論　文　概　要

○論文題目　Effects of nutrition on physical function during and after long term stay at International Space Station
（国際宇宙ステーション滞在宇宙飛行士を対象とした栄養摂取が筋力に及ぼす影響に関する研究）

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Background and objective: Exposure to microgravity reduces muscle mass, volume, and performance, especially in the legs, on both short and long flights. Though many types of exercise protocols have been proposed to aid in the maintenance of both muscle and bone during flight, the efficient method is required by combination of nutritional and mechanical countermeasures. According to various ground studies in the past, it is known that the ingestion of protein, especially combined with carbohydrate and exercise after ingestion improve in net protein synthesis and increase muscle mass. However, there are few studies on the relationship between nutrition and muscle strength during and after long term spaceflight. In this thesis, the main objective was to explore the association between protein intake and physical function in astronauts stayed at the International Space Station (ISS) by using data obtained from the National Aeronautics and Space Administration (NASA) Lifetime Surveillance of Astronaut Health Repository (LSAH). The objective of the first chapter is to investigate influence of the combined effect of protein and carbohydrate intake and exercise on microgravity-induced muscle atrophy during the long-term spaceflight. In the second chapter, its objective was to investigate the influence of protein intake and body composition status on physical performance in astronauts stayed at the ISS, analyzing individual data in detail.

Subjects and methods: These studies are retrospective cohort studies conducting the secondary analysis with data collected in NASA LSAH. I received approval from the LSAH Advisory Board for use of unattributable medical data, specifically the following: Nutrition Status Assessment data, Exercise Record, Isokinetic Assessment data, Biochemical Testing data, Bone Mineral Density data and Body Composition Assessment data of astronauts who met the criteria of the protocol and analyzed these data. Multivariable analyses were performed to evaluate the impact of protein intake on the physical performance measures considering covariates potentially associated with each model.

Results: Sixty-two healthy subjects met the study criteria. After adjustment for Sex, Age, Flight week, Calories intake and Physical performance at pre-flight, protein intake was positively associated with isokinetic concentric measurements at 60°for Knee Extension (β=51.66 and p<0.05), isokinetic concentric measurements at 30°for Ankle Plantar Flexion (β=32.86 and p<0.05) and isokinetic eccentric measurements at 30°for Ankle Plantar Flexion (β=79.85 and p<0.05). In addition, significant associations remain after controlling the exercise effect (β=51.35 and p<0.05;

ß=32.79 and $p<0.05$; ß=81.99 and $p<0.05$, respectively). However, no significant association between interaction of protein and carbohydrate intake and physical performance measures at 5 days after landing were observed in both models. In the analysis with physical performance measures at 30 days after landing, significant association between protein intake and isokinetic concentric measurements at 30°for Ankle Plantar Flexion (ß=30.9 and $p<0.05$) was still observed in both models. Regarding the association between physical performance and body composition status, only the low muscle strength group for Ankle Plantar Flexion measurements had significantly lower mean weight at post-flight (concentric measurements at 30°: - 2.7kg ($p<0.05$) ; eccentric measurements at 30°: -1.7 kg ($p<0.05$). The association of protein intake during spaceflight with physical performance at post flight in different Body Mass Index (BMI) level was examined, and positive association between protein intake and Ankle Plantar Flexion measurements in High BMI subjects (concentric measurements at 30°: ß=29.3 and $p<0.05$; eccentric measurements at 30°: ß=58.4 and $p<0.05$).

Discussion: Protein intake during spaceflight were related to physical performance for Knee Extension and isokinetic measurements for Ankle Plantar Flexion, even after taking the exercise effect into consideration. However, the nutrition countermeasure of protein and carbohydrate supplementation provided no synergetic benefit for muscle strength. In the overweight group, there was a negative impact on Ankle Plantar Flexion measures and significantly positive association between protein intake and Ankle Plantar Flexion strength.

Conclusion: This result supports that protein intake can serve as a major candidate for countermeasures program to offset the negative effects of long duration spaceflight on the performance of the most affected muscle group. The relationship between muscle strength and body composition shown in the second chapter is consistent with existing reports. Although more studies are needed to understand the relationship between BMI focused on fat mass and muscle performance, the fact that protein intake may be particularly useful in overweight subjects has important implications for future countermeasures to offset muscle protein loss and muscle weakness.