運動疲労の脳磁図研究

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A Magnetoencephalography Study on Physical Fatigue

by

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ABSTRACT

Enhanced central inhibition system caused by peripheral fatigue input and facilitation system caused by motivational input play an important role to determine the performance during physical fatigue. We tried to clarify the neural mechanism of central inhibition and facilitation systems during physical fatigue using magnetoencephalography (MEG) and a classical conditioning technique. As an experiment 1, participants underwent MEG recording during the imagery of maximum grips of the right hand guided by metronome sounds for 10 min. Thereafter, fatigue-inducing maximum handgrip trials were performed for 10 min; the metronome sounds were started 5 min after the beginning of the handgrip trials. We used metronome sounds as conditioned stimuli and maximum handgrip trials as unconditioned stimuli to cause central inhibition. The next day, MEG recording during the imagery of maximum grips of the right hand guided by metronome sounds were measured for 10 min. Levels of the fatigue sensation in the right hand and sympathetic nerve activity on the second day were significantly higher than those on the first day. In the right dorsolateral prefrontal cortex (Brodmann's area 46), the alpha-band event-related desynchronization (ERD) of the second MEG session relative to the first session

with the time window of 200 to 300 ms after the onset of handgrip cue sounds was identified. The ERD level in this brain region was positively associated with the change in subjective level of right hand fatigue after the conditioning session and was negatively associated with that of sympathetic nerve activity. As an experiment 2, participants underwent MEG recording during the imagery of maximum grips of the right hand guided by metronome sounds for 10 min. Thereafter, fatigue-inducing maximum handgrip trials were performed for 10 min; the metronome sounds were started 5 min after the beginning of the handgrip trials. The metronome sounds were used as conditioned stimuli and maximum handgrip trials as unconditioned stimuli. The next day, they were randomly assigned to two groups in a single-blinded, two-crossover fashion to undergo two types of MEG recordings, that is, for the control and motivation sessions, during the imagery of maximum grips of the right hand guided by metronome sounds for 10 min. The alpha-band ERDs of the motivation session relative to the control session within the time windows of 500 to 700 and 800 to 900 ms after the onset of handgrip cue sounds were identified in the sensorimotor areas. In addition, the alpha-band ERD within the time window of 400 to 500 ms was identified in the right dorsolateral prefrontal cortex (Brodmann's area 46). The ERD level in the right dorsolateral prefrontal cortex was positively associated with that in the sensorimotor areas within the time window of 500 to 700 ms. We demonstrated that the right dorsolateral prefrontal cortex is involved in the neural substrates of both the central inhibition and the facilitation systems during physical fatigue.

要　旨

抑制システムと促進システムは，身体的な疲労時のパフォーマンスを決定するために重要な役割を演じる．我々は，脳磁図と古典的条件付けを用いて抑制システムと促進システムの神経メカニズムを明らかにしようと試みた．実験 1 として，メトロノーム音に従って右手（利き手）の最大の握りのイメージを 10 分間実施した（メトロノーム音は，5 分後に開始した）．抑制を引き起こす無条件刺激として右手の最大の握りを施行する身体的疲労負荷課題を実施した．翌日，メトロノーム音に従って右手の最大の握りのイメージを 10 分間実施した．その結果，右の背外側前頭前野（ブロードマン 46 野）において，200 ～ 300 ms 後に事象関連脱同期が認められた．この事象関連脱同期レベルは，右手疲労の主観的なレベルと正の相関を認めた．実験 2 として，メトロノーム音に従って右手の最大の握りのイメージを 10 分間実施した（メトロノーム音は，5 分後に開始した）．抑制を引き起こす無条件刺激として右手の最大の握りを施行する身体的疲労を実施した．翌日，メトロノーム音に従って右手の最大の握りのイメージを 10 分間，意欲ありとなしの課題を実施した．意欲なしセッションと比較して意欲ありセッションでは，右の背外側前頭前野（ブロードマン 46 野）において，400 ～ 500 ms 後に事象関連脱同期が認められた．本研究により，右の背外側前頭前野

が，身体的疲労時，抑制システムと促進システムの両方に関係することが明らかになった．