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Original Article

The acute effect of nicotine intake on anaerobic exercise performance

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Abstract:
Nicotine is a substance continuously being discussed as a possible performance enhancing drug. The purpose of this study was to determine the effects of nicotine on cyclists during the Wingate anaerobic test. Healthy young adults (n=18, 11 men in the age of 22.7±2.9 and 7 women in the age of 23.6±1.6) participated in a crossover study in which they were randomly assigned sublingual tablets containing nicotine (4 mg) or a placebo. According to our results, we found consuming nicotine in this form and dose does not improve short-term maximum athletic performance.
Key words: nicotine, short-term maximum power, Wingate anaerobic test.

Introduction

In recent years, studies have investigated whether nicotine intake can improve athletic performance. Some recent studies show an increase in the number of athletes consuming nicotine found in cigarettes or chewing tobacco. For example, the prevalance of nicotine consumption in the form of cigarettes and smokeless nicotine products before and during the the 2009 Ice Hockey World Championships games suggested that about half of the ice hockey players were active users (Marclay & Saugy, 2010).

An extensive study collected 2,185 urine samples from 2010 to 2011 from athletes participating in 43 different sports and found that nicotine was consumed regularly by 15.3% of the athletes tested. These values are lower than in the general population, but athletes tend to smoke significantly less. Data showing the cumulative exposure to nicotine, nicotine metabolites and tobacco alkaloids were in some sports very high. Nicotine was found in 55.6% of American football players, 45.4% of ice hockey players, while for football players, basketball players and wrestlers the values ranged from 28.8% to 55.6% (Marclay, Grata, Perrenoud, & Saugy, 2011).

Increased regular intake of nicotine may contribute to enhanced athletic performance. Nicotine belongs to the group of simple alkaloids, which mainly affect the autonomous nervous system. Nicotine has long been reported to significantly improve attention, learning and memory function (Heishman, Kleykamp, & Singleton, 2010; Levin, 2013; Levin, McClernon, & Rezvani, 2006; Poltavski, Petros, & Holm, 2012). We also need to mention that a desireable effect of nicotine for some athletes might be the reduction of body fat, especially when consumed together with caffeine (Davis & Green, 2009; Jessen, Toubro, & Astrup, 2003).

Nicotine also probably has an effect on physical stress. It affects the release of catecholamines, such as epinephrine and norepinephrine, which have metabolic and hemodynamic effects (Metz, 2004). Besides increasing heart rate and blood pressure, nicotine has also been proven to increase myocardial contractility in animals and human subjects, with a subsequent increase in cardiac output (Behr, Leong, & Jones, 1981; Grassi et al., 1994; Hoyt, 2013; Okusaga & Postolache, 2013). Intake of nicotine from cigarette smoking is not suitable for aerobic performance because carbon monoxide binds to hemoglobin and reduces the transport capacity of the blood for oxygen transfer (Hoyt, 2013; Rotstein & Sagiv, 1986; Turner & McNicol, 1993). Like other stimulants such as caffeine, nicotine consumption in other forms probably increases an individual's aerobic power (Bridge et al., 2000; Hodgson, Randell, & Jeukendrup, 2013; McLellan & Bell, 2004; Stadheim et al., 2013). In a unique study, scientists Mündel and Jones (2006) demonstrated that transdermal nicotine application (7 mg) significantly increased the endurance performance on non-smoking men.

Also, studies evaluating the effects of nicotine on short-term maximum power using the Wingate test are rare. Weisman found no differences in anaerobic capacity in smokers, short-term abstinent smokers or non-smoking men (Williams, 2009). Other experiments showed nicotine's effect (via nicotine gum) on peak anaerobic power, anaerobic capacity and anaerobic fatigue in percentages. The results were not statistically significant (Meier, 2006).

Our study evaluates whether nicotine, received in the form of sublingual tablets (4 mg), increases

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any of the parameters of the 30-second Wingate anaerobic test, which is used for evaluating short-term maximum athletic power in a group of non-smokers. Findings are based on:

a) A number of urine samples demonstrating exposure to nicotine, nicotine metabolites and tobacco alkaloids in athletes where the sport they practice requires rapid power capabilities (Marclay & Saugy, 2010; Marclay et al., 2011).

b) The possible effects of nicotine on 30-second maximum power. Positive effects may include:

- significant increase in cardiac output and level of glucose in the blood (Benowitz, 2009; Benowitz, Jacob, Fong, & Gupta, 1994; Jessen et al., 2003; Turner & McNicol, 1993),
- cutaneous vasoconstriction and systemic venoconstriction, allowing increased blood flow to muscles (Eckstein & Horsley, 1960; Rotstein & Sagiv, 1960), and
- enhanced cognitive performance via reduced stress and increased motivation (Karaba-Jakovlijevič, Popadić-Gaćesa, Grujič, Barak, & Drapsin, 2007; Vandewalle, Peres, Heller, & Monod, 1985).

Materials & methods

The sample included 18 amateur athletes and physical education students (11 men in the age of 22.7±2.9 and 7 women in the age of 23.6±1.6) from the faculty of education. The average weight of the men was 75.3±9.5 kg, while for the women it was 62.7±7.5. The average height of the men was 177.6±5.3 cm, for the women it was 172.1±5.3 cm. The evaluated students were healthy non-smokers in good physical condition. They had already participated in Wingate anaerobic tests during previous years.

The students completed two laboratory tests at 7-day intervals while maintaining the same performance unaffected by biological body rhythms (Lorino, Lloyd, Crixell, & Walker, 2006). Each test consisted of two Wingate anaerobic tests during which they received a sublingual tablet with nicotine or a placebo. The NiQuitin Mini tablet (GlaxoSmithKline Consumer Healthcare, Ltd., Ireland) contains 4 mg of nicotine (as a nicotine resinate). One lozenge-shaped tablet is placed in the mouth to dissolve. Periodically, the lozenge should be moved from one side of the mouth to the other. This must be repeated until it has completely dissolved (approximately 10 minutes). The tablets of placebo are made by a pharmacist and contain NiQuitin mini xanthan gum with menthol. We based our period for nicotine intake on the work McEwen, West and Gaiger (2008), which determined that the highest mean blood nicotine levels from NiQuitin 4 mg lozenges occur 20 minutes after use.

Respondents completed two standard Wingate 30-s anaerobic tests in one day. Before each test, they warmed up and stretched intensively. The second test was administered 30 minutes after the first. During the break, the students were lying in rest position. 20 minutes prior to the second test, a nicotine or placebo tablet from prepared boxes was placed in each student's mouth by a researcher. Students were unaware of which tablet they had been given and were instructed not to swallow the tablet, but let it dissolve.

Before laboratory testing, each student warmed up individually. Five-minute testing was performed on an ergometer with a load of 1.5 $W.kg^{-1}$, interspersed with some short-term sprints and maximum cadence. The ergometer seat was adjusted to the optimal position of the test subject with the feet fixed on the pedals. During warm-up, the subject was told to give maximum effort from the beginning of the test, without strategically reserving energy. During the test we verbally motivated the subjects and tried to create a competitive atmosphere, because anaerobic tests depend heavily on the motivation of the subject (Karaba-Jakovlijevič et al., 2007; Vandewalle et al., 1985).

The Wingate anaerobic test determines basic parameters for maximum short-term anaerobic performance, including:

- maximum anaerobic power, meaning the highest power in the test
- anaerobic capacity, as the average power or total workout
- power drop, meaning the drop between the highest and lowest power (usually at the end of the test), which is expressed as a relative percentage of maximum power.

For testing, we used a mechanical bicycle ergometer calibrated for short-term power up to 1500 W with a cadence of 160 rpm. For each Wingate Anaerobic Test we used a resistance load of 0.106 $W{\cdot}kg^{-1}$ for men and 0.089 $W{\cdot}kg^{-1}$ for women. The load corresponded, using the ergometer's calibration curves, to a load of 6 $W.kg^{-1}$ (for a cadence of 60 rpm). This resistance load was chosen based upon a previous series of pre-tests (Heller, 2005) and is suitable for testing individuals with good fitness.

Data in the text are represented by average values ± SD. For analysis we used Monark Anaerobic test software. Peak power (P_{max}) is calculated by the average of highest values at chosen 5s intervals and minimum power (P_{min}) by the average of lowest values at 5s intervals. The data was then subjected to a t-test for paired values using Statistica software (6.0 version) and statistical significance was calculated.

The study was performed according to the Declaration of Helsinki (Vandewalle, Peres, & Monod, 1987) and was approved by the Ethics committee of the Pedagogical faculty at the J. E. Purkyne University in Usti nad Labem.

Results

The values of all monitored indicators (Wingate anaerobic tests before and after taking nicotine N1-2 or placebo C1-2) are presented in Table 1. The results of the repeated test show higher values in all measured parameters after the placebo tablet (C2), particularly values for peak power (P_{max}) and cadence (V_{max}). Power drop (PD) results for the second tests (N2, C2) indicate minimum effect of nicotine on fatigue. In view of the differences in the values of Power drop (PD) in the first (N1, C1) and second test (N2, C2), an obvious drop in performance in the group consuming the placebo was not statistically demonstrated (Table 2).

Table 1. Average values of Wingate test parameters (mean± sd) for the first and second tests

	N 1	N 2	C 1	C 2
P_{max} [W]	914.3±224.2	918.8±218.7	908.2±215.9	929.8±233.6
P_{max} [W.kg^{-1}]	12.7±2.3	12.7±2.7	12.6±3.0	12.9±3.1
$P_{average}$ [W]	700.6±154.7	707.7±158.7	693.9±152.8	707.8±166.5
$P_{average}$ [W.kg^{-1}]	9.7±1.5	9.8±2.0	9.6±2.0	9.8±2.1
P_{min} [W]	511.6±107.7	520.4±109.6	511.3±103.0	522.7±107.9
P_{min} [W.kg^{-1}]	7.1±0.9	7.2±1.4	7.1±1.3	7.2±1.3
PD [%]	43.3±6.0	42.6±6.0	42.7±6.5	43.0±6.5
V_{max} [rpm]	123.5±14.4	124.5±13.7	124.0±13.4	126.4±13.2

Note: P_{max} [W, W.kg^{-1}]= Peak Power, Maximum Power; $P_{averige}$ [W, W.kg^{-1}]= Average Power; P_{min} [W, W.kg^{-1}]= Minimum Power; PD [%]= Power Drop; V_{max} [rpm]= Maximum Cadence; N1,2= test conducted before and after taking a nicotine tablet; C1,2= Control test

Table 2 reveals no statistical significance in changing performance following nicotine intake, only the values of $P_{average}$ and P_{min} changed significantly after consumption of the placebo.

Table 2. Average values of the differences between the first and second test (mean ± sd) for nicotine tablet (n1-n2) and placebo (c1-c2)

	N1 - N2	P	ω²	C1 – C2	P	ω²
P_{max} [W]	4.5± 27.5	n.s.	n.s.	21.6±47.5	n.s.	n.s.
P_{max} [W.kg^{-1}]	0.1±0.4	n.s.	n.s.	0.3±0.7	n.s.	n.s.
$P_{average}$ [W]	7.1±17.8	n.s.	n.s.	13.9±21.4	p<0.04	p<0.2
$P_{average}$[W.kg^{-1}]	0.1±0.3	n.s.	n.s.	0.2±0.5	p<0.02	p<0.2
P_{min} [W]	8.8±12.3	n.s.	n.s.	11.4±11.9	n.s.	n.s.
P_{min} [W.kg^{-1}]	0.1±0.2	n.s.	n.s.	0.1±0.3	p<0.03	p<0.2
PD [%]	0.7±2.9	n.s.	n.s.	0.3±2.6	n.s.	n.s.
V_{max} [rpm]	1.0±3.2	n.s.	n.s.	2.4±2.8	n.s.	n.s.

Note: P_{max} [W, W.kg^{-1}]= Peak Power, Maximum Power; $P_{averige}$ [W, W.kg^{-1}]= Average Power; P_{min} [W, W.kg^{-1}]= Minimum Power; PD [%]= Power Drop; V_{max} [rpm]= Maximum Cadence; N1,2= test conducted before and after taking a nicotine tablet; C1,2= Control test

Discussion

Nicotine has a number of effects that probably affect athletic performance. This depends on the type of physical activity, the amount of nicotine, product type and method of application (Karaba-Jakovlijevič et al., 2007). Our results do not show nicotine intake in the form of an orodispersible tablet in a dose of 4 mg to improve short-term maximum power. The results are also identical with Meier's study (2006), which also did not prove significant improvement of peak anaerobic power, anaerobic capacity and anaerobic fatigue percentage after chewing nicotine gum. At the present time, the World anti-doping agency (WADA) has included nicotine on WADA's monitoring program for possible in-competition abuse and has also been trying to objectively evaluate the effect of this substance (WADA, 2013). If it is scientifically proven that nicotine can improve athletic performance, nicotine users will be scrutinized and it can be assumed that nicotine will become a prohibited substance. WADA presumes many athletes consume nicotine in sports where short-term maximum power is needed. In some such sports, a high number of urine samples show nicotine intake (Marclay & Saugy, 2010; Marclay et al., 2011).

The particular reasons athletes smoke, chew tobacco or otherwise take in nicotine are not entirely clear. One reason may surely be the intentional attempt to improve athletic performance. This is based on the assumption of positive effect on aerobic and anaerobic metabolism (glycolisis and oxidative phosphorylation) during muscular work. Nicotine increases cardiac output, muscle blood flow and glucose availability (Benowitz, 2009; Eckstein & Horsley, 1960; Rotstein & Sagiv, 1960). Our results show that for 30-second maximum athletic power, the effects of nicotine do not influence subsequent metabolic performance. Our findings are probably similar to those for other stimulating substances such as caffeine. There is also no evidence of ergogenic potential reviewed by athletes (Bell & Jacobs, 2001; Greer, Morales, & Coles, 2006; Hoffman et al., 2007; Lorino et al., 2006). This may be explained by the fact that the tested subjects were not athletes who regularly train with intermittent sprint exercise. For such subjects, a unique study confirmed the favorable ergogenic potential of caffeine (Beck et al., 2006). It is therefore probable that some metabolic processes important for loads (such as oxygen-independent ATP production etc.) are able to enhance athletic performance in individuals who train intensively. Additional intake of certain stimulants (caffeine for example, or use of nicotine) may have a subsequent ergogenic effect.

It can be also assumed that if nicotine consumption improves any particular athletic performance, this would most probably be cognitive athletic performance (Herman & Sofuoglu, 2010; Mündel & Jones, 2006; Levin, 2013; Omvik, 1996). It may be useful for athletes to relax, lower stress, increase motivation, improve concentration or mask fatigue. According to our results, short-term athletic performance is not influenced by nicotine consumption.

Conclusions

The study demonstrated no significant difference in mechanical performance between sublingual tablets with 4 mg of nicotine and those containing a placebo. These findings confirm some of the anticipated beneficial effects of nicotine on short-term maximum power.

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