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Explosive Strength and Kinesthesia under Acidosis

by

Zbigniew Waskiewicz[1]*, Adam Zajac*[2]*, Stanislaw Poprzecki*[3]*,*
Agnieszka Waskiewicz, Jerzy Checinski, Bogdan Bacik[4]

In this paper an attempt was made to describe the influence of repetitive, exhaustive anaerobic exercises on the ability to differentiate the sense of jumping strength. Regarding all difficulties and questionable data the main aim of this research was to determine if using simple experimental and diagnostic methods it is possible to ascertain if anaerobic fatigue can deteriorate this ability. The experiment was conducted on 32 male subjects, students of physical education aged 22,4±1,3 years (body height – 179,2±12,3 cm, body mass – 79,3±6,3 kg). The measurements were performed with the use of a Kistler 9281C tensometric platform with 9865B amplifier and BioWare™ (2812A1–20 type) acquisition set. Each subject performed 4 vertical jumps to attain maximal height followed by 2 jumps performed with 75% and 2 jumps with 50% of maximum height. Subjects jumped within own rhythm (no metronome) but the jumps were performed in succession. The experimental design related to fatigue consisted of the 30 s Wingate test (Bar–Or 1987) repeated 3 times with 5–min. rest intervals. The resistance for the Wingate test was set at 0.075 kp/kg of bodyweight.

The Wingate test performed three times caused significant changes in chosen biochemical mechanical variables. The repeated Wingate test caused a significant decrease in center of mass (COM) lift during maximal vertical jump. The anaerobic exercise did not influence negatively the sense of kinesthetic differentiation of lower limbs. The acidosis revealed a specific mechanism which caused larger errors in case of smaller "expected" force production.

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[1] - Department of Team Sports, Academy of Physical Education, 40-035 Katowice, Mikolowska 72A, Poland, waskiewicz@awf.katowice.pl
[2] - Department of Sport Theory
[3] - Department of Biochemistry
[4] - Departament of Biomechanics

Introduction

In order to understand the mechanism of transferring or comparing perceptual information it is necessary to understand basic human behaviors: attention, perception, learning and others (Gibson 1966). Kinesthesia may be treated as convergence of physiological and psychomotor factors. Sage (1984) described kinesthesia as “position and movement of different body parts determined on the basis of information different than visual and auditory”. Any discussion related to kinesthesia has to begin with the determination of physiological background. Mechanoreceptors, located in every part of human body provide proprioceptive information to the central nervous system (CNS). Bard *et al*.. (1995) stated, that kinesthesia is an important element in movement initiation, adjustment and adequacy to visual space calibration and internal “target image” created by a subject. Mechanoreceptors afferent information is synthesized and forms the notion of kinesthetic sense. Mechanoreceptors transfer information to the CNS about compression, **tension and** horizontal forces, which are connected to muscle, tendon and cartilage structures. This information allows CNS to determine the segmental position and displacement of chosen body parts according to themselves (Clark *et al*. 1979; Clark *et al*. 1985). Importance of kinesthesia during physical activities may be better understood thanks to determination of the individual segmental detection of movement and position (i.e. without vision and audition). Quantified kinesthesia measures are always based on the same fundament: specific joint angle reproduction, position of joint in multijoint movement, segmental displacement detection (Alegrucci *et al*. 1995; Bard *et al*. 1995; Benecke *et al*. 1986) or velocity corrections (Cordo 1990).

On the other hand many everyday life situations and sport disciplines (especially team sports) require intermittent bursts of power. This phenomenon is well visible in basketball, soccer and ice hockey where many explosive movements requiring anaerobic power are performed during a game situation. In all these situations a significant drop in power is evident during the later stages of competition indicating the onset of fatigue (Trump *et al*. 1996). Most often these decrements are explained by metabolic factors (Greer *et al*. 1998; Chmura *et al*.. 1998; Trump *et al*.. 1976). Little consideration has been given to the role of the central nervous system in the process of developing fatigue. Experimental data related to central nervous system fatigue is limited primarily because of limitations in objective measures. Several hypotheses indicate that the increased concentration of neurotransmitters (serotonin, dopamine and acetylcholine) as well as some neuromodulators like ammonia and various cytokines in critical regions of CNS impair performance, especially coordination and motor control (Davis and Bailey 1996). Another hypothesis is that when the muscle is fatigued then its neuromuscular feedback system can be deteriorated and works improperly. Motor control of our muscles is dependent upon sensory and proprioreceptive mechanoreceptors (Golgi tendon units, muscle spindles and joint receptors), thus any disturbances in this area may lead to decreased efferent muscle response and worse effects of performance (Johnston *et al.*. 1998; Kennedy *et al*.. 1982).

In this paper an attempt to describe the influence of repetitive, exhaustive anaerobic exercises on the ability to differentiate the sense of jumping strength was made. Regarding all difficulties and questionable data the main aim of this research was to determine if using simple experimental and diagnostic methods it is possible to ascertain if anaerobic fatigue can deteriorate this ability.

Material and methods

The experiment was conducted on 32 male subjects, students of physical education aged 22,4±1,3 years (body height – 179,2±12,3 cm, body mass – 79,3±6,3 kg). None of the subjects had a recent or remote history of significant lower extremity or spinal surgery and vestibular or central nervous system problems. Written consent for participation in this research project was obtained from all subjects after they were informed of the purpose and nature of the study.

The measurements were performed with the use of a Kistler 9281C tensometric platform with 9865B amplifier and BioWare™ (2812A1–20 type) acquisition set. Each subject performed 4 vertical jumps to attain maximal height followed by 2 jumps performed with 75% and 2 jumps with 50% of maximum height. Subjects jumped within own rhythm (no metronome) but the jumps were performed in succession.

The experimental design related to fatigue consisted of the 30 s Wingate test (Bar–Or 1987) repeated 3 times with 5–min. rest intervals. The resistance for the Wingate test was set at 0.075 kp/kg of bodyweight and variables such as maximal P_{MAX} [W] and relative P_{REL} [W/kg] power, total W_T [kJ] and relative W_{TREL} [J/kg] external work were registered. To determine the intensity of anaerobic metabolism lactate (LA) concentration, base excess BE and blood pH were measured in the 4th min. after the cessation of each Wingate test. Blood samples from the fingertip were used for the evaluation of LA concentration, which were carried out enzymatically using commercial kits (Boehringer Diagnostika, Germany) and spectrophotometer UV–1201 Shimadzu (Japan).

Acid–base equilibrium variables were evaluated with the use of BMS 3 MK 2 Blood Microsystem Acid Base Cart ABC 1 Radiometer (Copenhagen, Dennmark).

The ANOVA and Tukey post-hoc tests with repeated measures were used in order to determine the differences between measures and its significance.

Results

The three consecutive Wingate tests caused significant changes in chosen biochemical variables. The analysis of variance showed that LA concentration increased linearly after each Wingate test, from 1.907±0.306 at rest to 15.966±2.144 after the 3rd test and these changes very statistically significant (F=279.72, p=0.00001). Similar changes occurred in the acid-base equilibrium variables: blood pH and base excess decreased significantly from 7.390±0.017 at rest to 7.140±0.020 post exercise (F=673.04, p=0.00001) and -0.007±1.110 to -22.870±1.163 respectively. It should be underlined that the anaerobic exercise protocol caused major changes in acid-base equilibrium what probably influenced basic motor functions and efficiency of performance.

A similar tendency was observed in mechanical variables describing work and power registered during consecutive Wingate tests. Second and third repetition of anaerobic exercise were characterized by significantly lower values of total and relative work, as well as maximal power and relative maximal power. Mean values and ANOVA with repeated measures results are presented in table 1.

The analysis of COM lift during the vertical jump (fig. 1) show that raw data of maximal attempts are characterized with a significant decrease (F=17.51, p=0.001). It may be the effect of increased fatigue and probably decreased energy substrates responsible for short term energy production. Therefore a significant decrease in raw values of 75%-75%-50%-50% consecutive jumps is observed. It is related with mathematical relations between data and cannot be treated as any specific rule. Because of this, statistical significance of these differences can not be analyzed. On the other hand one should interpret some irregularities. Analyses of mean values of the second jump at 50% of maximal height show that it is equal or even higher than that of the first one. This suggests significant “overcorrecting” in system what leads to an increased absolute error of exercise .

Table 1

Mean values and differences in mechanical variables between consecutive Wingate tests

Variables	Wingate 1		Wingate 2		Wingate 3		Differences		
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	1-2	2-3	1-3
WT [kJ]	20,92	2,90	18,56	2,98	16,97	2,55	**2,35**	**1,60**	**3,95**
rWT [J/kg]	256,12	18,16	227,46	26,55	207,83	19,29	**28,66**	**19,63**	**48,29**
P_{max} [W]	932,20	154,45	875,10	179,61	828,35	165,00	**57,10**	**46,75**	**103,85**
rP_{max} [W/kg]	11,38	0,87	10,65	1,27	10,10	1,13	**0,73**	**0,55**	**1,28**

Legend: bolded are significant differences at p=0.01

Similar changes appeared in case of rate of force development (RFD) where significant changes were registered in maximal values after each Wingate test (F=16.55, p=0.001) and the causes of this effect were explained above. In case of RFD as well as COM lift differences in consecutive jumps performed at different height were statistically significant and also in that the explanation should be similar (fig. 3).

A completely different situation was observed in case of data expressed as error in relation to “expected” value (fig. 2, 4). This value (in %) sustains on identical level after rest and three consecutive Wingate tests. It means that subjects under specific conditions do not differ significantly in relation to error of reproduced jump height. These results are confirmed by ANOVA between hypothetical “expected” height and “actual” height produced. There were no significant differences in any of the four measurements points (rest and Wingate 1-3). It shows univocally, that poped developed in different experimental designs and at different levels of fatigue had no negative effect on movement efficiency. It also means that the CNS does not change motor programs or improves them in order to realize specific tasks according to the observed changes.

It should also be stated that comparison of errors from 75% and 50% effort jumps shows surprising results. The differences between these values are almost 100% what means that the subject produced almost twice as large error during jumps at 50% of maximal height (p=0.001). Results suggest that it was more difficult to differentiate lower limbs at smaller heights what suggests the application of smaller forces.

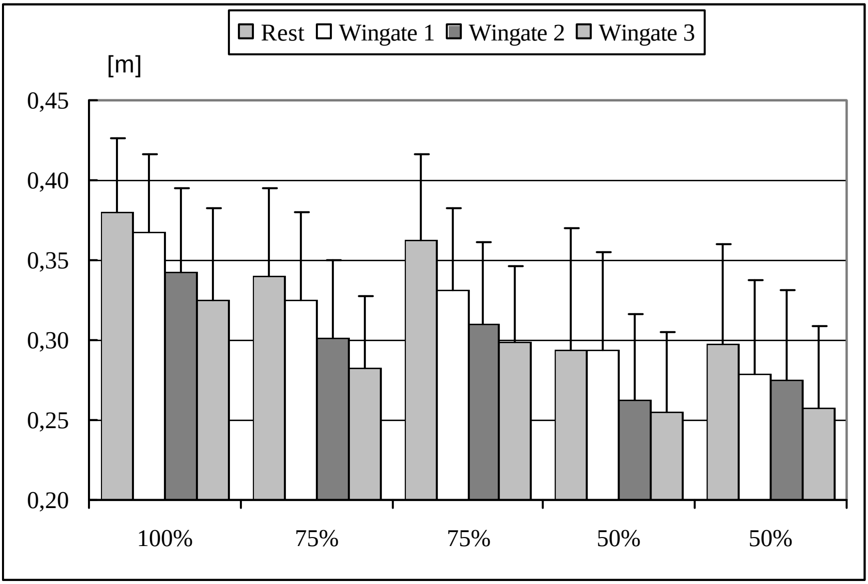

Fig. 1

Level of absolute COM lift values at rest and after three consecutive Wingate tests

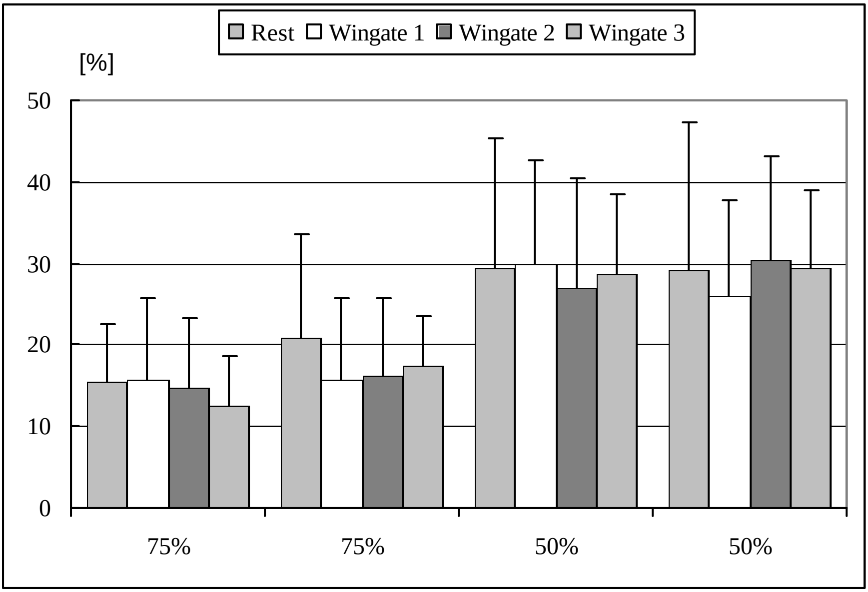

Fig. 2

Level of relative error of COM lift values at rest and after three consecutive Wingate tests

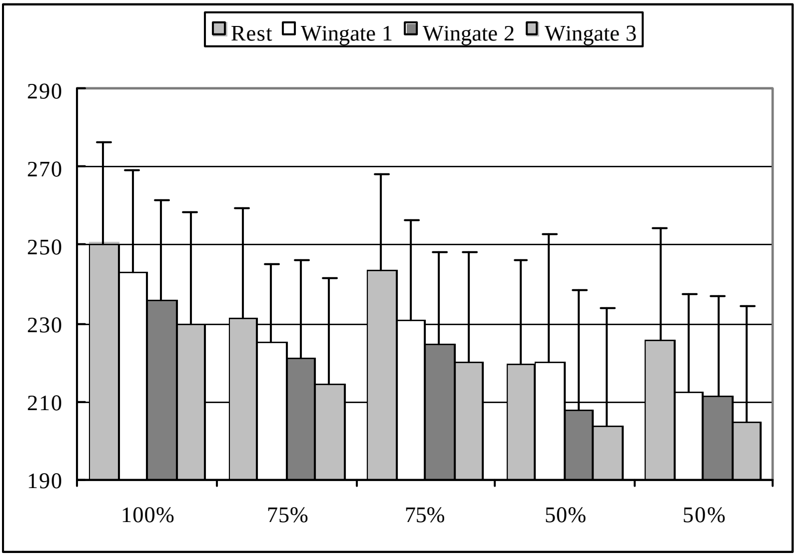

Fig. 3

Level of absolute RFD values at rest and after three consecutive Wingate tests

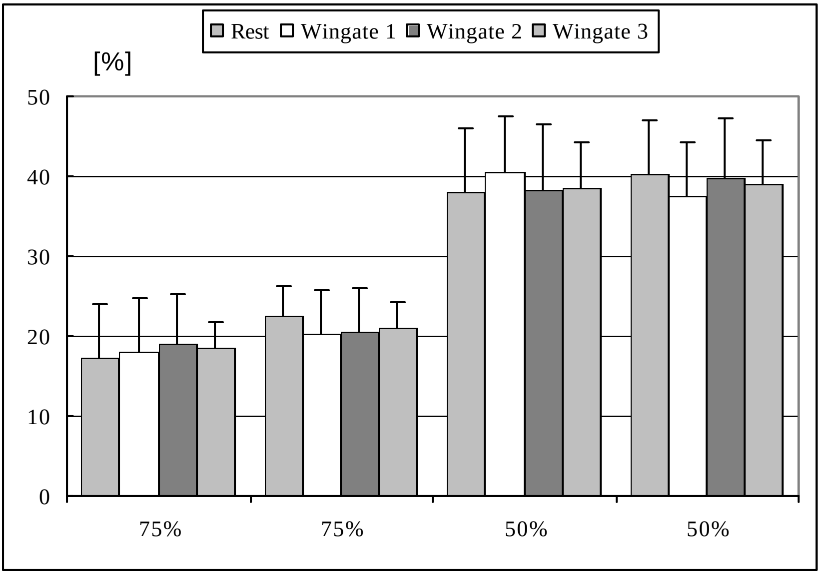

Fig. 4

Level of relative error in RFD values at rest and after three consecutive Wingate tests

Discussion

It is generally accepted that physical efforts of anaerobic character may cause deteriorations in receptors and sensory system functioning, however results of presented paper show that in case of large muscle groups it may be non-significant. Intense exercises may result in fatigue as a combination of physiological processes at the central at peripheral level. In case of kinesthesia these levels are strongly correlated because efficiency in muscle strength differentiation depends to the same level from central processing and proprioceptive information. Research data shows that in case of peripheral subsystem at least two factors play an important role in muscle force generation (von Holst 1954; Bigland–Ritchie *et al.* 1978, 1986b; Kent-Braun 1998; MacKenzie 1992). First of all, the substrate level (ATP, PCr) pool and the rate of its resynthesis in a relatively short time (Karlsson and Saltin 1970; Whitlock and Terjung1987; Spriet 1990; Soderlund and Hultman1991) and secondly, the muscle twitch potentiation disturbances (Eerbek and Kernell 1991). A decrease in force potential leads to a decrease in work capacity causing specific “internal perturbation” what may effect coordination. Simultaneously fatigue may cause changes in sensory information inflow and probably distract central processing. It was determined experimentally that muscle fatigue may cause a decrease in afferent spindle fiber firing, probably because of ?-motoneuron activation decrease (Hagbarth and Macefield 1995). This phenomenon changes the quantity and quality of information being processed in some parts of the CNS responsible for afferent information integration and influences on a-motoneurons firing, leading to dysfunction of proper muscle corrective functioning (Nardone *et al.* 1997).

The acquired results do not support the idea that anaerobic fatigue deteriorates explosive strength differentiation. However, the significant decrement in maximal height of COM uniesienie was registered (what seems to be obvious because of energetic reasons), the precision of proper height reproduction did not occur. Only differences between relative percentage error of 50% and 75% of expected height were statistically significant but it was not the effect of fatigue. The cause of these changes is based mainly in the scale of task and specific “overcorrecting” processes in height and afferent information verification. The influence of large muscle anaerobic exercises is on the other hand difficult to establish univocally. Existing research data confirm the negative effect of such types of exercise as well as experimental reports in which there was no confirmation of disturbances in motor control. Williams *et al.* (1976) showed that in case of high level coordination exercise (dynamic ladder climbing), the type of procedure (medium or light fatigue) has no influence on quality of performed task, as well as on the rate of learning. Another experiment (Thomas *et al.* 1975) showed completely different effect of fatigue on stabilometer balancing, so the task with similar background processing characteristics. The fatigue caused significant deterioration of performance and skill acquisition process, and this phenomenon occurred in both sexes.

As it was mentioned earlier, the opinions about a negative influence of muscular fatigue on performance and learning of different movement activities exist (Thomas *et al.* 1975; Johnston *et al.* 1998; Williams *et al.* 1976). Little research was carried out to determine the relationship, between fatigue, as a result of exhausting intermittent exercises and level of strength differentiation. There were suggestions that intense weight training may cause significant, immediate fatigue in neuromuscular system leading to a decrease in force production ability and neuronal functions of muscle (Hakkinen 1988; Hakkinen *et al.*1993). It should also be stated, that the mechanism of “neuronal” and “hypertrophic” changes appearing in muscle after exercise is not clear (Skurvydas 1998).

Since the result in many sport disciplines is highly dependent upon psychomotor efficiency the necessity of research projects describing specific aspects of motor control under the influence of different types of exercises or metabolic circumstances is confirmed. The research data showed that physical efforts with medium intensity improve psychomotor behaviors through increase of activation (Bender and McGlynn 1976; Davey 1973; Levitt and Gutin 1971; Chmura 1994, 1998). Duffy (1972) and Schmidt (1988) stated, that the critical level of intensity (volume), above which the activation negatively influences performance or learning. The relation between the CNS activation and the above mentioned phenomenon has an inverted “U” shape.

Conclusions

The analysis of acquired results and review of existing data allowed formulating the following conclusions:

1. The repeated Wingate test caused a significant decrease in COM lift during vertical jump.
2. Anaerobic exercise did not influence negatively the sense of kinesthetic differentiation of lower limbs.
3. The acidosis revealed a specific mechanism which caused larger errors in case of smaller “expected” force production.

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