Original Article

Effect of maximal exercise on the electrophysiological evaluation of leg muscles in young healthy males

Asmaa' K. Hamod* **MBChB**
Shakir M. Sulaiman** **MBChB, PhD**
Istabrak M. Salih*** **FICMS**

J Fac Med Baghdad
2010, Vol. 52, No.1
Received: April 2009
Accepted: June 2009

Summary:

Background: Bicycling is a type of aerobic exercise that it is beneficial for the health of cardiovascular, pulmonary, and musculoskeletal systems .In this study, utilization of some of electrophysiological tests is to assess changes , from the functional point of view, in the peripheral nerves & their muscles that occur in relation to maximal exercise.

patients & methods: 100 young healthy males , age (18-35) years old, were collected during the period from 1st of April to 1st of October 2008 at the department of neurophysiology in the Ibn Sinna teaching hospital , Mosul city. They underwent electroneurographic assessment of common peroneal & tibial nerves, in addition to electromyographic assessment of Tibialis Anterior & Gastrocnemius muscles before & after exercise challenge test on bicycle ergometer.

Results: In this study, there is a higher value regarding compound motor action potential amplitudes & motor conduction velocity of both nerves, with increase in the values of motor unit potential amplitudes & interference pattern of both muscles post exercise in comparison to the pre exercise. In addition, there is positive correlation between MUP amplitude of Gastrocnemius muscle & tibial nerve.

Conclusion : the results indicates that within this age group the exercise challenge test leads to increase in the force produced with no signs of muscular fatigue electrophysiologically .

Keywords: Electromyography, cycling exercise, muscle fatigue.

Introduction:

Physical exercise is any body activity that enhance or maintains physical fitness and an overall health. It is the function of musculoskeletal system controlled by the nervous system. Bicycling is a type of aerobic exercise that requires oxygen to get energy, & does not produce any waste materials. But If the intensity of exercise is increased beyond a certain point, aerobic metabolism alone cannot supply energy at the rate needed leading to anaerobic metabolism that causes fatigue due to the accumulation of lactic acid (1)

Assessment of muscular & peripheral nervous system to quantify exercise & fatigue is done through the electrophysiological studies (Nerve conduction studies (Electroneurography) (ENG) & Needle electromyography (EMG)). These are reliable method that can be used to evaluate the functional changes of the muscular & nervous systems & can even give an idea about their structural background. (2) EMG parameters commonly used are: EMG amplitude and EMG power spectrum (e.g., median power frequency (MDF), mean power frequency) (3).

**Ministry of Health*
***Dept. of Physiology, College of Medicine, University of Mosul.*
****Dept. of Medicine, College of Medicine, University of Musol.*

They are used to code the muscular status as follows (4):

- The simultaneous increase of both amplitude and mean spectral frequency is coded as a force increase;
- The simultaneous decrease of both amplitude and mean frequency is coded as a force decrease;
- The increase of the amplitude and the decrease of the mean frequency is coded as muscular fatigue (5).
- The increase of the mean frequency and the decrease of the amplitude is coded as recovery.

In a methodological review, the spectral frequencies are not direct physiological variables, and thus their elucidation is not straightforward and may lead to ambiguous interpretations. Alternative and relevant information that can be extracted from EMG signals is based on the estimation of the motor conduction velocity as a physiological parameter that is related to the fiber membrane and contractile properties (6). The force produced by the muscle increases with the percentage of FT fibers and, conversely, at any given force output, the velocity increase with the percentage of FT fibers (7). Some of the variation in EMG amplitude and frequency have been attributed to the proportion of fast and slow fibers in the underlying muscle, the placement of the electrodes,the thickness of fat under the skin, and the age (8)

Patients and Methods:

The study had been conducted at the department of neurophysiology in the Ibn Sinna teaching hospital, Mosul city, during the period from 1st of April to 1st of October 2008. 100 young males were volunteered for the study, their ages (18-35) years old, height (155-183) cm , and weight (51-108)kg. All of them were healthy males with no past history of chronic disease or orthopaedic problem, and were normal on physical & neurological examination. No subject had the habit of taking regular exercise.They were asked about: age, marital status, smoking, occupation, residency, dominant hands, weight, and height, past medical & surgical history. Each subject underwent first, electroneurographic assessment (motor nerve conduction study) including: distal motor latency (DL), motor conduction velocity (MCV) & compound motor action potential amplitude (CMAP) [for the common peroneal (CPN) and posterior tibial nerves (PTN) of the dominant side].The conduction velocity of tibial nerve was not estimated, because proximal stimulation need needle electrode for the stimulation at the gluteal area. Second, Electromyographic studies (Needle EMG) including: spontaneous activities, motor unit potential (MUP) amplitude, the interference pattern and the presence of polyphasic potentials [for the Tibialis anterior (TA) and Gastrocnemius (Gn) muscles on the same side that undergoes the electroneurophysiological studies) Then, the subject perform exercise challenge test on a bicycle ergometer that commenced at 25watts (153 kg-m/min), and the workload was raised by 25 watts each minute until 85% of maximal predicted heart rate was reached that remain steady on that level for 2 min maintenance then the cycling ended .

{0.85 X [210 – 0.65 X age in years] = 85% of maximal predicted heart} (9)

However, the total duration of the exercise challenge test was 10-15 min.When the exercise completed, electromyographic and electroneurographic assessment was repeated. The room temperature was monitored and kept between 25-28°C during the test procedure and the skin temperature was measured by a thermometer at the axilla. **The EMG machine :** DANTEC Neuromatic® 2000M Elektronik Medicinsk og Videnskabeligt Måleudstyr A/S Tonsbakken 16-18, DK-2740 Skovlunde , Denmark.

Ergometer bicycle: was an electronically braked type ,Cateye ergociser EC- 3200.

Collected data were analyzed by SPSS software. ANOVA was used to compare the independent groups. A P-value equal to or less than 0.05 is considered to be significant. The percentage fall was calculated as:

$$\%\text{fall} = \frac{\text{pre exercise (baseline) value} - \text{post exercise value}}{\text{pre exercise value}} \times 100$$

Results:

Table (1) illustrated the comparison related to motor conduction studies showing that P value was highly significant for MCAP amplitude (P<0.001) of the tibial nerve & MCAP amplitude of common peroneal (P<0.002) & conduction velocity of the same nerve. While P value was not significant in case of distal motor latencies of both nerves.

Regarding results of needle EMG, Table (2) showed that their MUP amplitudes and interference pattern had higher values post exercise in comparison to pre exercise. Figure (1) shows that there is a significant positive correlation between gastrocnemius muscle & tibial nerve. Table (3) detects the distribution of the study sample results according to the body mass index (BMI). The P value was significant in case of interference pattern & MUP amplitude of MUP of Gn &TA.

Table (1) Motor conduction test of TN and PN results before and after maximal exercise:

Nerve	Parameters	Mean ± SD		p-value
		Pre-exercise	Post-exercise	
	Distal latency	4.44 ± 0.42	4.45 ± 0.44	0.06
Tibial N	CMA Pamplitude *	7.49 ± 1.45	7.93 ± 1.49	<0.001 *
	Distal latency	3.83 ± 0.34	3.88 ± 0.41	0.072
Peroneal N	MotorCV *	47.71± 3.72	55.82± 2.61	0.04 *
	CMA Pamplitude *	6.83 ± 1.05	7.43 ± 1.08	0.002 *

Using paired t-test.

Table (2) Needle EMG of gastrocnemius and tibialis anterior muscle test results before and after maximal exercise:

Muscle	Parameters	Mean ± SD		p-value
		Pre-exercise	Post-exercise	
	Spontaneous activity	0± 0	0± 0	NS
	Motor unit potential			
(Gn)	a. Duration	9.64 ± 1.73	9.92 ± 0.83	0.076
	b. MUP Amplitude*	224.5 ± 21.34	254.1 ± 38.46	<0.001 *
	c. no. of phases	3.13 ± 0.34	3.17 ± 0.38	0.103
	Interference pattern *	1.0 ± 0.0	1.28 ± 0.45	<0.001 *
	Spontaneous activity	1.0 ± 0.0	1.0 ± 0.0	NS
TA	Motor unit potential			
	a. Duration	11.00 ± 1.0	11.24 ± 1.14	0.063
	b. MUPAmplitude *	239.49 ± 13.3	256.75 ± 10.08	<0.001 *
	c. no. of phases	3.06 ± 0.24	3.12 ± 0.33	0.083
	Interference pattern *	1.01 ± 0.10	1.28 ± 0.45	<0.001 *

NS = Not significant using paired t-test.

Table (3) Distribution of study sample results according to BMI:

BMI (kg/m^2) Parameter	Mean ± SD (% variation)		p-value
	<25 (n=68)	≥25 (n=32)	
Gastrocnemius muscle			
Duration	2.73 ± 4.24	3.42 ± 4.23	0.450
MUPAmplitude *	6.5 ± 14.1	0.52 ± 10.57	0.036 *
No. of phases	4.41 ± 11.38	2.34 ± 11.05	0.394
Interferencepattern *	19.12 ± 39.62	46.88 ± 50.7	0.004 *
Tibial nerve			
Distal latency	0.43 ± 4.67	2.45 ± 4.37	0.31
CMAP amplitude	0.77 ± 2.74	-0.27 ± 2.86	0.085
Tibialis anterior muscle			
Duration	1.9 ± 3.22	3.36 ± 4.28	0.060
MUPAmplitude *	0.82 ± 3.46	-1.4 ± 4.02	0.006 *
No. of phases	0.3±11.68	-0.62±6.67	0.68
Interferencepattern *	46.88 ± 50.7	17.65±38.4	0.002 *
Common Peroneal nerve			
Distal latency	0.81 ± 8.1	3.19 ± 6.02	0.44
MCV	0.14 ± 5.52	-1.71 ± 5.57	0.121
CMAP amplitude	0.42 ± 3.05	-0.37 ± 4.51	0.310
Skin temperature	3.55 ± 1.73	3.56 ± 1.83	0.985
Pulse rate	22.46 ± 7.70	24.69 ± 6.73	0.163

Using unpaired t-test.

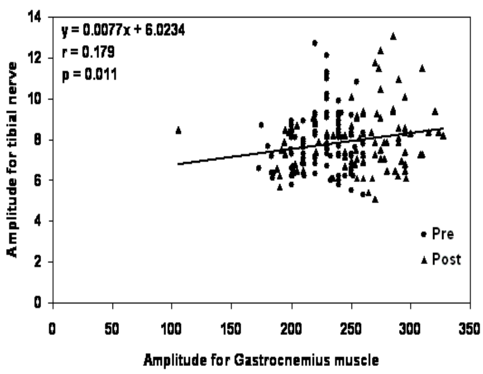

Figure (1) Relationship of amplitude between gastrocnemius muscle and tibial nerve

Discussion:

Changes in motor conduction study properties were present in that, there was increase in CMAP amplitudes for the tibial nerve & common peroneal nerve (maximal depolarization) with the increase in motor conduction velocity of CPN pre to post exercise. But it has been found that distal motor latency did not correlate with exercise. Motor conduction velocity shows increase in its value post exercise , this is mainly because that faster motor units have higher conduction velocities for their motor unit action potentials than slow motor units (10) due to altered electrical properties of the sarcolemma & these are known to vary between fast & slow muscle fiber types in mammals .The alteration in the electrical properties of the sarcolemma may be attributed to the extensive potassium shifting with exercise which can cause more than a doubling of the extracellular K^+ (11). Additionally, warming up facilitates the activation of sodium conductance thereby increasing its rate of transmission (12). Wakeling et al (2002) explained these results as that the faster fibers occurred independently of any difference in muscle fiber diameter (13).Another explanation was suggested by Stuart et al (2006) who stated that the greater power output obtained with passive heating was achieved through an elevated rate of ATP turn over (14). Regarding results of needle EMG, surely, the presence of a significant change in the interference pattern of both muscles indicates that there were asignificant increases in the number of the functioning motor units which reflect the number of the nerve fibers supplying them. Interestingly, these results are due to that the preferential recruitment of the faster muscle fibers would occur at the faster speeds during locomotion, and it is partially related to the strain rate of muscle fascicles (15). Additionally, different motor units may be recruited in the task-specific fashion during locomotion, which means that under certain cyclical locomotor condition the recruitment pattern of different types of motor units are related to the mechanical requirements of locomotor task. this preferential recruitment can occur across a range of locomotor speeds .Wakeling(2004) correlates the rapid shortening velocity of the muscle fascicles to the preferential recruitment of faster motor units, & he showed that different populations of motor units are being recruited for the different trials (16) .Also the results were in accordance with the finding of Rozitis et al (2006), who reported that a selective recruitment of the faster motor units occurred within Gn muscle was in response to the increasing muscle fascicle strain rates. This preferential recruitment of the faster fibers for the faster tasks indicates in some circumstances motor unit recruitment can match the contractile properties of the muscle fibers to the mechanical demands of the contraction (17). On the other hand, Emma & Wakeling 2008 stated that the motor units were not always recruited in an orderly manner, indicating that recruitment is a multi-factorial phenomenon that is not yet fully understood .Regarding the relationship between the amplitude of gastrocnemius muscle & tibial nerve (Figure 1), there is a positive correlation between them.This finding was consistent with the finding of Hug, F.2003.The Gn activity.Pattern may change with the different usage of it, & may be related tothe subject-specific pedaling techniques, the overall neuromuscular coordination ,the pedal force control, & the relative muscle strain (18) .Regarding the correlation with BMI , the study showed the significant association in case of MUP amplitude & interference pattern. This could be due to that amplitude is attenuated by local tissue between the electrodes & the muscle & that, signal weakened by the subcutaneous fat (19). In additional, action potentials of motor units located more distantly from the electrodes may not be recorded at all (20).

Conclusions:

The majority of subjects studied; responded to maximal cycling exercise with an increase in the ENG & EMG values, implying that there is increase in the force production. In addition, different populations of motor units are used to different movement tasks, having different mechanical properties & are recruited according to the mechanical demands on the whole muscle . The individual variation, decrease energy cost, genetic composition & central command seemed to affect the test. It is recommended that electrophysiological study should be conducted to study the changes in peripheral nervous system & skeletal muscles following maximal exercise not only cycling , but also other types of sports like walking & swimming using computerized EMG devices. It is also recommended for further future study of EMG of maximal exercise regarding healthy old age group, gender & ethnical groups.

References:

1. Wilmore, J. , Knuttgen, H. , (2003). Aerobic exercise and endurance improving fitness for health benefit. The physical & sport medicine, 31(5), 45. Retrieved 2006 from ProQuest database.

2. Kimura, J. (1986) Electrodiagnosis in disease of nerve and muscle . Principles &practice, 5th ed.,F.A.Davis Comp., Philadelphia .

3. Day, S. (2003) .Important factors in surface EMG measurement ,2003.from www.bortec.ca.

4. Confronto, S.,Bibbo, M., D'Alessio. (2005). Muscular Fatigue from Electromyographic recording: Real –Time monitoring during exercise training.3rd Eur. Medi. and Biol. Eng.Conf. IFMBE Proceeding Praha, Czech Republic

5. De Luca, C. (2000)The use of surface electromyography in biomechanics. Journal of Applied Biomechanics , 13, 135-63.

6. Farina, D., Macaluso, A., Ferguson, R.A,, DeVito, G. (2004a)Effect of power, pedal rate, and force on average muscle fiber conduction velocity during cycling. JAppl Physiol ; 97:2035-41.

7.Fitts, R.H., & Widrick, J.J. ,(1996). Muscle mechanics: adaptations with exercise training. Exercise and Sport Science Reviews, 24:427-473.

8. Petrofsky, J.S.(2001): The use of biofeedback to reduce Trendelenburg gait. In press Europ J Appl Physiol .

9. Lange-Anderson, K., Shepard, R. J., Denolin, H., Varnauskaus, E. & Masironi, R. (1971): Fundamentals of exercise testing, Geneva, WHO, P.22.

10. Wakeling, J. M. & Syme, D. A. (2002) . Wave properties of action potentials from fast & slow motor units of rats. Muscle Nerve 26,659-668.

11. Ole M.Sejersted and Gisela Sjogaard ,(2000), dynamics and consequences of K^+ shifts in skeletal muscle and heart during exercise,. physiol Rev. 80:1411-1481.

12. Kimura, J. (2001) Electrodiagnosis in disease of nerve and muscle . Principles &practice, 3rd edition Oxford university press, Inc.

13.Wakeling, J. M., Kaya, M., Temple, G. K., Johnston, I. A. & Herzog,W.(2002). Determining patterns of motor recruitment during locomotion. J.Exp.Biol. 205, 359-369.

14.Stuart R. Gray, Giuseppe De Vito, Myra A. Nimmo, Dario Farina, and Richard A. Ferguson.(2006). skeletal muscle ATP turnover and muscle fiber conduction velocity are elevated at higher muscle temperatures during maximal power output development in humans,. Am J physiol Regul Comp Physiol 290:R367- R382 .

15.Citterio, G. & Agostoni, E.(1984) . Selective activation of muscle fibers according to bicycling rate. J. Appl. Physiol. 57,371-379.

16. Wakeling, J. m. & Rozitis, A. I. (2004). Spectral properties of myoelectric signals from different motor units distinguished ramped contractions of the leg extensors. J. Exp. Biol.207,2519-2528.

17. Rozitis, A. I., Wakeling,J. M., & Uehli, K.,(2006). Muscle fiber recruitment can respond to the mechanics of the muscle contraction. J. R. Soc. Interface. 3(9):533-44.

18. Van Ingem Schenau, G. J., P. J. M. Boots, G. deGroot, R. J. Snackers, & W. W. L. M. Woenzel.(1992). The constrained control of force & position in multi-joit movements . Neuroscience 46:197-207.

19. Keenan, k., Farina, D., Maluf, K., (2005). Influence of amplitude cancellation on the simulated surface electromyogram. J. Appl. Physiol., 98,120-131.

20. Barkhaus, P., & Nandedkar, S. (1994) . Recording characteristics of the surface EMG electrodes. Muscle Nerve, 17, 1317-1323.