Neuroscience Letters 461 (2009) 235–239

Contents lists available at ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

Increase in corticospinal excitability of limb and trunk muscles according to maintenance of neck flexion

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ARTICLE INFO

Article history:
Received 21 January 2009
Received in revised form 3 June 2009
Accepted 16 June 2009

Keywords:
Corticospinal excitability
Brain activation
Neck flexion
Transcranial magnetic stimulation

ABSTRACT

The effect of maintenance of neck flexion on corticospinal excitability of limb and trunk muscles was investigated using transcranial magnetic stimulation (TMS). Nine healthy young subjects participated in this experiment. Every measurement was performed with subjects sitting on a chair. Target muscles were the first dorsal interosseous (FDI), biceps brachii (BB), triceps brachii (TB), rectus abdominis (RA), erector spinae (ES), rectus femoris (RF), biceps femoris (BF), tibialis anterior (TA), and gastrocnemius (GcM) on the right side. TMS was applied to the left primary motor cortex, and motor evoked potential (MEP) was measured from the muscles listed above. Optimal stimulus location and resting motor threshold (RMT) were identified for each target muscle, and stimulus intensity used was 120% of RMT. MEPs of the target muscle were recorded with the chin resting on a chin support (chin-on condition) with neck in 20° of flexion, and with voluntary maintenance of the neck flexion posture (chin-off condition). Amplitude and latency of MEP and background activity of target muscles were analyzed. For FDI, BB, TB, ES, and RF, amplitude of MEP increased and latency shortened in the chin-off compared with the chin-on condition. No significant difference in background activity of each target muscle was found between the two conditions. Corticospinal excitability of limb and trunk muscles was selectively enhanced while neck flexion was maintained.

A basic dynamic posture in which the ankle, knee, and neck joints and the trunk are slightly flexed is consistently shown in individuals at the sudden initiation of movement and in those pursuing a moving visual target [13]. We have revealed that maintaining the neck flexion that is part of the dynamic posture leads to shortening of reaction times for finger movement and saccadic eye movement while sitting [8], and for shoulder flexion while standing [11]. We compared the saccadic reaction time between conditions comprising the chin resting on a chin support (chin-on condition) and voluntary maintenance of neck flexion (chin-off condition) at various flexion angles. The results indicated that neck flexion angle has a significant effect on reaction time in the chin-off condition but not in the chin-on condition [8]. We also found that the shortening of saccadic reaction time during vibratory stimulation of the neck extensors was similar to that produced by moderate isometric contraction of the shoulder girdle elevators [9]. This finding suggests that the shortening of the various reaction times with maintenance of neck flexion is the result of extensive activation of the central nervous system associated with an increase in afferent information from the muscle spindles in the neck extensors [9]. It is likely that one of the neural mechanisms producing this effect is a non-specific and ascending brain activation system regulated by a broad network comprising the brainstem and forebrain [14,19]. The neural pathway in this activation system is likely to be as follows: afferent information from the neck extensors projects mainly to the brainstem reticular formation via spinoreticular fibers [4,17]. Then, the firing signal originating from the tegmentum mesencephali and the pedunculopontine tegmental, raphe and caeruleun nuclei in the reticular formation projects to broad areas of the cerebral cortex via the thalamus and basal forebrain [4,17,19].

We previously revealed that the extensive activation of the central nervous system accompanying maintenance of neck flexion extends to sensory-related brain regions. This was demonstrated by recording the P100 component of visual-evoked potential [15] and the middle-latency auditory-evoked potential [10]. Furthermore, maintenance of neck flexion enhanced the amplitude of contingent negative variation (CNV) of event-related brain potential (ERP) in a paradigm of warning stimulus – response stimulus – arm flexion while standing, suggesting that the extensive activation extends to the frontal lobe in which supplemental motor and premotor areas are contained [11]. However, no studies to date have addressed the

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doi:10.1016/j.neulet.2009.06.047

effects of maintenance of neck flexion on the state of activation of the motor output system including the primary motor cortex.

Transcranial magnetic stimulation (TMS) is a non-invasive method for evaluating the state of activation of the motor output system [3]. TMS of the primary motor cortex excites the pyramidal neurons trans-synaptically, giving rise to a series of descending volleys in the corticospinal pathways [1,21]. As a result, TMS evokes electromyographic (EMG) responses in the skeletal muscles with a brief latency that is compatible with conduction along the fast-propagating corticospinal axons; these EMG responses are called motor evoked potentials (MEPs) [1]. The amplitude and latency of MEPs are modulated by voluntary contraction of target muscles [20], motor imagery [2], and peripheral afferent stimulation [6]. Such modulation of MEPs is believed to represent the changes in corticospinal excitability [2]. If the extensive activation of the central nervous system with maintenance of neck flexion extends to corticospinal pathways, the amplitude of MEP presumably increases and the latency shortens.

This study used TMS to examine whether corticospinal excitability changes with maintenance of neck flexion, and whether the changes in corticospinal excitability occur in particular areas of the primary motor cortex based on the MEP response of various upper limb and postural muscles.

Nine healthy young adults (seven women and two men, 22–33 years old) participated in this study. We selected subjects who exhibited shortening of saccadic reaction time associated with maintenance of neck flexion from the participants of our previous studies [11]. No subject had any history of neurological or orthopedic impairment. Informed consent was obtained in accordance with the Declaration of Helsinki from all subjects following an explanation of the experimental protocols, which were approved by our institutional ethics committee.

All measurements were performed while subjects sat on a steel-frame chair with the back resting against a vertical wall, with the elbows, hips, and knees flexed to 90°, and the forearms pronated to 90° (Fig. 1). Subjects kept an intermediate position of the wrist and ankle joints. The axillae were slightly elevated and fixed by a cotton band hanging from the steel-frame. The length of the band was individually fitted so as to avoid compressing the axillary nerve.

Neck angle was defined by the rotation angle of the tragus around the acromion in the sagittal plane, with the starting position (0°) being the quiet sitting posture. This angle was determined for each subject using a custom-made angular detector with the central point set at the acromion and regulating the distance between the acromion and the tragus (Fig. 1). The head inclination angle in the sagittal plane was determined as the angle between the auriculoinfraorbital line and the gravitational line. An angular detector (Level + Angle Detector, Mitsumoto, Japan) using the principle of a pendulum was placed on the temple. The head inclination angle in the frontal plane was determined as the angle between the line (Fpz (international 10–20 system) – mental protuberance) and the gravitational line, and measured using the Position Sensor System (C1373, Hamaphoto, Japan). This system is composed of two light-emitting diode targets (LED targets) and a sensor head, and emits analog outputs of coordinates for each LED target in two dimensions. The LED targets were placed over the Fpz and the mental protuberance. Analog outputs of the two LED targets were displayed on an oscilloscope (DS6612, Iwatsu, Japan). The head inclination angles in the sagittal and frontal planes during measurements were monitored by experimenters to maintain constancy in the sensory stimulus from the vestibular organ.

Surface electrodes (M-00-S, Medicotest, Denmark) were used with bipolar derivation to monitor and record surface electromyographic (EMG) activity of the following muscles: first dorsal interosseous (FDI), biceps brachii (BB), triceps brachii (TB), rectus abdominis (RA), erector spinae (ES), rectus femoris (RF), biceps femoris (BF), tibialis anterior (TA), and gastrocnemius (GcM), and the upper part of trapezius (Tra). The electrodes were placed on

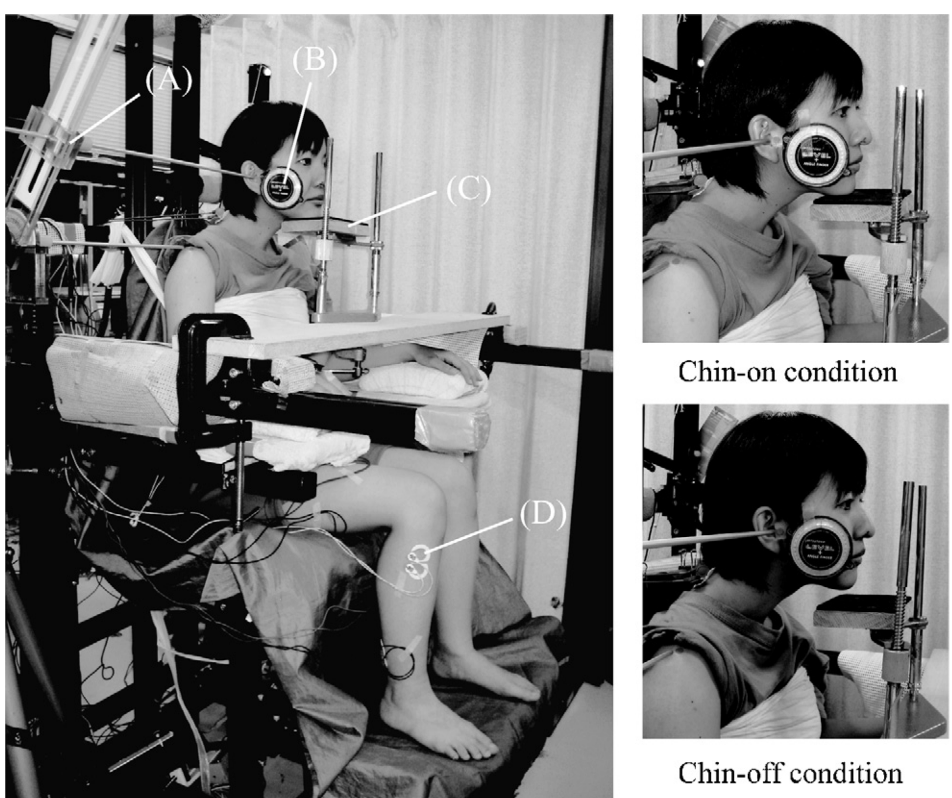

Fig. 1. Experimental setup. (A) Angle detector for neck angle; (B) angle detector for head inclination angle; (C) chin stand; (D) surface electrode.