.75**	**8.85**	**10.05**	**10.25**	**17 781.25**	**238.50**
SD	**0.79**	**0.88**	**0.96**	**6.26**	**0.08**	**1.72**	**1.21**	**1.53**	**1.46**	**2 465.16**	**27.01**
Skew	−0.21	0.25	0.81	−1.86	0.00	0.85	−0.14	−0.44	−1.33	0.57	0.31
Kurt	−3.49	−1.97	−1.20	3.60	1.50	−1.29	−3.67	−2.92	1.17	−2.13	−2.03

TABLE 2
Anaerobic capacities of selected female table tennis players

Group B											
Player	**Ppeak**	**Pmean**	**Pmin**	**F-Index**	**La rest**	**La max**	**La 3**	**La 5**	**La 7**	**Work**	**Rel Work**
	W/kg	**W/kg**	**W/kg**	**%**	**mmol/L**	**mmol/L**	**mmol/L**	**mmol/L**	**mmol/L**	**Joules**	**J/kg**
F1	7.9	6.7	5.40	31.30	1.6	6.6	10.4	11.3	10.8	12 663	201.0
F2	7.0	5.8	4.90	30.30	1.9	6.5	11.7	12.0	12.1	12 065	175.0
F3	8.4	6.6	5.10	38.70	1.2	4.5	9.2	8.7	8.6	11 942	199.0
F4	8.8	7.1	6.40	27.00	1.6	3.2	7.1	7.4	7.6	13 301	225.0
No cases	4	4	4	4	4	4	4	4	4	4	4
Min	7	5.80	4.90	27	1.20	3.20	7.10	7.4	7.60	11 942	175
Med	8.15	6.65	5.25	30.8	1.60	5.50	9.80	10	9.70	12 364	200
Max	8.80	7.10	6.40	38.7	1.90	6.60	11.70	12	12.10	13 301	225
Average	**8.03**	**6.55**	**5.45**	**31.83**	**1.58**	**5.20**	**9.60**	**9.85**	**9.78**	**12 492.75**	**200.00**
SD	**0.78**	**0.54**	**0.67**	**4.94**	**0.29**	**1.65**	**1.95**	**2.16**	**2.05**	**624.11**	**20.43**
Skew	−0.80	−1.04	1.46	1.16	−0.52	−0.51	−0.53	−0.21	0.13	0.79	0.00
Kurt	0.13	1.97	2.12	2.10	1.65	−3.11	−0.04	−3.84	−3.13	−1.35	1.45

The anaerobic capacities of the subjects as measured by the WAnT 30 second test are presented in TABLE 1 and TABLE 2 and indicated that the male group developed a mean power of 7.95 watts per kg^{-1} and a peak power of 9.60 watts per kg^{-1}, which power output declined by 33.08% over a 30 second period. For the female group the corresponding values were a mean power of 6.55 watts per kg^{-1} and a peak power of 8.03 watts per kg^{-1}, which power output declined by 31.83% over a 30 second period.

The peak power, calculated in this study, ranged from 8.7 watts per kg^{-1} to 10.4 watts per kg^{-1} in the male group and 7.0 watts per kg^{-1} to 8.8 watts per kg^{-1} in the female group. The fatigue index varied from 23.80% to 37.50% in males and 27.00% to 38.70% in females.

TABLE 3
One way ANOVA table

		Sum of squares	**df**	**Mean square**	**F**	**Sig**
PPEAK	Between	4.961	1	4.961	8.117	.029
Groups		3.668	6	0.611		
	Within	8.629	7			
Groups						
	Total					
PMEAN	Between	3.920	1	3.920	7.304	.035
Groups		3.220	6	0.537		
	Within	7.140	7			
Groups						
	Total					
PMIN	Between	2.000	1	2.000	2.927	.138
Groups		4.100	6	0.683		
	Within	6.100	7			
Groups						
	Total					
FINDEX	Between	3.125	1	3.125	0.098	.764
Groups		190.535	6	31.756		
	Within	193.660	7			
Groups						
	Total					
LAREST	Between	0.101	1	0.101	2.271	.183
Groups		0.267	6	4.458E-02		
	Within	0.369	7			
Groups						
	Total					

LAMAX	Between	0.405	1	0.405	0.143	.719
Groups		17.050	6	2.842		
	Within	17.455	7			
Groups						
	Total					
LA3	Between	1.125	1	1.125	0.426	.538
Groups		15.830	6	2.638		
	Within	16.955	7			
Groups						
	Total					
LA5	Between	8.000E-02	1	8.000E-02	0.023	.885
Groups		21.100	6	3.517		
	Within	21.180	7			
Groups						
	Total					
LA7	Between	0.451	1	0.451	0.143	.719
Groups		18.998	6	3.166		
	Within	19.449	7			
Groups						
	Total					
WORK	Between	55936464.500	1	55936464.500	17.300	.006
Groups		19399661.500	6	3233276.917		
	Within	75336126.500	7			
Groups						
	Total					
RELWORK	Between	2964.500	1	2964.500	5.169	.063
Groups		3441.000	6	573.500		
	Within	6405.500	7			
Groups						
	Total					

A one way analysis of variance (ANOVA) was used to test all variables for significant differences between the two groups. In three variables (PPEAK, PMEAN and WORK) there are significant differences between the two measured groups. A canonical discriminant analysis showed that there is a high correlation (0.939) but because of the low number of variables it is not statistically significant.

TABLE 4
Canonical discriminant function

Function	Eigenvalue	% of variance	Cumulative %	Canonical correlation
1	7.508[a]	100.0	100.0	0.939

DISCUSSION

During high intensity exercise, lactate accumulates as the result of lactic acid production being greater than its removal. At a physiological pH level, lactic acid, a strong organic acid, dissociates a proton (H^+) and almost completely dissociates into hydrogen and lactate ions; therefore, the term lactic acid and lactate are used synonymously (Brooks, 1985). A strong correlation between blood and muscle lactate concentrations exists during exercise (Foster, Schrager, & Snyder, 1995; Jacobs, 1986; Karlsson & Jacobs, 1982). However, it is erroneous to interpret blood lactate accumulation as being wholly reflective of muscle lactate production. Blood lactate concentration depends on the existence of a net positive gradient for lactate between muscle tissue and the blood, and is affected by dilution in the body's water; by removal by organs such as the liver, heart and inactive skeletal muscle; and by the temporal lag before lactate produced in the muscle appears in the blood (Foster, Schrager, & Snyder, 1995). Therefore, at high muscle lactate concentrations there may be a significant time lag before lactate equilibrates with the blood. In our measurements we found peak lactate concentrations in the blood after the 7th minute in group A, and after the 5th minute in group B. Also, the values of peak lactate concentrations were significantly higher in group A.

It is generally agreed that most anaerobic tests are reliable in motivated subjects and that they correlate highly with each other, but there is less agreement about what they measure. It is difficult to determine the amount of aerobic and anaerobic involvement in tests lasting more than a few seconds. WAnT measures the performance of several muscle groups combined and therefore cannot yield information about any specific muscle or muscle group.

The practical problem of measuring the anaerobic characteristics of table tennis players during sporting activity has meant that the majority of assessments have been carried out in the laboratory on cycle ergometers and not in the practice hall at the table. However, many sports, including table tennis, require intermittent exercise, and such tests therefore represent artificial situations.

The desirability of a minimum quantity of strength in table tennis has long been recognized. Unfortunately the advantages of maximum levels of strength in table tennis have not yet been recognized by all physical educators, athletes and coaches. This neglect of the strength factor was the result of an unscientific acceptance by almost everyone concerned that the development of large amounts of strength in the musculature inevitably resulted in a condition known as muscle-bound. Being muscle-bound was supposed to limit both the range and speed of table tennis strokes.

The importance of strength in table tennis is not always obvious. However, the need to produce powerful strokes, the need for maximum power is apparent. From this point of view we can observe power as the result of two factors: strength to produce the force and speed to increase the rate at which the force can be applied (first of all by putting a spin on a spin play).

The registered changes are different due to different choices of force settings that would elicit the highest possible peak power and mean power. In the present study we used the recommended force settings 0.075 $kpkg^{-1}$ bw, a force equivalent to mechanical work of 4.41 J per pedal revolution per kilogram of body weight. It is difficult to compare the findings of several authors (e.g. Inbar & Bar-Or, 1977; Inbar et al., 1989; Rhodes, Cox, & Quinney, 1986) because of their different testing protocols, incompatible athletic proficiency and unequal ages. Skinner and O'Connor (1987) tested 44 male athletes from several specialties who performed the WAnT. There were no significant differences between "anaerobic" and "aerobic" athletes in mean power (8.8 to 9.3 $W.kg^{-1}$). The peak power of the group was 11.2 $W.kg^{-1}$ and the fatigue index was 38.1%. Although there are no significant differences in mean power, the "anaerobic athletes" had higher initial values but fatigue more rapidly, while the "aerobic" athletes had lower initial values but fatigue less rapidly. There are no data for table tennis players. Inbar (1985) found that the highest absolute values in W for mean and peak power were found in rowers. In Fig. 1 (male) and Fig. 2 (female) anaerobic performance capacities of elite Israeli athletes in various sport events are compared with Slovenian table tennis players.

Fig. 1
Anaerobic performance capacity (relative to body mass) of elite male Israeli athletes in various sport events and Slovenian table tennis players

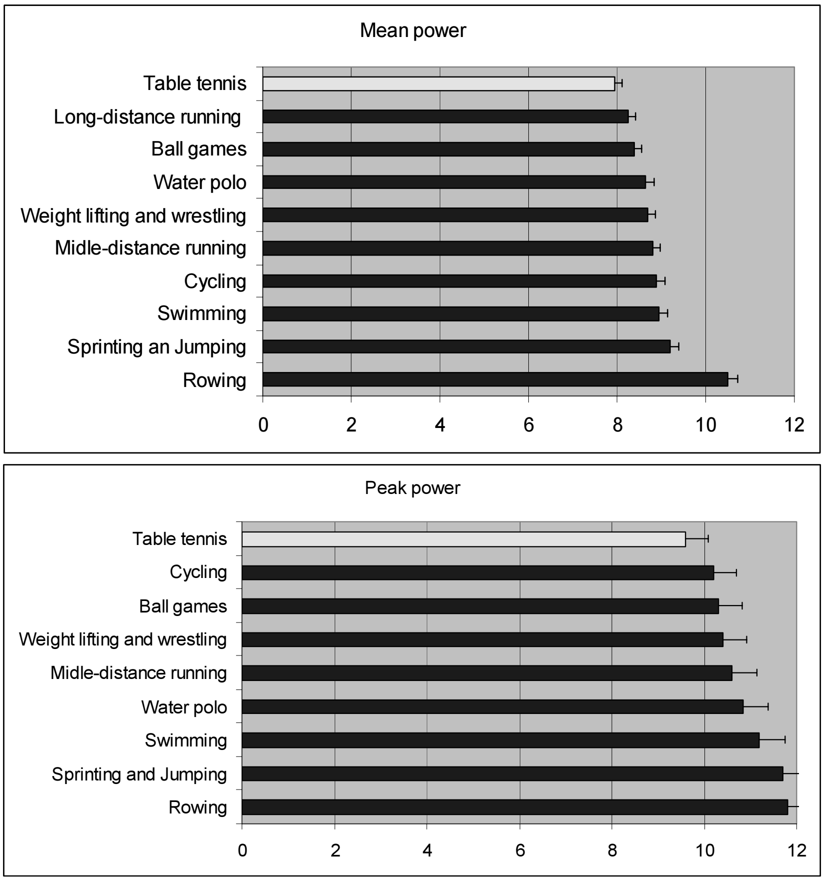

Fig. 2
Anaerobic performance capacity (relative to body mass) of elite female Israeli athletes in various sport events and Slovenian table tennis players

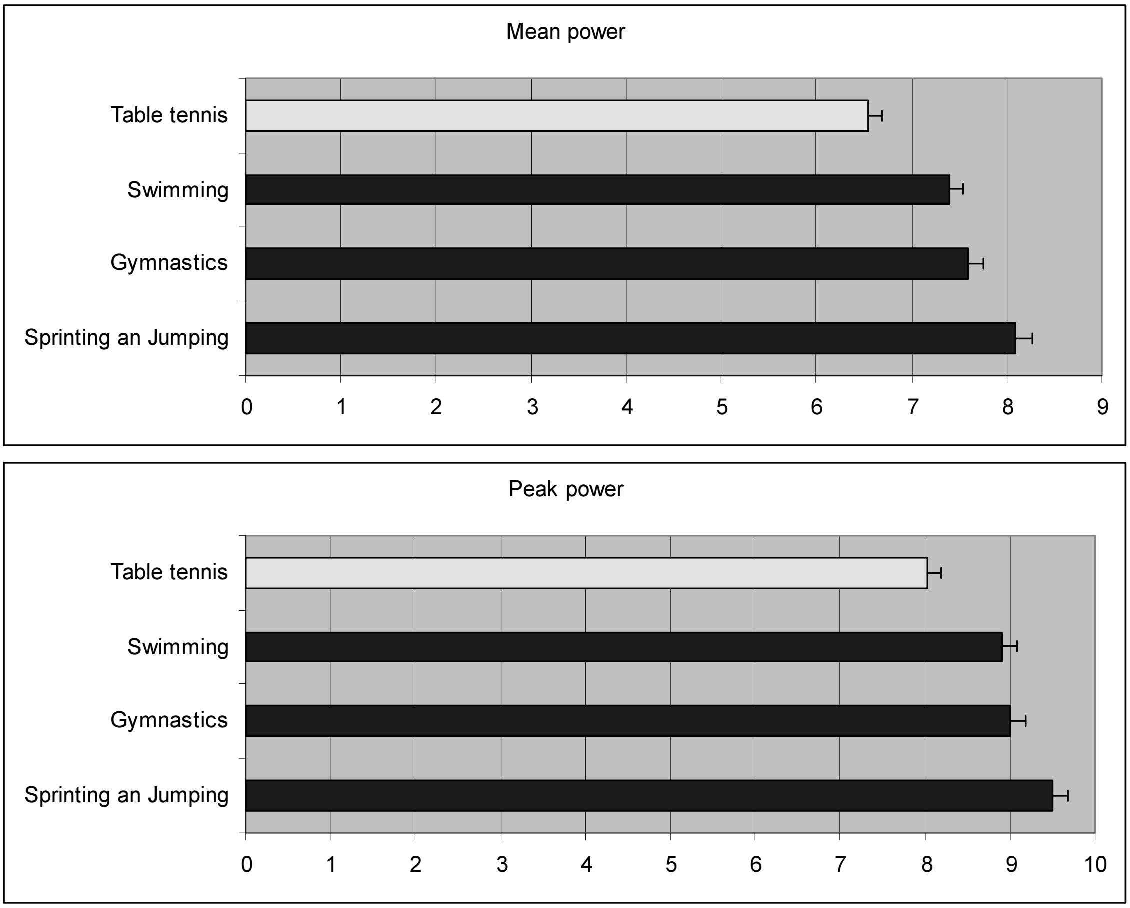

TABLE 5
The anaerobic performance capacity of Slovenian and Australian table tennis players

	Peak power (watts.kg^{-1})	Total power (watts.kg^{-1})	Power decline (%)
Australia – male	9.89	7.60	39.95
Slovenia – male	9.60	7.95	33.08
Australia – female	7.68	6.13	32.59
Slovenia – female	8.03	6.55	31.83

Allen (1986) tested 21 male and female table tennis players nominated by four State table tennis associations performed the WAnT. As shown in TABLE 5, there were some differences between Slovenian and Australian players. Despite the fact that we do not have enough data about physical preparation programs, it is difficult to find a reason why there are differences.

CONCLUSIONS

Based on the established sensitivity of the WAnT to detect changes brought about by the basic physical preparation of table tennis players, our research addresses the problem of training effects on anaerobic performance.

We can conclude that performance under conditions measured by WAnT is primarily anaerobic with a major lactic component. The work rate at the end of such a performance test can perhaps be considered to be an indirect estimate of the lactic anaerobic power output.

Despite being involved in an anaerobic sport, it appears that these athletes – both male and female – do not possess appropriately developed anaerobic energy delivery systems. These capacities should be well developed in athletes who depend on anaerobiosis during long stretches where they are trying to win points, especially if they play the half distance or are defensive players.

In spite of the fact that the group we measured is so small, much more research must be done on this topic.

REFERENCES

Allen, G. D. (1986). Physiological characteristics of elite table tennis athletes and their responses to high level competition. In *Australian sports commission's: Applied sports research program*. Australian sports commision.

Bangsbo, J., Gollnick, P. D., Graham, T. E., Juel, C., Kiens, B., Mizuno, M., & Saltin, B. (1990). Anaerobic energy production and O_2 deficit-debt relationship during exhaustive exercise in humans. *Journal of Physiology*, 539–559.

Bar-Or, O., Dotan, R., Inbar, O., Rothstein, A., Karlsson, J., & Teach, P. (1980). Anaerobic capacity and muscle fibre type distribution in man. *International Journal of Sports Medicine, 1*, 82–85.

Bar-Or, O. (1987). The Wingate anaerobic test: An update on methodology, reliability and validity. *Sports Medicine, 4*, 381–391.

Beneke, R., Pollmann, C., Bleif, I., Leithäuser, R., & Hütler, M. (2002). How anaerobic is the Wingate anaerobic test for humans? *European Journal of Applied Physiology, 87(4/5)*, 388–392.

Billat, V. L., Sirvent, P., Py, G., Koralsztein, J. P., & Mercier, J. (2003). The concept of a maximal lactate steady state: A bridge between biochemistry, physiology and sport science. *Sports Medicine, 33(6)*, 407–426.

Bogdanis, G. C., Nevill, M. E., Boobis, L. H., & Lakomy, H. K. (1996). Contribution of phosphocreatine and aerobic metabolism to energy supply during repeated sprint exercise. *Journal of Applied Physiology, 80(3)*, 876–878.

Boobis, L. H., Williams, C., & Wooton, S. A. (1982). Human muscle metabolism during brief maximal exercise. *Journal Physiology*, *338*, 21–22.

Bouchard, C., Taylor, A. W., Simoneau, J. A., & Dulac, S. (1991). Testing anaerobic power and capacity. In J. D. MacDougall, H. A. Wegner, & H. J. Green (Eds.), *Physiological testing of the high performance athlete* (pp. 175–221). Champaign, IL: Human Kinetics.

Brooks, G. A. (1985). Anaerobic threshold: Review of the concept and direction for future research. *Med. Sci. Sports Exer., 17*, 31–35.

Calbet, J. A. L., Chavarren, J., & Dorado, C. (1997). Fractional use of anaerobic capacity during a 30 and a 45 s Wingate test. *European Journal of Applied Physiology, 76*, 308–313.

DeVries, H. A. (1986). *Physiology of exercise.* Dubuque, Iowa: Wm. C. Brown Publisher.

Evans, J. A., & Quinney, H. A. (1981). Determination of resistance settings for anaerobic power testing. *Canadian Journal of Applied Sport Sciences, 6*, 53–56.

Foster, C., Schrager, M., & Snyder, A. C. (1995). Blood lactate and respiratory measurement of the capacity for sustained exercises. In P. J. Maud & C. Foster (Eds.), *Physiological assessment of human fitness* (pp. 57–59). Champaign, IL: Human Kinetics.

Gastin, P. B. (2001). Energy system interaction and relative contribution during maximal exercise. *Sports Medicine, 31(10)*, 725–741.

Gastin, P. B., & Lawson, D. L. (1994). A variable resistance all-out test to generate accumulated oxygen deficit and predict anaerobic capacity. *European Journal of Applied Physiology, 69*, 331–336.

Gladden, L. B. (2004). Lactate metabolism: A new paradigm for the third millennium. *Journal of Physiology, 558(1)*, 5–30.

Hermansen, L., & Medbø, J. I. (1984). The relative significance of aerobic and anaerobic processes during maximal exercise of short duration. *Med. Sport Sci., 17*, 56–67.

Inbar, O. (1985). *The Wingate anaerobic test: Its performance, characteristics, application and norms.* Netanya, Israel: Wingate Institut.

Inbar, O., Bar-Or, O., & Skinner, J. S. (1996). *The Wingate anaerobic test.* Champaign, IL: Human Kinetics.

Jacobs, I., Bar-Or, O., Karlsson, J., Dotan, R., Tesch, P., Kaiser, P., & Inbar, O. (1982). Changes in muscle metabolites in females with 30 s of exhaustive exercise. *Medicine and Science in Sports and Exercises, 14*, 457–460.

Jacobs, I., Bar-Or, O., Karlsson, J., Dotan, R., Tesch, P. A., Kaiser, P., & Inbar, O. (1982). Lactate in human skeletal muscle after 10 and 30 s of submaximal exercise. *Journal of Applied Physiology, 55*, 365–367.

Jacobs, I., Tesch, P. A., Bar-Or, O., Karlsson, J., & Dotan, R. (1983). Changes in muscle metabolites in females with 30 s of exhaustive exercise. *Medicine and Science in Sports and Exercises, 14*, 457–460.

Jacobs, I. (1986). Blood lactate: Implication for training and sports performance. *Sports Medicine, 3*, 10–25.

Jones, N. L., McCartney, N., Graham, T., Spriet, L. L., Kowalchuk, J. M., Heigenhauser, G. J. F., & Sutton, J. R. (1985). Muscle performance and metabolism in maximal isokinetic cycling at slow and fast speeds. *Journal of Applied Physiology*, *59(1)*, 132–136.

Karlsson, J., & Jacobs, I. (1982). Onset of blood lactate accumulation during muscular exercise as a threshold concept: Theoretical considerations. *International Journal of Sports Medicine, 3*, 190–201.

Kavanagh, M. H., & Jacobs, I. (1988). Breath by breath oxygen consumption during performance of the Wingate test. *Canadian Journal of Applied Sport Sciences, 13(1)*, 91–93.

Kondrič, M., & Furjan-Mandić, G. (2002). *Telesna priprava namiznoteniškega igralca*. Ljubljana: Faculty of sport.

MacDougall, J. D., Wenger, H. A., & Green, H. J. (1991). *Physiological testing of the high performance athlete.* Windsor: Canadian association of sport sciences.

O'Brien, B., Payne, W., & Gastin, P. (1997). A comparison of active and passive warm ups on energy system contribution and performance in moderate heat. *Aust. J. Sci. Med. Sport, 29(4)*, 106–109.

Petz, B. (1981). *Osnovne statističke metode za nematematičare.* Zagreb: SNL.

Rhodes, E. C., Cox, M. H., & Quinney, H. A. (1986). Physiological monitoring of National hockey league regulars during the 1985–1986 season. *Canadian Journal of Applied Sport Sciences*, *11*, 36.

Shepard, R. (1987). *Exercise physiology*. Toronto, Philadelphia: B. C. Decker Inc.

Skinner, J. S. (1987). Wingate test: Cross-sectional and longitudinal analysis. *Medicine and Science in Sports and Exercises, 19(2)*, 73.

Skinner, J. S., & Morgan, D. W. (1985). *Limits of human performance.* Champaign, IL: Human Kinetics.

Smith, J. C., & Hill, D. W. (1991). Contribution of energy systems during a Wingate power test. *British Journal of Sports Medicine, 25(4)*, 196–199.

Weicker, H., & Strobel, G. (1994). *Sportmedizin-biomechanisch-physiologische Grundlagen und ihre Bedeutung.* Stuttgart: Fischer.

Withers, R. T., Sherman, W. M., Clark, D. G., Esselbach, P. C., Nolan, S. R., Mackay, M. H., & Brinkman, B. (1991). Muscle metabolism during 30, 60, and 90 s of maximum cycling on an air-braked ergometer. *European Journal of Applied Physiology, 63(5)*, 354–362.

FYZIOLOGICKÉ ANAEROBNÍ CHARAKTERISTIKY SLOVINSKÝCH ELITNÍCH HRÁČŮ STOLNÍHO TENISU

(Souhrn anglického textu)

Cílem tohoto výzkumu byla analýza anaerobních charakteristik slovinských elitních hráčů a hráček stolního tenisu. Celkem 8 osob bylo rozděleno do dvou skupin. První skupina zahrnovala čtyři nejlepší slovinské hráčky a druhá skupina zahrnovala čtyři nejlepší slovinské hráče. Pro měření jsme používali Wingate test (WAnT). Při WAnT se provádí šlapání po dobu 30 sekund při maximální rychlosti proti konstantnímu silovému nastavení, aby se dosáhlo nejvyšší střední a vrcholové síly. Pro silové nastavení jsme použili původní doporučenou rovnici (0,075 kpkg^{-1} bw, síla odpovídající stupni mechanické práce o 4,41 J rev.$^{-1}$kilogram^{-1}bw) na ergometru Monark 634. Pro odhad koncentrace laktátu v krvi a svalech jsme odebírali vzorky krve o 20 µL z heparinem ošetřených ušních lalůčků účastníků před a bezprostředně po ukončení testu a také vždy 3, 5 a 7 minut po zkoušce pro analýzu laktátu. Údaje jsme zpracovávali pomocí statistického software SPSS 8.0 pro Windows a pomocí software pro WAnT. Anaerobní vlastnosti subjektů naměřené 30sekundovou zkouškou WAnT ukázaly, že skupina mužů vyvinula střední sílu 7,95 wattů.kg^{-1} a vrcholovou sílu 9,60 wattů.kg^{-1} a že silový výkon se po 30 sekundách snížil o 33,08 %. U skupiny žen činila odpovídající hodnota střední síly 6,55 wattů.kg^{-1} a vrcholová síla 8,03 wattů.kg^{-1}, přičemž silový výkon se po 30 sekundách snižoval o 31,83 %. Vrcholová síla vypočtená při tomto průzkumu se pohybovala od 8,7 wattů.kg^{-1} do 10,4 wattů.kg^{-1} ve skupině mužů a od 7,0 wattů.kg^{-1} do 8,8 wattů.kg^{-1} ve skupině žen. Na základě stanovené citlivosti WAnT pro detekci změn vyvolaných základní tělesnou přípravou hráčů stolního tenisu se náš výzkum týká problematiky účinků tréninku na anaerobní výkon.

Klíčová slova: stolní tenis, motorické testy, anaerobní schopnosti, anaerobní Wingate test.

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First-line publications
Kondrič, M. (1996). The expert system for orientation of children into table tennis in the Republic of Slovenia. *International Journal of Table Tennis Sciences, 3*, 125–130.

Kondrič, M., & Mišigoj-Duraković, M. (2002). Changes of certain anthropometric characteristics in boys 7 to 18 years of age. *International Journal of Physical Education, 39*, 30–35.

Kondrič, M., & Leskošek, B. (2002). Computer supported system for the evaluation of fitness of Slovenian youth table tennis players. *International Journal of Table Tennis Sciences, 4(5)*, 117–126.

Kondrič, M., Mišigoj-Duraković, M., & Metikoš, D. (2002). A contribution to understanding relations between morphological and motor characteristics in 7 and 9 year old boys. *Kinesiology, 34(1)*, 5–15.

Kondrič, M., Furjan-Mandić, G., & Medved, V. (2006). Myoelectric comparison of table tennis forehand stroke using different ball sizes. *Acta Universitatis Palackianae Olomucensis. Gymnica, 36(4)*, 25–31.