

## THE DIAGNOSTICS POSSIBILITIES OF ANAEROBIC POWER AND CAPACITY BY USING THE PEDAR SYSTEM

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### Abstract

The aim of this study was to evaluate the possibilities of execution of the 60 second Bosco test of anaerobic power and capacity using the Emed system with mobile pedographic system Pedar in field conditions. Apart from evaluating the common parameters of maximal anaerobic power and anaerobic capacity of an individual using the above mentioned system, we also focused on differences in the variables of each limb. The system Emed with mobile pedographic facility Pedar is possible to be used for the diagnostics of anaerobic power and capacity evaluated by Bosco test in field conditions. We did not notice any statistically important difference in aerial and contact phase of the dominant and non-dominant limb during the 60 seconds of the test while observing the signs of domination of the limbs. Therefore there were not any signs of domination of the limbs.

### Keywords

Anaerobic power and capacity; Bosco test; Pressure distribution measurement.

### Introduction

In the last 50 years, the level of aerobic (oxidative) power and capacity defined by the maximal consumption of oxygen and the derived parameters and their diagnostics have been standardized and the tests of measuring the aerobic power and capacity are generally recognized [11]. Under the terms of secular trends amongst the population, only some of the norms and specifications of the predictive equation containing particular components of aerobic capability [9] appear to be a matter of revision. The aerobic capabilities influencing the endurance performance are an important part of the battery for evaluating the health-orientated capability of the individual as a factor influencing the health in a significant way.

However, there is a different situation with anaerobic abilities. In the general approach towards the problematic of anaerobic abilities and their diagnostics, there are still persisting problems and doubts [3]. The processes as well as the mechanisms of the anaerobic way of releasing the energy in the bone muscle at the activities of the maximal and submaximal intensity are diagnostically rarely available, therefore it is possible to encounter a wide range of conceptions and methodological solutions which always accent some and also suppress other aspects of the anaerobic metabolism [6]. There is no generally accepted parameter for evaluating the level of anaerobic power and capacity. The maximum values of the afterload blood lactate are often used for evaluating the anaerobic capacity despite of problems with the interpretation of the physiological meaning [4].

Tests of anaerobic abilities are missed out while evaluating the health-orientated capability for complicated interpretation of the health impact on as wide a range as possible of age categories. Currently they are appearing as a possible component of test batteries evaluating the general level of health-orientated capability. Ortega et al. [10] observes the validity and reliability of the test for the determination of the health-orientated capability, beside other things, also for the determination of anaerobic abilities. Čaba [2] proved close connection between the output in Bosco test and the items of the test battery Eurofit, describing the power endurance parameters of the lower limb such as long jump from standing, sit up, and endurance running in adolescents. From the results of Bosco test it is partly possible to predict a specific level of health-orientated capability in adolescents.

In the diagnostics of the prerequisite for short term highly intense activity performed in the conditions of oxygen deficit, there are used anaerobic load tests which track the changes of the performance in time. It means that they register not only the maximal anaerobic lactate performance but also the decrease in the performance during the test. A separate category of the anaerobic capability tests is a test of repetitive jumps. Bosco test of repetitive jumps [1] enables the determination of anaerobic capacity by defining the height of the jumps and anaerobic performance in the test. The way of the execution of the test doesn't represent any risk of complicated execution and termination of the test (in comparison with other anaerobic tests, i.e., the Kindermann-Schnabel one). The content of the test is performing of all series of the consequential repetitive vertical jumps, as maximal as possible, in the time period of 60 seconds. The performance in the jump phase of the jump test in first 15 seconds shows close connection towards the representation of fast muscle fibre [5].

The test is usually executed in a lab on the jump ergometer which enables to evaluate the overall number of jumps (spring), the average time of one jump (s), absolute work (kJ), and relative work (J/kg).

The system Emed with foot pressure inset Pedar (Novell, Germany) is a modern system for measuring the distribution of the pressure and local load under the sole, between the foot and the shoe, in static and dynamic conditions. It enables both lab and also field testing during natural activities such as walking, running, bike riding, therefore the results are more relevant in real life. It also enables to diagnose not only the data expressing the plantar pressure but also to diversify while in contact with the mat between the eccentric and concentric phase. The eccentric component in vertical jump includes the impact on the mat and retaining the potential energy by the extensors of lower limbs. The concentric phase generates the power from the chemo-mechanical conversion of the energy and the utilization of saved elastic energy for the spring [9].

## **1 Aim of the Research**

The goal of this project was to evaluate the possibilities of execution of the 60 second Bosco test of the anaerobic capabilities using the Emed system with mobile pedographic Pedar system in field conditions. Apart from evaluating the common parameters of maximal anaerobic power and the capacity of the individual using the above mentioned system, we focused on the differences of the variables of particular limbs.

## **2 Methodology**

The measurement was taken in a test group of 18 men participants. Because of incorrect performing of the test, the results of three participants were excluded, and the results of another person were excluded because of not finishing the load test. The basic anthropometric characteristics of the assessed individuals are shown in Tab. 1.

**Tab. 1:** Basic characteristic of tested people (arithmetic mean  $\pm$  SD)

Quantity	Age [years]	Weight [kg]	Height [m]	Laterality LL left	Laterality LL right
14	21.2 $\pm$ 1.1	74.1 $\pm$ 8.4	1.81 $\pm$ 0.05	6	8

LL – lower limb

Source: Own research

The physical height was measured in a straighten-up position without shoes using the altimeter Anthropometer A 213 (Trystom spol. s.r.o., Czech Republic) with the accuracy 0.1 cm. The physical weight was measured on the personal scales Amboss©Seca 899 (Hamburg, Germany) with the accuracy 0.1 kg.

For the load test we used the 60 second Bosco test of repetitive jumps [1]. Its content is the series of consequential repetitive maximal vertical jumps in 60 seconds.

The evaluated variables were the capacity in the test and the overall work as an indicator of anaerobic capacity, jump height, time of the aerial phase ( $T_f$ ) and their summarization in the time period of 60 seconds, and the contact phase ( $T_c$ ). We observed the signs of tiredness determined as the index evaluated by the decrease of performance in a time. The variables  $T_f$  and  $T_c$  were evaluated together for both limbs and also separately for each limb afterwards.

The tested participants stretched before performing the test. The test itself was started from the position of a squat, the angle under the knee was 90°, arms akimbo. We watched the technique of performing the test as well as the angle in the knee which was not allowed to be less than 90°. The testing took place in the sports hall on artificial surface.

For measuring of the powers impacting the mat we used the Emed system with the foot pressure inset Pedar (Pedar-x; Novel, Munich, Germany), which was placed directly into the shoe of the tested person. The frequency of the recorded dynamic parameters was 100 Hz.

In the third and the fifth minute after the test the measurement of the afterload concentration of lactate (la) in the blood was taken by the Lactate meter HP-Cosmos Sirius (HP Cosmos©, Germany).

Determination of the dominance of lower limbs was done by the performance test on stairs. We monitored which limb would be in dominant position, e.g. which limb would be used first by the tested person for stair climbing and descending. The laterality had already been verified before the test, observing the dominant limb in participants kicking a ball.

For the statistic processing of the research data we used the method of descriptive and inductive statistics. The data were processed in the Excel program.

### 3 Results

The measured data in Bosco test were split into 6 intervals of 10 seconds each. In these intervals we set the number of jumps and the time of contact with the inset. Other counted variables were based on the following formulas [1]:

$$v = 0.5 \times g \times T_f \quad (1)$$

$v$  – speed of take-off [ $\text{m}\cdot\text{s}^{-1}$ ], where  $T_f$  is the time of aerial phase and  $g$  is the constant of acceleration.

$$h = 0.125 \times g \times T_f^2 \quad (2)$$

$h$  – jump height [m].

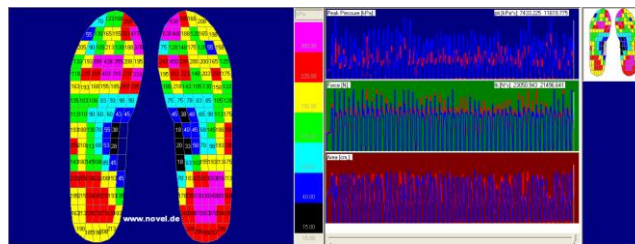
$$A = m \times g \times h = 0.125 \times g^2 \times T_f^2 \times m \quad (3)$$

$A$  – work [J], where  $m$  is the weight of the tested individual [kg].

$$IU = (\text{work max} - \text{work min}) \quad (4)$$

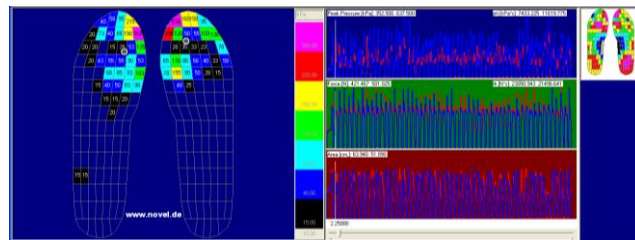
$IU$  – Fatigue index.

The example of the record and graphic processing of the data Novel is shown in Fig. 1 for the landing phase. Fig. 2 shows the contact with the inset after the phase of taking off and leaving the inset.



Source: Own research

**Fig. 1:** An example of the record and graphic processing of data using the Pedar system while landing on the inset



Source: Own research

**Fig. 2:** An example of record and graphic processing of the data using the Pedar system after the take-off phase and leaving the inset

The general results of Bosco test for both limbs together are shown in Tab. 2.

**Tab. 2:** The results of Bosco test (arithmetic mean  $\pm$ SD)

Person	Number of jumps	Contact phase [s]	Aerial phase [s]	Speed of take-off [m.s <sup>-1</sup> ] average	Jump height [m]	Jump height average [m]	Work [J]	Fatigue index
1	53	36.96 ( $\pm$ 0.05)	26.78 ( $\pm$ 0.03)	2.51 ( $\pm$ 0.16)	14.08 ( $\pm$ 0.32)	0.27 ( $\pm$ 0.32)	11281.24 ( $\pm$ 28.26)	841.59 ( $\pm$ 93.9)
2	55	39.25 ( $\pm$ 0.04)	20.77 ( $\pm$ 0.04)	1.85 ( $\pm$ 0.21)	9.68 ( $\pm$ 0.04)	0.18 ( $\pm$ 0.04)	8066.89 ( $\pm$ 32.17)	471.88 ( $\pm$ 26.63)
3	68	32.45 ( $\pm$ 0.03)	27.55 ( $\pm$ 0.03)	1.99 ( $\pm$ 0.13)	13.78 ( $\pm$ 0.03)	0.2 ( $\pm$ 0.03)	8511.65 ( $\pm$ 16.64)	260.3 ( $\pm$ 13.86)
4	46.5	40.27 ( $\pm$ 0.09)	19.73 ( $\pm$ 0.07)	2.08 ( $\pm$ 0.32)	8.43 ( $\pm$ 0.05)	0.18 ( $\pm$ 0.05)	4876.88 ( $\pm$ 28.25)	508.64 ( $\pm$ 34.14)
5	62.5	34.4 ( $\pm$ 0.08)	25.6 ( $\pm$ 0.09)	2.01 ( $\pm$ 0.45)	13.17 ( $\pm$ 0.08)	0.21 ( $\pm$ 0.08)	9298.26 ( $\pm$ 57.56)	916.38 ( $\pm$ 62.89)
6	72	43.34 ( $\pm$ 0.13)	16.66 ( $\pm$ 0.06)	1.13 ( $\pm$ 0.3)	5.71 ( $\pm$ 0.04)	0.08 ( $\pm$ 0.04)	4812.86 ( $\pm$ 34.08)	759.95 ( $\pm$ 48.8)
7	49	41.43 ( $\pm$ 0.15)	18.57 ( $\pm$ 0.08)	1.86 ( $\pm$ 0.38)	8.97 ( $\pm$ 0.08)	0.18 ( $\pm$ 0.08)	6600.68 ( $\pm$ 49.02)	722.67 ( $\pm$ 88.12)
8	80.5	21.26 ( $\pm$ 0.03)	38.74 ( $\pm$ 0.05)	2.36 ( $\pm$ 0.25)	22.84 ( $\pm$ 0.05)	0.28 ( $\pm$ 0.05)	15005.38 ( $\pm$ 35.47)	1091.2 ( $\pm$ 44.7)
9	56	40.48 ( $\pm$ 0.23)	19.52 ( $\pm$ 0.1)	1.71 ( $\pm$ 0.51)	10.5 ( $\pm$ 0.13)	0.19 ( $\pm$ 0.13)	8750.07 ( $\pm$ 106.51)	2981.64 ( $\pm$ 547.56)
10	69	29.17 ( $\pm$ 0.05)	30.83 ( $\pm$ 0.06)	2.19 ( $\pm$ 0.27)	17.04 ( $\pm$ 0.05)	0.25 ( $\pm$ 0.05)	13370.9 ( $\pm$ 40.9)	1017.42 ( $\pm$ 46.62)
11	54	33.61 ( $\pm$ 0.07)	26.39 ( $\pm$ 0.07)	2.4 ( $\pm$ 0.32)	15.91 ( $\pm$ 0.07)	0.29 ( $\pm$ 0.07)	1248.1 ( $\pm$ 54.48)	1050.46 ( $\pm$ 64.6)
12	47	41.51 ( $\pm$ 0.14)	18.49 ( $\pm$ 0.07)	1.93 ( $\pm$ 0.33)	8.84 ( $\pm$ 0.05)	0.19 ( $\pm$ 0.05)	6070.56 ( $\pm$ 36.48)	702.69 ( $\pm$ 56.52)
13	61	36.31 ( $\pm$ 0.05)	23.69 ( $\pm$ 0.05)	1.9 ( $\pm$ 0.22)	11.38 ( $\pm$ 0.04)	0.19 ( $\pm$ 0.04)	7590.15 ( $\pm$ 27.3)	381.08 ( $\pm$ 25.07)
14	60	33.54 ( $\pm$ 0.06)	26.46 ( $\pm$ 0.05)	2.16 ( $\pm$ 0.23)	14.28 ( $\pm$ 0.05)	0.24 ( $\pm$ 0.05)	9384.57 ( $\pm$ 31.08)	770.28 ( $\pm$ 54.97)

Source: Own research

The majority of the tested people are based on Heller and Vodička [7] recreational sportspeople who show the values of the aerial phase around 36.6 s and the contact phase 23.4 seconds. With ranking into this category corresponded also the average values of afterload lactate, which were on the level  $7.8 \pm 2.6$  mmol/l at the 3<sup>rd</sup> minute and on the level  $8.9 \pm 1.9$  mmol/l at the 5<sup>th</sup> minute. The tested people were mainly present in the zones of anaerobic lactate load.

The values of the variable  $T_c$  fluctuated between 21.26 s and 43.34 s. At the lower values of the contact phase we can find higher number of jumps (correlation coefficient  $r = -0.73$ , where the indirect high dependence is  $0.90 > r \geq 0.70$ ).

The lowest values of the contact phase were noticed from its beginning until 20 seconds in the test. With coming tiredness the values were increasing. The values of variables  $T_f$  fluctuated between 16.66 s and 30.83 s. While watching the relationship of variable number of jumps and the aerial phase we noticed middle (significant) dependence ( $r = 0.64$ ).

While watching the signs of domination of the limbs in the test, we didn't notice any statistically significant differences in the aerial phase at the dominant and non-dominant limb during the 60 seconds of the test, not even in the closing part of the test, where tiredness can usually be observed. The average values of the differences at variables in the aerial and the contact phase are shown in Tab. 3.

**Tab. 3:** Average values of the difference  $T_f$  and  $T_c$  – the lower limbs

Intervals 10s	1.	2.	3.	4.	5.	6.
$T_c$ [s]	0.00	0.00	-0.01	0.00	0.00	-0.01
$T_f$ [s]	-0.02	-0.02	-0.03	-0.02	-0.02	-0.03

Source: Own research

## Conclusion

The system Emed with pedographic facility Pedar is possible to be used in diagnostics of anaerobic power and capacity evaluated by the Bosco test in field conditions. The hypothesis number 1 was confirmed. Apart from the evaluated variables, where it is possible to get the usual jump ergonomic, such as the maximal anaerobic power and the capacity of the individual, it is possible to evaluate, thanks to the above-mentioned system, the detailed distribution of the pressure on the sole and e.g. the technique of performing the takeoff from the whole foot or its upper part. The advantage of this system is the possibility of its transportation and usage in field conditions and on different surfaces.

While watching the signs of domination of the limbs in the tests, we did not notice any statistically significant differences in the aerial phase at the dominant and non-dominant limb during the 60 seconds of the test, not even in the closing part of the test, where tiredness can usually be observed. We did not confirm the hypothesis number 2 which assumes the higher tiredness sign at the non-dominant limb evaluated with prolonging the contact phase and shortening the aerial phase.

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## Literature

- [1] BOSCO, C.; LUHTANEN, P.; KOMI, P. V.: A simple method for measurement of mechanical power in jumping. *Eur J Appl Physiol.* 1983, Vol. 50, No. 6, pp. 273–282.
- [2] ČABA, L.: *Význam Boscova testu při určení zdravotně orientované zdatnosti adolescentů.* Disertační práce. UK FTVS: Praha, 2014. Thesis supervisor Jan Heller.
- [3] FOSTER, C.; FARLAND, C. V.; GUIDOTTI, F. et al.: The Effects of High Intensity Interval Training vs Steady State Training on Aerobic and Anaerobic Capacity. *J Sports Sci Med.* 2015, Vol. 14, No. 4, pp. 747–755.

- [4] GREEN, S.; DAWSON, B.: Measurement of Anaerobic Capacities in Humans. Definitions, Limitations and Unsolved Problems. *Sports Medicine*. 1993, Vol. 15, No. 5, pp. 312–327.
- [5] [5] ZEMKOVÁ, E.; HAMMAR, D.: Jump Ergometer in sport performance testing. *Acta Univ. Palacki. Olomuc. Gymn.* 2005, Vol. 35, No. 17, pp. 17–35.
- [6] HELLER, J.: Diagnostika anaerobního výkonu a anaerobní kapacity pomocí "all - out" testů. *Těl. Vých. Mlád.* 1995, Vol. 61, No. 4, pp. 35–40.
- [7] HELLER, J.; VODIČKA, P.: *Praktická cvičení z fyziologie tělesné zátěže*. 1<sup>st</sup> edition. Praha: Karolinum, 2011. 115 pp. ISBN 978-80-246-1976-7.
- [8] HNÍZDIL, J.; HAVEL, Z. et al.: *Rozvoj a diagnostika vytrvalostních schopností*. Ústí nad Labem: PF UJEP, 2010. ISBN: 978-80-7414-476-9.
- [9] HOVEY, R.: *Examination of the Bosco jump test*. [online]. 1989, Division of Graduate Studies and Research McGill University Montreal: Quebec, Canada, [accessed 2015-30-12]. Available from WWW: [https://www.researchgate.net/profile/Richard\\_Hovey/publication/38433214\\_Examination\\_of\\_the\\_Bosco\\_jump\\_test/links/0deec52432e660b31c000000/Examination-of-the-Bosco-jump-test.pdf](https://www.researchgate.net/profile/Richard_Hovey/publication/38433214_Examination_of_the_Bosco_jump_test/links/0deec52432e660b31c000000/Examination-of-the-Bosco-jump-test.pdf)
- [10] ORTEGA, F. B.; ARTEGO, E. G.; RUIZ, J.R. et al.: Reliability of health-related physical fitness tests in European adolescents. The Helena study. *International Journal of Obesity*. 2008, 32, s. 47–57.
- [11] THODEN, J. S.: Testing aerobic power. In: MacDougall, J. D.; Wenger, H. A. and Green, H. J. (Editors) *Physiological testing of the high performance athlete*. 1991, *Human Kinetics*: Champaign. p. 107–173.

## MOŽNOSTI DIAGNOSTIKY ANAEROBNÍCH SCHOPNOSTÍ SYSTÉMEM PEDAR

Cílem projektu bylo zhodnotit možnosti provedení 60ti sekundového Boscova testu anaerobních schopností pomocí systému Emed s mobilním pedografickým systémem Pedar v terénních podmínkách. Kromě vyhodnocení běžných parametrů maximálního anaerobního výkonu a anaerobní kapacity jedince pomocí uvedeného systému jsme se zaměřili na rozdíly v proměnných u jednotlivých končetin. Systém Emed s mobilním pedografickým zařízením Pedar lze využít k diagnostice anaerobních schopností hodnocených Boscovým testem v terénních podmínkách. Při sledování projevu dominance končetin během testu jsme nezaznamenali statisticky významné rozdíly v letové a kontaktní fázi u dominantní a nedominantní končetiny během 60 sekund trvání testu, nedošlo tedy k projevům dominance končetin.

## MÖGLICHKEITEN DER DIAGNOSTIZIERUNG VON ANAEROBEN FÄHIGKEITEN MIT DEM SYSTEM PEDAR

Ziel des Projekts war, die Möglichkeiten der Durchführung des sechzig Sekunden dauernden Bosco-Test anaerober Fähigkeiten mit Hilfe des Systems Emed mit dem mobilen pedografischen System Pedar unter Geländebedingungen zu bewerten. Außer der Bewertung der gängigen Parameter der maximalen anaeroben Leistung und der anaeroben Kapazität des Einzelnen mit Hilfe des angeführten Systems konzentrieren wir uns auf die Unterschiede in den veränderlichen Werten der einzelnen Gliedmaßen. Das System Emed mit der mobilen pedografischen Anlage Pedar ist einsetzbar zur Diagnostik anaerober Fähigkeiten, die mit dem Bosco-Test unter Geländebedingungen bewertet wurden. Bei der Beobachtung dieses Dominanzausdrucks während des Tests haben wir keine statistisch relevanten Unterschiede in der Flug- und Kontaktphase bei den dominanten und nicht dominanten Extremitäten während des sechzig Sekunden dauernden Tests vermerkt. Es gab also keine Anzeichen von Dominanz der Extremitäten.

## MOŻLIWOŚCI BADANIA WYDOLNOŚCI BEZTLENOWEJ PRZY WYORZYSTANIU SYSTEMU PEDAR

Celem projektu była ocena możliwości przeprowadzenia 60-sekundowego Testu Bosco wydolności beztlenowej przy pomocy systemu Emed z mobilnym systemem pedograficznym Pedar w warunkach terenowych. Oprócz badania zwykłych parametrów maksymalnej mocy anaerobowej przy pomocy ww. systemu skupiono się na różnicach w zmiennych dotyczących poszczególnych kończyn. System Emed z mobilnym urządzeniem pedograficznym Pedar można wykorzystać do diagnozowania wydolności beztlenowej przy pomocy Testu Bosco w warunkach terenowych. Obserwując przejawy dominacji kończyn podczas testu nie odnotowano podczas 60 sekund trwania testu statystycznie istotnych różnic w fazie lotu i kontaktu z podłożem w przypadku kończyny dominującej i niedominującej, co oznacza brak pojawienia się dominacji kończyn.