1. Title
Effects of centrifuge-induced artificial gravity and ergometric exercise as a countermeasure against cardiovascular and musculoskeletal deconditioning induced by long exposure to microgravity

2. Research Term

3. Research Fields
Space Medicine

4. Research Categories
Emphasis Research

5. Research Theme

6. Investigators and Organization
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8. Summary of Research

Introduction
We manufactured centrifuge-induced artificial gravity loading system as well as ergometric exercise for cardiovascular deconditioning in humans. In order to examine the device also prevent the myatrophy and osteoporosis, we examined the effect of this artificial gravity with exercise on the prevention of space deconditioning including cardiovascular deconditioning, myatrophy, and osteoporosis.

Methods
We employed −6° head-down bedrest as the microgravity exposure simulation. All the life was conducted in head-down position with 2,100kcal of feeding and water intake of 1,200ml. Care was provided by nursing staff.

Two bedrest studies were conducted. As the pilot study, the relation between artificial gravity and exercise load was examined to reveal the reverse relationship. The first study loaded 1.4G 60W for 30 min, in 11/14 days of bedrest. The second one was conducted by the combination with high gravity-low exercise (1.4G, 60W for 20 min) and low gravity-high exercise (0.3G, up to 80% of maximum O₂ uptake) in 10/20 days of bedrest.

Results
1. Anti-G score
Anti-G score is the sum of the (duration of G-load)×(loaded gravity). There was no difference in the control group, whereas countermeasure group increased the anti-G score significantly in 14 days of bedrest, but in 20 days of bedrest, there was no significant difference in both groups.

2. Cardiac dimension
Echocardiography revealed that the cardiac dimension was reduced in left ventricular wall thickness, left ventricular volume, and stroke volume in control group, whereas no significant difference in the countermeasure group in 20 days of bedrest.

3. Fluid shift and cardiovascular parameters
Fluid shift from the thorax to the leg during artificial gravity load was significantly suppressed by the countermeasure.

4. Muscle sympathetic nerve activity
Response to 30° head-up tilt in muscle sympathetic nerve activity was significantly suppressed in countermeasure group but not in the control group in 14 days bedrest study.

5. Plasma renin activity and angiotensin II
Plasma levels of renin and angiotensin II were elevated in the control but not in the countermeasure group in 14 and 20 days of bedrest study.

6. Orthostatic tolerance
14 days of bedrest study showed that the orthostatic tolerance was enhanced by 11/14 days of countermeasure, but not in 10/20 days of countermeasure.

7. Calf muscle function (in 20 days bedrest)
Maximum voluntary contraction and contraction endurance time were collapsed after bedrest, but countermeasure suppressed this collapse. Blood flow recovery after exercise was reduced by bedrest but suppressed by the countermeasure.

8. Ventilation response and heart rate response (in 20 days bedrest)
Ventilation response, heart rate response, tidal volume, maximum oxygen uptake were all reduced in the control group, but no significant difference was found in the countermeasure group.
9. Muscle volume by MRI (in 20 days of bedrest)
The quadriceps femoris, hamstring, and abductors were reduced in their volume in the control group, but not in the countermeasure group.

10. Urinary deoxypyridinorine showed a significant decrease in the countermeasure for 14 days, but not in 20 days of bedrest. No significant difference was found in the control group.

Conclusion
The estimated cause of cardiovascular deconditioning are considered as follows;
1) Hypovolemia due to fluid shift
2) Attenuated vascular response to sympathetic discharge due to the lack of shear stress
3) Reduced physical fitness

9. Publication List