THE STUDY OF THE TONUS OF THE AXIAL MUSCLES IN HUMANS

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Abstract: The tonus of axial muscles is of interest in connection with considerable differences in innervation of axial and proximal muscles in comparison with distal ones. Such studies are also of practical importance as at many diseases the pathology of axial tonus precedes changes in distal muscles. With the help of the bar with the built-in strain gauge, rigidly attached to a ceiling, a head or the shoulders were fixed relative to external space. During head fixation the torque was caused by resistance in neck region of a body and equalled to about 0.1 Nm. If the shoulder girdle was fixed, the torque grew up to 0.8 Nm, in this case it was caused by twisting in lumbar segment. After the increase of vertical load with the help of elastic bands (prophylactic loading suit "Penguin 3"), the torque grew 1.5-2 times. The torque increased with decrease of frequency of rotation (from 0.1 up to 0.18 Nm for muscles of a neck and from 0.6 up to 1.2 Nm for the trunk). The increase of resistance with reduction of frequency suggests that active contractile responses "assisting to rotation" are evoked in shortening muscles. The tonus of axial muscles in patients with Parkinson disease was appreciably increased in comparison with healthy persons. In contrast to healthy persons in the patients the resistance practically did not depend on frequency of platform rotation.

Key words: axial muscles, neck, trunk, tonus, human, Parkinson disease

Introduction

Investigation of the mechanisms of maintenance and control of the tonus of axial muscles and of the role of proprioception from these muscles in the postural regulation and the function of oculomotor system is one of the important and urgent tasks of the biomechanics and physiology of movements. Its importance is due to the fact that till now majority of the researchers tried to explain muscular tonus by the application of results obtained in studies of phasic reflex reactions. The frameworks of such approach ignores the questions of tonic readiness, mechanisms of distribution of a tonic background, role of the tonus in spatial orientation and perception of a body configuration. Besides in connection with methodical difficulties, the study of tonus was as a rule limited to distal muscles, to which it is easy to apply necessary changes of length (mainly the muscles producing movements in elbow and ankle joints). However, axial and proximal muscles substantially differ from distal ones by innervation, character of activity, the role in maintenance of a posture and deserve more detailed study. Besides, it is possible to assume that the information from axial muscles close to the body axis plays the special role in the elaboration of internal representation of a body configuration, orientation of its longitudinal axis and so on. Is not accidentally, that just with a trunk the central nervous system associates the reference system under the conditions of deficiency of the information about external space [1, 2]. In this connection proprioception from axial and proximal muscles could play extremely important role in the control of different postural and motor reactions, in particular, in the control of eye movements directed on maintenance of stable anchorage to external space [3, 4].

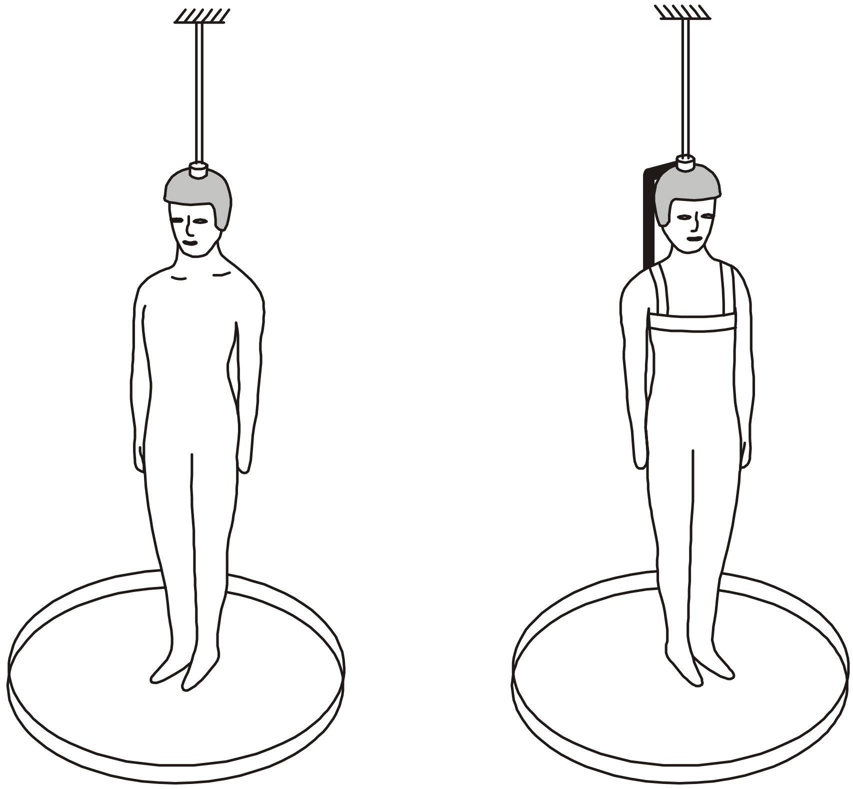

Fig. 1. The scheme of the experimental facility. a – measurement of the neck torque; b – measurement of the waist torque.

The studies of tonus of axial muscles could also have significant practical importance, as during many diseases the pathology of axial tonus precedes changes in usually tested distal muscles.

The present work represents the first part of the comprehensive research covering various aspects of the specified problem: from realization of the first quantitative measurements of axial muscles tonus in different spine segments, to determining the role of axial muscles proprioception in the control of vertical posture and eye movements. Besides of importance for a basic science, the information about tonus of axial muscles at the healthy people could be used for an estimation of results of neurosurgery in the patients with Parkinson disease. Such work in co-operation with N.N. Burdenko Institute of Neurosurgery (Russia) is under way.

The preliminary results in form of abstracts appeared in [5, 6].

Material and Methods

The experimental facility (Fig. 1) represented a turning platform with electric drive capable to turn around vertical axis in the angular range from ±6° to ±20°. The frequency of platform rotation could be adjusted from 0.006 up to 0.03 Hz. If necessary, the stabilograph could be placed on a platform for recording the movement of the common centre of gravity of the subject in sagittal and frontal planes.

The facility was equipped with a set of fixating devices: allowing to fix a head; a head and shoulder girdle; a head, a shoulder girdle and pelvis relative to external space. These fixing devices were mounted on the mobile carriage suspended under a ceiling, so, that fixating device preventing rotation, did not interfere with body inclinations in sagittal and frontal planes. The bar connecting the carriage to the fixing device was equipped with a strain

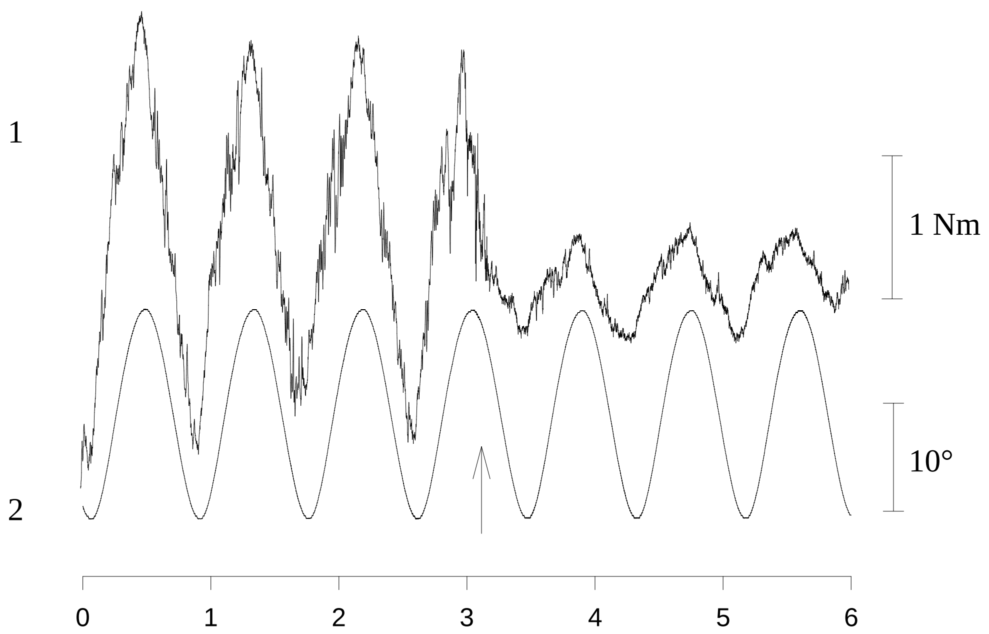

Fig. 2. The comparison of torque due to resistance of axial muscle in lumbar and neck regions. An the beginning of trial the mobility in neck region was excluded by rigid fixation of a board attached to subject's back to a helmet. In a moment marked by arrow fixating bar was removed. 1 – torque; 2 – platform rotation, horizontal axis – time, minutes.

gauge, which measured the torque arising during turns. (Torque produced by resistance of axial muscles.)

There was also fixing device with hinges for prevention of pelvis rotation relative to feet. This device also had such design that it did not interfere with movement of a body in forward-backward and lateral direction. Thus under the conditions of experiment it was possible to twist a body on small angles at three various levels:

1) at the level of a neck (fixing of a head relative to a ceiling of a room);

2) at the a level of lumbar trunk segment (fixing of a head and a shoulder girdle);

3) under the conditions of legs rotation relative to pelvis (fixing of all upper parts of a body including a pelvis).

The set of fixing devices could also ensure some other kinds of stimulation of axial muscles, for example, distributed torsion (a situation when angular deformation is distributed to all body axis proportionally to compliance of different segments).

Besides, the facility included: six-channel strain gauge amplifier, set of self-made electromechanical vibrators for vibratory stimulation of muscle proprioceptors, device for recording of the horizontal direct current electrooculogram on the basis of nanovoltmeter, computer with analog-to-digital converter for data input, storage and processing.

For calculation of amplitude and phase of the basic frequency of a torque signal in relation to sine wave movement of the platform the Fourier-analysis was used. The torque changes were characterized by amplitude and phase. The same parameters (amplitude and phase) were calculated for electrooculogram signal.

The typical experimental protocol looked as follows: the subject in opaque glasses stood on a rotary platform turning alternatively to the right and to the left by ±6.5° with the period from 50 up to about 160 seconds. The large periods were used, as at such periods the angular speeds were below vestibular threshold for the perception of rotation. The subject could stand without contact with any external object or when he grasped by a hand the handle connected to a rigid wooden frame. The conditions of contact, according to results of former works of our group [3], influence the development of proprioceptive illusions.

a b

0 1 2 3 4 5 6 0 1 2 3 4 5 6

c d

Fig. 3. The influence of increased load on the tonus of axial muscles. The prophylactic loading suit «Penguin-3» was used for creating axial load (trials B and D). Elastic bands of «Penguin-3» were released in trials A and C. Experiments were performed at higher (A and B) and lower (B and D) frequency of platform rotation. In each part of the picture higher trace – torque, lower trace – movement of the platform; horizontal axis – time, minutes.

These reactions could be studied under normal conditions and under the conditions facilitating the increase of muscle tone (for example, during standing under additional vertical loading produced by elastic bands). The duration of each trial was 360 seconds.

5 healthy people and 6 patients with Parkinson disease of a different degree of severity were investigated. In healthy people 4 trials for each of 4 angular speeds (periods equalled to 160 s, 90 s, 63 s, 50 s) and 2 experimental conditions (neck or waist torsion) were performed. With each patient one trial with measurement of tone of a trunk muscles and two trials with measurement of tone of neck muscles were carried out (at different angular speeds of platform rotation).

In present paper only results concerning biomechanical aspects of study are presented and discussed.

Results and Discussion

Under the condition of head fixation the torque was caused by resistance in neck segment of a spine and in healthy people was equal to 0.1 ± 0.06 Nm. If a shoulder girdle was fixed, the torque grew up to 0.8 ± 0.5 Nm, in this case it was caused by twisting in a lumbar segment (turn of a pelvis relative to feet was excluded by fixation) (Fig. 2). Increase of vertical load with the help of elastic bands gave rise to the torque increase by 1.5-2 times (Fig. 3). As the bands increased activation of muscles ensuring maintenance of orthograde posture it is possible to assume that measured torque was produced, basically, by muscular forces and

Fig. 4. The dependence of torque in lumbar region on the velocity of rotation. In a moment marked by arrow the frequency of platform rotation was decreased from 0.02 Hz to 0.01 Hz. Note the increase of torque amplitude after decrease of frequency. 1 – torque; 2 – platform rotation, horizontal axis – time, minutes.

Fig. 5. Records of the torque in neck region in patient with Parkinson disease. The decrease of velocity of rotation (compare A and B) does not produce the increase in torque. Note that after the platform arrest in neutral position torque does not return to zero (A, end of the trial). 1 – torque; 2 – platform rotation, horizontal axis – time, minutes.

reflected a level of tonus. The torque increased with reduction of frequency of rotation (from 0.10 ± 0.02 Nm up to 0.18 ± 0.06 Nm for muscles of a neck and from 0.60 ± 0.37 Nm up to 1.20 ± 0.64 Nm for trunk muscles) (Fig. 4). The torque of passive elastic – viscous forces would grow with growth of angular speed, or, at least, would not vary. Therefore increase of resistance with reduction of frequency suggests that in shortening muscles the active contractile responses "assisting to rotation" are observed. These responses (shortening reaction) amplified with growth of speed. Hence, the torque of resistance to twisting was brought about, primarily, by mechanical properties of tonically active muscles of a neck, and trunk, including reactions of these muscles to changes of length.

In the patients (Fig. 5 and 6) the torque of forces of resistance in the neck segment equalled on the average 0.3 Nm (from 0.12 up to 0.6). The torque of force of resistance in waist segment was about 3.5 Nm (from 1.5 up to 5.2). Thus, in patients the tone of axial muscles was appreciably increased in comparison with healthy persons especially for trunk muscles. The curve of resistance vs. time was close to sinusoid with superimposed higha b

Fig. 6. Records of the torque in neck region (A) and lumbar region (B) in other patient with Parkinson disease. Note the different scale for torque on this figure and more regular character of torque changes with angle of platform turn. 1 – torque; 2 – platform rotation, horizontal axis – time, minutes.

frequency fluctuations due to parkinsonian tremor. This sinusoid lead the movement of a platform approximately by 10 seconds. At the same time in healthy subjects this curve was much less regular. In contrast to healthy subjects in the patients the resistance practically did not depend on frequency of turns of a platform. Besides in the healthy subjects the curve of the torque was symmetric relative to zero line, in contrast in 4 of 6 patients it was asymmetric.

Conclusions

Torque of forces of resistance arising during torsion of a body of the vertically standing human relative to longitudinal axis was measured at different levels and at different angular speeds.

In the healthy people the paradoxical phenomenon – a decrease of the torque with an increase of frequency of platform rotation was observed.

It was shown that the torque of resistance to body torsion is primarily due to mechanical properties of tonically activated muscles of a neck and trunk including active reactions of these muscles to changes of length.

The measurements of the tonus of axial muscles revealed significant differences between healthy persons and patients with Parkinson disease. In the patients with Parkinson disease the resistance practically did not depend on frequency. Thus, this method has appeared more sensitive than a technique of stabilography from the point of view of revealing tonus pathology, in particular of its latent asymmetry.

Acknowledgements

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ИССЛЕДОВАНИЕ ТОНУСА АКСИАЛЬНОЙ МУСКУЛАТУРЫ ЧЕЛОВЕКА

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Тонус аксиальной мускулатуры представляет интерес в связи с существенными различиями в иннервации аксиальных и проксимальных мышц по сравнению с дистальными. Его исследования могут иметь и практическое значение, так как при многих заболеваниях нарушения аксиального тонуса предшествуют изменениям в дистальных мышцах.

С помощью жестко прикрепленной к потолку штанги со встроенным датчиком момента голову или плечи человека фиксировали относительно внешнего пространства. При фиксации головы моменты были обусловлены сопротивлением в шейном отделе позвоночника и составляли у здоровых около 0,1 Нм. Если фиксировали плечевой пояс, моменты возрастали до 0,8 Нм, в этом случае они были обусловлены скручиванием в поясничном отделе. При увеличении вертикальной нагрузки с помощью упругих тяг (профилактический нагрузочный костюм «Пингвин 3»), моменты возрастали в 1,5-2 раза. Моменты увеличивались при уменьшении частоты вращения (с 0,1 до 0,18 для мышц шеи и с 0,6 до 1,2 Нм для корпуса). Моменты пассивных упруго-вязких сил возрастали бы с ростом угловой скорости, или, в крайнем случае, не менялись бы. Поэтому увеличение сопротивления с уменьшением частоты говорит о том, что в укорачивающихся мышцах наблюдаются активные сократительные ответы, "помогающие вращению". Эти ответы (реакция укорочения) усиливались с ростом скорости.

Тонус аксиальной мускулатуры у больных паркинсонизмом был заметно повышен по сравнению со здоровыми людьми, особенно для мускулатуры туловища. В отличие от здоровых у больных сопротивление практически не зависело от частоты поворотов платформы. Библ. 6.

Ключевые слова: аксиальная мускулатура, тонус, человек, болезнь Паркинсона

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