# Stationary Lower-Body Movement System to Mitigate Muscle Atrophy in Spaceflight

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ABSTRACT

Long-duration spaceflight can elicit increases in muscle disuse, thereby leading to a decrease in muscle mass. The consequences of these negative effects include decreases in muscle strength and mobility, and an increase in injury risk. The large muscle groups of the lower body are particularly susceptible to these adaptations. **PURPOSE**: To design, fabricate, and test a compact, lightweight device that incorporates pneumatic principles and airflow restriction to provide varied resistance during lower-body movements. **METHODS**: The custom device was originally designed in three-dimensional modeling software (Solidworks Premium, Waltham, MA). Components of the device included: boots, accompanying braces, ball valves, clevis mounting brackets, rod clevis ends, and double-acting pneumatic cylinders. Testing of this Stationary Lower-Body Movement System (SLMS) was completed three ways: use of a force platform, a muscle damaging exercise protocol, and use of finite element analysis (FEA). To measure the retraction stroke, we applied the piston of the cylinder to a force plate and measured the force exerted. To determine if exercise using SLMS elicited muscle damage, one active male and one untrained female participant (both 24 yrs) followed a specific protocol, in the following order: 1) no exercise, alcohol consumption, or smoking; 2) first blood draw; 3) control testing; 4) second blood draw; 5) SLMS testing; 6) third blood draw. Seven days separated 1) and 2), two days separated 2) and 3), 24 hours separated 3) and 4), seven days separated 3) and 5), and 24 hours separated 5) and 6). Control testing (10 sets x 10 reps at 48 bpm cadence) included unilateral knee flexion and extension while lying supine with the heel of the feet on low-friction sliders on a gym floor. Exercise with SLMS (10 sets x 10 reps @ 293 N load, and 5 sets x 10 reps at 1,116 N load) included the same posture, movements, and cadence. Serum concentrations of creatine kinase were measured during each blood draw and later analyzed. Finally, specific FEA analyses were conducted that included static compression, static tension, fatigue lifespan, and fatigue damage tests. **RESULTS**: The range of force capability of SLMS ranged from 58 N to 1,116 N, depending on the amount of airflow restriction. Creatine kinase concentrations increased four times from baseline following exercise using SLMS in the female participant, but concentrations did not change in the male participant. According to FEA, a constant amplitude of 293 N, run for 1 million cycles, subcomponents of SLMS (i.e., the boot and bracket) can withstand 38,050 and 14 million cycles, respectively. About 7.143% damage was incurred after 1 million cycles. **CONCLUSION**: SLMS, a compact device that was fabricated and tested in our laboratory, is resilient and reliable with regard to its function as a lower-body exercise device. Exercise using SLMS may elicit muscle damage in untrained females.