EFFECT OF HOT CONDITIONS ON VOLUNTARY CONTROL OF MOTOR UNIT ACTIVITY IN HUMANS

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INTRODUCTION

Cold ambient temperature conditions are known to affect muscle performance characteristics, such as force output, power, and contraction velocity [1]. Spectral and amplitude characteristics of electromyogram (EMG) during inuscle contraction are modulated by the cold and hot ambient temperature [2]. Voluntary control of single motor unit action potentials (MUAP) is a widely used method for investigation of fine movements. Local cold application to skin has been shown to be of contradictory impact on the effectiveness of single MUAP control [3]. General moderate cooling of the organism demonstrated very little effect on the MUAP control, even in the state of vigorous cold shivering [4]. The influence of hot environment conditions on fine voluntary control of single motor unit activity still has not been investigated. The aim of the present study was to investigate how effectively man recruits the ordered number of motor unit action potentials in hot versus temperate conditions.

MATERIALS and METHODS

Six subjects were instructed to recruit the ordered number of MUAP:s. The MUAP:s were recorded with the help of electromyograplucal device MG440 (Mikromed, Hungary) from the distal portion of the long head of *m. triceps brachii,* using surface bipolar electrodes (rectangular, 6 x 12 mm, interpolar distance 14 mm, lead). The subjects were allowed to watch the MUAP:s on the screen, and to listen to them by loud-speaker (audio and visual biofeedback) to control the fulfillment of the task.

The subjects using audio and visual biofeedback choose the most stable and large-amplitude MUAP during weak voluntary isometric contraction. After that they inhibited the activity of all the other MUAP:s, visible on the screen by changing the intensity of contraction and arm or hand position. Then the subjects were asked to demonstrate "operability" of the chosen MUAP by voluntary modulation of the firing rate of the MUAP, and by recruitment and commencement of their activity.

After that subjects performed 40 attempts to recruit the ordered number of MUAP:s in each task (from 1 to 7 MUAP:s in the train). The effectiveness of the

recruitment of MUAP:s was estimated by calculating the per cent of the right attempts (N) in each trial. The per cent of mistakes (N-1, N+1, N-2, N+2) was also computed. Mean number of discharges in the attempt, mean interspike interval, mean firing rate of motor unit impulsing, and mean duration of the train were also calculated.

The reference investigation was conducted at temperate conditions (after 30 min at +27°C, thermal comfort). The investigation of MUAP control in hot conditions (30-40 min exposure to ambient temperature +45°C) were initialized immediately after sweating started.

T-tests for paired samples were used for comparison between temperate and hot conditions.

RESULTS

At temperate conditions (+27°C) after 30 min exposure mean skin temperature stabilized at the level of 32.3±0.5°C. The ordered number of MUAP:s was successfully recruited in all the tasks. Thus, from 60 to 80% of the attempts were correct when subjects performed the tasks from "1 MUAP" to "5 MUAP:s", but only from 50 to 60% attempts were correct when subjects had to recruit "6 MUAP:s" or "7 MUAP:s" (see Table 1). The wrong attempts were distributed rather uniformly between the trains with the lack of MUAP:s (N-1, N-2) and with extra MUAP:s (N+1, N+2). The mean number of discharges in the train was very close to its ordered number (Table 2). The discharge frequency of motor units depended on the task: it was 6-7 imp per sec when the task was "2 MUAP:s", and it was 10-12 imp per sec during the task "6 MUAP:s" or "7 MUAP:s".

After 30-40 min exposure to hot air (+45°C) mean skin temperature increased to 37.1±0.5°C, and sweating was the characteristic of this condition. Core temperature did not significantly change. The striking specifity of the motor unit activity in the heated organism was the appearance of double spike and splited MUAP:s at the beginning of recruitment. At least 40-50% of MUAP:s in the train were usually doublets. These doublets were characterizedby a very short intervals between first and second spikes (5-20 ms), and by prolonged intervals between the doublets (1.5-2 times longer than in regular single discharges). The other peculiarity of motor unit behavior in the hot condition was that single spike MUAP:s which appeared at the end of the train were characterized by 20-30% shorter interspike intervals if compare with the single spike MUAP:s in temperate conditions. Accordingly, their firing rate was 2-3 imp per sec higher in comparison with motor unit activity in temperate conditions. This peculiar behavior of MUAP:s in the hot conditions puzzled subjects and made control of recruitment of MUAP:s extremely difficult, because total duration of the train became very difficult to be predicted. Since, the prolonged interdoublet intervals helped subjects to count discharges and they managed to performe the task in hot conditions (Tables 1 and 2).

Table 1

The mean number of correct attempts (%, ±SD) during recruitment of the ordered number of motor unit action potentials

Task	**Temperate** condition	Hot condition
1	58.58k6.79	50.32k16.96
2	66.92± 11.27	70.00±9.51
3	62.52± 10.55	71.84rt3.34
4	68.77k16.63	66.28rt7.16
5	62.43± 10.09	60.38k14.16
6	53.11k21.45	48.60± 18.56
7	50.17±25.37	45.45± 19.35

P>0.05 in all instances

Table 2

The mean number of motor unit action potentials (±SD) during recruitment of their ordered number in different thermal conditions

Task	**Temperate** conditions	**Hot** conditions
1	1.39k0.20	1.28rt0.14
2	2.05k0.04	2.09k0.14
3	3.00 rt0.06	3.07rt0.11
4	3.96rt0.06	4.02k0.08
5	5.09±0.12	5.20±0.18
6	5.96k0.21	6.21±0.20*
7	6.91k0.30	7.06±0.07*

* - P<0.05.

CONCLUSIONS

1. The present investigation showed that biofeedback aided control of fine movements in the man, such as recruitment of single motor unit potentials, is highly effective both in temperate and hot conditions. The per cent of correct attempts was not significantly different in these two conditions. Since, there was a tendency in the hot condition to recruit one extra action potential in comparison to temperate conditions.
2. Heating the organism influenced the pattern of motor unit activity in humans. First, in hot condition motor units were usually recruited in a form of doublet and splited discharges, and this influenced the duration of the impulsing train of a motor unit, because interdoublet interval was 1.5-2 times longer than the regular interval. Second, interspike intervals between regular single action potentials in hot condition were significantly shorter than at temperate conditions.
3. Appearance of doublets and decrease of interspike intervals of single spike action potentials might be due to motoneuron properties rather than to muscle fiber ones. We suppose that inputs from central warm thermoreceptors can influence the membrane properties of spinal motoneurones.
4. Increased motor unit firing rate is known to convert muscle contraction pattern from unfused to fused tetanus. It results in more economical and less heat productive contraction [5]. We can figure out that there is a distinct thermoregulatory purpose in doublets and shortening of single spike action potential interspike intervals to decrease heat production without any decrease in the muscle force output.

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