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Muscle activity during different stepping modes in decerebrate cat

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Abstract: We compared an EMG activity of several hindlimb muscles moved the hip (iliopsoas, adductor magnus, biceps femoris), knee (rectus femoris, vastus medialis), and ankle (tibialis anterior, gastrocnemius medialis, soleus) joints, in decerebrate cats stepped under epidural electrical stimulation in two directions: forward and backward. For most cats, an activity of hip flexor was lower, hip extensors – higher, knee extensors – lower, ankle flexor – lower, ankle extensor – higher for BW stepping. For all muscles these differences were statistically significant (Wilcoxon test). These data point out to different balance in flexion and extension during stepping in opposite directions.

Keywords: locomotion; spinal cord; CPG; flexor and extensor muscles; decerebrate model

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1. Introduction

Most bipeds and quadrupeds are able to the different locomotor modes. The most well studied form is forward (FW) stepping being the frequently used in daily needs. Other locomotor modes like backward (BW) stepping can be used during mostly specific behavioral tasks like avoidance or postural corrections [1; 2]. Unlike FW stepping, BW locomotion is less studied. Several data pointed out to similar spinal networks generate both FW and BW stepping [3] but evidence for an opposite opinion also exists [4].

One of widely used model for the locomotor studies is decerebrate animal. These animals have the spinal (so called central pattern generator, CPG) and brainstem locomotor networks but no commands from the diencephalic and telencephalic level. Despite the weak investigation of the BW stepping in decerebrate animal, an ability of them to stepping BW under electrical epidural stimulation (ES) was repeatedly obtained [5; 4]. The locomotor behavior in limbed vertebrates is based upon a coordinated activity of flexor and extensor muscles; this coordination is believed to be specific for the different locomotor modes, for example, walking or running [6]. Hence, we investigated peculiarities of the hindlimb muscles in decerebrate cat during locomotion in different directions: FW and BW stepping.

2. Materials and Methods

Fourteen normal pigmented adult cats weighing 3.0–4.0 kg were used. All experimental procedures were conducted in accordance with a protocol approved by the Animal Care Committee of the Pavlov Institute of Physiology, St. Petersburg, Russia and followed the European Community Council Directive (2010/63EU) and the guidelines of the National Institute of Health Guide for the Care and Use of Laboratory Animals, Animal Welfare Assurance #A5952-01.

Cats were decerebrated at the precollicular-postmammilar level under deep isoflurane (2–4%) anesthesia. A laminectomy was performed in the lumbar area corresponding to the L5–L7 segments. An EMG recording was carried out using bipolar EMG electrodes

(0.2 mm flexible stainless-steel Teflon-insulated wires; AS632, Cooner Wire, Chatsworth, CA, USA) implanted into the several hindlimb muscles moved the hip (iliopsoas, IP, adductor magnus (AM), biceps femoris (BF)), knee (rectus femoris (RF), vastus lateralis (VL)), and ankle (tibialis anterior (TA), gastrocnemius medialis (GM), soleus (SL)) joints. Decerebrated animal was fixed in a rigid frame, the hindlimbs were positioned on the treadmill. To evoke locomotion by ES, a ball electrode (d = 0.5 mm) was positioned on the dorsal surface of the spinal cord. We used the following parameters of stimulation: frequency, 5 Hz; pulse duration, 0.2–0.5 ms; current, 80–300 mkA. The signals from the EMG electrodes were differentially amplified, digitized at 20 kHz with an A/D board and subsequently processed using an algorithm previously elaborated [5; 7]. sub-periods, and EMG activity was estimated in each sub-period according to the potentiometric curve of one hindlimb. Two non-parametric tests: Mann-Whitney test and paired Wilcoxon two-tailed test were used.

3. Results

3.1. EMG data

Only in five cats, all eight muscles were analyzed simultaneously; in other cats, a limited number of muscles were registered. As a result, IP muscle was analyzed for 14 cats, AM – for 11 cats, BF – for 6 cats, RF – for 9 cats, VL – for 9 cats, GM – for 8 cats, TA – for 11 cats, and SL – for 8 cats.

A wide range of the EMG data was obtained (Table 1), being a possibly reason for only for 4 muscles (IP, RF, VL, TA) a difference between two locomotor modes were obtained using a Mann-Whitney test. But using a paired Wilcoxon two-tailed test it became possible to reveal a difference between two locomotor modes – for all muscles but SL (Table 1, bottom raw).

3.2. Table

Table 1. An EMG signal amplitude for nine hindlimb muscles during forward (FW) and backward (BW) stepping evoked by the epidural stimulation of the L5-L7 segments of the spinal cord. MW – Mann-Whitney test; PW – paired Wilcoxon two-tailed test.

	IP	AM	BF	RF	VL	TA	GM	SL
FW	0,743 ±0,427	0,2884 ±0,3935	0,009 ±0,007	0,296 ±0,380	0,149 ±0,166	0,560 ±0,339	1,250 ±0,765	1,402 ±0,956
BW	0,400 ±0,296	0,656 ±0,534	0,048 ±0,043	0,051 ±0,043	0,019 ±0,013	0,251 ±0,169	1,318 ±1,218	1,306 ±0,826
MW	p=0.024 *	p=0.116 ns	p=0.065 ns	p=0.002 **	p=0.019 *	p=0.008 **	p=0.160 ns	p=0.878 ns
PW	p=0.0006 ***	p=0.042 *	p=0.031 *	p=0.0117 *	p=0.004 **	p=0.001 ***	p=0.008 **	p=0.843 ns

Locomotion is underlined a several basic synergistic patterns. Investigating these synergies during BW and FW stepping in intact cats, Buford and Smith revealed that both timing and amplitude for EMG were different for these locomotor modes [3]. In particularly a faster decreasing in IP activity, and longer activity in BF and GM were observed during BW stepping; both accompanying our present data. In opposite, a greater not lower activity of the VL during BW stepping was obtained, and no differences – for the TA [3]. One possible reason for these differences is an impossibility of our decerebrated cats with the spine and pelvis fixed in a rigid frame to the flexion of lumbar vertebral region being the important factor for the intact BW stepping [3]. In any case, we proposed a different balance in flexion and extension during stepping in opposite directions.

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