proceedings

MDPI

Proceedings

Cutaneous stimulus registration and information processing differ during constant finger force and position

Keisuke Yunoki [1], Tatsunori Watanabe [1], Takuya Matsumoto [1,2], Takayuki Kuwabara [1], Xiaoxiao Chen [1], Kanami Ito [1], Haruki Ishida [1], Takayuki Horinouchi [1] and Hikari Kirimoto [1,*]

[1] Department of Sensorimotor Neuroscience, Graduate School of Biomedical and Health Sciences, Hiroshima University, Hiroshima, Japan; d205546@hiroshima-u.ac.jp (K.Y.); twatan@hiroshima-u.ac.jp (T.W.); d203652@hiroshima-u.ac.jp (T.M.); m203434@hiroshima-u.ac.jp (T.K.); d185984@hiroshima-u.ac.jp (X.C.); m212173@hiroshima-u.ac.jp (K.I.); m215749@hiroshima-u.ac.jp (H.I.); m215699@hiroshima-u.ac.jp (T.H.); hkirimoto@hiroshima-u.ac.jp (H.K.)

[2] Research Fellow of Japan Society for the Promotion of Science, Tokyo, Japan

* Correspondence: hkirimoto@hiroshima-u.ac.jp (H.K.)

Abstract: During static muscle contractions, there are two load types: maintenance of a joint angle against internal and external forces (position task) and maintenance of a constant force against a rigid resistance (force task). Previous studies have reported that heteronymous monosynaptic Ia facilitation was greater while homonymous inhibition was smaller in the position task as compared to the force task, even though a similar net torque was generated in both tasks. However, a difference in afferent cutaneous processing between these two tasks has not been fully understood. The aim of this study was to determine whether cutaneous stimulus registration and information processing differ between these two tasks by investigating the amplitude of cutaneomuscular reflex (CMR) and the gating of somatosensory evoked potentials (SEPs). Eighteen healthy participants performed position and force tasks with matched loads (20% maximum voluntary contraction) with the right index finger. During each task, electrical stimulation was applied to the right index finger, and CMR and SEPs were recorded from the right first dorsal interosseous muscle and C3′ of the International 10–20 system, respectively. The E2 amplitude of CMR and the reduction of N33 amplitude of SEPs were greater in force than position task. These results suggest that processing of cutaneous sensation is enhanced in force than position task, and, together with the previous study demonstrating the greater proprioceptive sensory processing in the position task, this study may contribute to the development of rehabilitation exercise programs.

Keywords: Cutaneomuscular reflex; Somatosensory evoked potentials; Postural control; Load type

Citation: Lastname, F.; Lastname, F.; Lastname, F. Title. *Proceedings* **2021**, *68*, x. https://doi.org/10.3390/xxxxx

Published: date

1. Introduction

During static muscle contractions, there are two load types: maintenance of a joint angle against internal and external forces (position task) and maintenance of a constant force against a rigid resistance (force task). Previous studies have reported that heteronymous monosynaptic Ia facilitation was greater while homonymous inhibition was smaller in the position task as compared to the force task, even though a similar net torque was generated in both tasks [1-3]. These studies have suggested that proprioceptive information was required more in the position task as compared to the force task. However, a difference in afferent cutaneous processing between these two tasks has not been fully understood. The aim of this study was to determine whether cutaneous stimulus registration and information processing differ between these two tasks by investigating the amplitude of cutaneomuscular reflex (CMR) and the gating of somatosensory evoked potentials (SEPs).

2. Materials and Methods

Eighteen healthy subjects (15 males and 3 females, 21-35 years old) participated in this study. Informed consent was obtained from all subjects involved in the study.

Subjects were seated in a chair with the right hand positioned in the custom-designed apparatus, which was used in the previous study (Figure 1) [4]. The custom-designed device consisted of a wheel connected to a force transducer or inertial load by means of pulley and nylon line. All the subjects performed two submaximal tasks with similar torque levels. In the force task (Figure 1a), 20% maximum voluntary contraction (MVC) force level was maintained with the metacarpophalangeal joint angle fixed in 10° of abduction. The metacarpophalangeal joint angle was not fixed during the position task (Figure 1b), and subjects were required to maintain a target position corresponding to 10° abduction of the metacarpophalangeal joint while supporting a load equivalent to 20% MVC. During each task, CMR and SEPs were recorded in separate trials.

CMR in response to the digital nerve stimulation to the right index finger using the ring electrodes was recorded from the right first dorsal interosseous (FDI) muscle. Stimulus intensity was fixed at 3 times the sensory threshold with a repetition rate of 5 Hz. Stimulus duration was 0.2 ms. A total of 250 responses were averaged in each task.

SEPs in response to the digital nerve stimulation to the right index finger were recorded from C3′ (2 cm posterior to C3 of the International 10-20 system). The stimulus settings were identical to CMR recordings as described above, except for the repetition rate, which was set as 2 Hz. A reference electrode was placed on the right earlobe. SEPs were recorded during rest and the force and position tasks. A total of 300 responses were averaged for each condition.

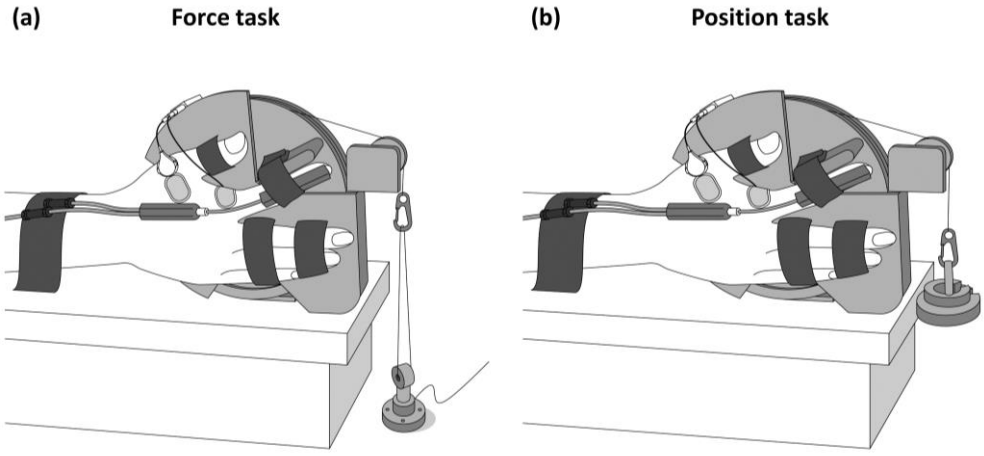

Figure 1. Experimental setup with the right hand attached to the custom-designed apparatus which consisted of a wheel connected to a force transducer (a) or inertial load (b) by means of pulley and nylon line.

3. Results

Figure 2 presents CMR results. During the CMR recordings, background electromyographic (bEMG) activities in the right FDI muscle were comparable between the force and position tasks ($p = 0.618$, paired t-test). The E2 amplitude was greater in force than position task ($p < 0.01$, Wilcoxon signed-rank test). In contrast, no significant difference was observed between force and position tasks for the E1 and I1 amplitudes (E1: $p = 0.306$, Wilcoxon signed-rank test; I1: $p = 0.170$, paired t-test).

Figure 3 presents SEPs results. One-way repeated measures analysis of variance revealed significant main effects of condition on N20 and N33 amplitudes (N20: $F_{(2,34)}$ =

3.372, $p = 0.046$, partial $\eta^2 = 0.166$; N33: $F_{(2,34)} = 4.506$, $p = 0.033$, partial $\eta^2 = 0.210$, $\varepsilon = 0.698$). Post-hoc analysis showed that the N33 amplitude during force task was significantly smaller than that during position task ($p < 0.01$). Post-hoc analysis indicated that there were no significant differences in N20 amplitude between force and position tasks. No significant main effect of condition was revealed for the P25 and P45 amplitudes (P25: $F_{(2,34)} = 0.840$, $p = 0.441$, partial $\eta^2 = 0.047$; P45: $F_{(2,34)} = 2.296$, $p = 0.116$, partial $\eta^2 = 0.119$).

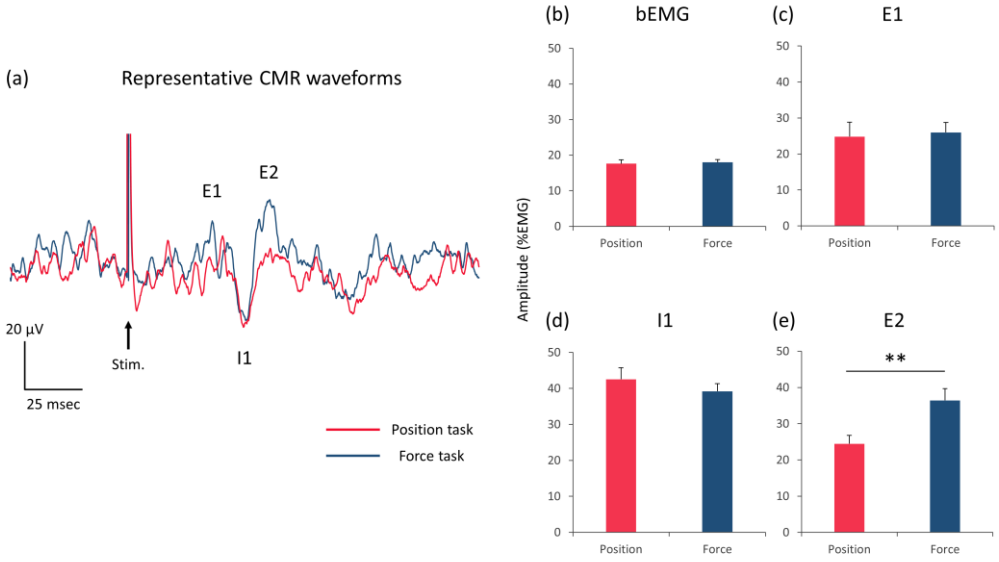

Figure 2. Representative CMR waveforms (a) and background electromyographic (bEMG) activities in the right FDI muscle (b) and the mean amplitude of each of the CMR components: E1 (c), I1 (d), and E2 (e). Significant difference between force and position tasks for E2 component: **: $p < 0.01$.

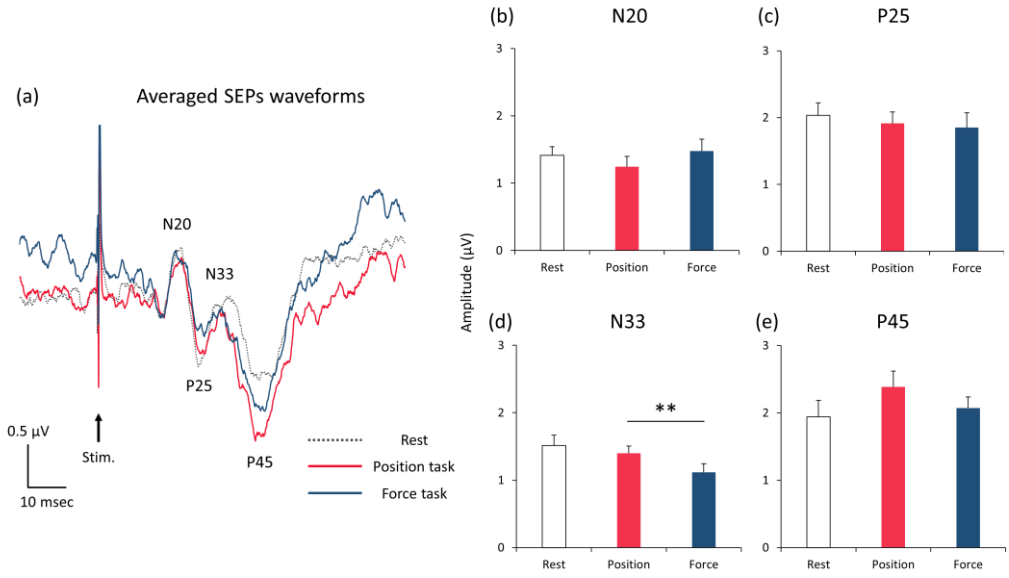

Figure 3. Averaged SEPs waveforms (a) and the mean amplitude of each of the SEPs components: N20 (b), P25 (c), N33 (d), and P45 (e). Significant difference between force and position tasks for N33 component: **: $p < 0.01$.

4. Discussion

In the present study, we found the E2 amplitude of CMR and the reduction of N33 amplitude of SEPs to be greater in force than position task.

The E2 component of CMR is thought to be mediated via transcortical pathway [5]. Thus, we suppose that the increased E2 amplitude in the force task might be attributed to enhanced descending drive from motor-associated cortical areas to α motor neuron pool.

The attenuation of SEPs amplitude during muscle contraction is known as gating, which is considered to be important for filtering out irrelevant sensory inputs during a movement. Our finding of greater gating of SEPs in response to Ia sensory fibers stimulation in position than force task [4] may, thus, suggest enhanced processing of cutaneous sensation in the force task.

Author Contributions: Conceptualization, K.Y., T.W., and H.K.; methodology and investigation, K.Y., T.M., T.K., X.C., K.I., H.I., and T.H.; formal analysis, K.Y. and H.K.; writing the original draft, K.Y.; visualization, K.Y.; supervision, T.W. and H.K.; funding acquisition, T.M., T.W., and H.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research was partially supported by Grants-in-Aid for Scientific Research (KAKENHI) from the Japan Society for the Promotion of Science (19H01091, 19H03977, 20K19708, 20J21369).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Baudry, S.; Enoka, R.M. Influence of load type on presynaptic modulation of Ia afferent input onto two synergist muscles. *Exp. Brain Res.* **2009**, *199*, 83–88, doi:10.1007/s00221-009-1951-x.
2. Baudry, S.; Jordan, K.; Enoka, R.M. Heteronymous reflex responses in a hand muscle when maintaining constant finger force or position at different contraction intensities. *Clin. Neurophysiol.* **2009**, *120*, 210–217, doi:10.1016/j.clinph.2008.10.013.
3. Baudry, S.; Maerz, A.H.; Gould, J.R.; Enoka, R.M. Task- and time-dependent modulation of ia presynaptic inhibition during fatiguing contractions performed by humans. *J. Neurophysiol.* **2011**, *106*, 265–273, doi:10.1152/jn.00954.2010.
4. Kirimoto, H.; Tamaki, H.; Suzuki, M.; Matsumoto, T.; Sugawara, K.; Kojima, S.; Onishi, H. Sensorimotor modulation differs with load type during constant finger force or position. *PLoS One* **2014**, *9*, doi:10.1371/journal.pone.0108058.
5. Jenner, J.R.; Stephens, J.A. Cutaneous reflex responses and their central nervous pathways studied in man. *J. Physiol.* **1982**, *333*, 405–419, doi:10.1113/jphysiol.1982.sp014461.