FUNCTIONAL TASK TEST:

Data Review

June 30, 2014

Neuroscience, Exercise Physiology & Cardiovascular Laboratories

NASA-Johnson Space Center, Houston, TX

Background

After space flight there are changes in multiple physiological systems including:

- Cardiovascular function

- Sensorimotor function

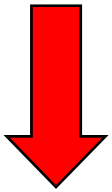
- Muscle function

How do changes in these physiological systems impact astronaut functional performance?

Objectives

1. Determine the effects of space flight on astronaut's ability to perform mission critical functional tasks.

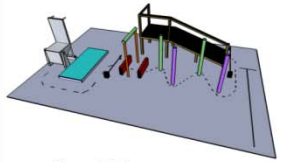
2. Identify the key physiological factors that contribute to decrements in functional performance.



Inform the design of targeted countermeasures

Functional Task Test (FTT)

Functional Performance



Seat Egress and Walk

Ladder Climb

Recovery from Fall/Stand

Rock Translation

Construction Activity

Torque Generation

Jump Down

Map

Physiological Measures

Muscle

- Strength
- Power
- Control
- Neuromuscular Drive

Sensorimotor

- Balance
- Gait
- Dynamic Visual Acuity
- Fine Motor Control

Cardiovascular

- Plasma Volume
- Heart Rate
- Blood Pressure

Interdisciplinary testing regimen maps postflight functional performance to related physiological changes.

Subject Groups

Shuttle: 7 subjects
12-16 day flights

ISS: 12 subjects (total n=13)
6 month flights

Bed Rest:
Controls: 11 subjects
Exercise: 9 subjects
Exercise + Testosterone: 8 subjects

70 days bed rest

Testing Schedules

Preflight — L-180, L-60, L-30

Postflight — R+0, R+1, R+6, R+30

Preflight — L-180, L-60, L-30

Postflight — R+1, R+6, R+30

Pre-bed rest — BR-12, BR-7, BR-1

Post-bed rest — BR+0, BR+1, BR+6, BR+12

70 days in bed rest

Using Bed Rest as a Sensorimotor Analog

Space flight modifies:

Vestibular and body load information

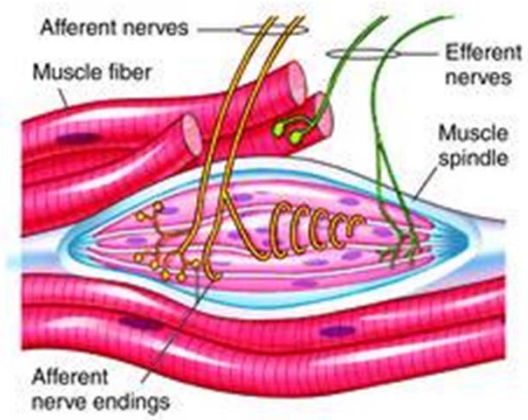
Bed rest modifies:

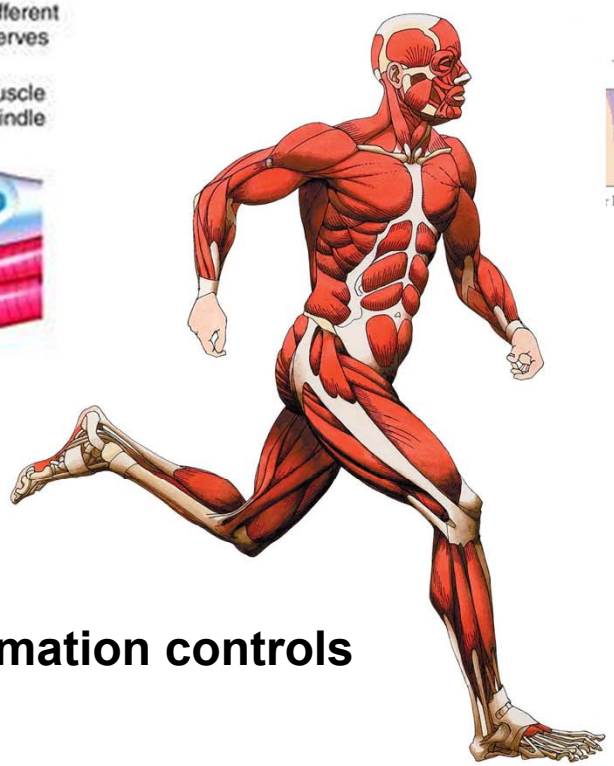
Body load information

Bed rest serves to delineate the role of body unloading in space flight performance changes

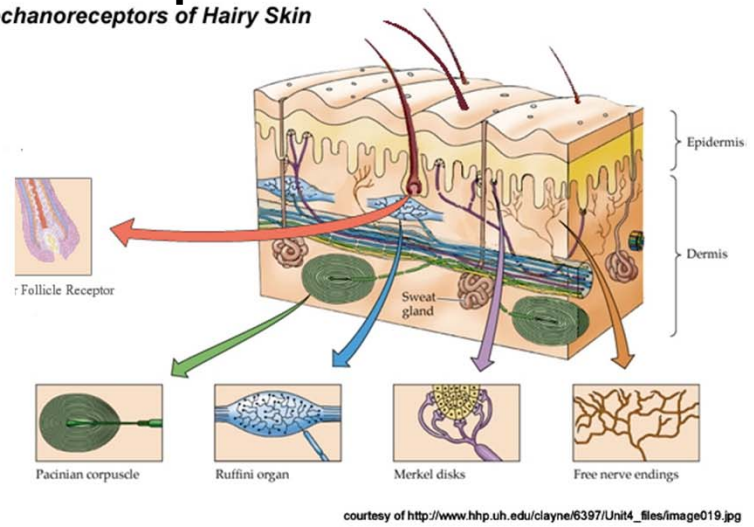
Receptors that Detect Body Load

Muscle Spindles



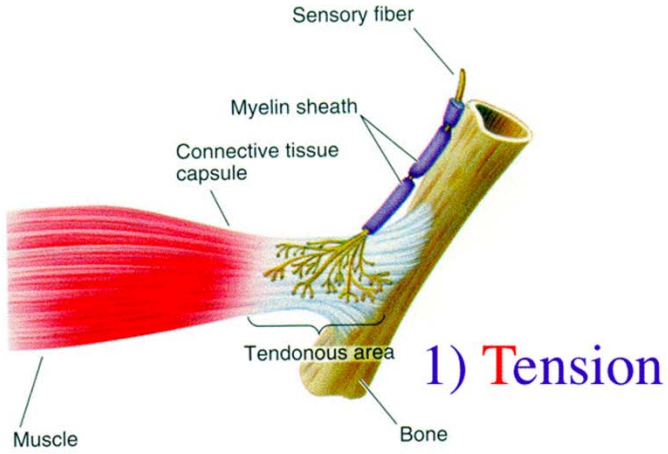


Mechanoreceptors



courtesy of http://www.hhp.uh.edu/clayne/6397/Unit4_files/image019.jpg

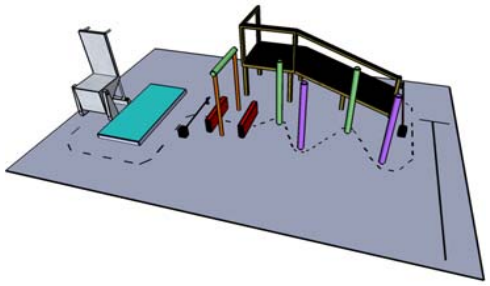
Golgi Tendon Organ



Body loading information controls motor output:

- **Balance control**
- **Generation of stepping patterns**
- **Termination of gait**

Functional Tests



Seat Egress and Walk

Ladder Climb

Torque Generation

Rock Translation

Recovery from Fall/Stand

Construction Activity

Jump Down

Functional Tests: Parameter List

TestName	TestCondition	Parameter
All Tests		Heart Rate
Activity Board		Time to Complete Activity Board Test
Egress	Seated & Reclined	Lag Time of Head Yaw relative to Trunk Yaw
Egress	Seated & Reclined	RMS of Head Yaw relative to Trunk Yaw
Egress	Seated & Reclined	Time from Start through End of Slalom Section
Egress	Seated & Reclined	Time from Portal Entry through Slalom Section
Egress	Seated & Reclined	Time to Decend Ramp
Egress	Seated & Reclined	Time from Start to Portal Entry
Egress	Seated & Reclined	Total Time to Complete Entire Egress Course
Egress	Seated & Reclined	Time to Ascend and Decend Ramp
Egress	Seated & Reclined	Time from Start through Portal Completion
Egress	Seated & Reclined	Time to Complete Portal Section
Egress	Seated & Reclined	Time from Portal Completion through Slalom Section
Egress	Seated & Reclined	Time from Start to Top of Ramp
Egress	Seated & Reclined	Time from End of Slalom Course to Top of Ramp
Fall Recovery	Prone & Stand	Diastolic Blood Pressure
Fall Recovery	Prone & Stand	Heart Rate
Fall Recovery	Prone & Stand	Pulse Pressure
Fall Recovery	Prone & Stand	R-R Interval (High Frequency)
Fall Recovery	Prone & Stand	R-R Interval (Low:High Frequency Ratio)
Fall Recovery	Prone & Stand	R-R Interval
Fall Recovery	Prone & Stand	Systolic Blood Pressure (Low Frequency)
Fall Recovery	Prone & Stand	Systolic Blood Pressure
Fall Recovery	Stand	Settling Time of the Vertical Ground Reaction Force during Transition from Prone to Stand
Fall Recovery	Stand	Mean Sway Speed of Vertical Ground Reaction Force: 2D-Resultant
Fall Recovery	Stand	Mean Sway Speed of Vertical Ground Reaction Force: Anterior-Posterior
Fall Recovery	Stand	Mean Sway Speed of Vertical Ground Reaction Force: Medial-Lateral
Jump Task		Air Time of Jump
Jump Task		Settling Time of the Vertical Ground Reaction Force upon Landing
Jump Task		Peak Vertical Ground Reaction Force upon Landing
Jump Task		Time Difference of Take-Off Between the Leading and Lagging Feet
Jump Task		Time to Peak Vertical Ground Reaction Force upon Landing
Ladder Climb		Time to Climb 40 Rungs on the Ladder
Rock Translation		Time to Move Rocks to Second Rack and Back to First Rack
Rock Translation		Time to Move Rocks to Second Rack Only
Torque Generation	Isometric	Torque Generation: Maximum Isometric Force
Torque Generation	Isotonic	Torque Generation: Number of Turns during Isotonic Test
Torque Generation	Isotonic	Torque Generation: Total Work during Isotonic Test

Physiological Tests: Parameter List

TestName	TestCondition	Parameter
All Tests		Heart Rate
Bench Press	Force Control	Bench Press Force Control: No Visual
Bench Press	Force Control	Bench Press Force Control: Visual
Bench Press	Max Isometric Force	Bench Press Maximum Isometric Force
Bench Press	Max Isometric Force	Bench Press Rate of Force Development
Bench Press	Power Endurance	Bench Press Maximum Power (Endurance Test)
Bench Press	Power Endurance	Bench Press Total Work
Knee Extension	Force Control	Knee Extension Force Control: No Visual
Knee Extension	Force Control	Knee Extension Force Control: Visual
Knee Extension	Twitch	Interpolated Twitch: Central Activation Capacity
Knee Extension	Twitch	Interpolated Twitch: Central Activation Ratio
Knee Extension	Twitch	Knee Extension Maximum Isometric Force
Knee Extension	Twitch	Knee Extension Rate of Force Development
Leg Press	Max Isometric Force	Leg Press Maximum Isometric Force
Leg Press	Max Isometric Force	Leg Press Maximum Isometric Force Normalized to Body Weight
Leg Press	Max Isometric Force	Leg Press Rate of Force Development
Leg Press	Power Endurance	Leg Press Maximum Power (Endurance Test)
Leg Press	Power Endurance	Leg Press Total Work
Line Test		Percent Correct Steps during Line Test
Line Test		RMS of Torso Linear Acceleration (Resultant) over Line Test Trial
Line Test		RMS of Torso Roll Velocity over Line Test Trial
Line Test		RMS of Torso Pitch Velocity over Line Test Trial
Line Test		RMS of Torso Yaw Velocity over Line Test Trial
Line Test		Time to Complete Line Test Trial
Line Test		Tandem Walk (Line Test) Parameter
Fine Motor		Time to Complete Pegboard Task
Plasma Volume		Blood Volume
Plasma Volume		Hematocrit
Plasma Volume		Hemoglobin
Plasma Volume		Plasma Volume
Plasma Volume		Plasma Volume Index
Plasma Volume		Red Cell Volume
Posture Test		Equitest Score
Locomotion	Dynamic	Head pitch: Sum of FFT Spectral Powers between 1.5-2.5 Hz
Locomotion	Dynamic	Maximum Lag from the Cross-Correlation of Head Pitch and Torso Pitch
Locomotion	Dynamic	Maximum Value of the Cross-Correlation of Head Pitch and Torso Pitch
Locomotion	Dynamic	Maximum Lag from the Cross-Correlation of Head Pitch and Torso Vertical Position
Locomotion	Dynamic	Maximum Value of the Cross-Correlation of Head Pitch and Torso Vertical Position
Locomotion	Dynamic	Average Step Time while Walking for the DVA Test
Locomotion	Dynamic	Standard Deviation of Step Time while Walking for the DVA Test
Locomotion	Dynamic	Torso Pitch: Sum of FFT Spectral Powers between 1.5-2.5 Hz
Locomotion	Dynamic	Torso Vertical Position: Sum of FFT Spectral Powers between 1.5-2.5 Hz
Locomotion	Dynamic	Visual Acuity Score Post Bed Rest relative to Average Pre Bed Rest

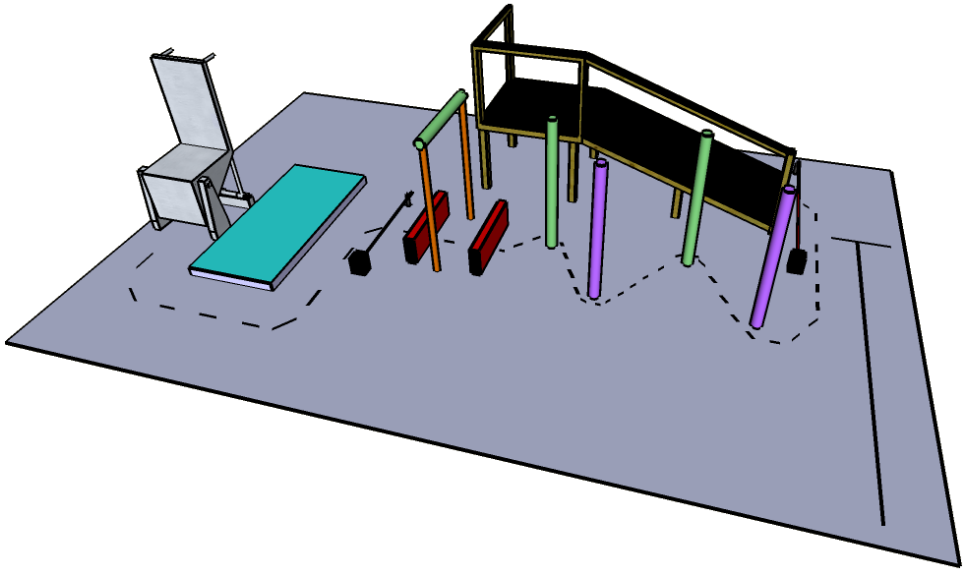
Instrumentation for Functional Testing

Body motion sensors on head and trunk: kinematics

Holter monitor: ECG

Portapres: continuous blood pressure

Seat Egress and Walk Test

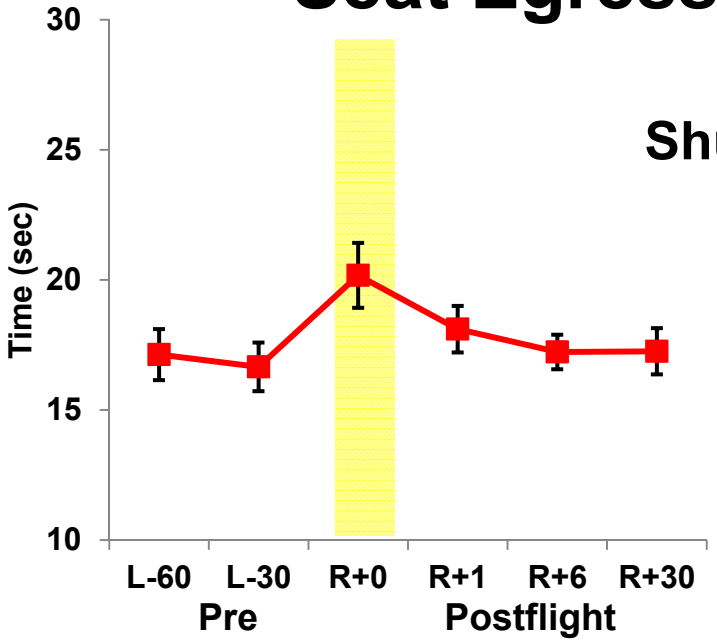


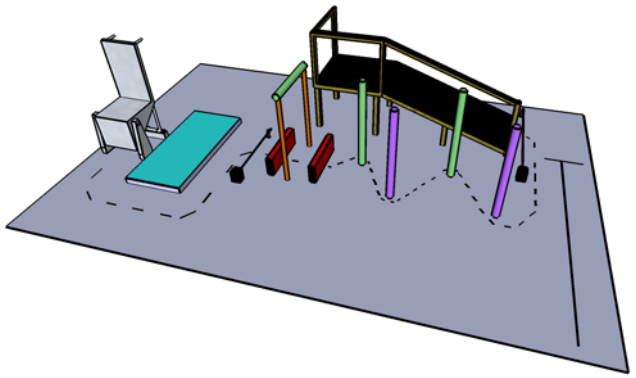
Subject unbuckled a harness, stood up from a seat and then completed an obstacle course.

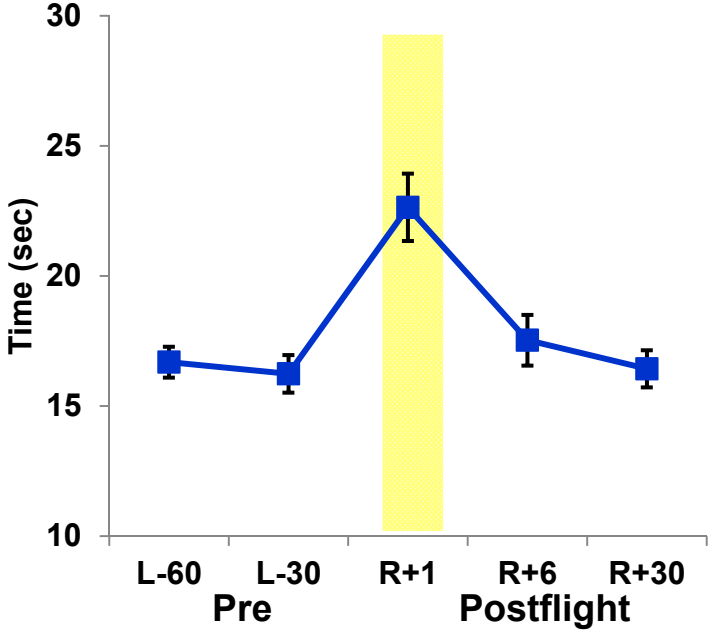
Testing occurred with:

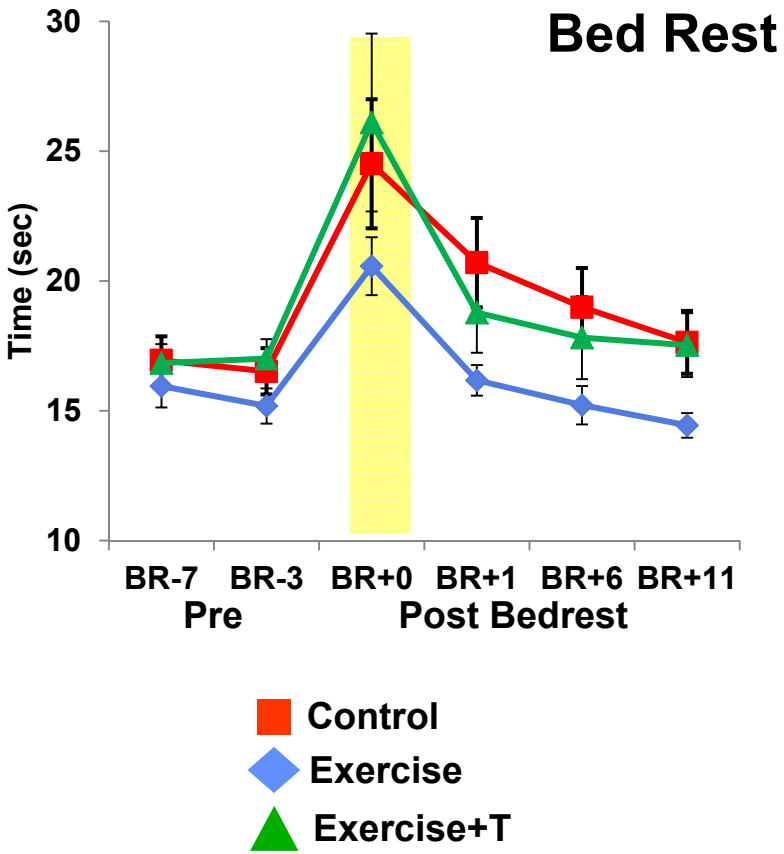
- Seat upright (Upright Seat Egress)
- Seat positioned with its back to the floor (Supine Seat Egress)

Seat Egress and Walk Test (Upright)

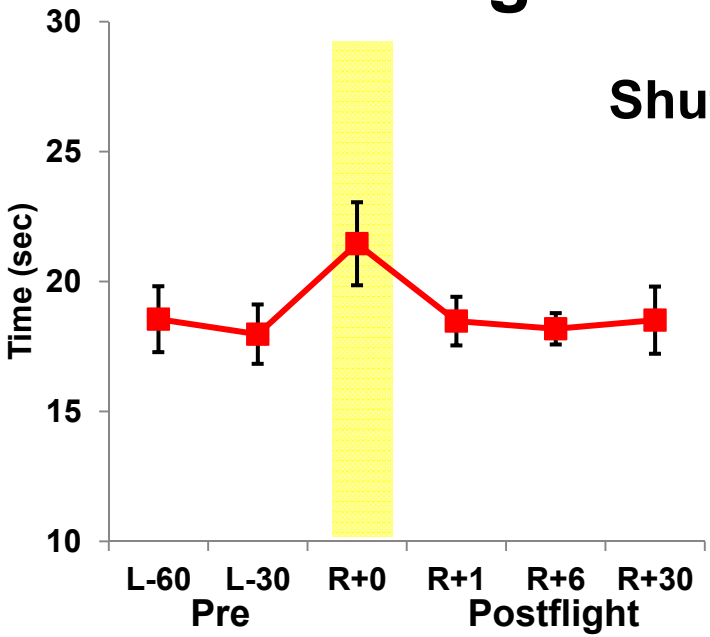


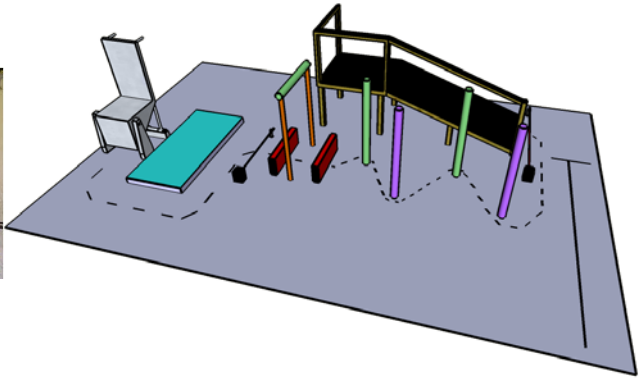


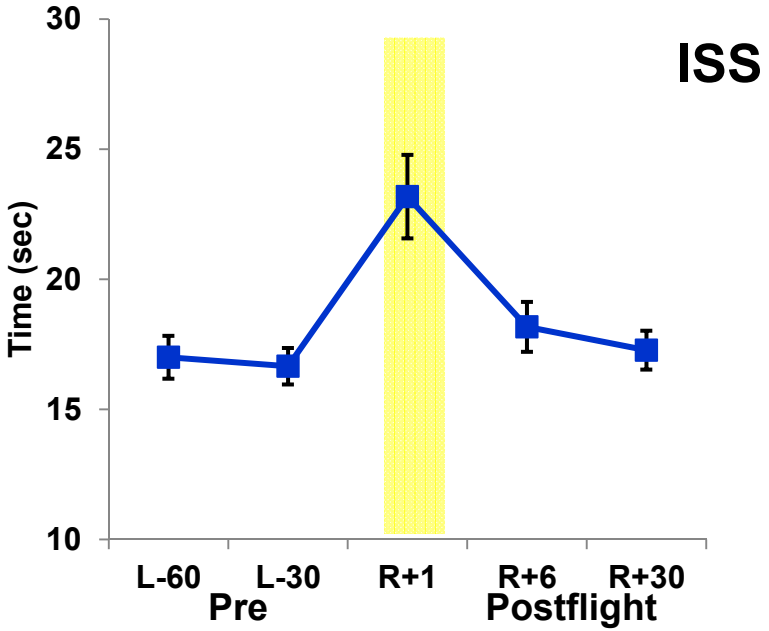


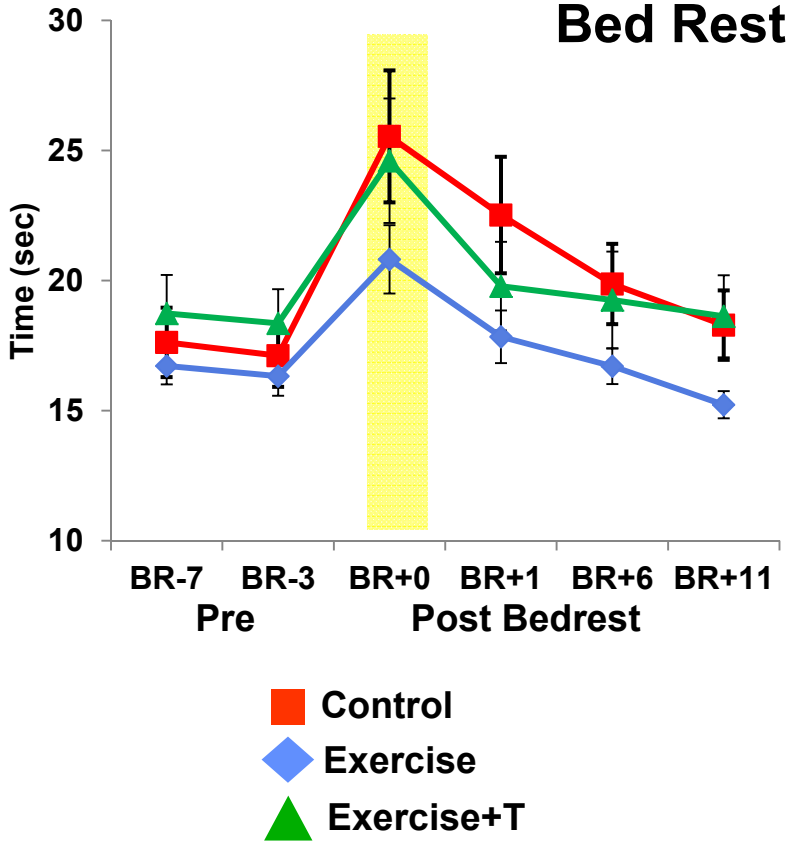


Seat Egress and Walk Test (Supine)





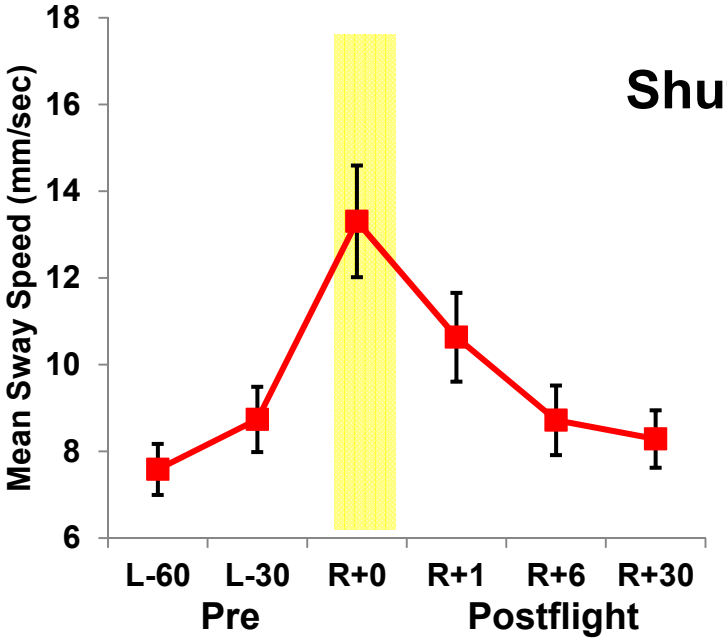


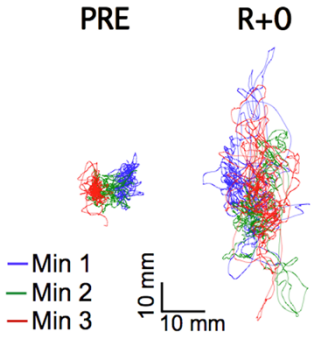


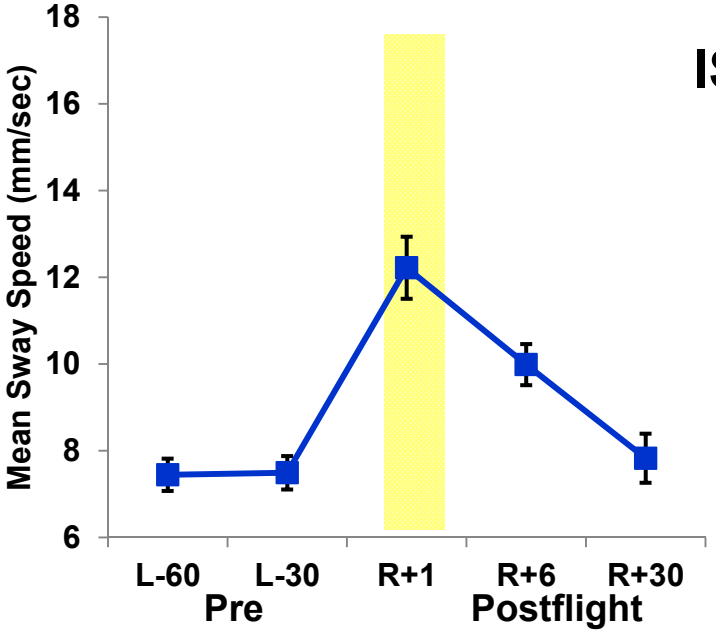
Recovery from Fall/Stand Test

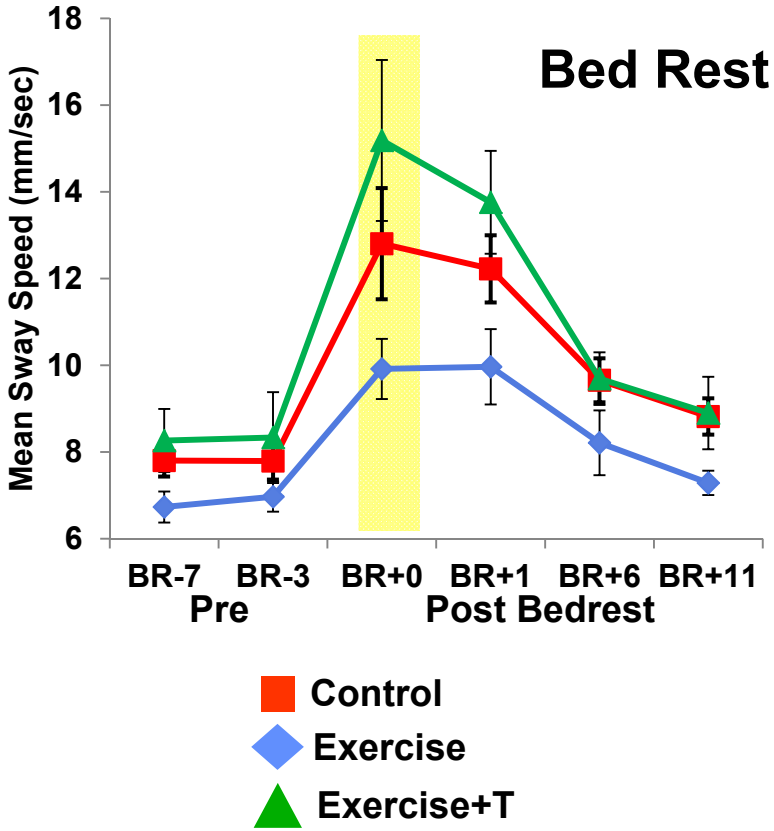
Subjects were asked to lie face down on a foam surface for 2 minutes and then stand up as quickly as possible and step on a force plate and remain standing for 3 minutes.

Recovery from Fall: Mean Sway Speed

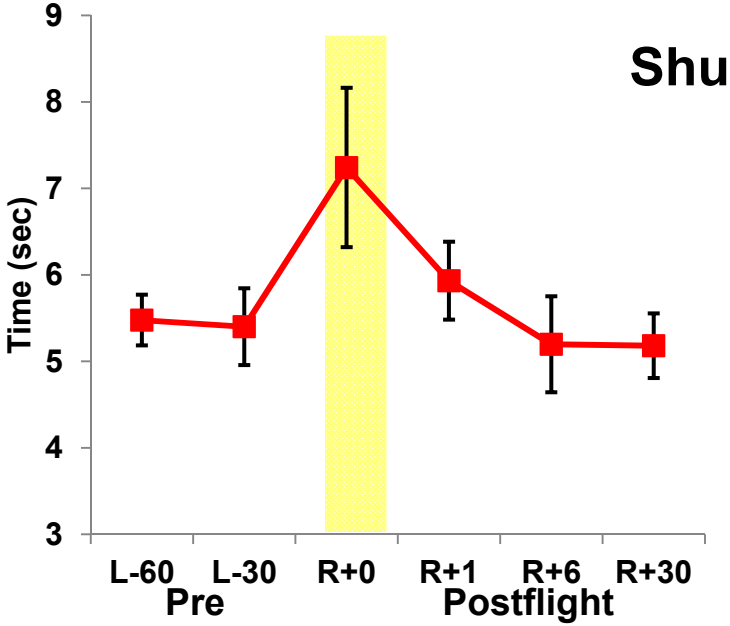


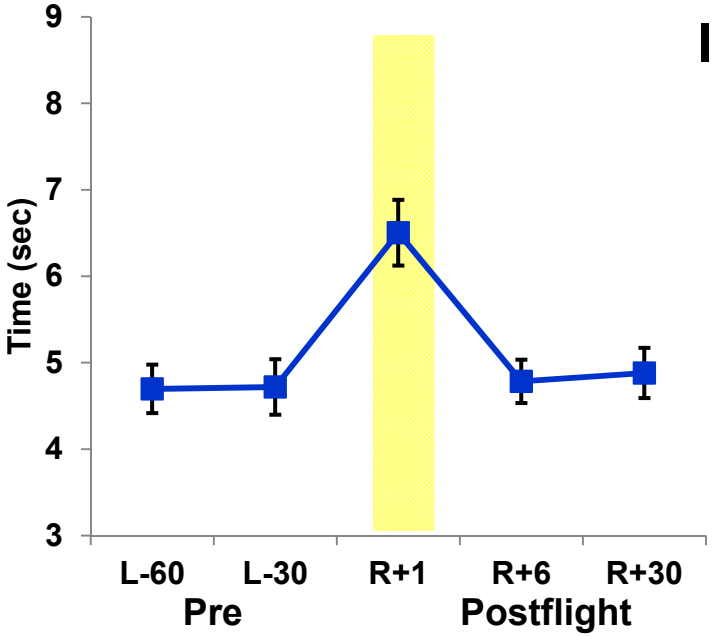


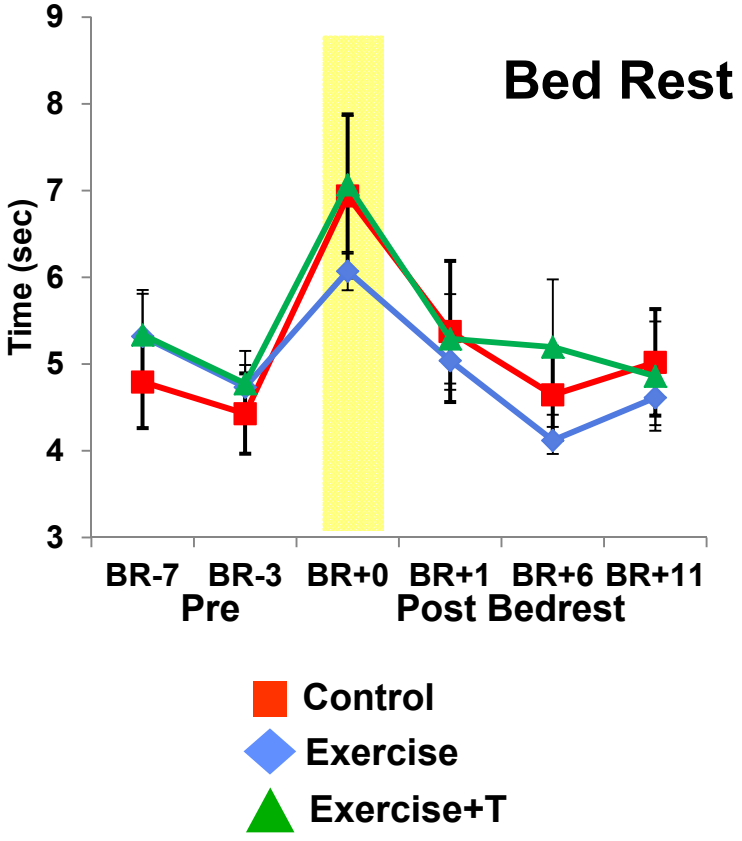




Recovery from Fall: Postural Settling Time



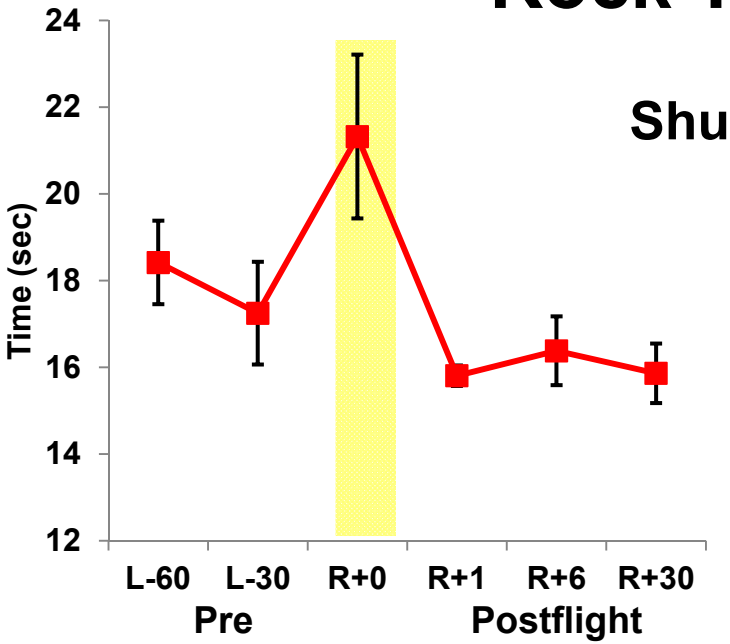


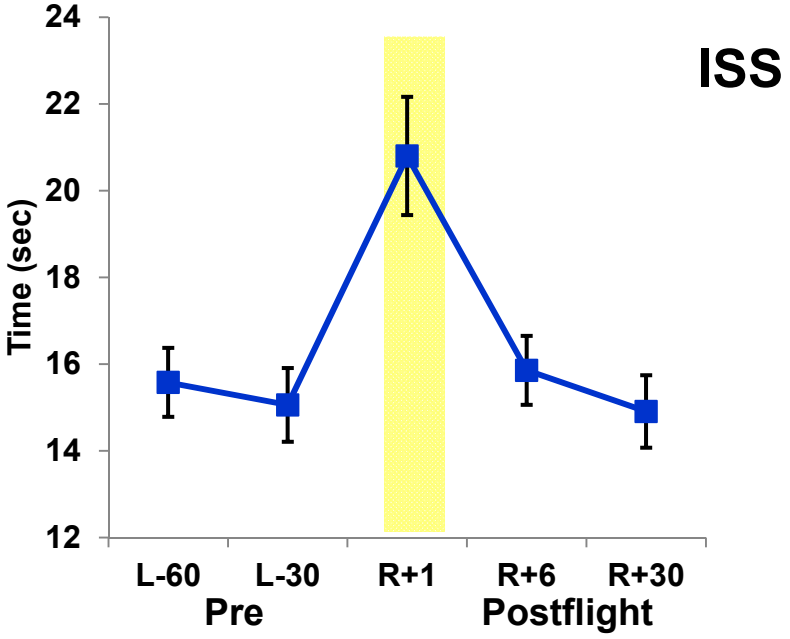


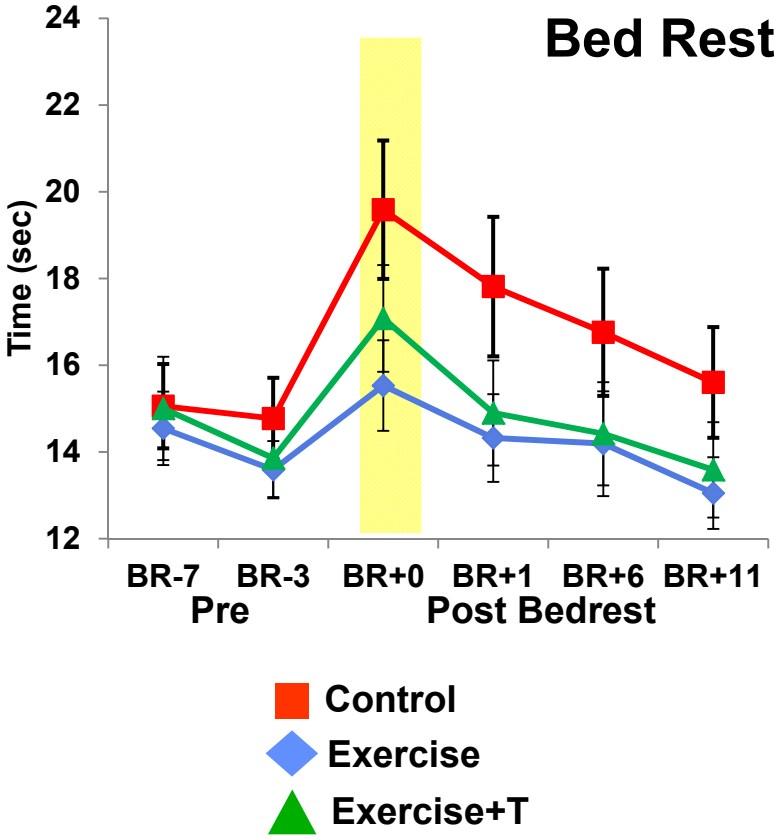
Rock Translation Test

Subjects transferred three weights with handles (2.7 kg, 4.5 kg, 9 kg), one at a time, a distance of 2.4m and placed them in a receptacle and then transferred the weights back to the initial receptacle.

Rock Translation Test



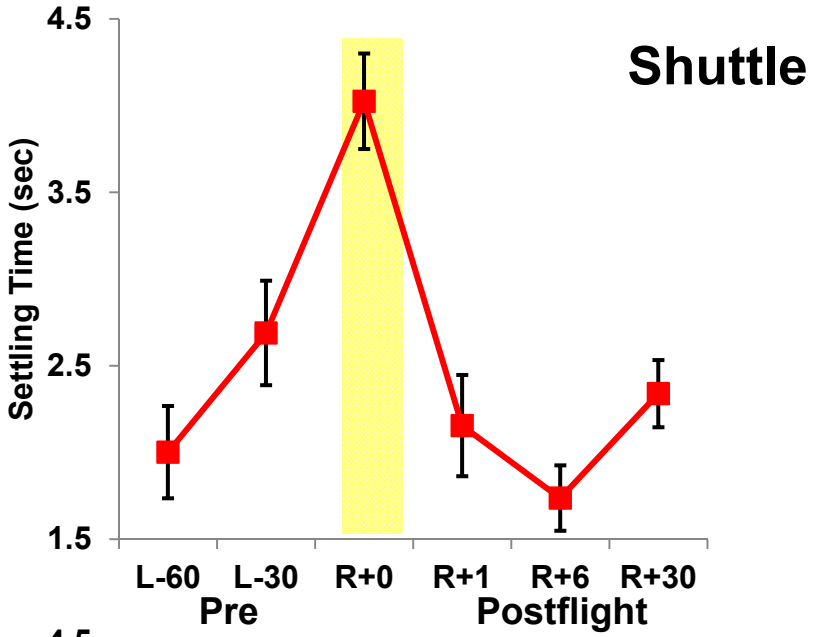


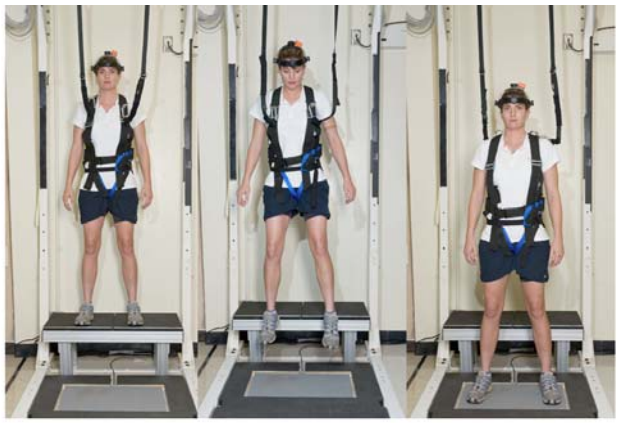


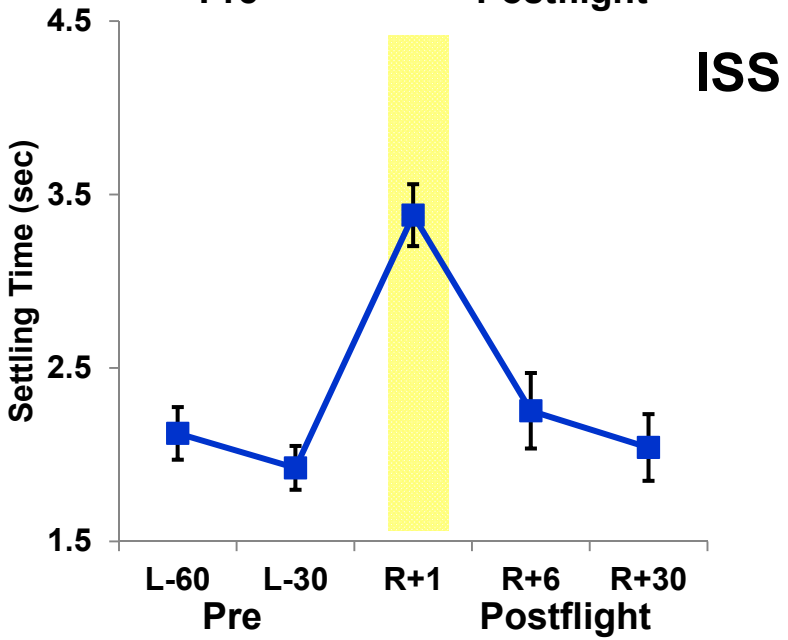
Jump Down Test

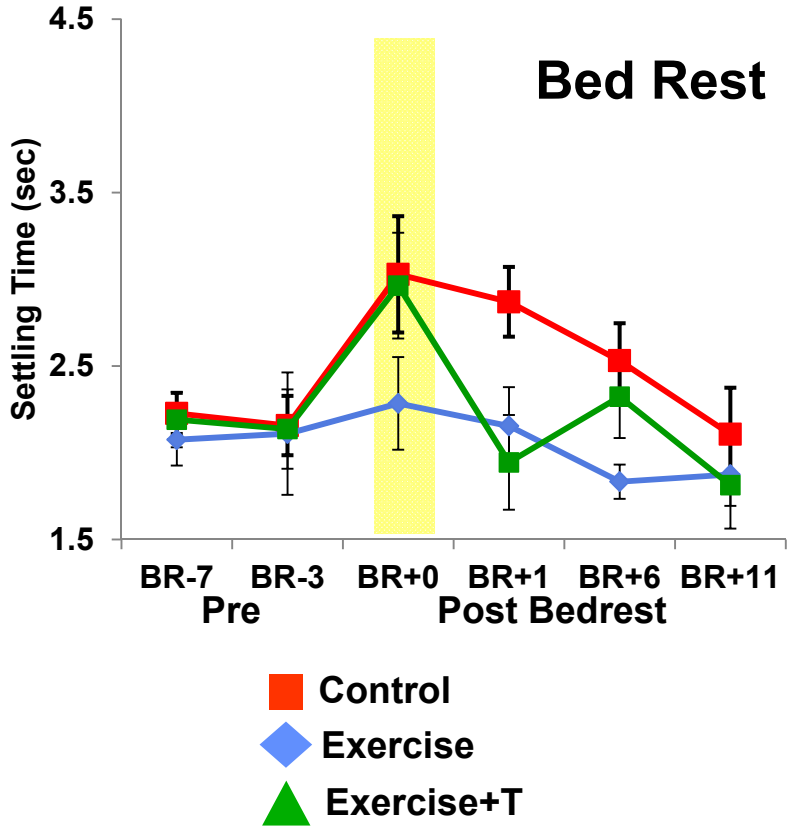
Subjects jumped down from a platform (30 cm height) onto a force plate to measure postural stability

Jump Down Test: Postural Settling Time







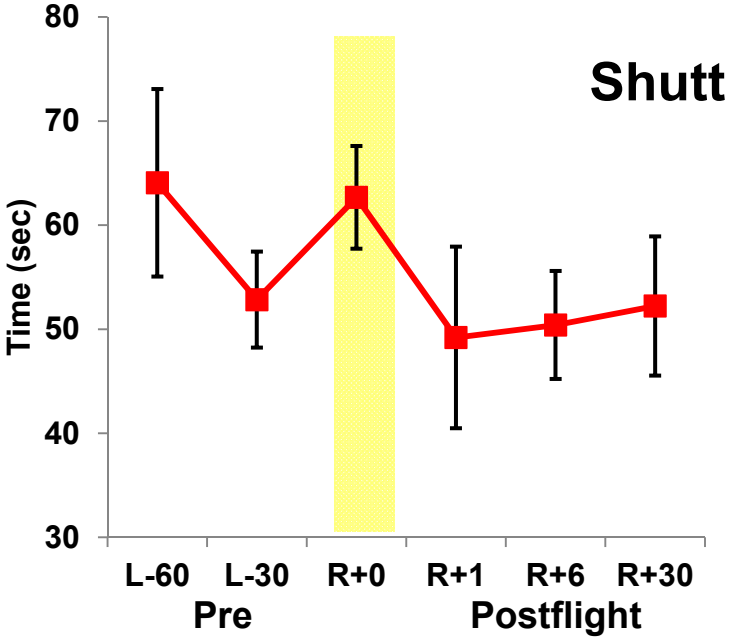


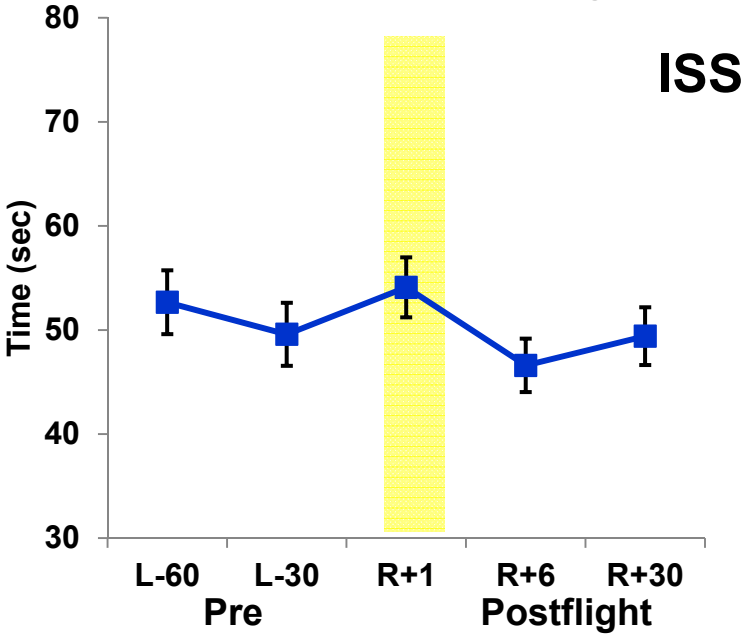
Construction Activity Board

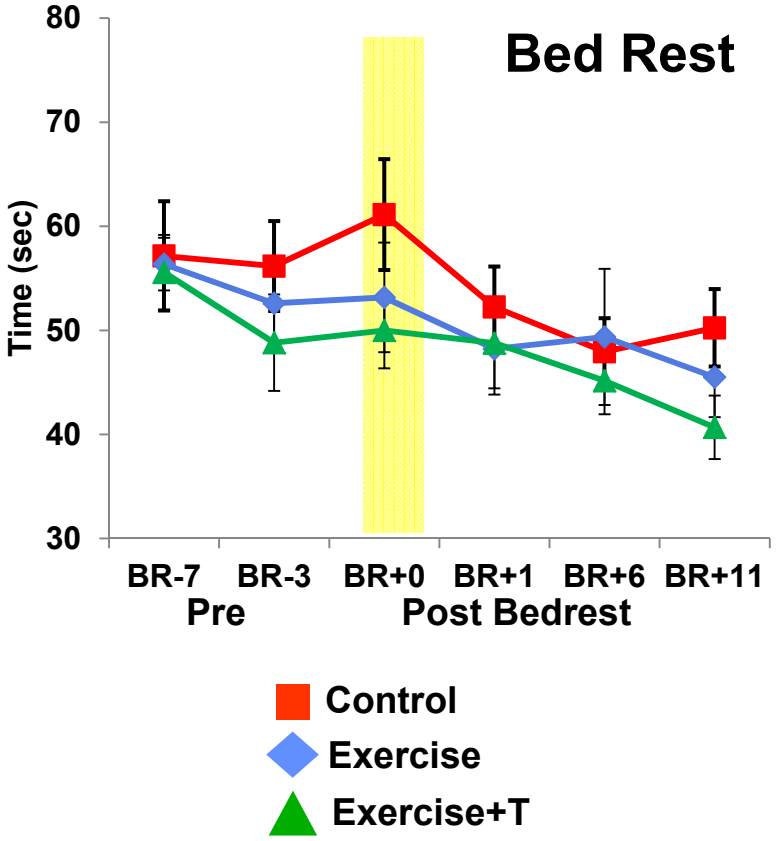
Subjects performed a variety of standard construction and assembly tasks:

- Connecting hoses to receptacles
- Mating a series of electrical connectors
- Using a cordless power tool to remove and tighten bolts on a handle assembly

Construction Activity Board







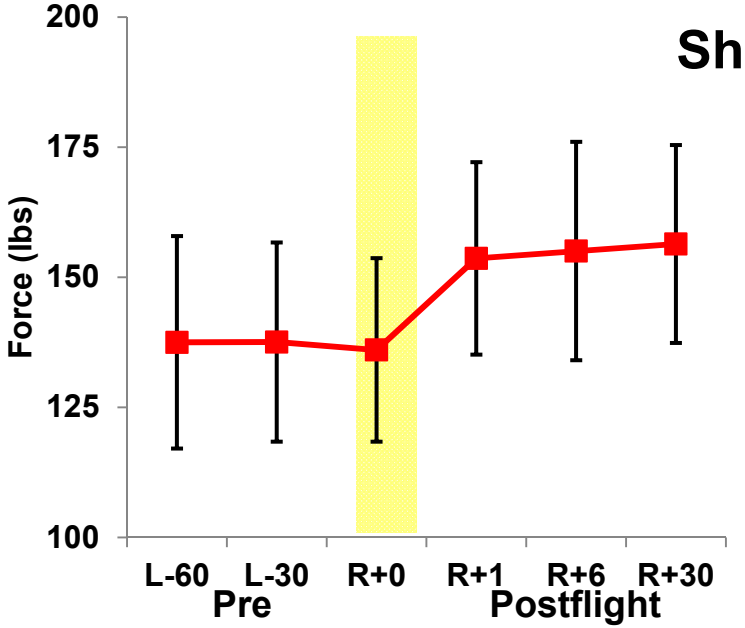
Torque Generation Test

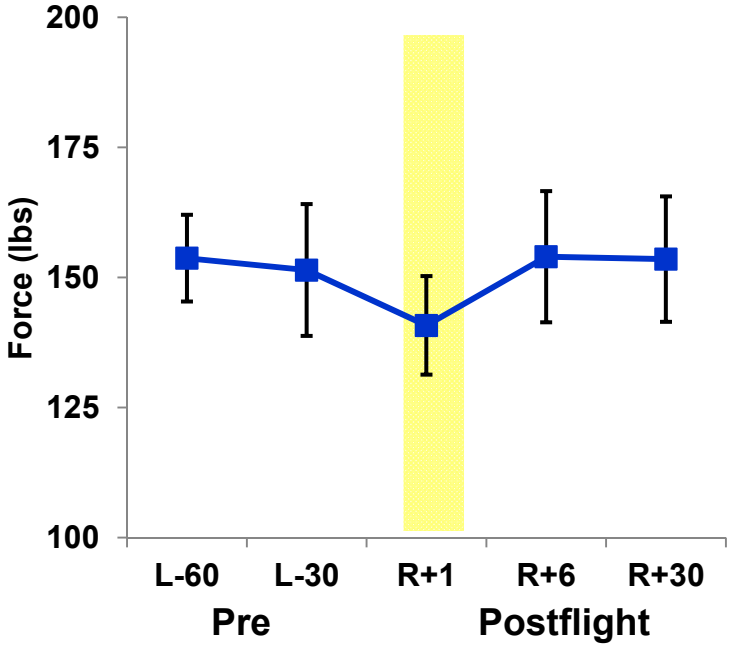
To simulate a hatch-opening task subjects applied torque to a wheel assembly while standing in two conditions:

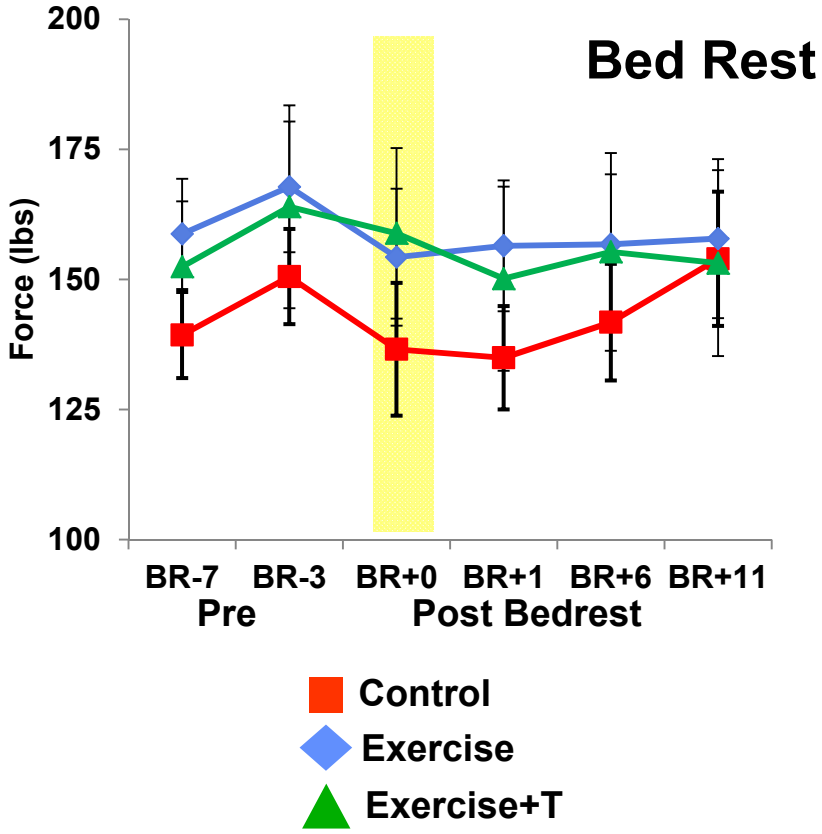
1) Wheel fixed: subjects applied peak torque.

2) Wheel freely moveable with constant resistance. Subject turned the wheel as many times in 20 sec. at 50% peak torque.

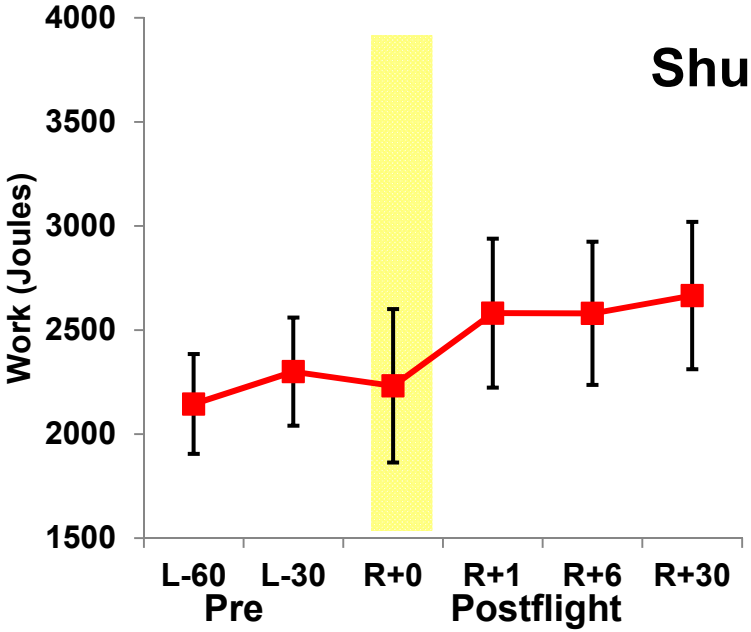
Torque Generation Test: Max. Isometric Force

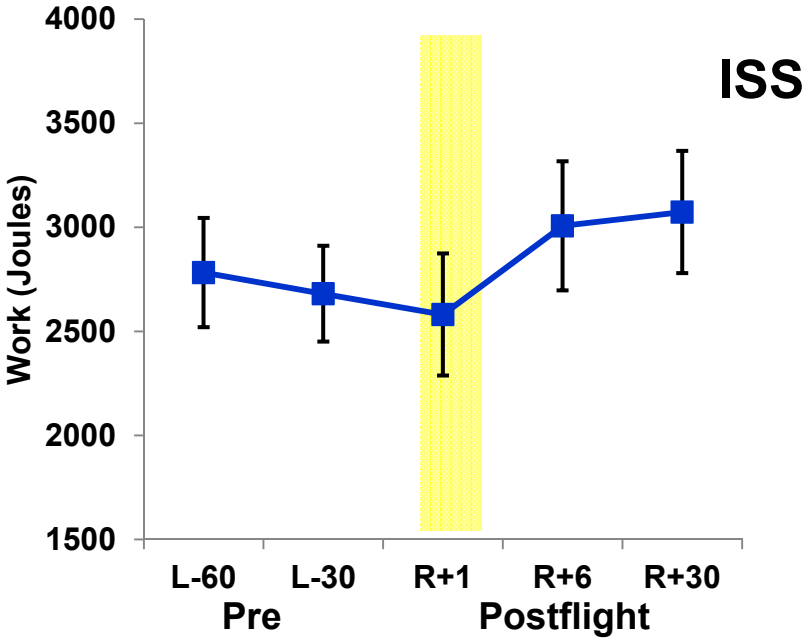


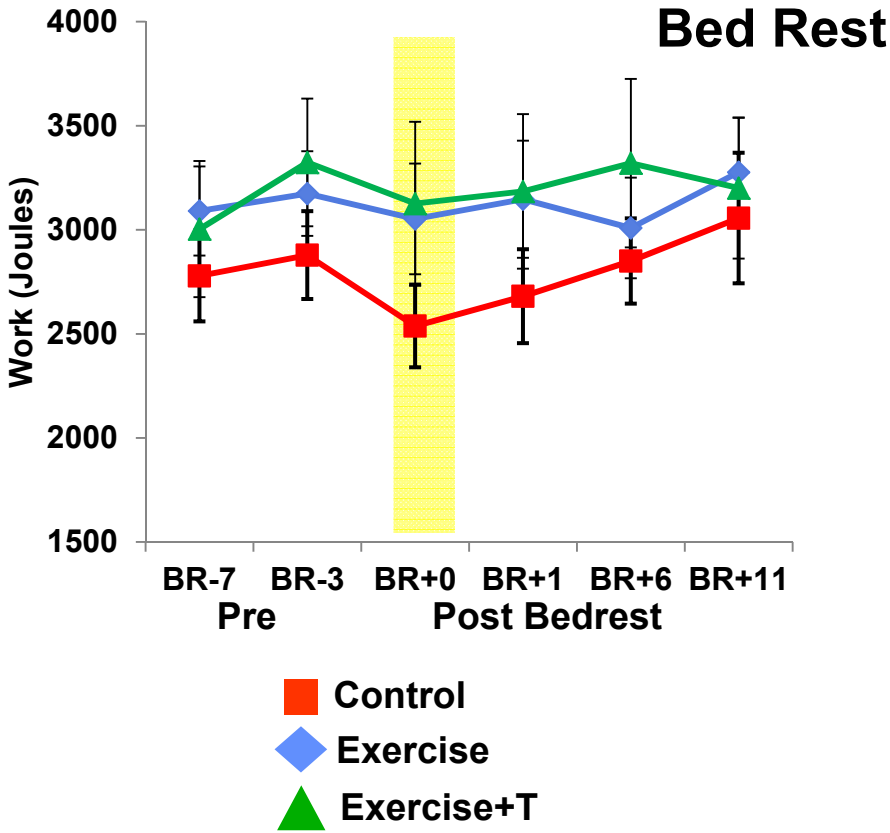




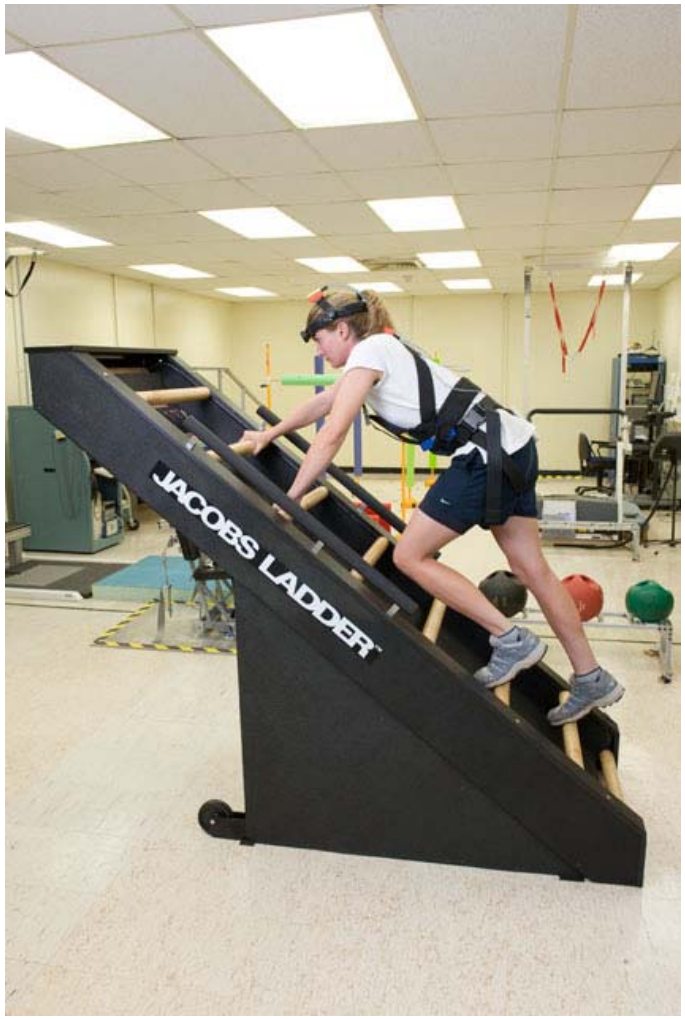
Torque Generation Test: Total Work





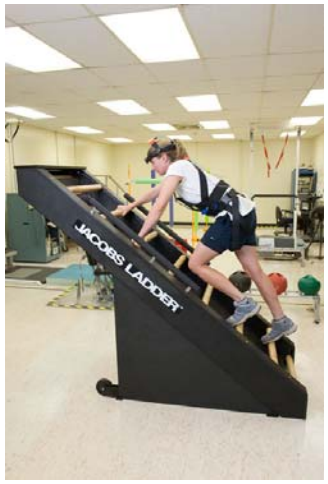


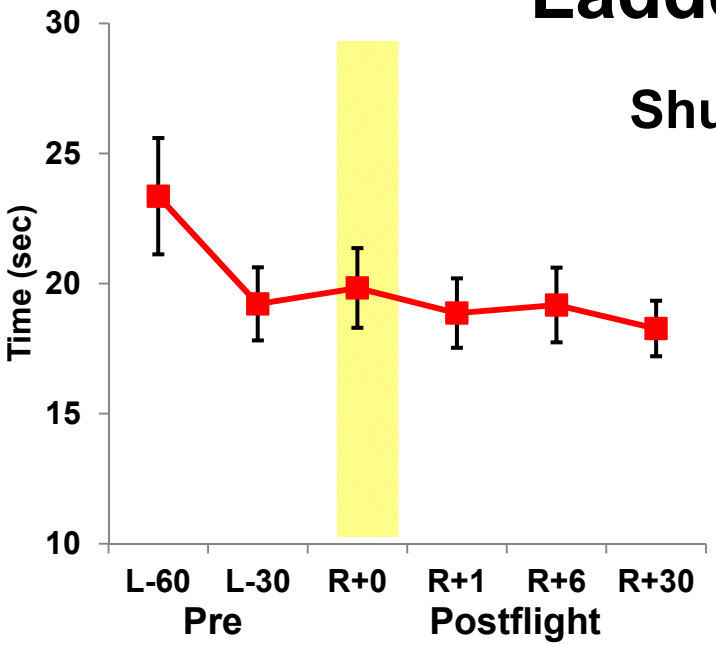
Ladder Climb Test

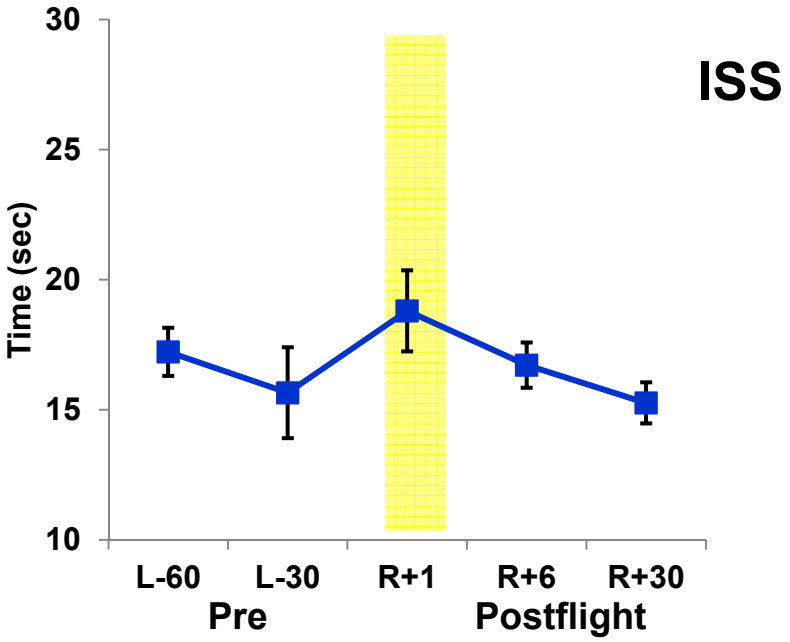


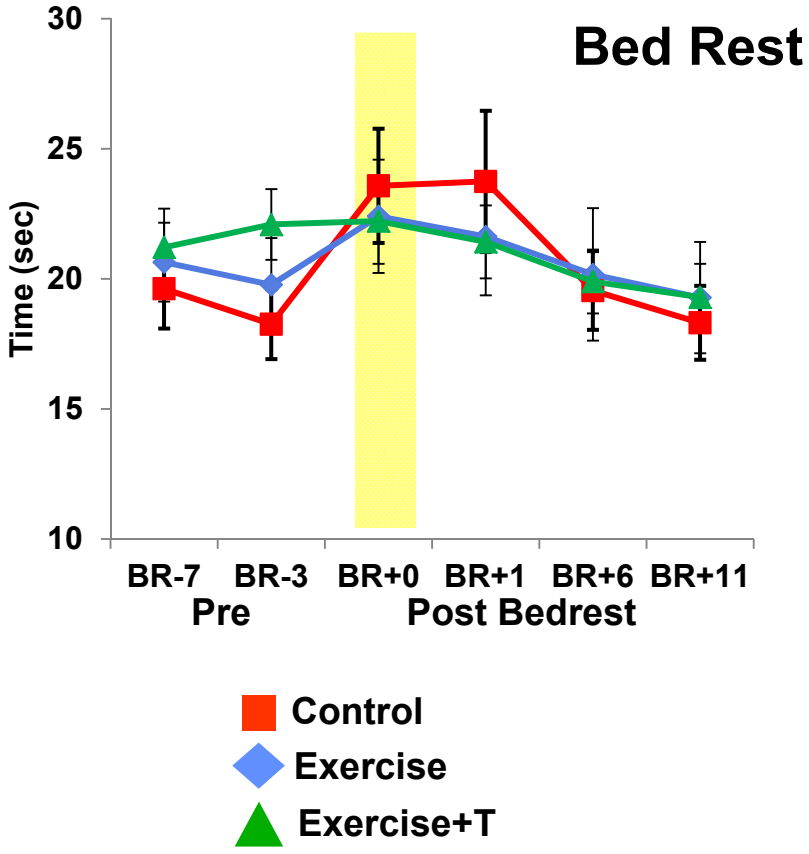
To simulate ladder climbing subjects climbed 40 rungs on a passive treadmill ladder at a self-generated pace.

Ladder Climb Test

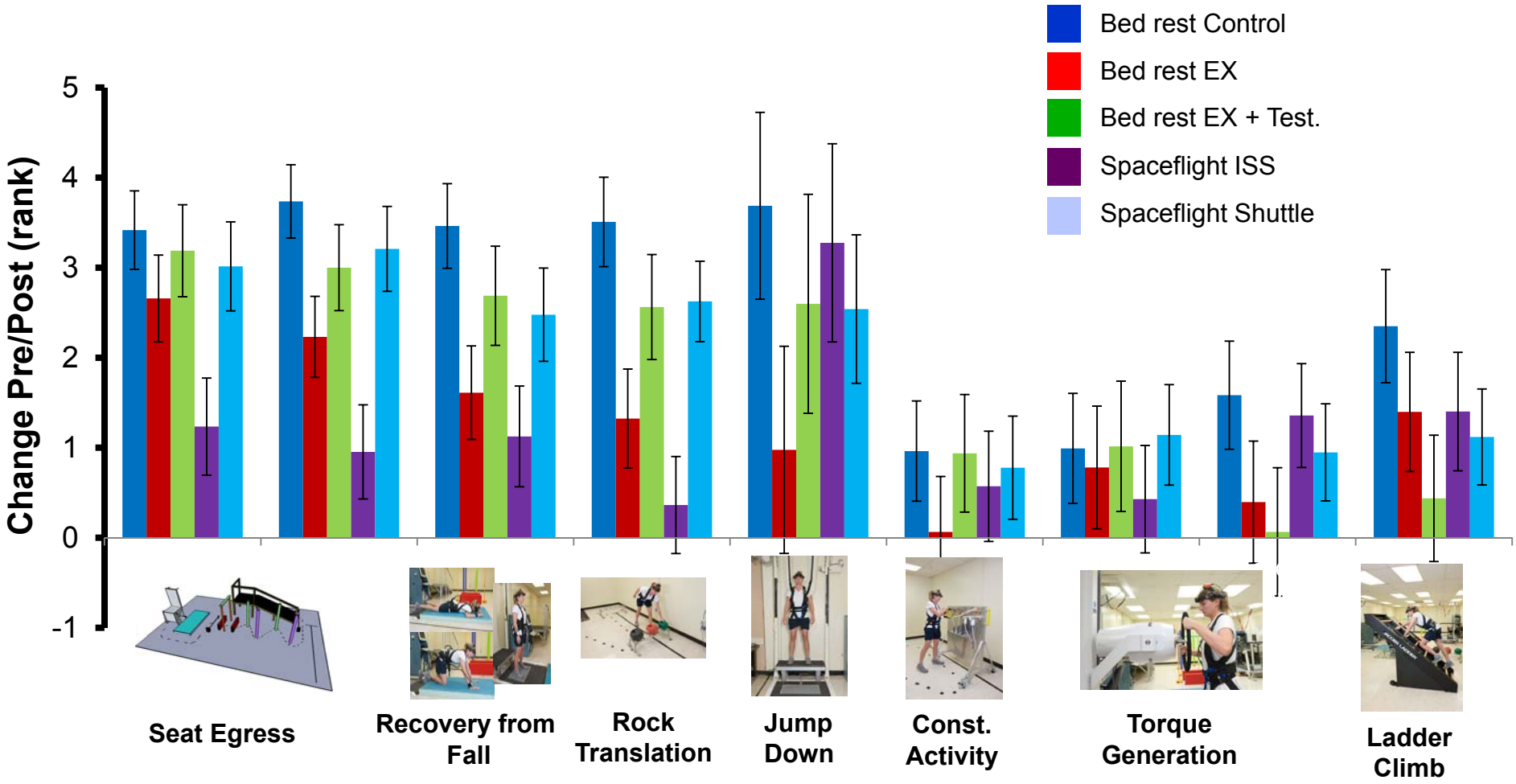








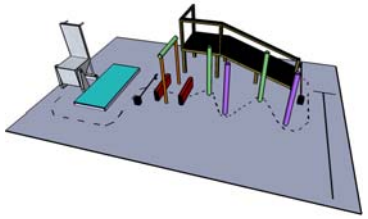
Comparison of Functional Tests



Functional tests with requirements for postural equilibrium to complete (Seat Egress, Recovery from Fall, Rock Translation, Jump Down) showed greatest postflight decrement in performance

Summary: Functional Tests

High Demand for Postural Stability Control



Seat Egress and Walk

Rock Translation

Recovery from Fall/Stand

Jump Down

Low Demand for Postural Stability Control

Construction Activity

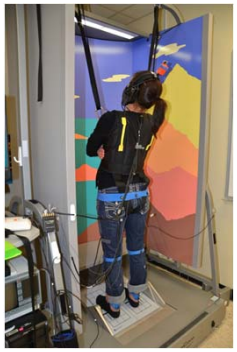
Torque Generation

Ladder Climb

Both space flight <u>and</u> bed rest subjects (control and exercisers) showed greatest deficits in functional tests with higher demand for postural stability control.

Physiological Tests

Sensorimotor
Postural stability
Fine motor control
Gait control
Dynamic visual acuity




Cardiovascular
Plasma volume
Heart Rate
Blood Pressure

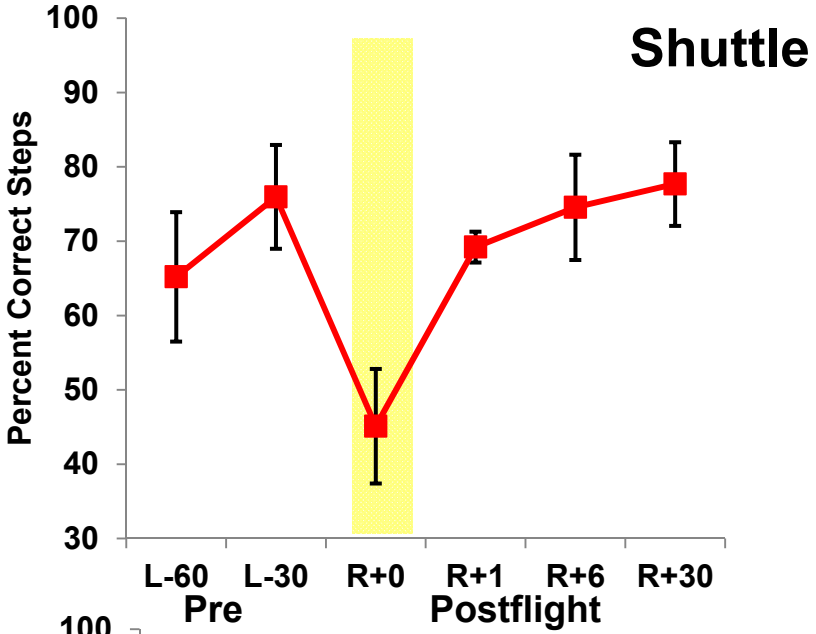
Muscle Performance
Lower body:
Max. isometric force, power/endurance, force control and neuromuscular drive
Upper body:
Max. isometric force, force control, power/endurance

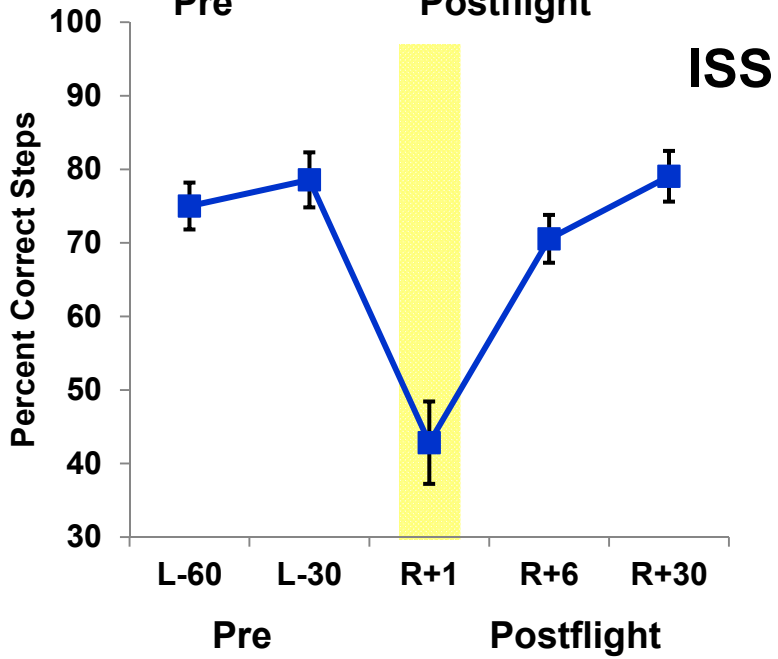


Tandem Walk Test

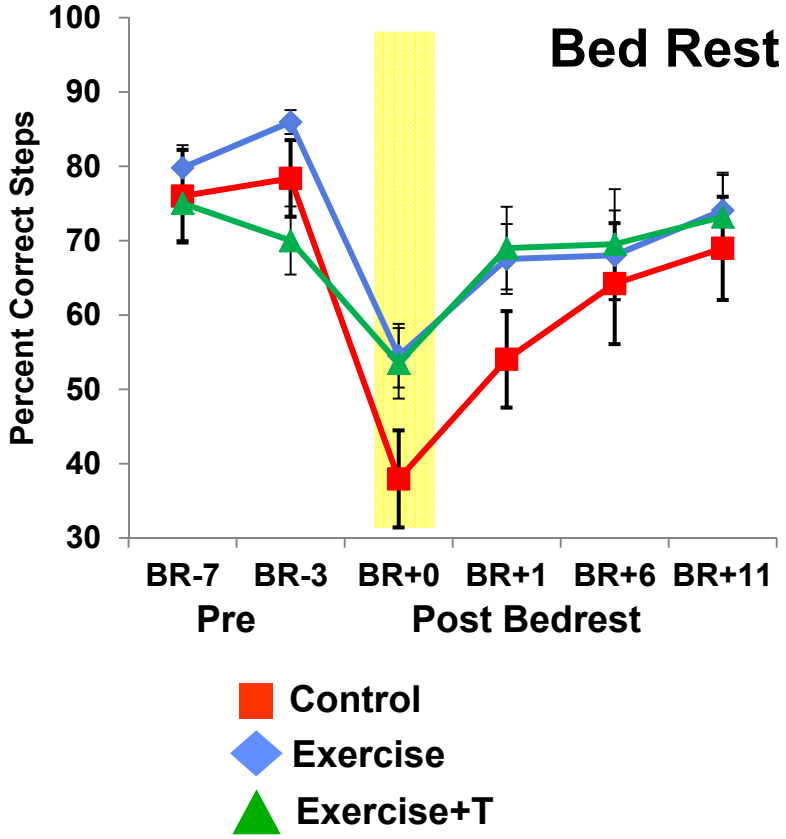
Subjects attempted to walk 10 steps with the eyes closed, arms folded across the chest, while placing the feet in a tandem heel-to-toe position for each step.

Tandem Walk Test: Percentage of Correct Steps

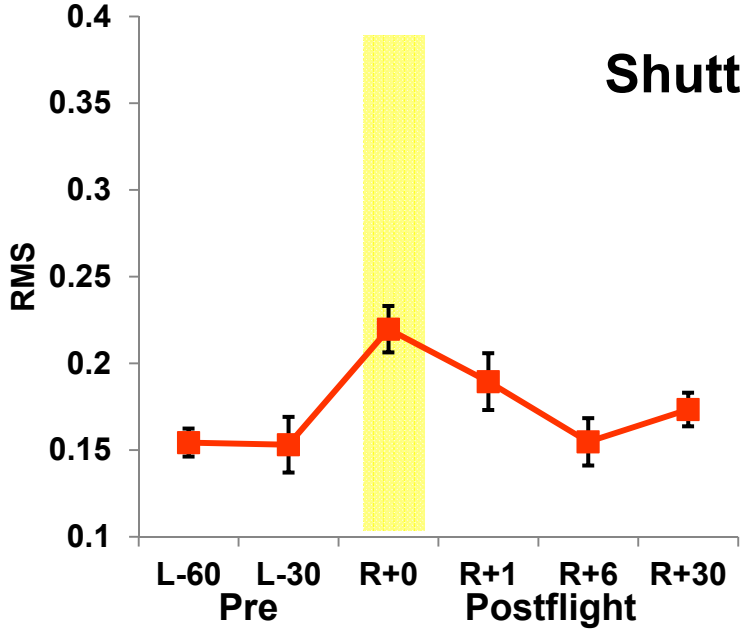


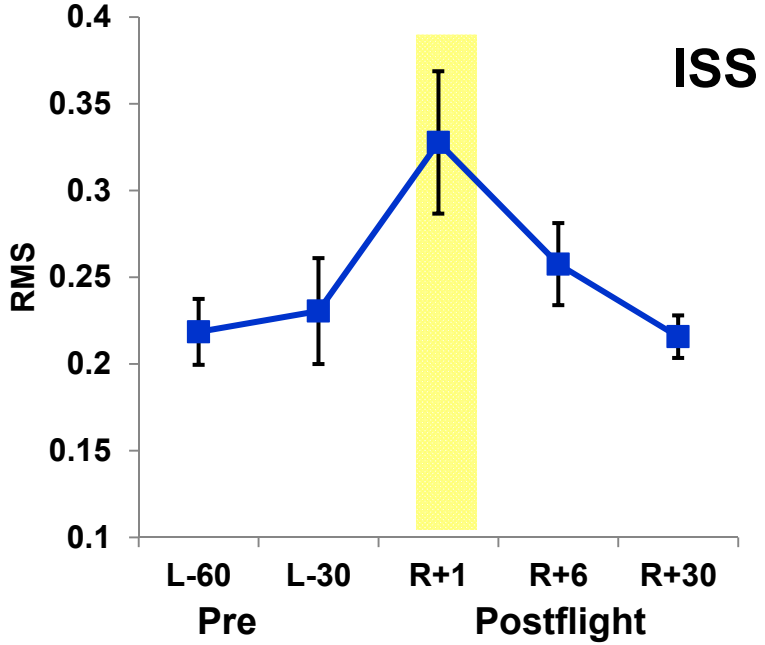


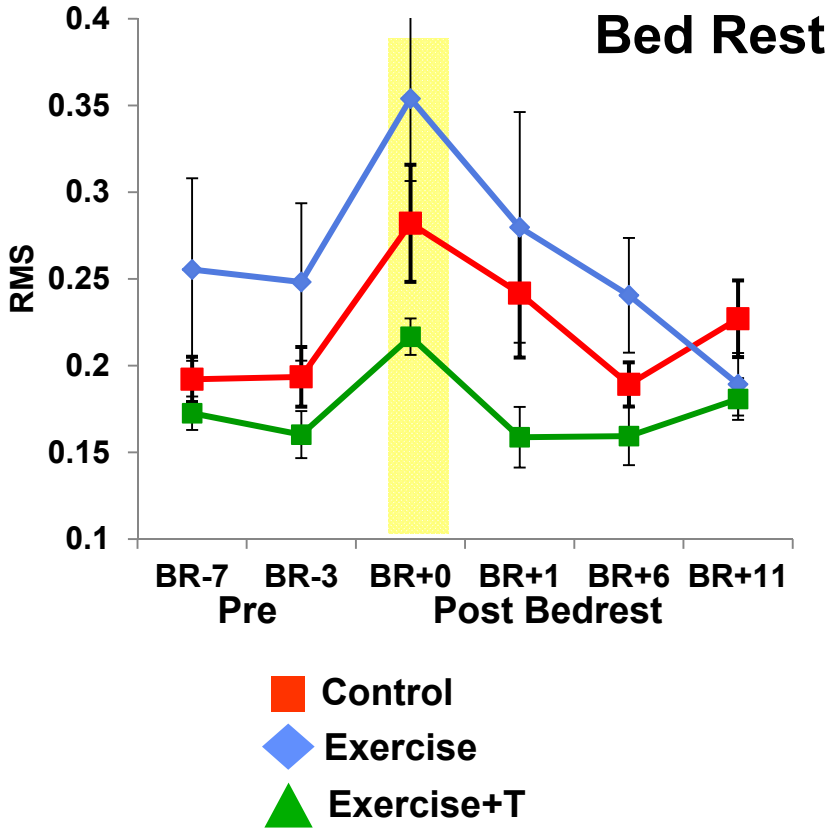
Incorrect Steps: sidestepped, opened eyes, or paused for more than three seconds between steps

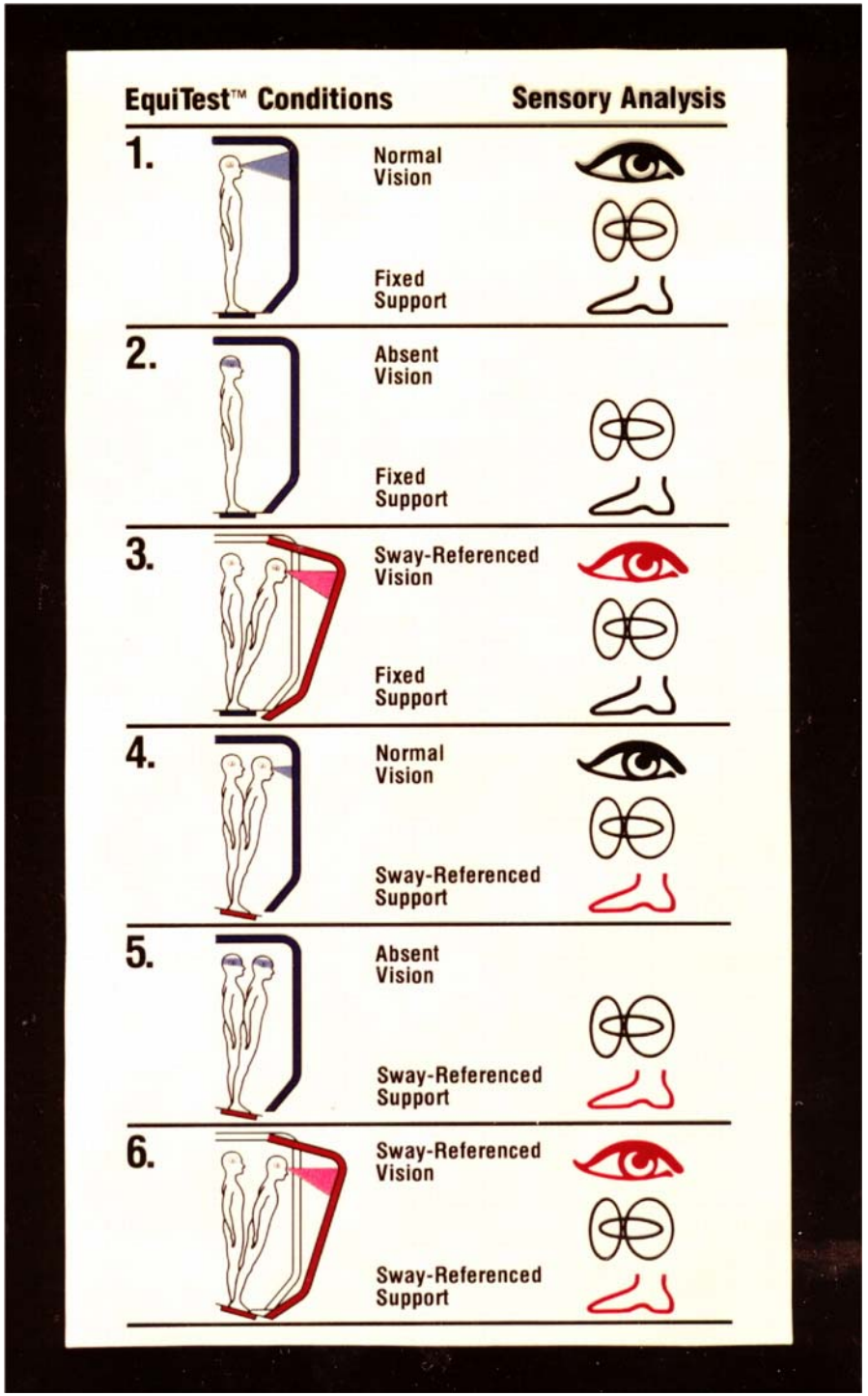


Tandem Walk Test: Torso Roll Velocity RMS

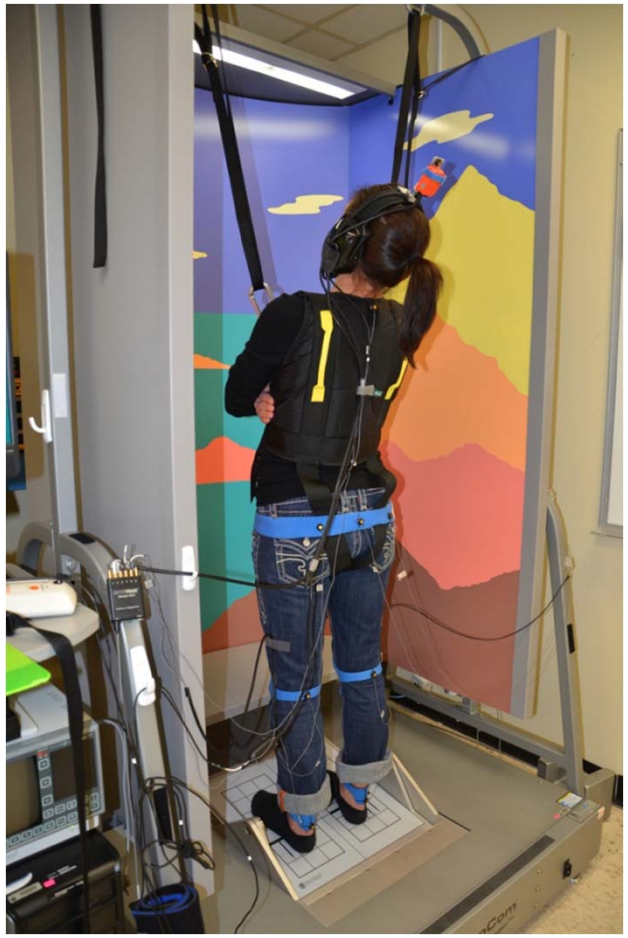






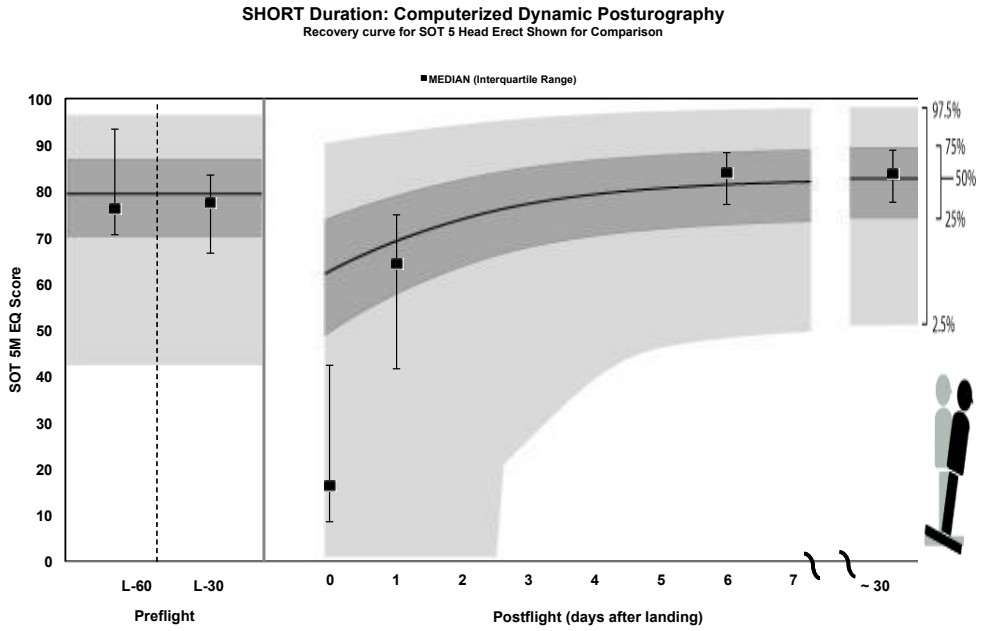


Postural Control Test

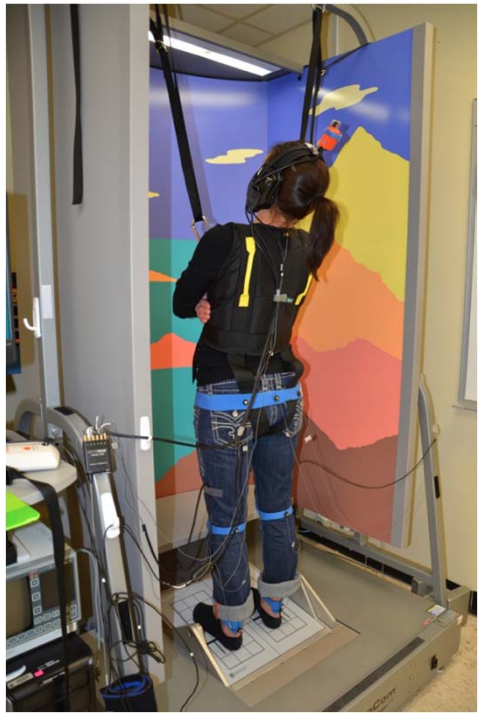


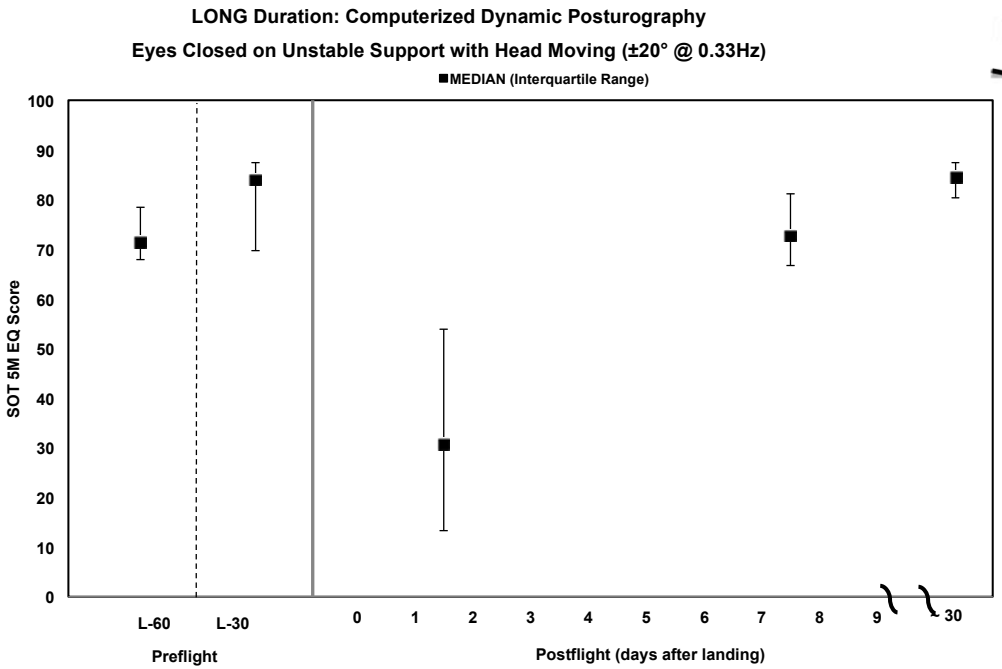
cEQ = (12.5 – Peak to Peak Sway)/12.5 * % trial completed

Postural Equilibrium Control: Space Flight



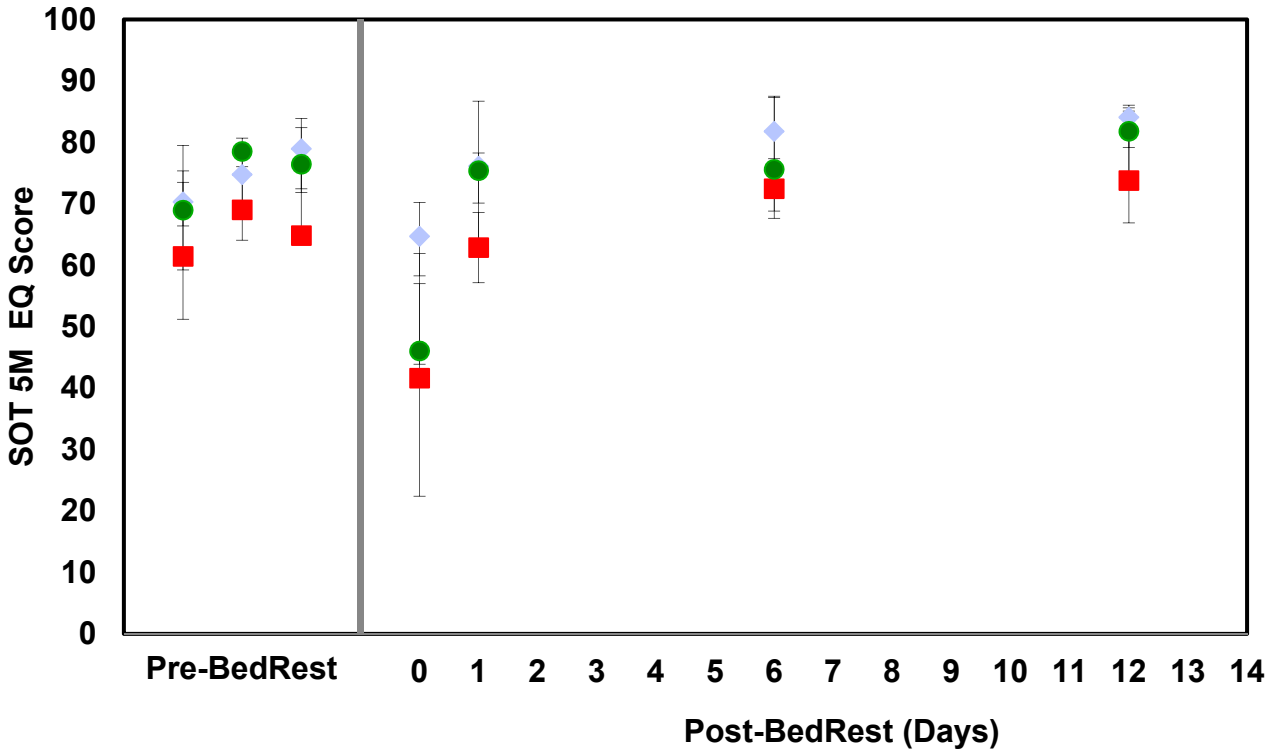
Shuttle





ISS

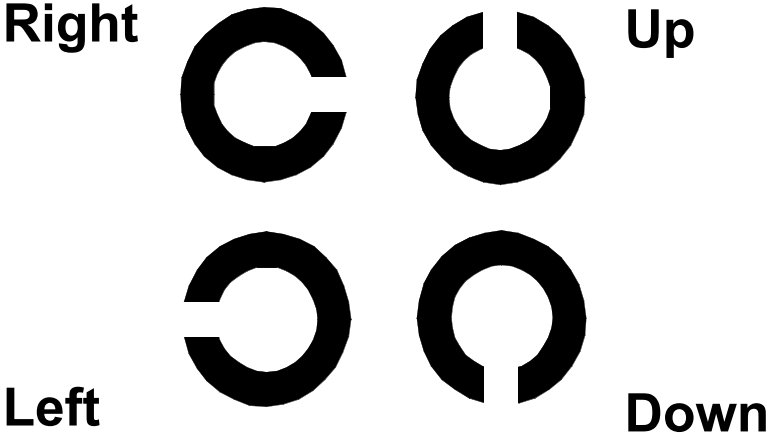
Postural Equilibrium Control: Bed Rest



Control
Exercise
Exercise+T

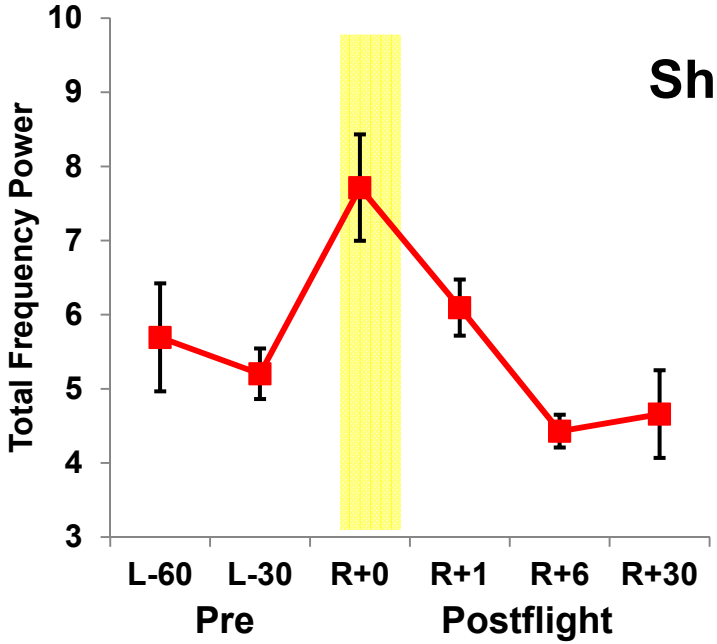
Locomotion/Dynamic Visual Acuity Test

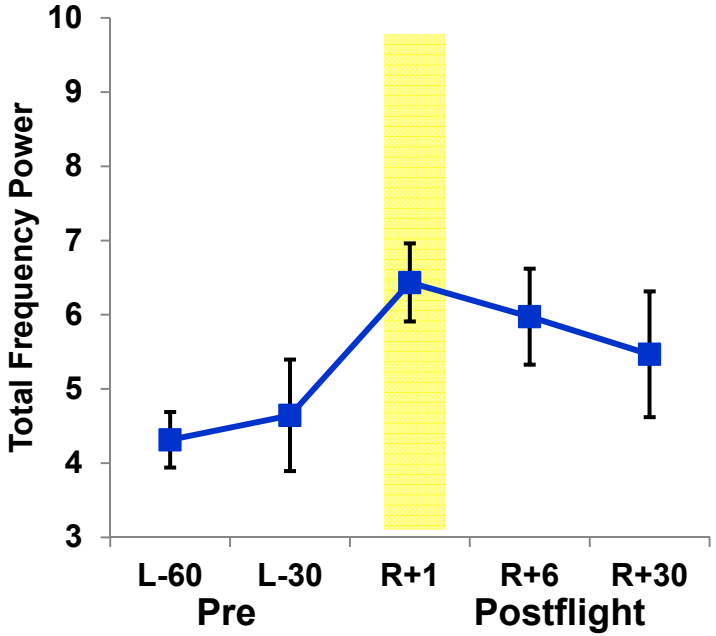
Landolt-C

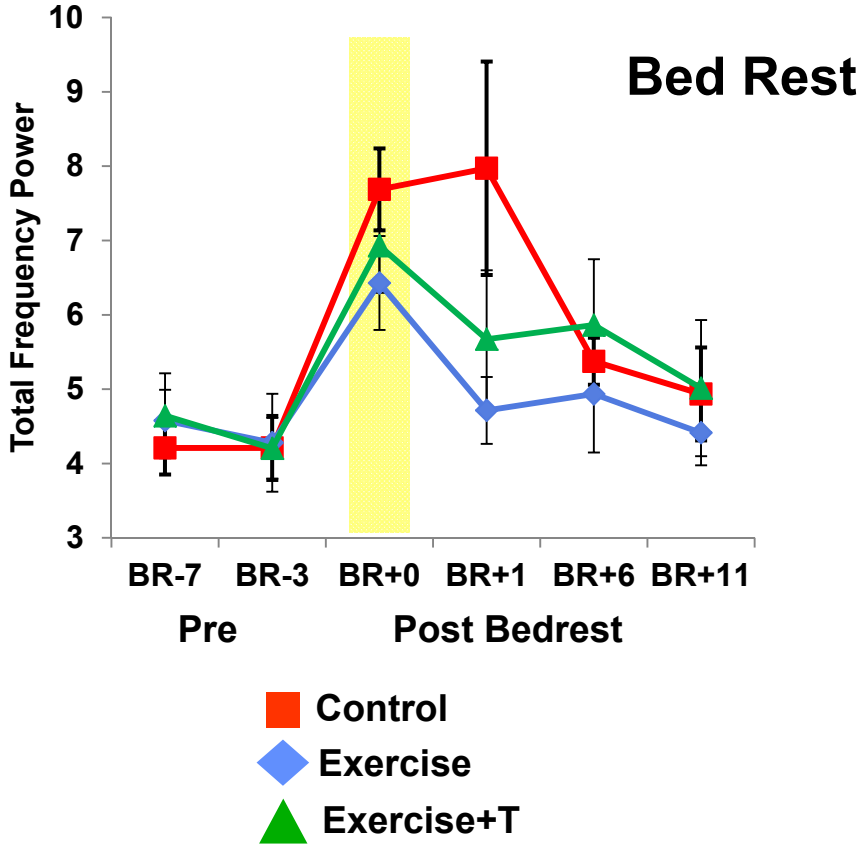


Subject walked at 6.4 km/h for 90 s on a treadmill while performing a dynamic visual acuity (DVA) test consisting of identifying gaps in the letter C presented on a computer screen.

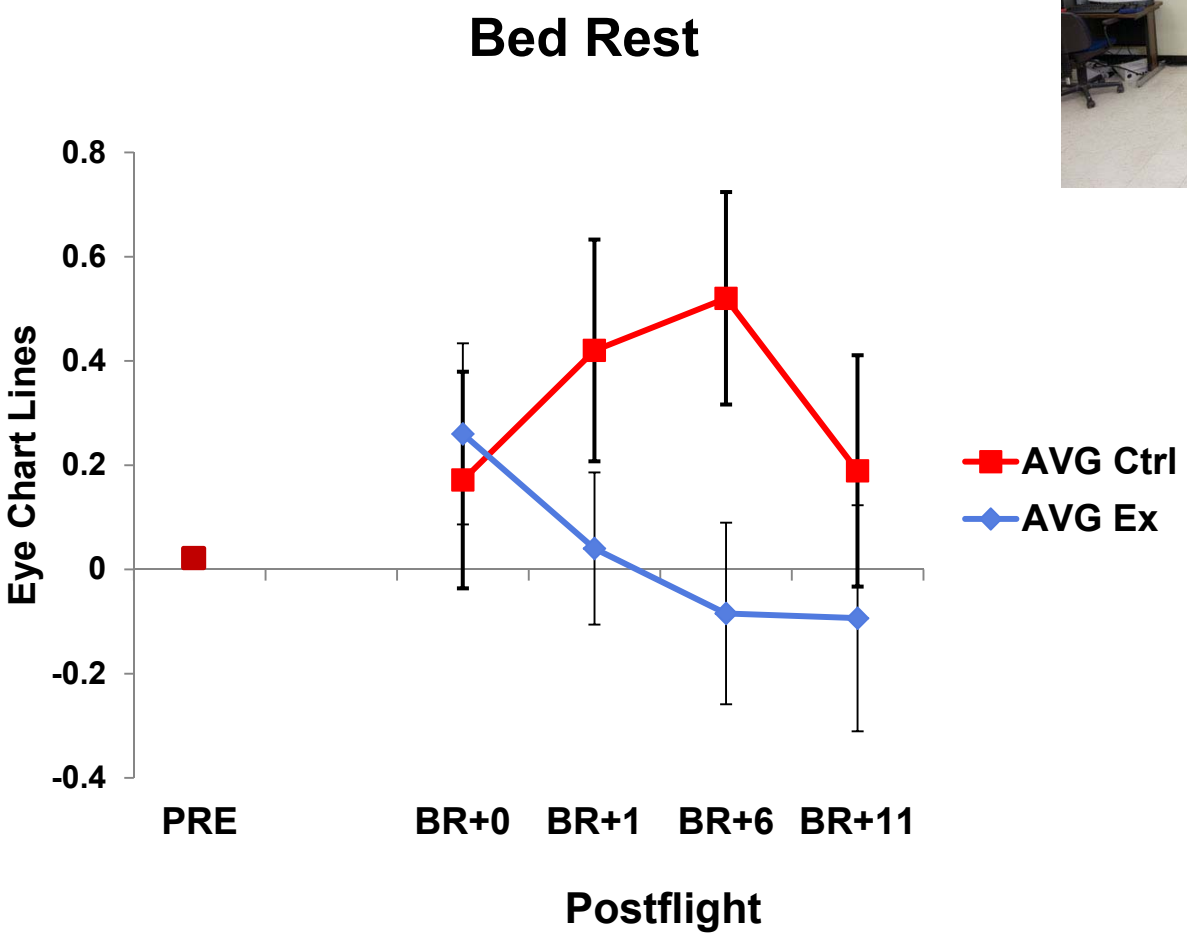
Locomotion: Torso Pitch Stability



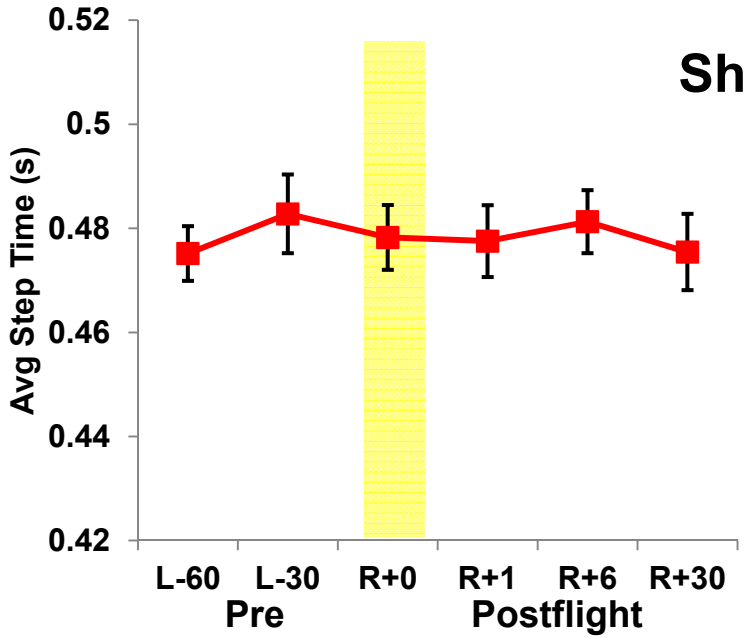


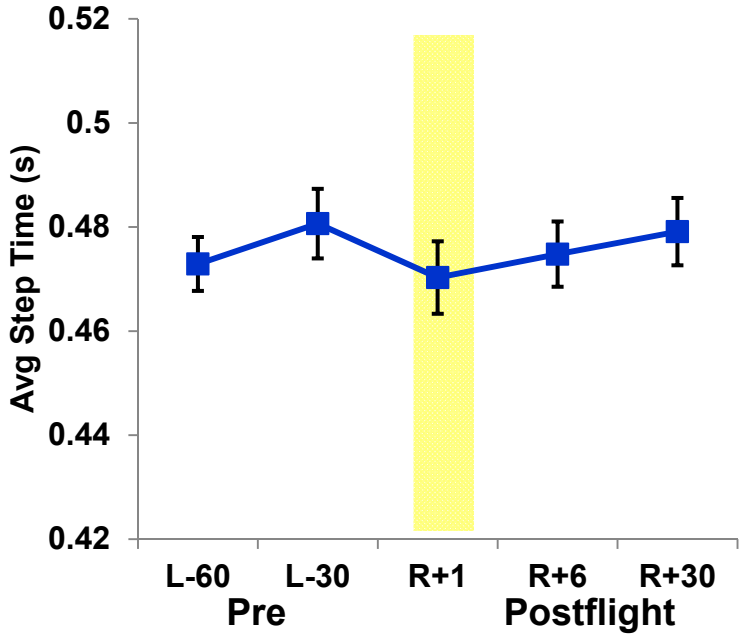


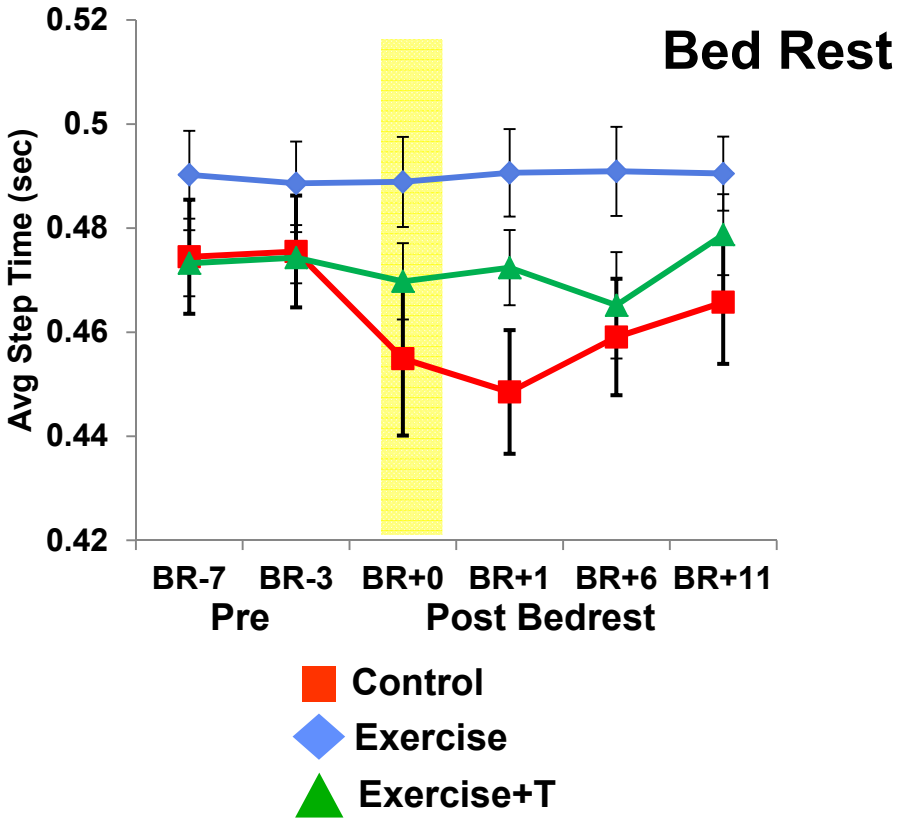
Locomotion: Dynamic Visual Acuity Test



Locomotion: Gait Cycle Timing/Step Time



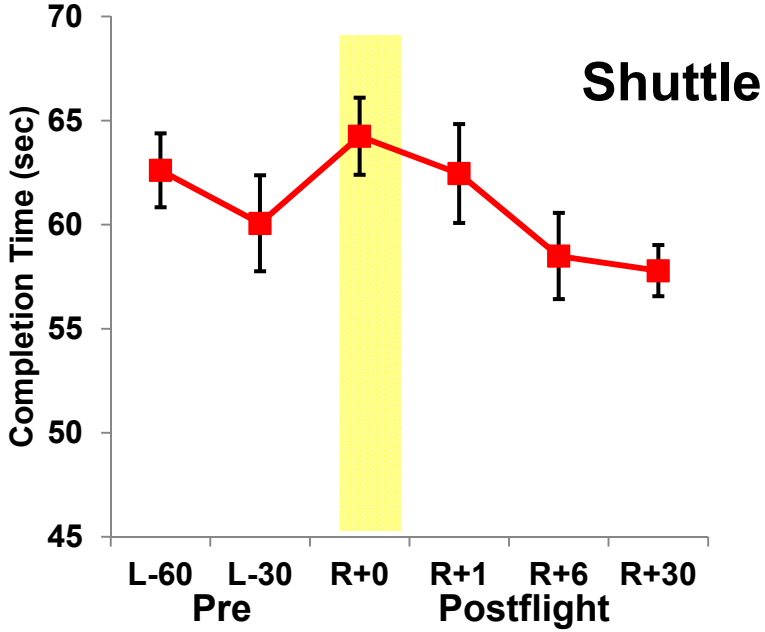


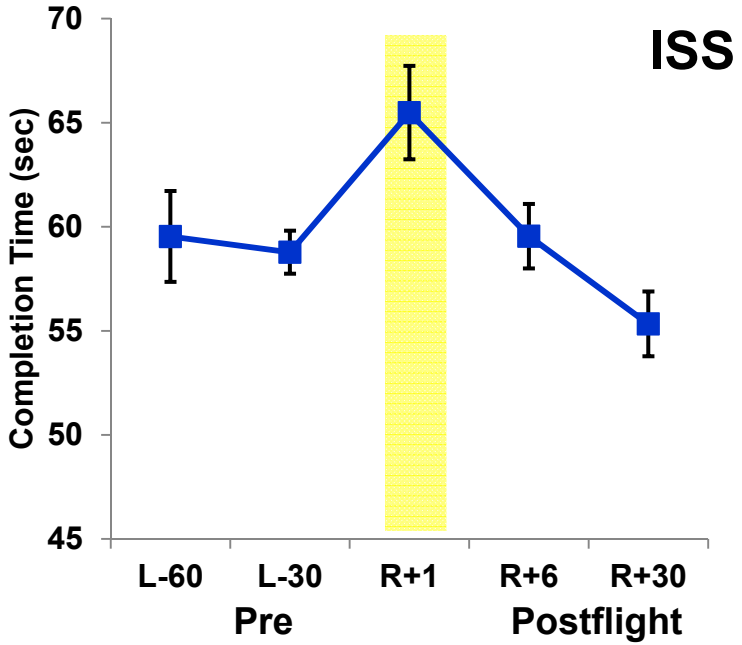


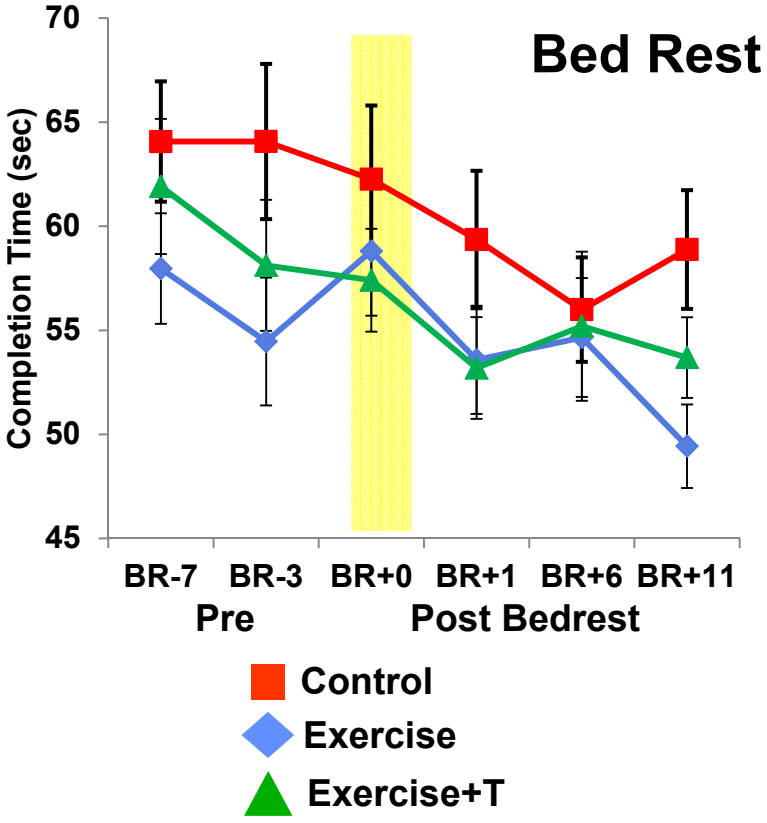
Fine Motor Control Test

The Grooved Pegboard Test was used to assess fine motor control. Subjects were required to rotate pegs with a key along one side to match the insertion hole.

Fine Motor Control Test







Summary: Sensorimotor Tests

- Tests of balance and dynamic gait control control show greatest deficits for both space flight and bed rest.
- Bed rest control subjects show alterations in gait cycle timing and dynamic visual acuity.
- Fine motor control not reduced after Shuttle and bed rest; trend for reduction after ISS.
- Bed rest data indicate that body support unloading is a contributing factor in postflight functional performance decrement.
- Points to the importance of providing axial body loading as a central component of an integrated training system.

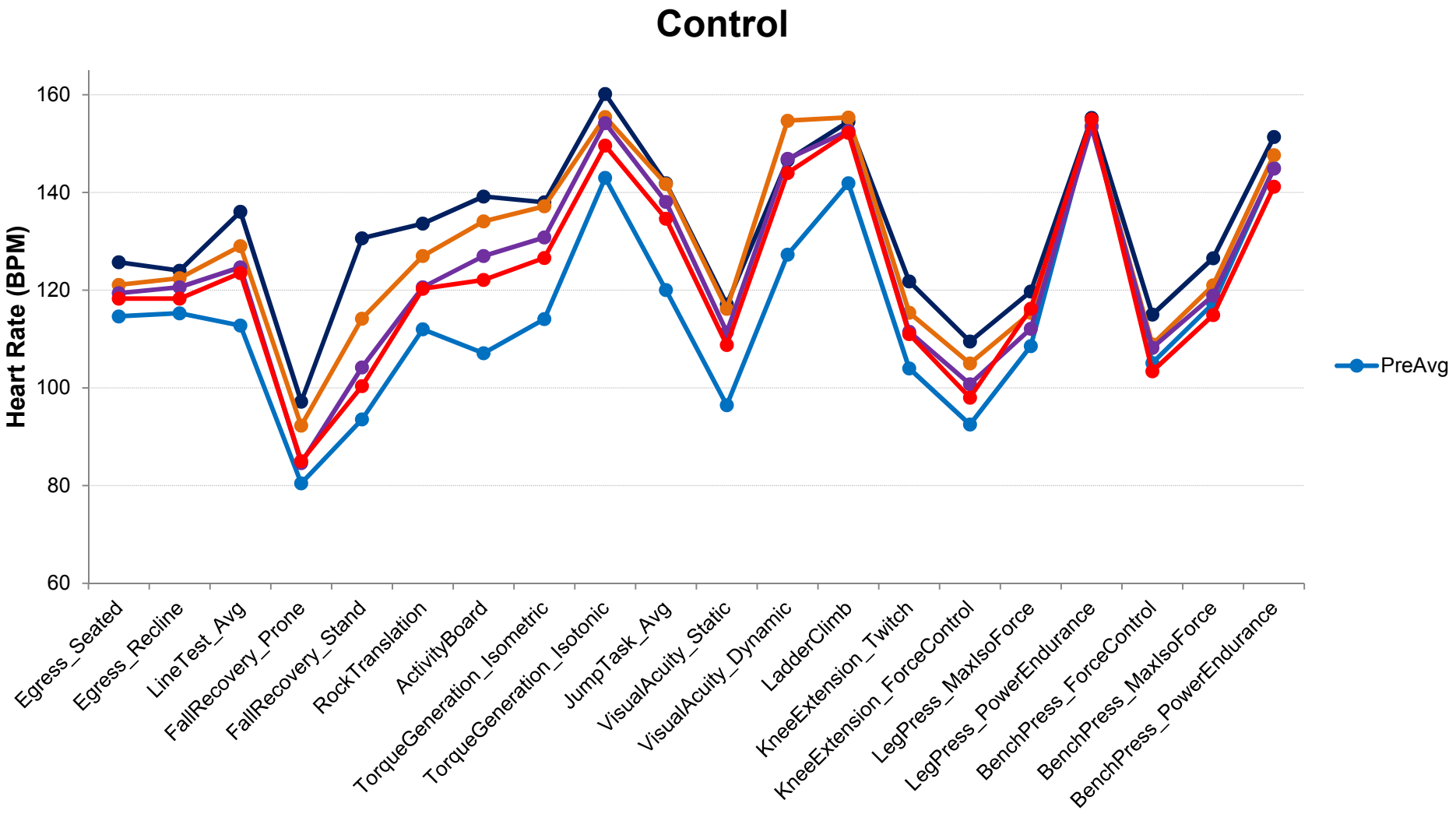
Functional Task Test: Cardiovascular

Goals

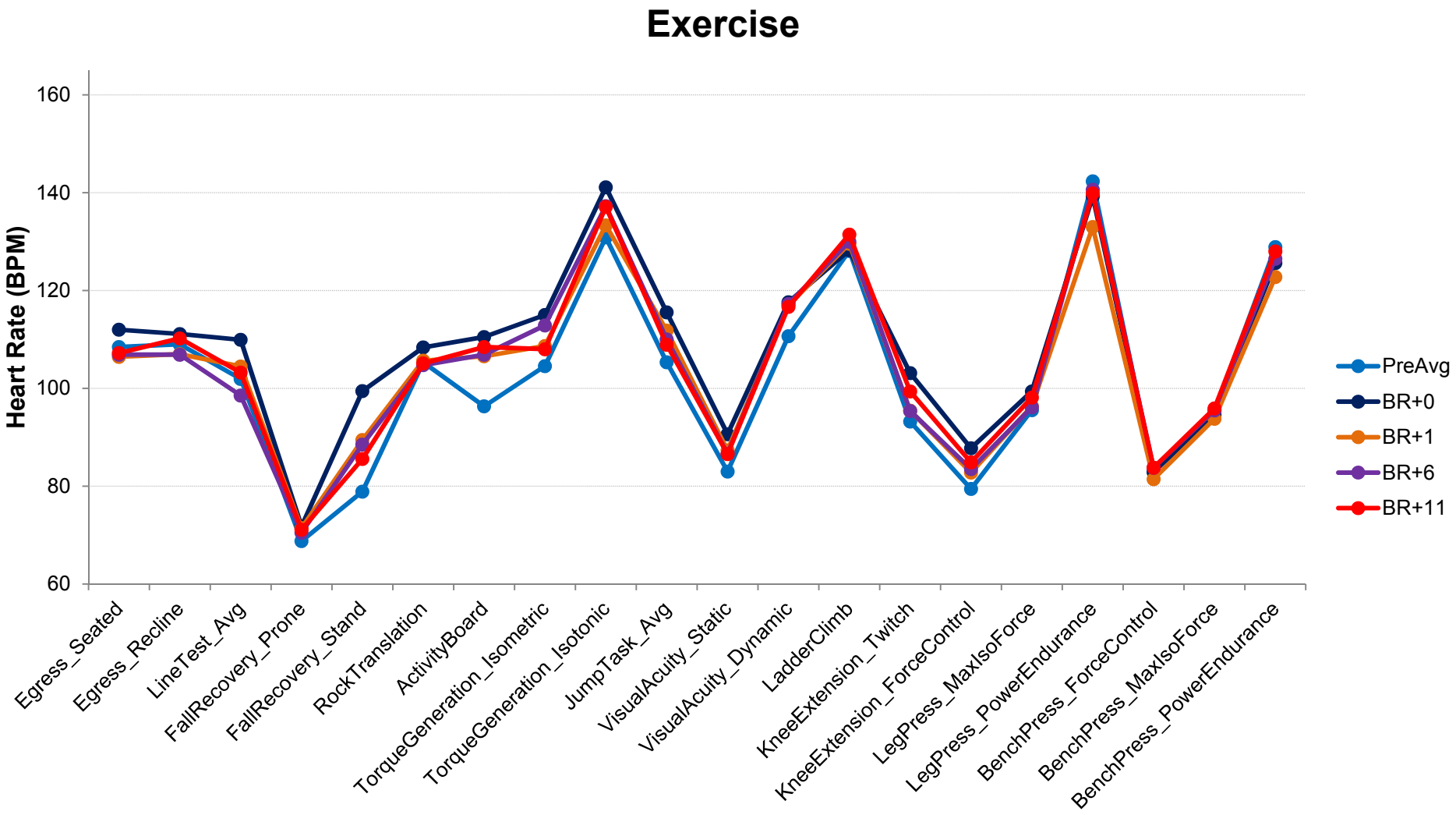
- Identify CV responses during multiple functional tasks.
- Determine if exercise prevents the negative CV adaptations during bed rest and maintains functional task performances.
- Use the ‘Recovery from Fall, Stand Test’ as a controlled orthostatic challenge to identify changes in the CV system that may contribute to functional task impairment.

Measurements

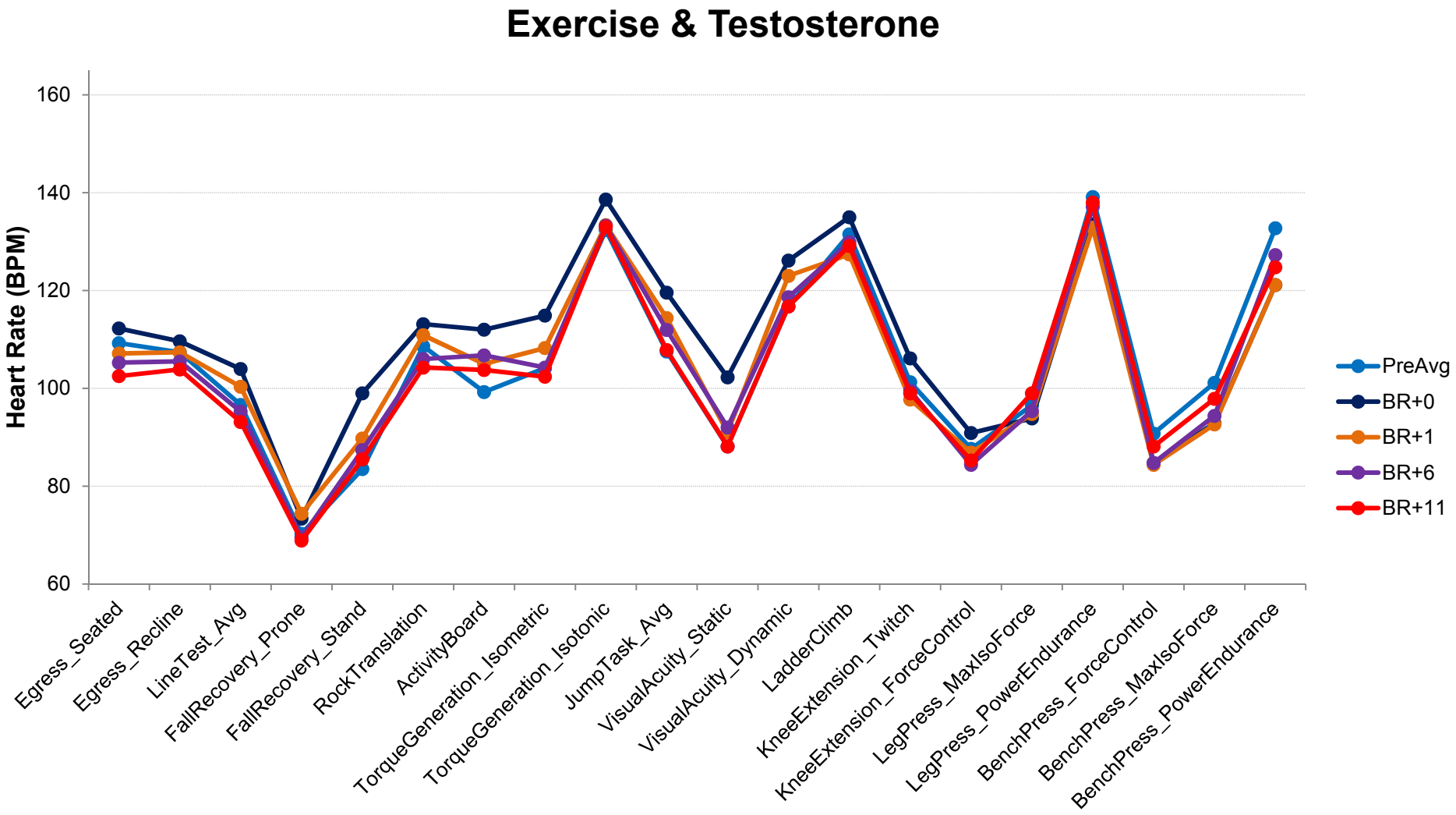
- Heart rate, plasma volume, blood pressure



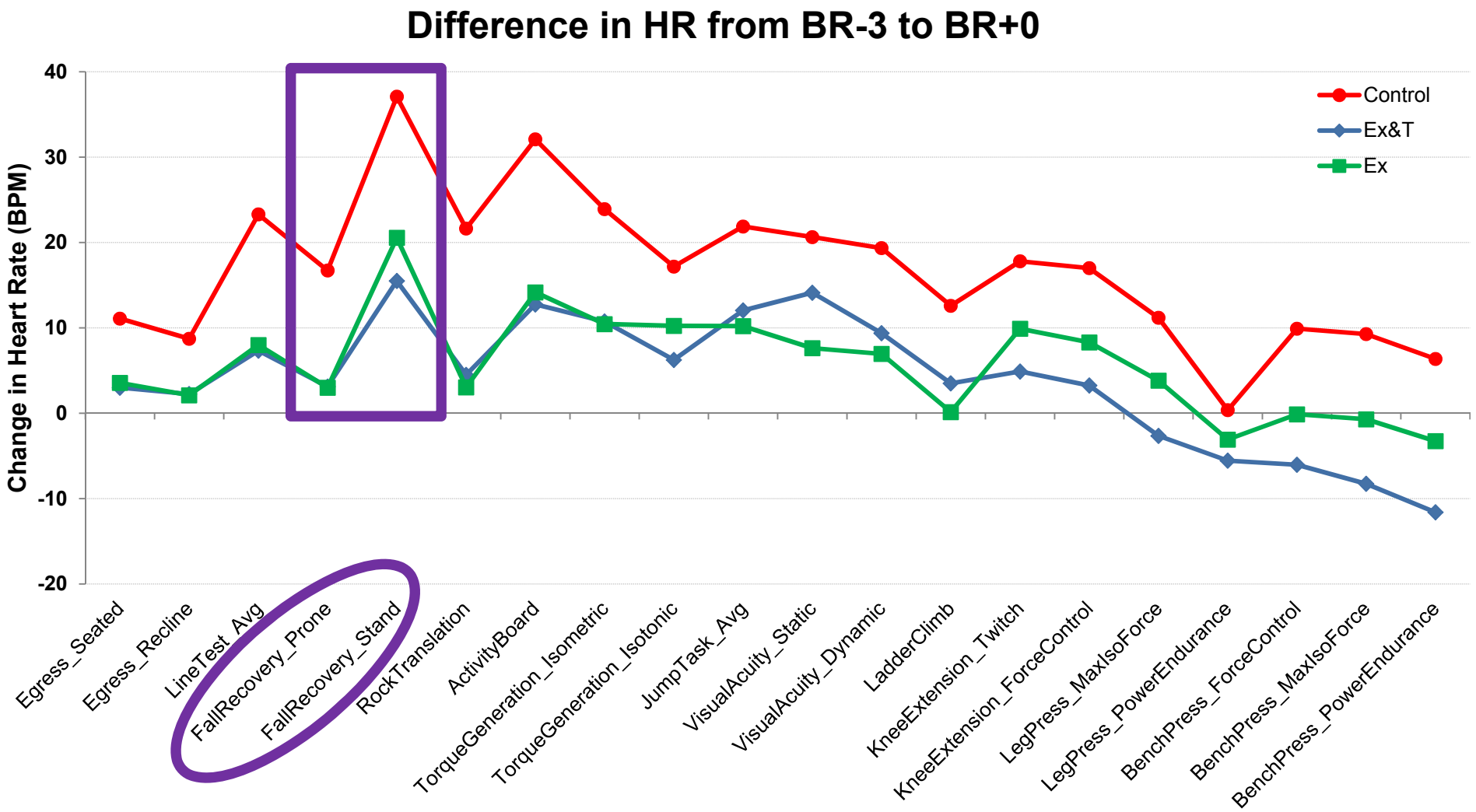
- Following bedrest HR is elevated during multiple Functional Tasks.
- Returns towards Pre-BR values over 11 days.



- Exercise reduces the elevated HR following bedrest.
- Smaller difference in HR between pre- and post-BR



- Testosterone does not provide an additional benefit beyond Exercise alone in minimizing the change in HR between pre- and post-bedrest.



- Are certain functional tasks “riskier” due to greater CV stress?

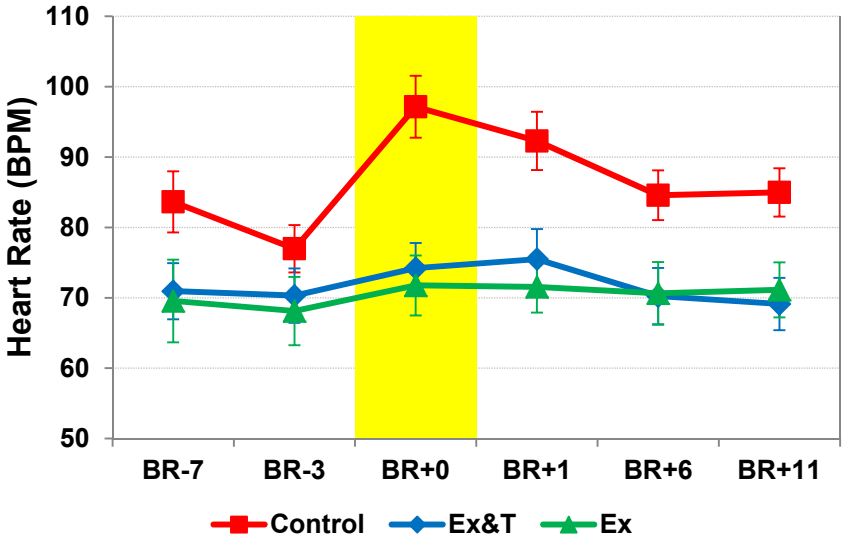
Functional Task: Recovery From Fall

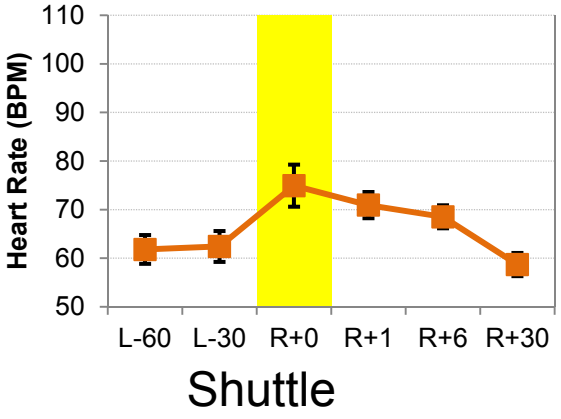
Prone: 2 min → Stand: 3 min

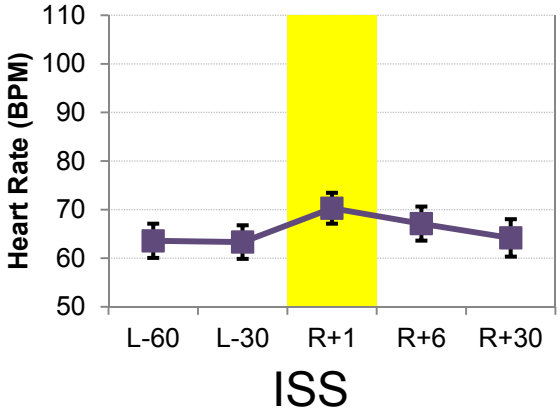
- Controlled maneuver
- Provides orthostatic stressor to CV system
- 3 min to minimize probability of syncope
- Continuously monitor BP and HR
- Incorporate balance/sway measures

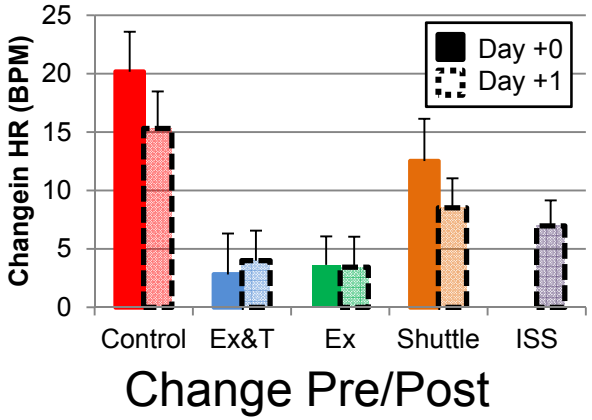
- All subjects completed the task.
- No signs of pre-syncope.

Prone Heart Rate



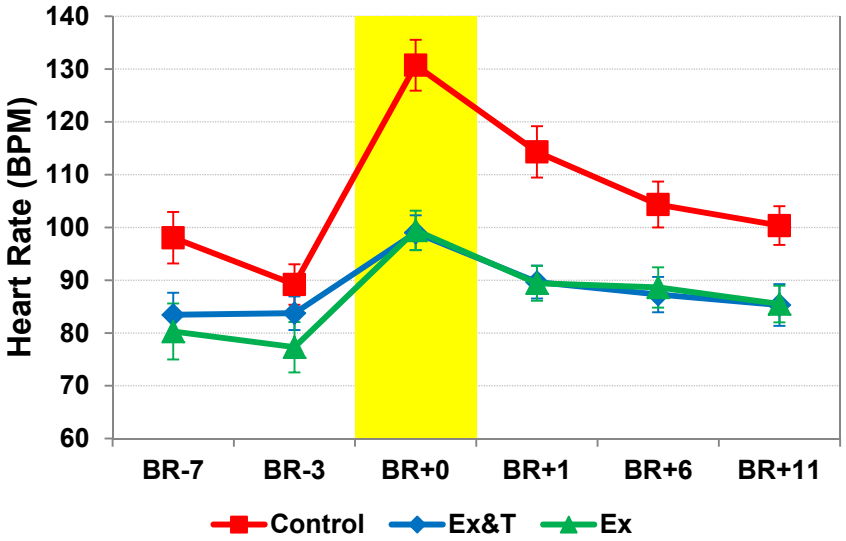


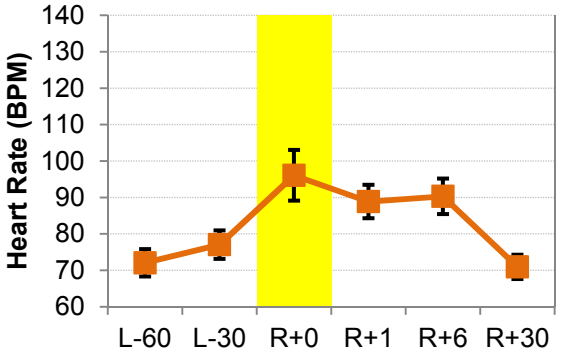




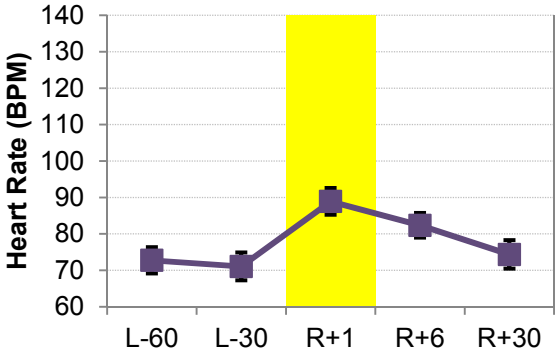
1. Exercise protects prone HR from rising.
2. Appears to be no difference between Ex and Ex&T groups.

Standing Heart Rate

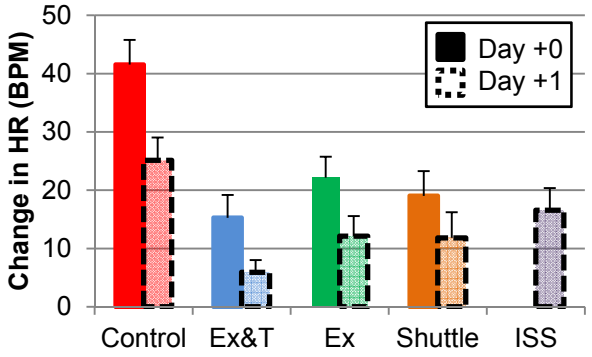




Shuttle



ISS

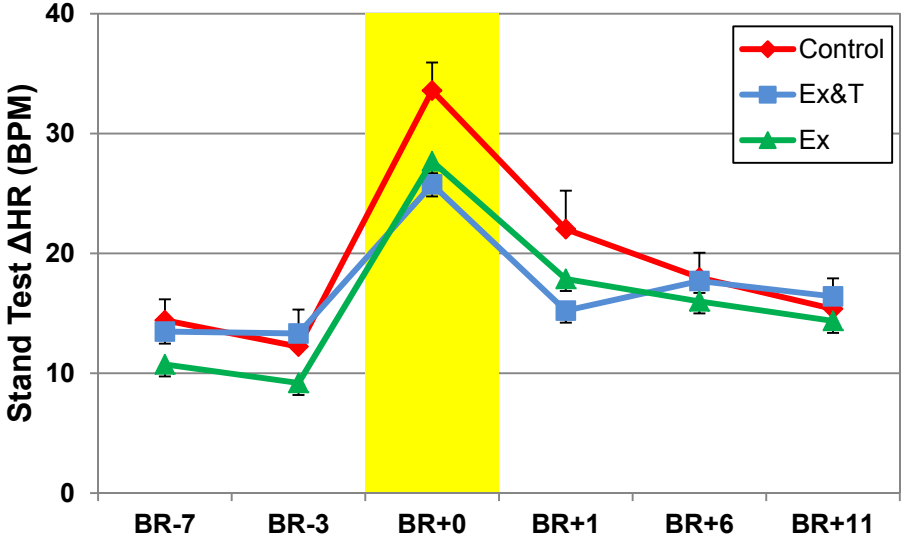


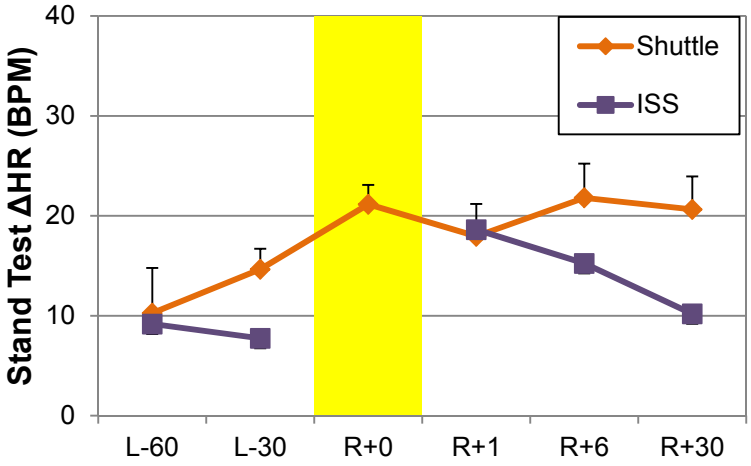
Change Pre/Post

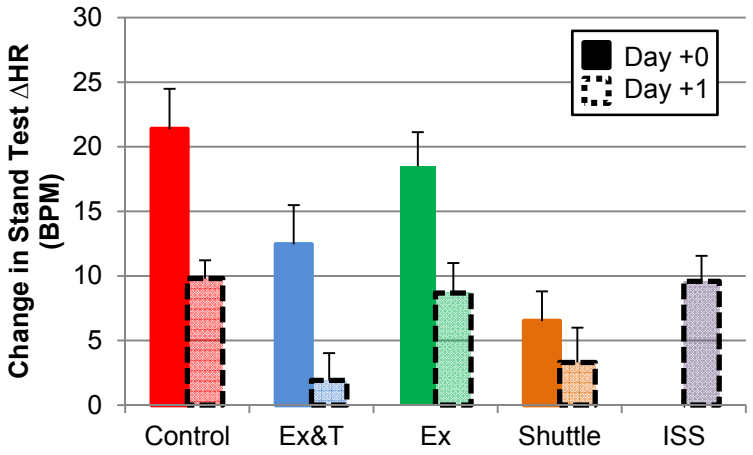
1. Exercise attenuates the increase in standing HR.
2. No difference between Ex and Ex&T groups.
3. Recovered by BR+11?

Stand Test Heart Rate Response

ΔHR



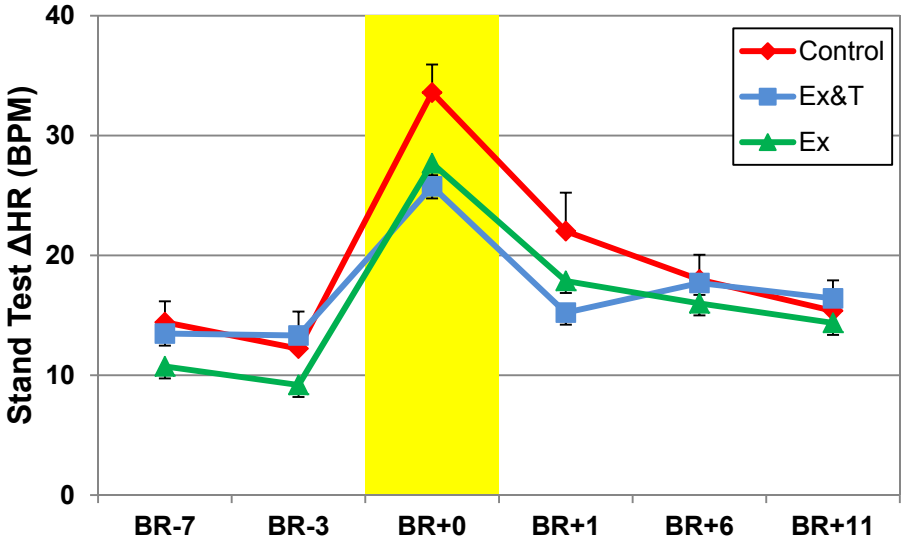




1. Standing HR response is increased on BR+0.
2. The increase is reduced on BR+1, but may remain elevated on BR+11.
3. Is there a difference between Ex&T and Ex on BR+0?

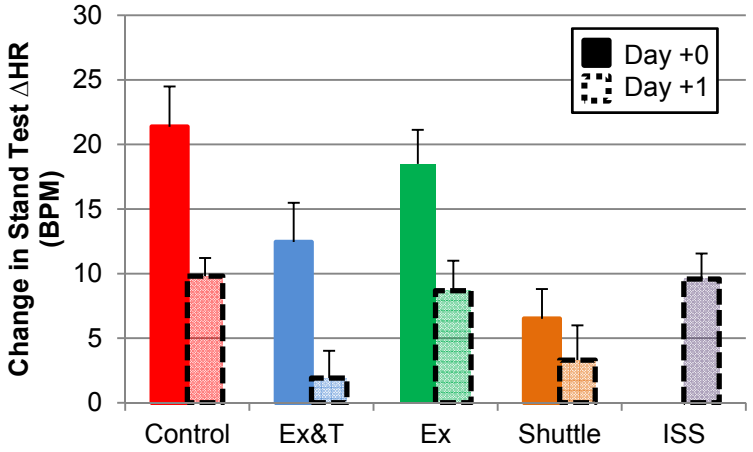
Potential Factors Contributing to an Elevated HR Response

1. Cardiac dysfunction
2. ↓ PV
3. Altered autonomic function



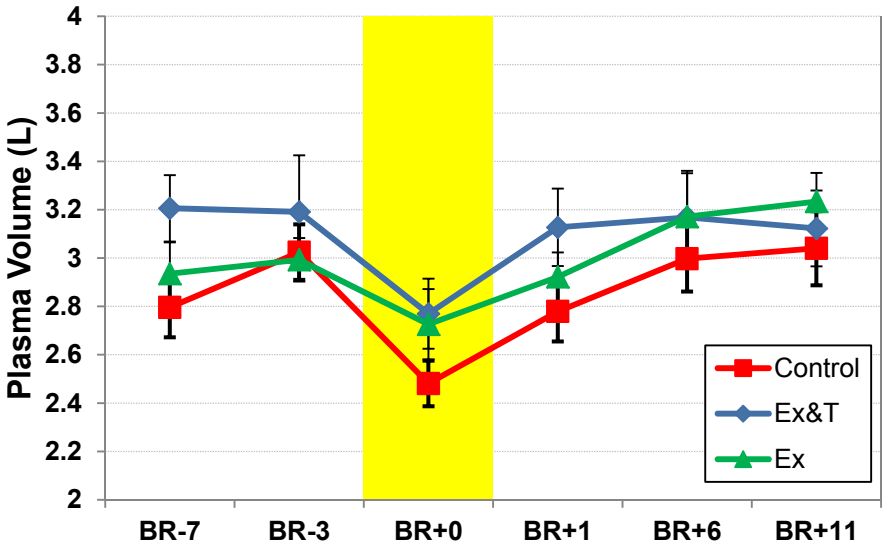
- Previous bed rest studies suggest a reduced LV mass and diastolic dysfunction, leading to reduced SV.
- Exercise training during 2-8 weeks of bed rest prevents these changes, preserves cardiac function.

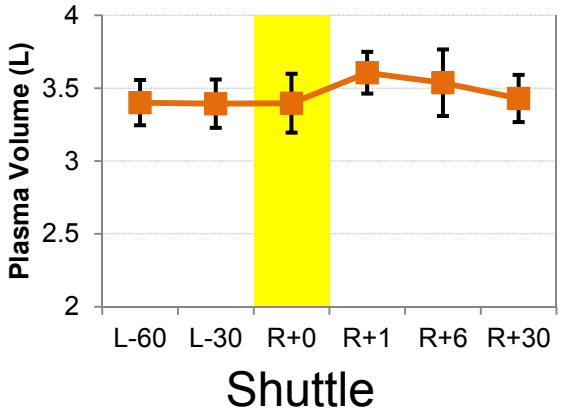
Shibata, et al. J Appl Physiol. 108:1177-1186, 2010.

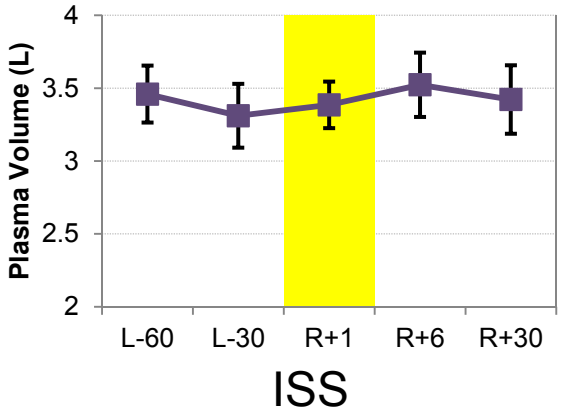


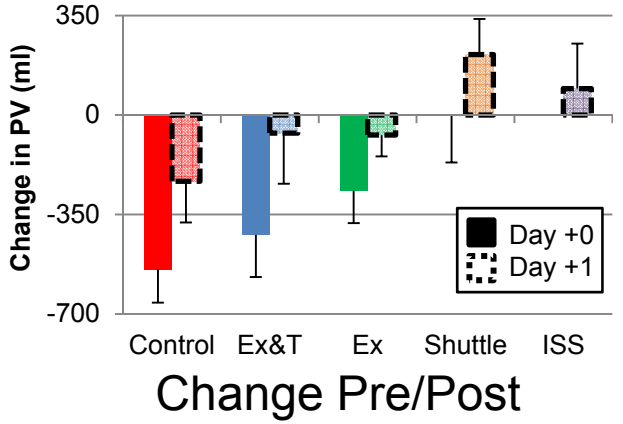
1. Does the difference from BR+0 to BR+1 indicative of remaining cardiac dysfunction?
2. Does Testosterone provide protection against cardiac dysfunction?

Plasma Volume









1. PV decreases following bed rest in all groups.
2. Recovers by BR+1.

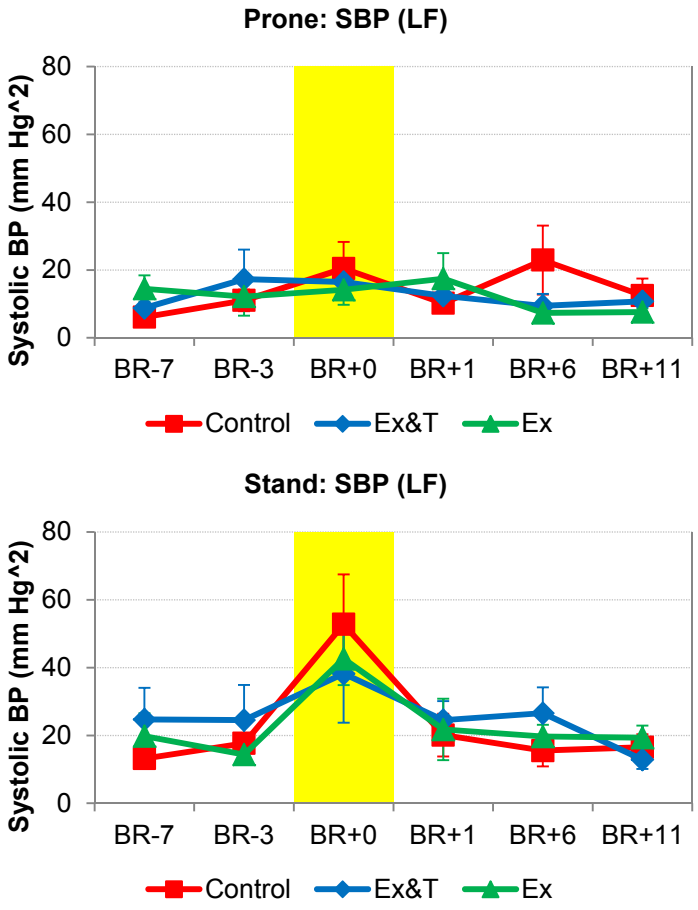
Autonomic Function

- During and/or post spaceflight sympathetic outflow is increased and exaggerated.
- Following 10 d of HDT, blood volume is reduced and greater reductions in arterial pressure during CV stress are compensated for by ↑HR (via increased SNS activity) to maintain BP.

Ertl, et al. J Physiol. 538:321-329, 2002.

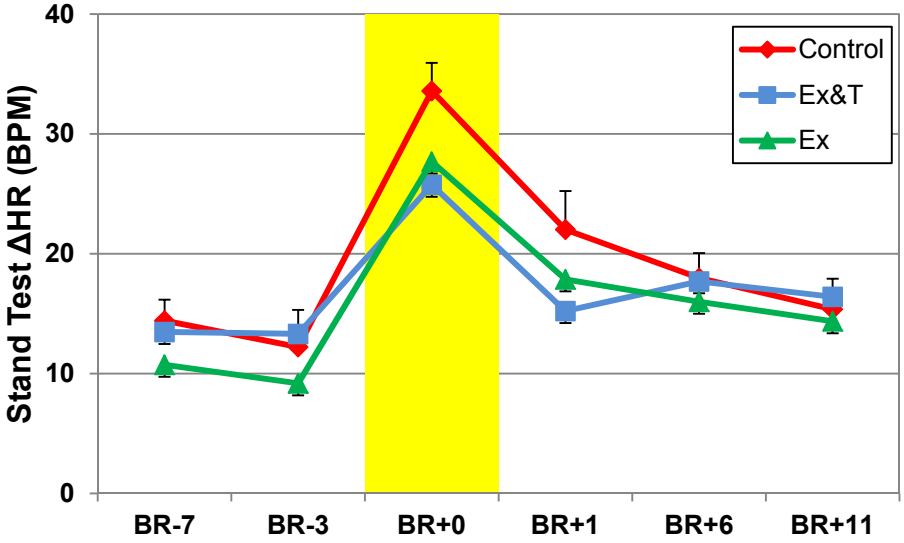
Ten Harkel, et al. Acta Physiol Scand. 604:89-99, 1992.

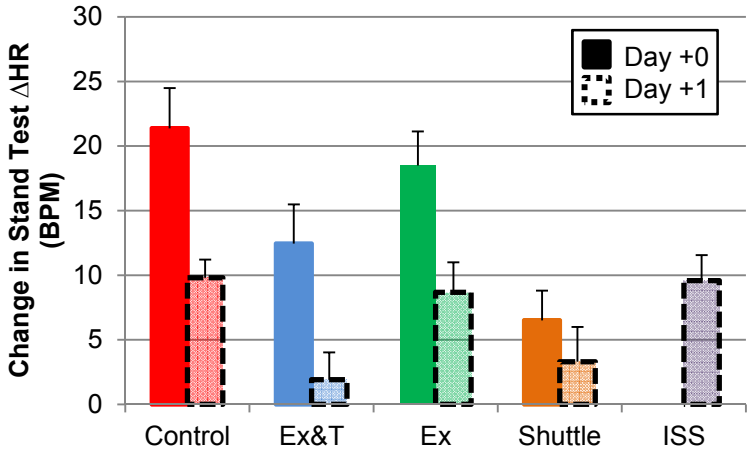
Sympathetic modulation:



1. Sympathetic modulation is augmented following bed rest.
2. Recovers by BR+1, suggesting an appropriate response to a fall in SV on BR+0.

Functional Task Impairment: CV Adaptations Following Bed Rest





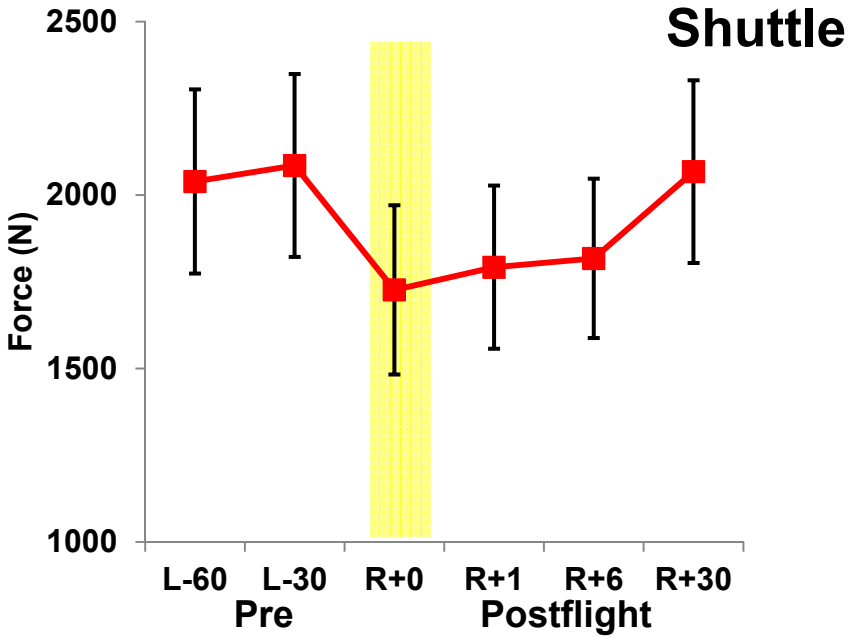
1. Following bed rest, prone HR is elevated in Control, but not Exercise subjects.
2. To accomplish the Functional Task of moving from Prone to Standing:
   - Greater ↑HR on BR+0
   - Exercise may provide some protection?
   - Does Exercise + Testosterone provide more protection?
   - HR remains 3-5 bts/min greater on BR+11
3. PV is decreased on BR+0 and almost completely recovers by BR+1.
4. Syncope did not occur during 3 min of quiet standing.

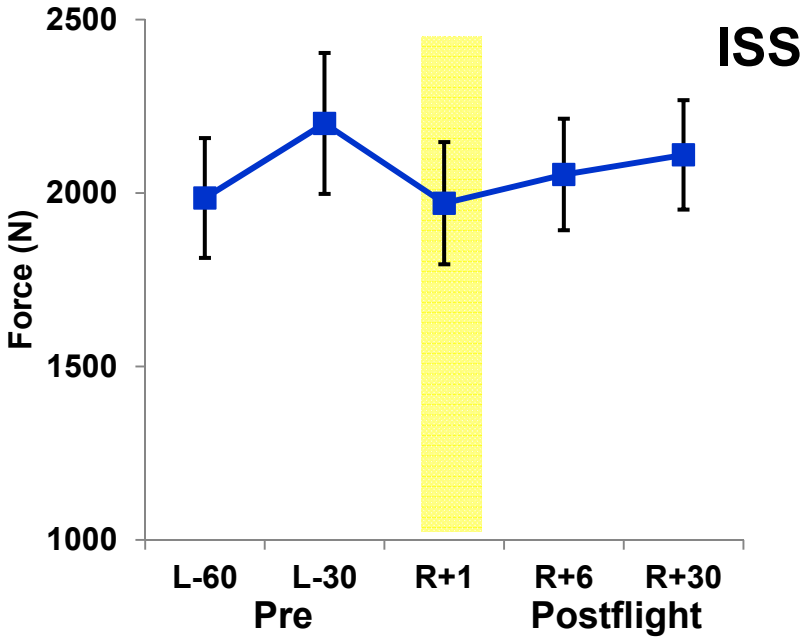
Lower Limb Muscle Performance

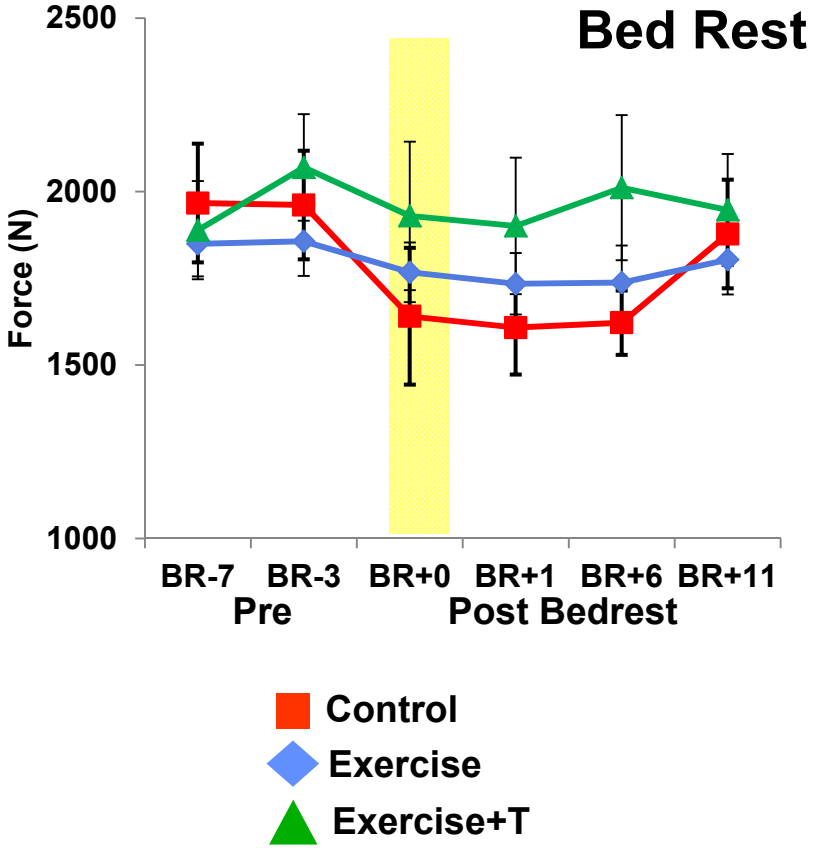
Maximum Isometric Force: Subject in leg press system pushes against a fixed force plate.

Power/Endurance: Subject pushes a weight away as fast as possible (40% max force, 21 repetitions, ballistic, concentric only, magnetic brake catches weight).

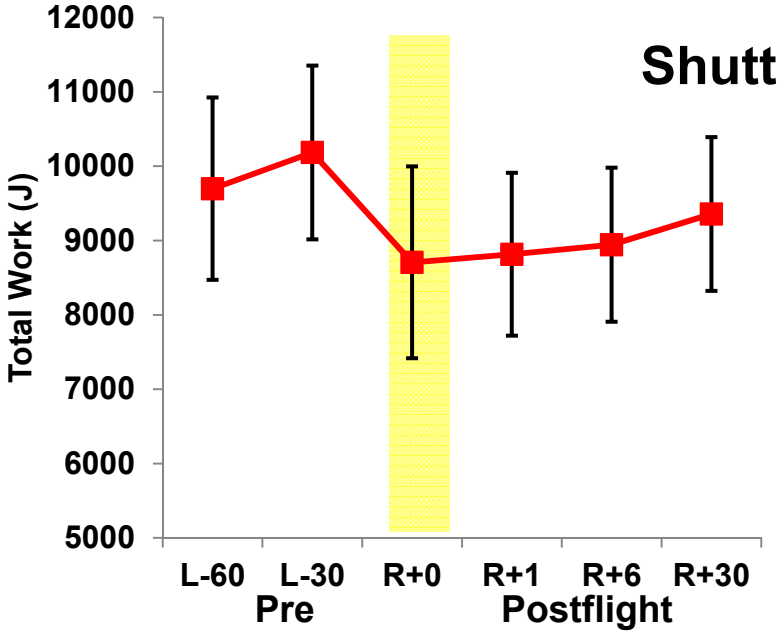
Lower Body Maximum Isometric Force

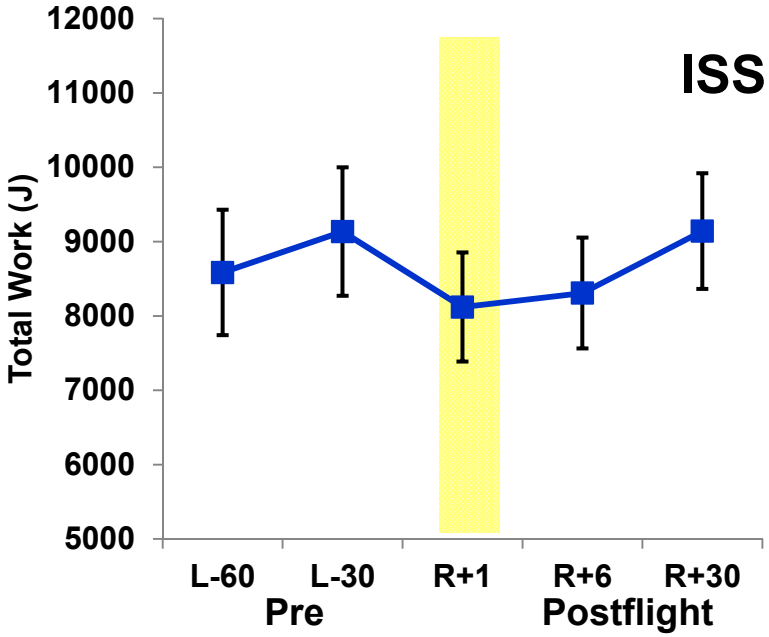


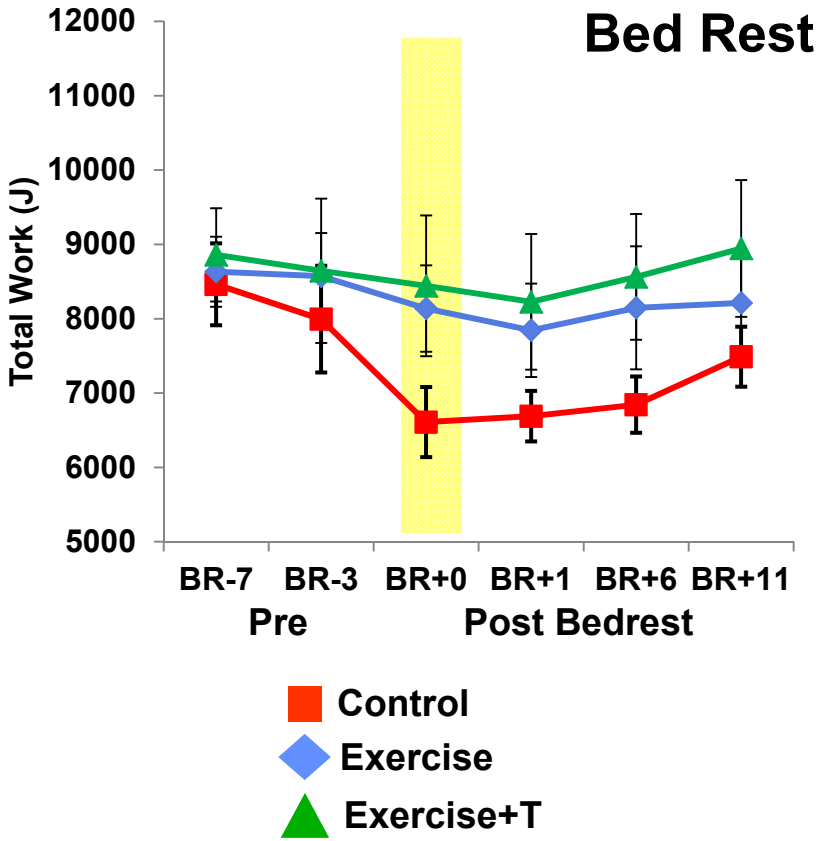




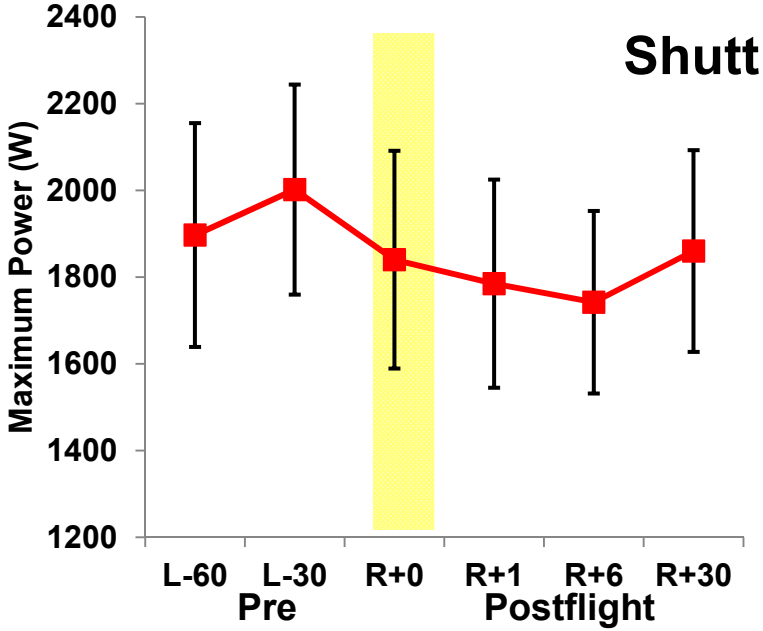
Lower Body Total Work

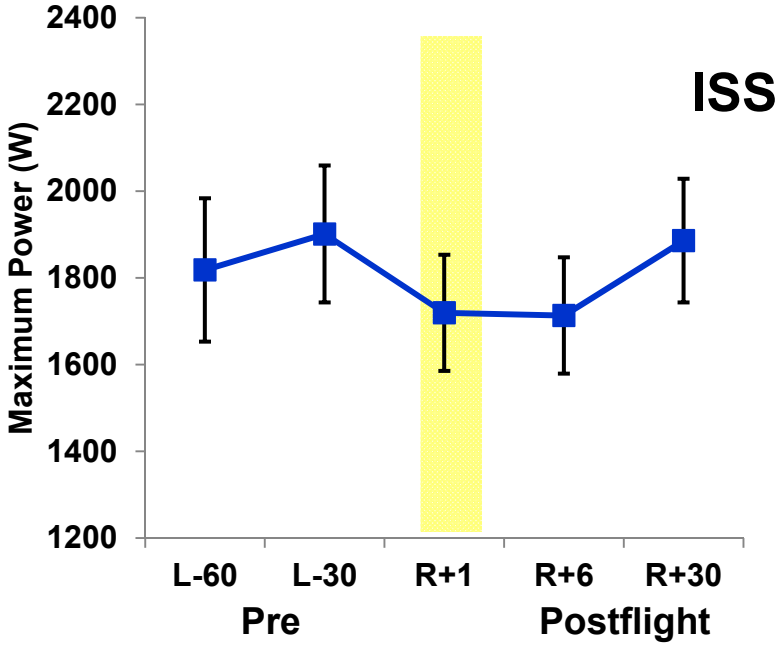




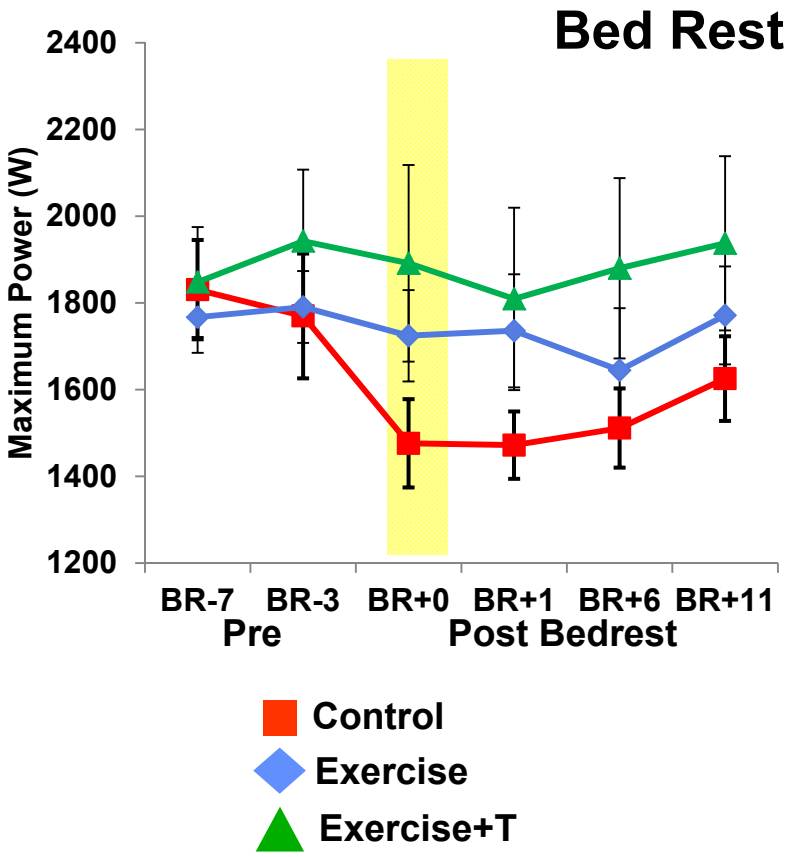


Lower Body Max. Power





Ex &T Dominated by one subject

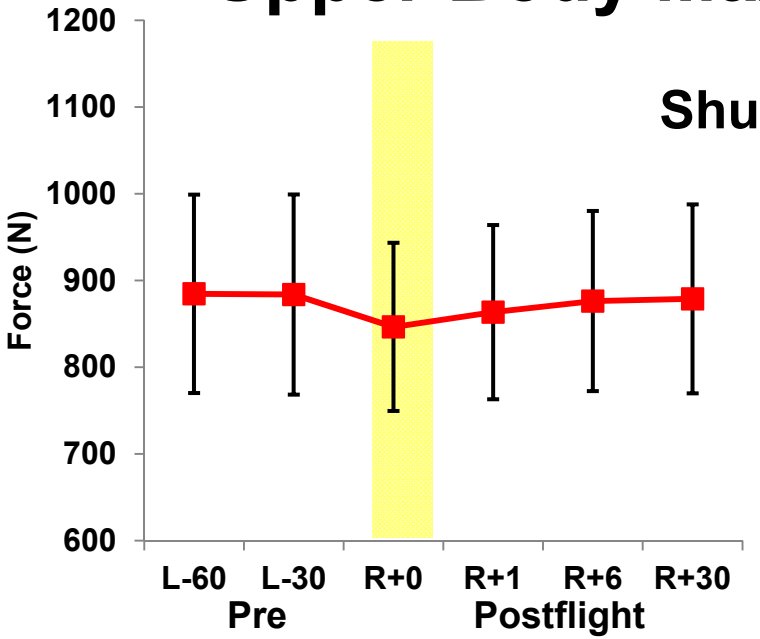


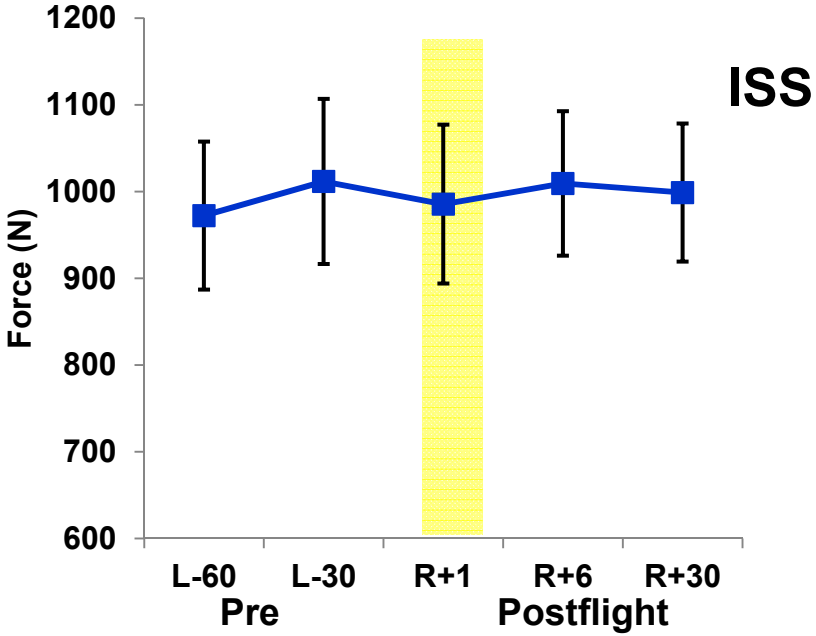
Upper Limb Muscle Performance

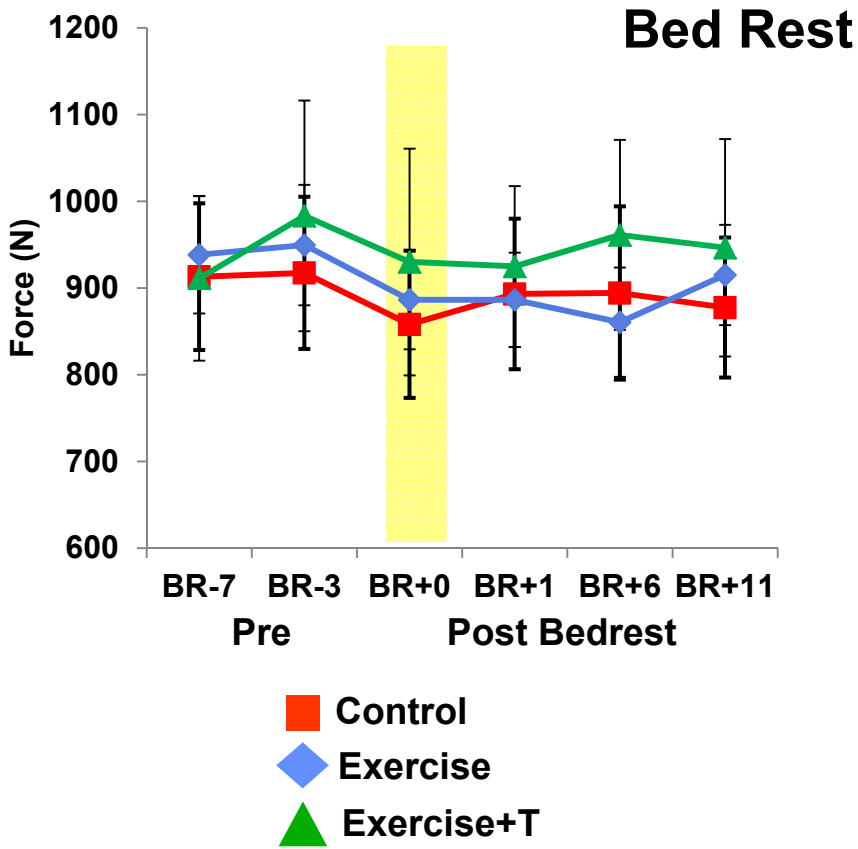
Maximum Isometric Force: Subject in leg press system pushes against a fixed force plate.

Power/Endurance: Subject pushes a weight away as fast as possible (40% max force, 21 repetitions, ballistic, concentric only, magnetic brake catches weight).

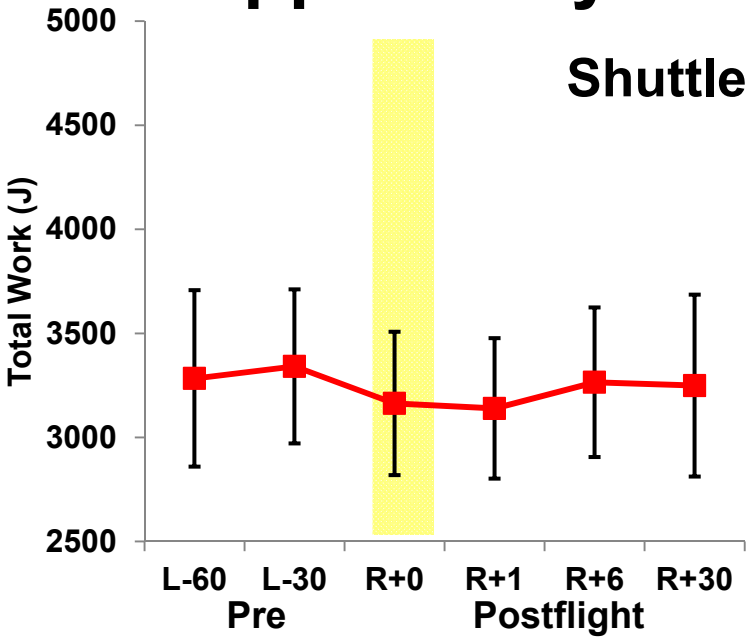
Upper Body Maximum Isometric Force

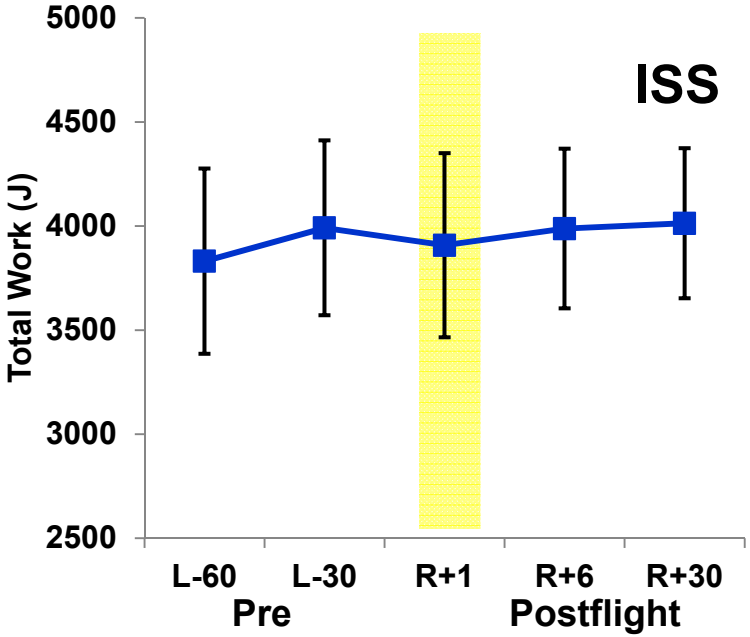


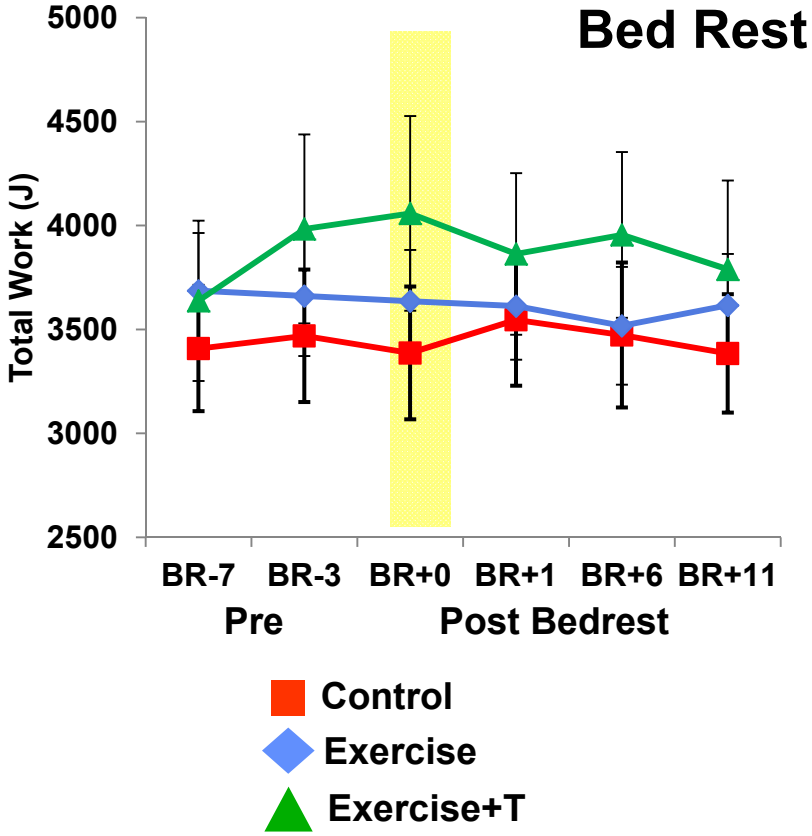




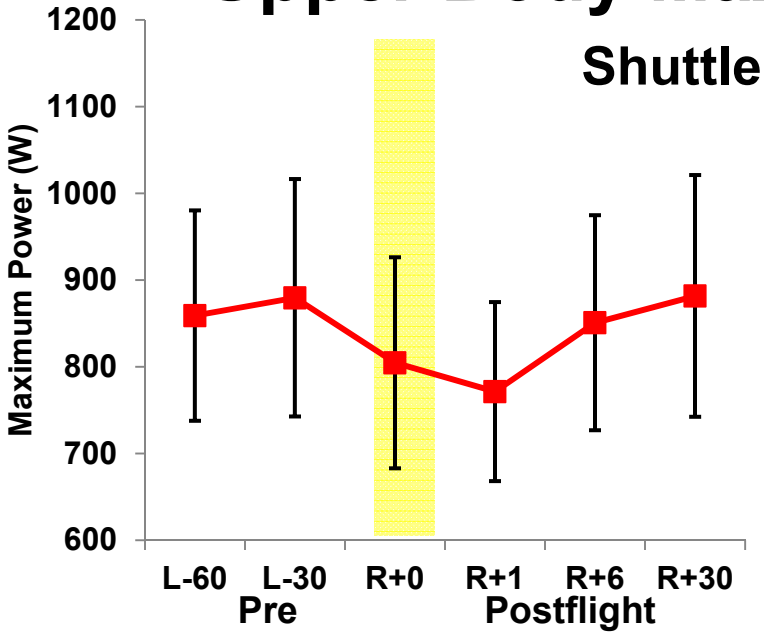
Upper Body Maximum Total Work

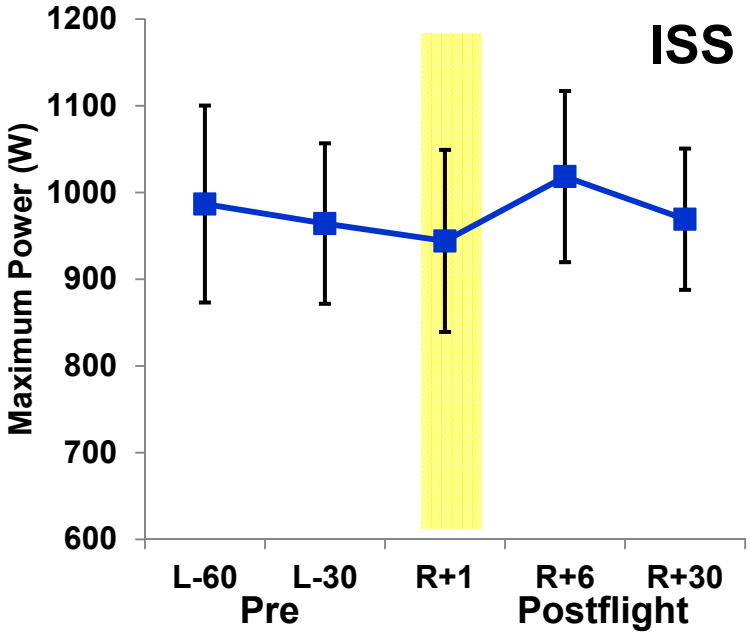


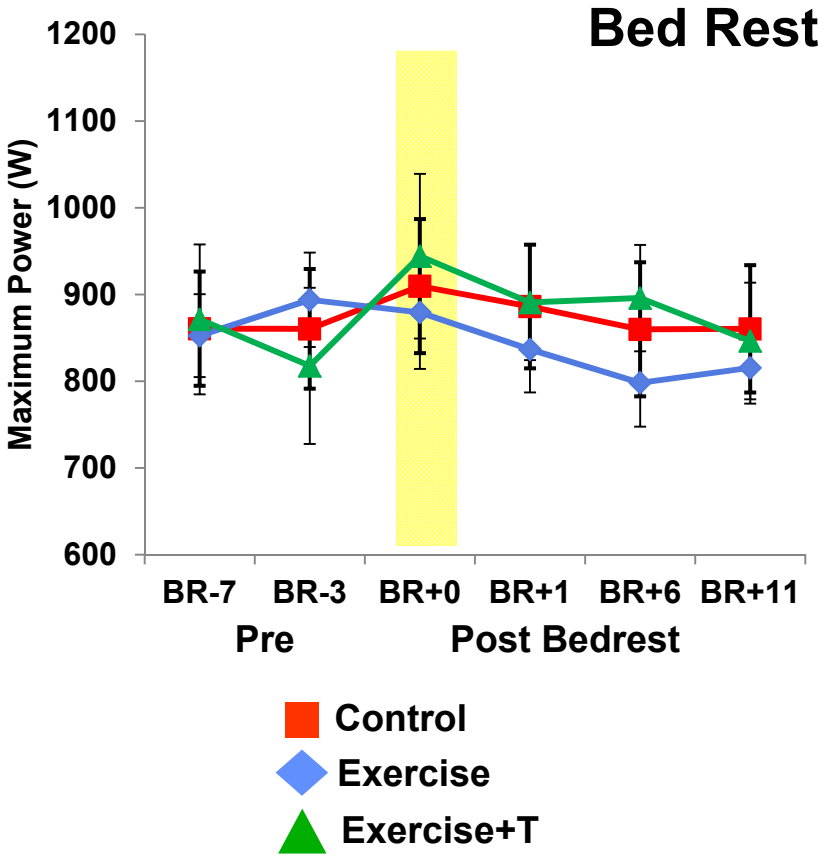




Upper Body Maximum Max. Power



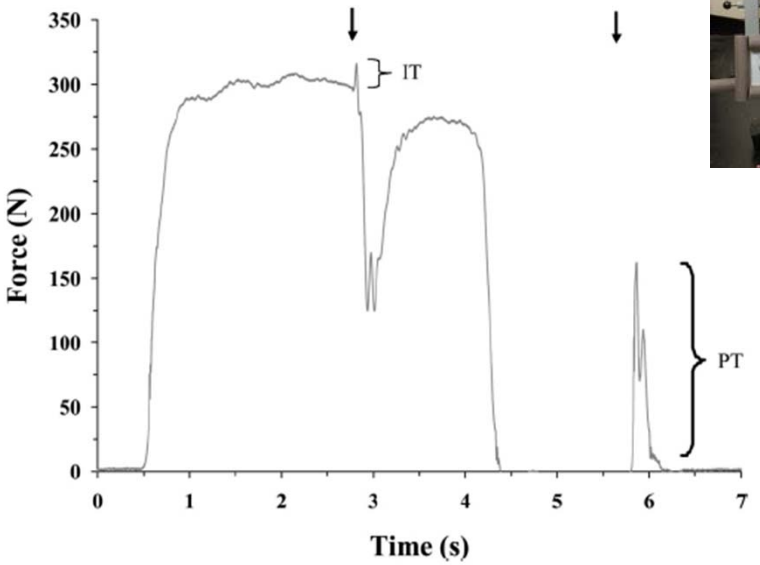


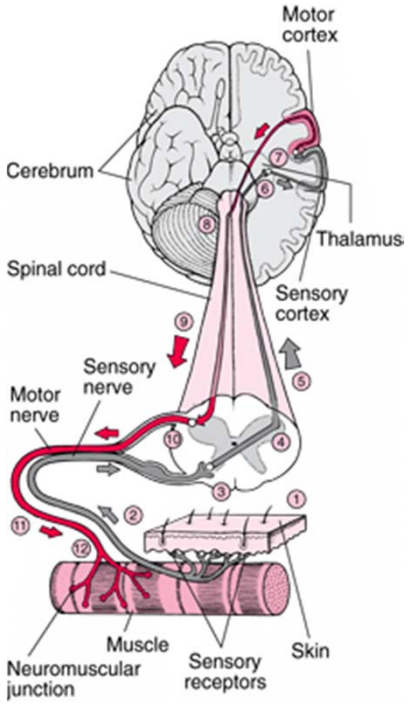


Central Neural Activation Capacity

Loss of muscle strength due to space flight could be caused by changes in two factors:

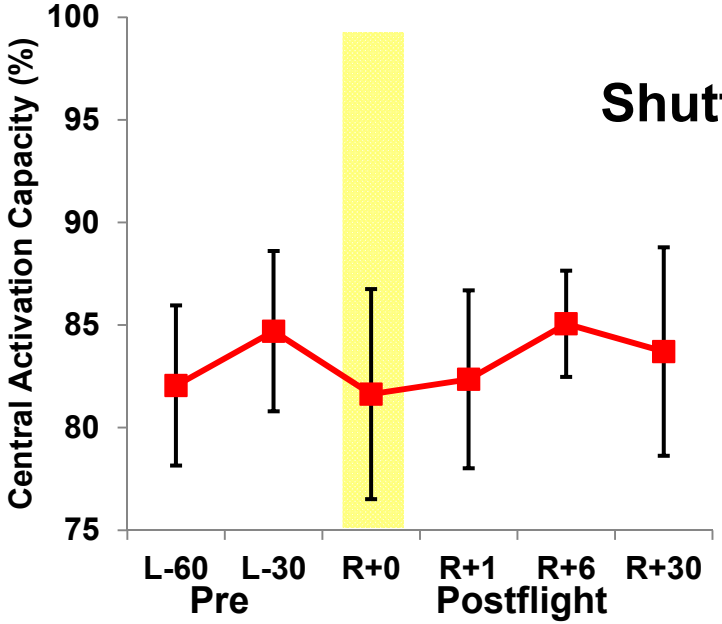
1) Change in central neural activation, leads to changes in ability to recruit muscle fibers
2) Muscle atrophy

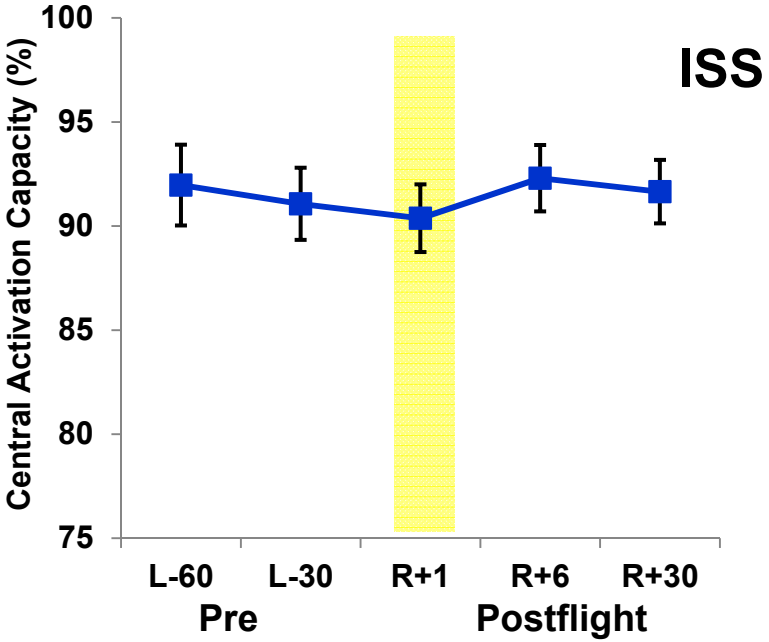


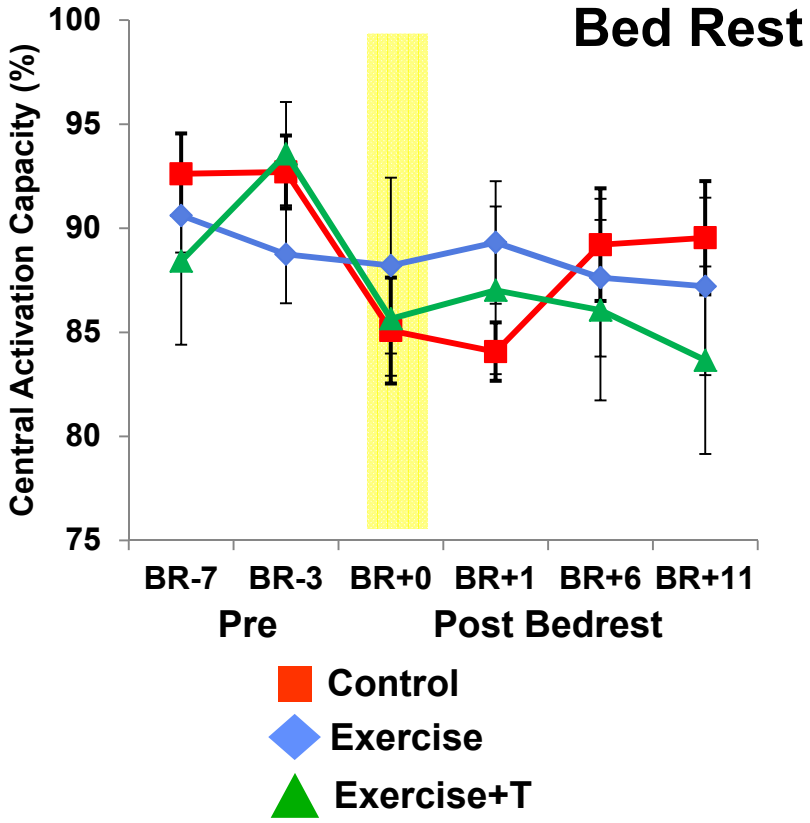


Twitch interpolation method used to assess neural activation capacity. Electrical muscle stimulus was provided to thigh muscle during maximal isometric leg extension.

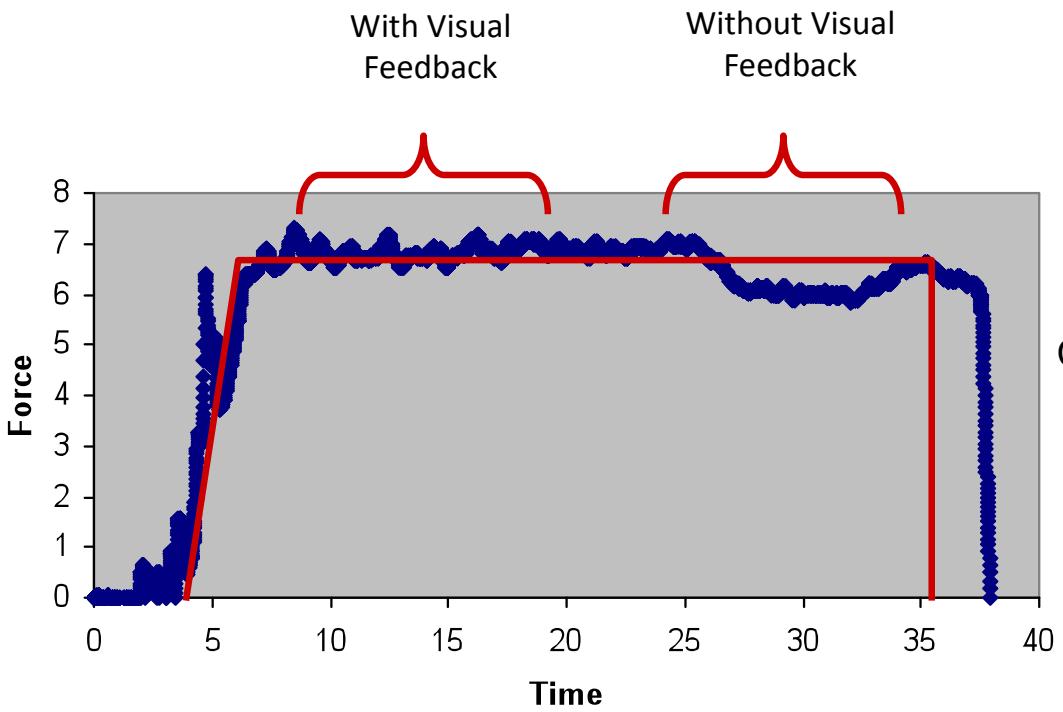
Central Neural Activation Capacity







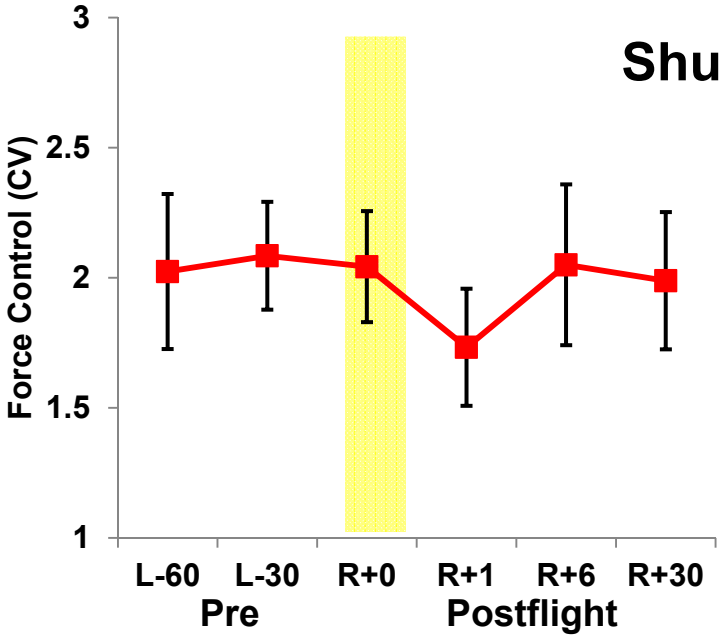
Assessment of Force Control

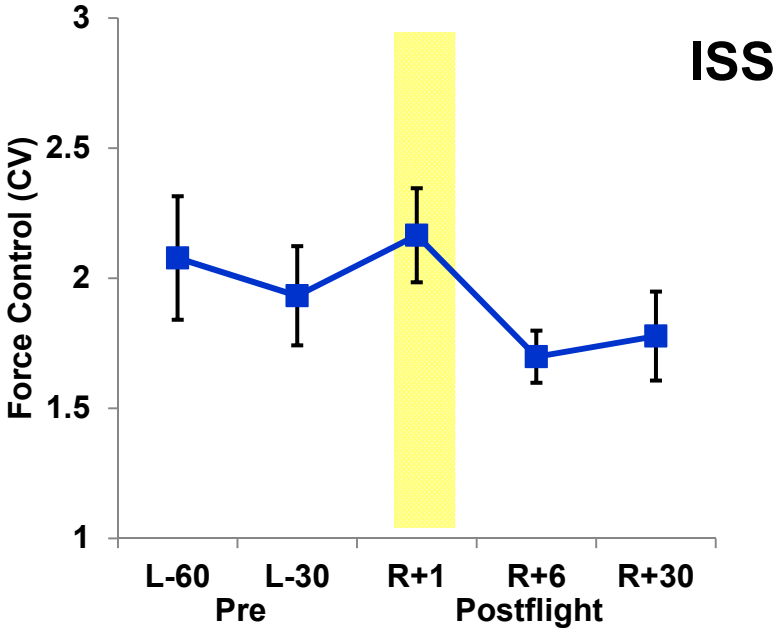


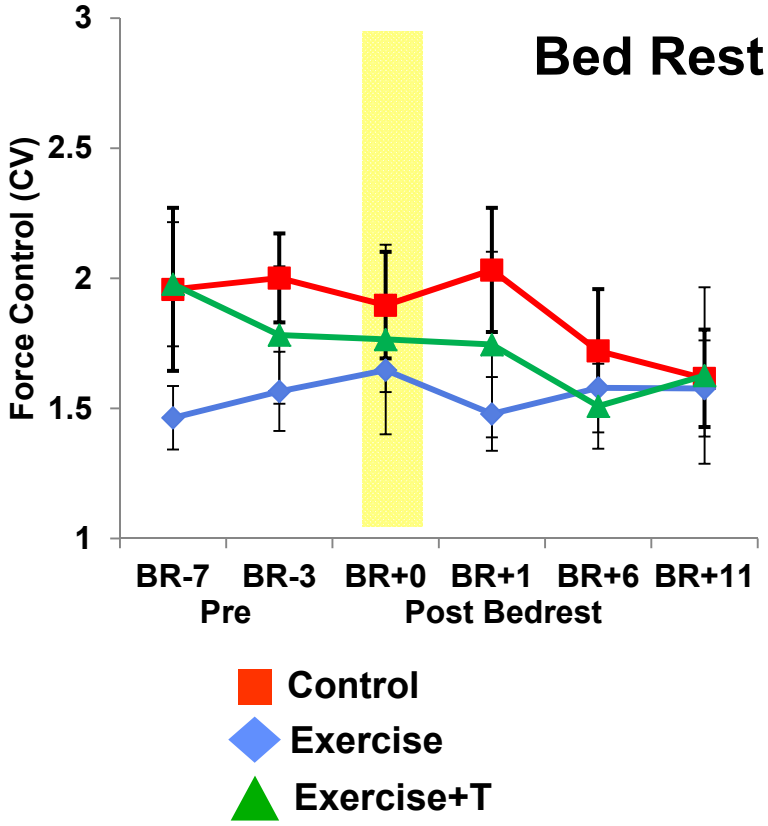
Coefficient of Variation (COV) = SD force output / mean force output

Subject matched leg or arm force with a reference force displayed on computer screen during isometric arm and leg extension (5% max force). Test done with and without visual feedback

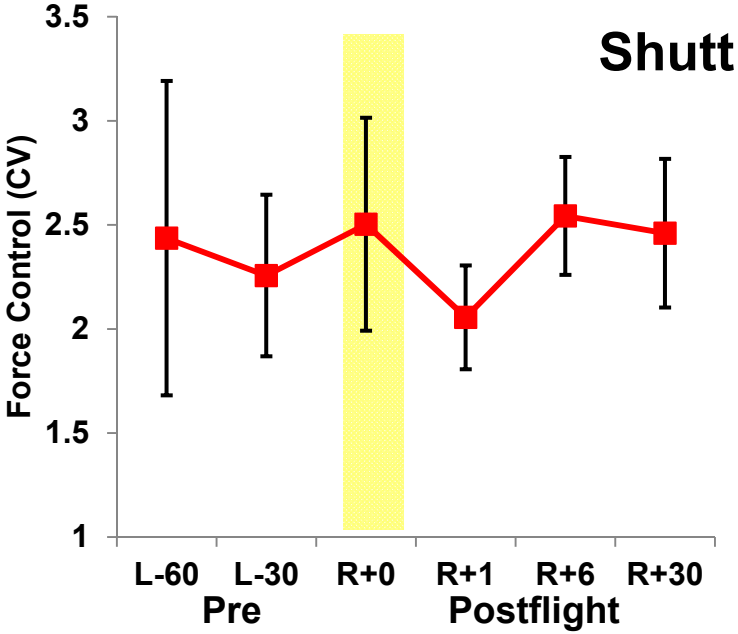
Lower Limb Force Control: With Visual Feedback

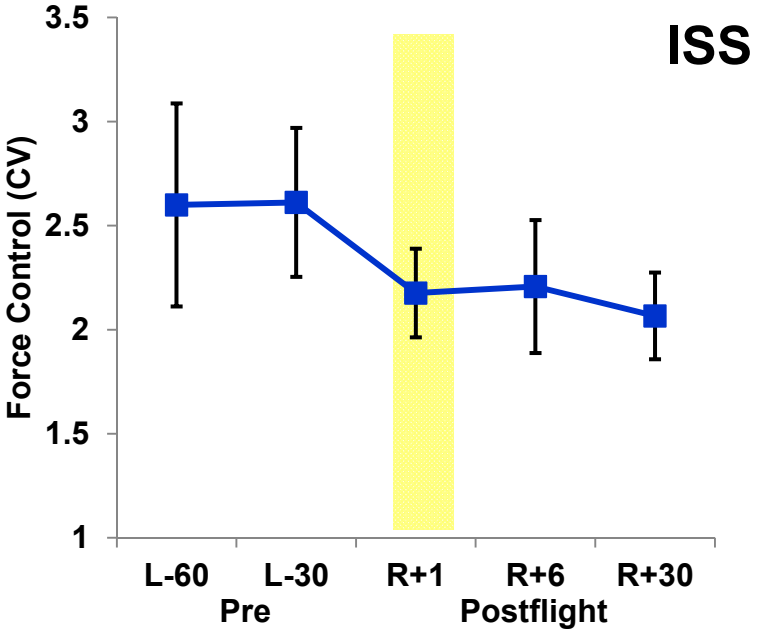


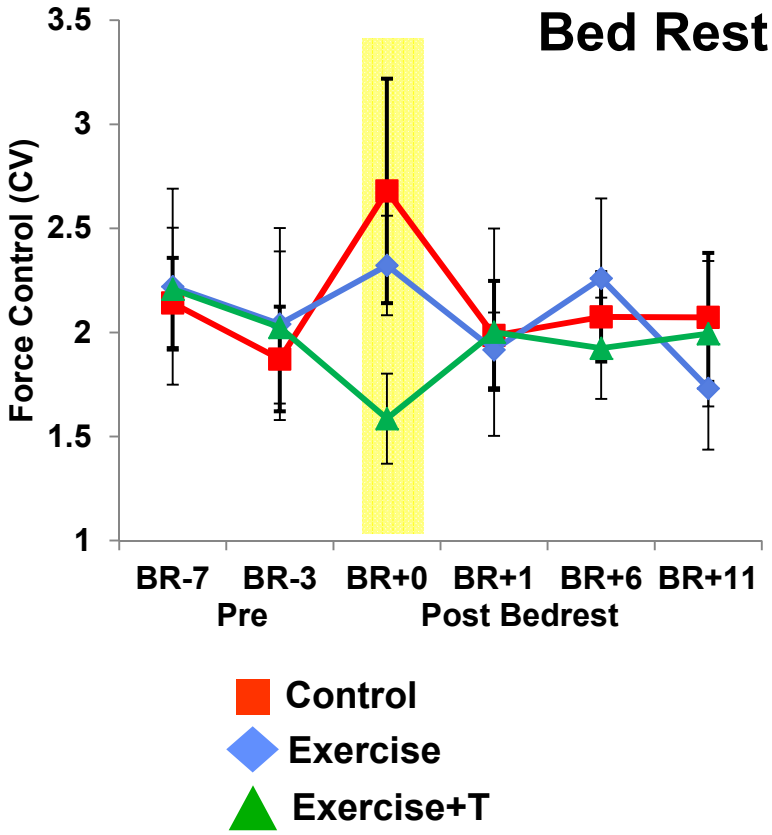




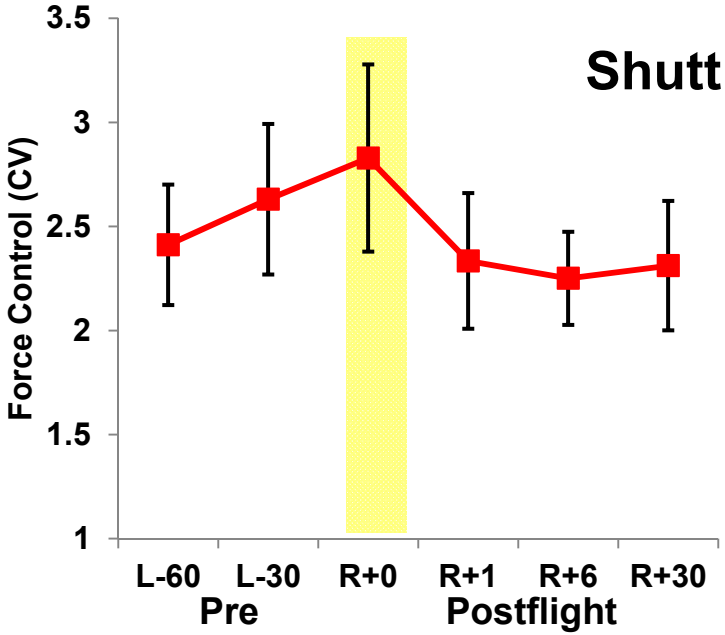
Lower Limb Force Control: Without Visual Feedback

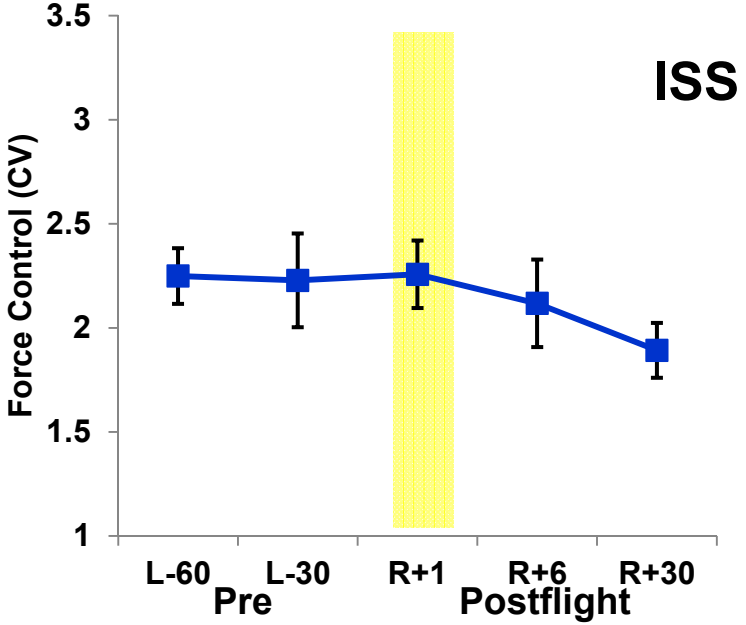


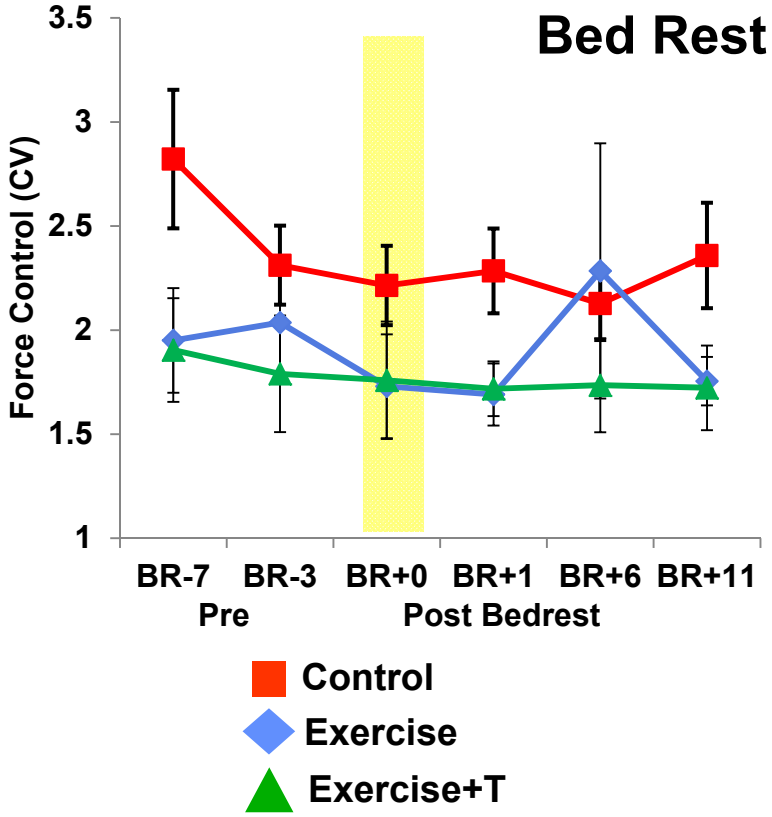




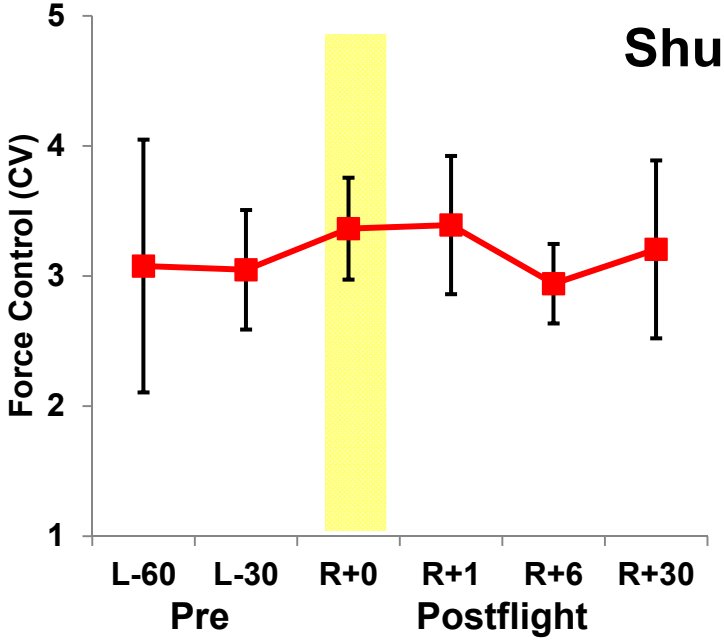
Upper Limb Force Control: With Visual Feedback

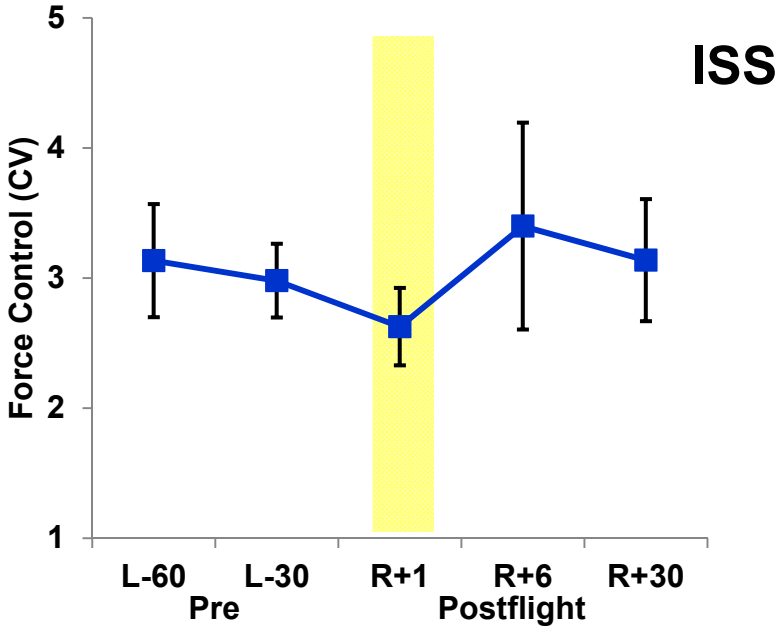


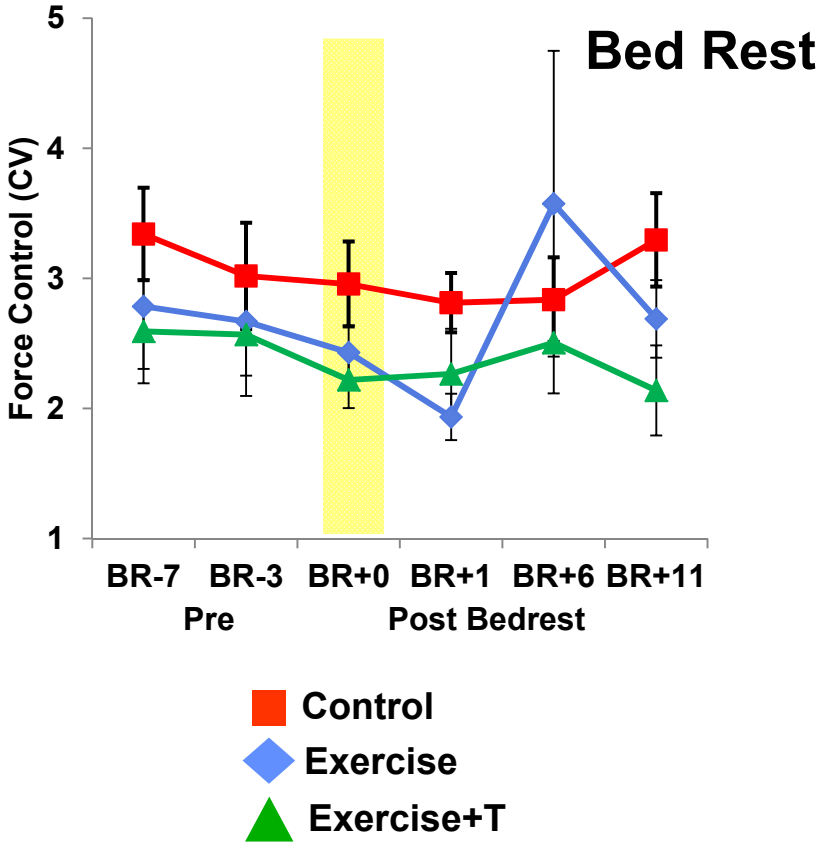




Upper Limb Force Control: Without Visual Feedback



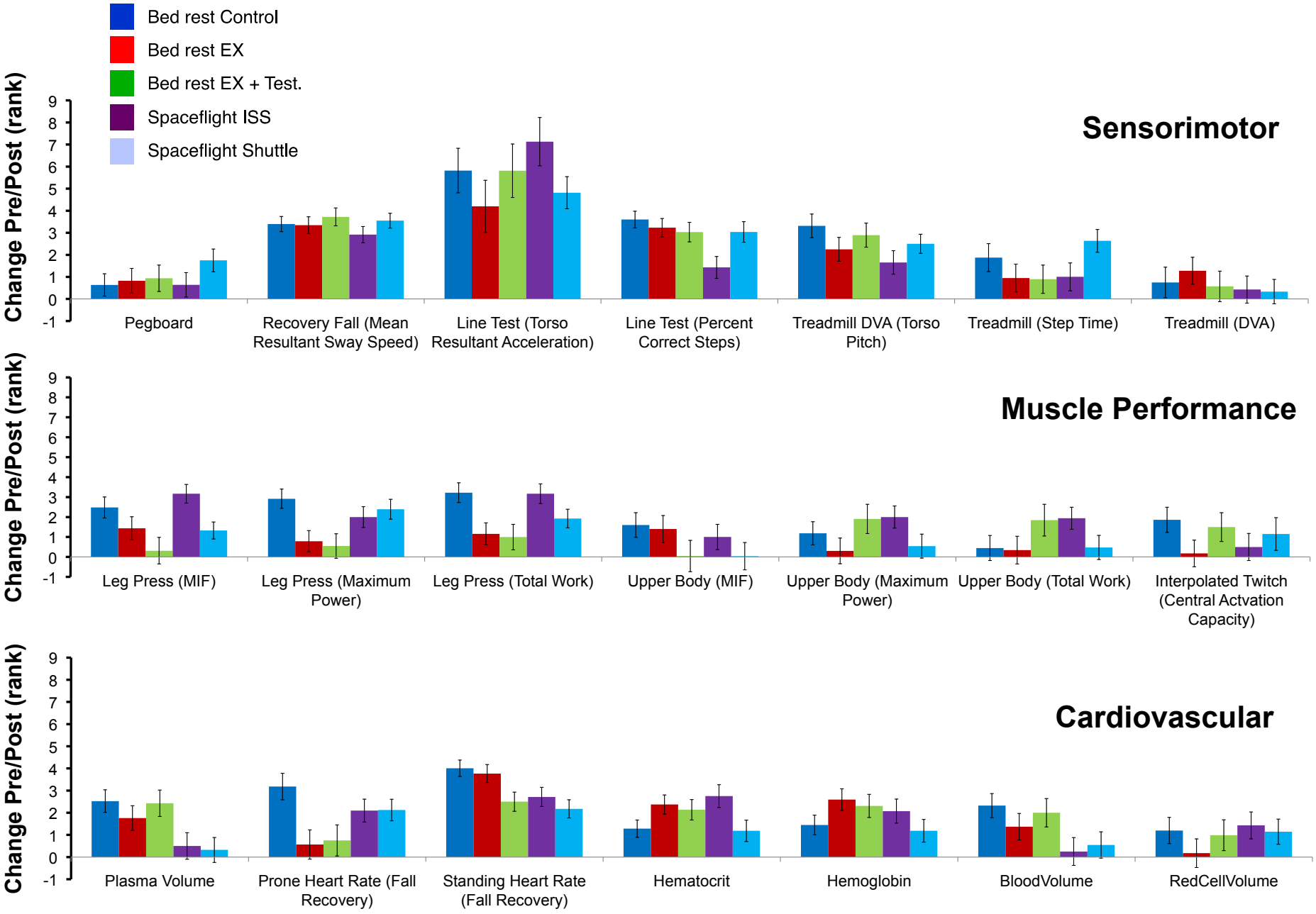




Summary: Muscle Performance

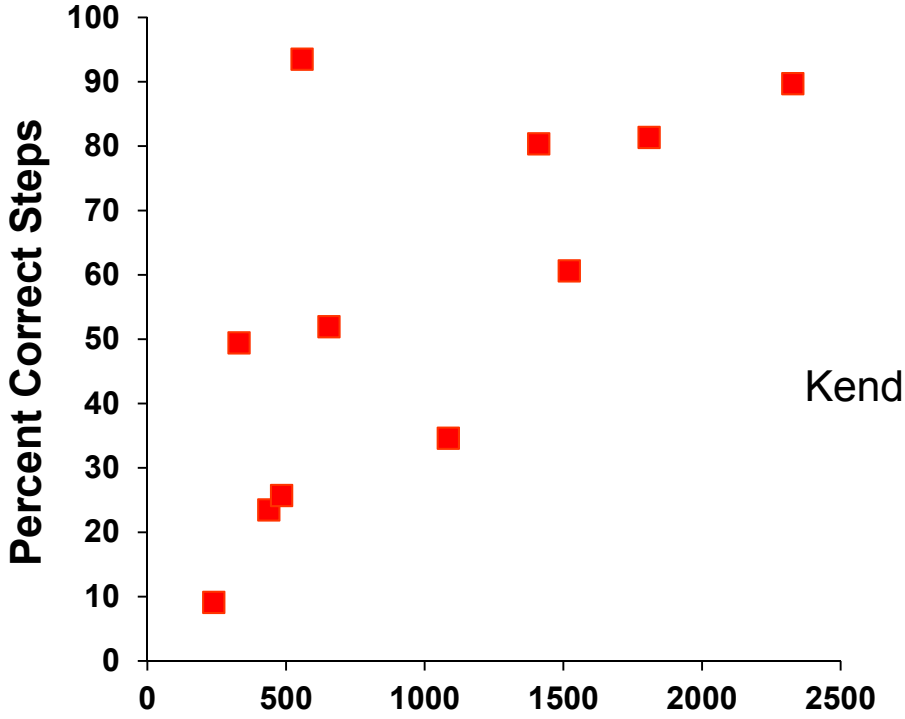
- Control bed rest subjects show decreased muscle performance of lower limbs.
- Central neural activation capacity altered for control bed rest subjects.
- No overall changes in force control were detected in all groups.

Comparison of Physiological Tests



Inflight Treadmill Exercise and Postflight Dynamic Walking Performance

Tandem Walk Test

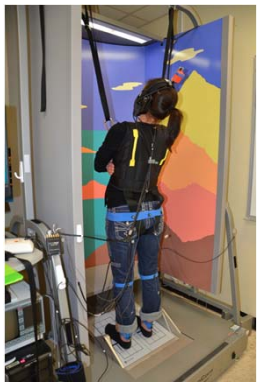


Kendalls Tau= 0.60 ($p < 0.01$)

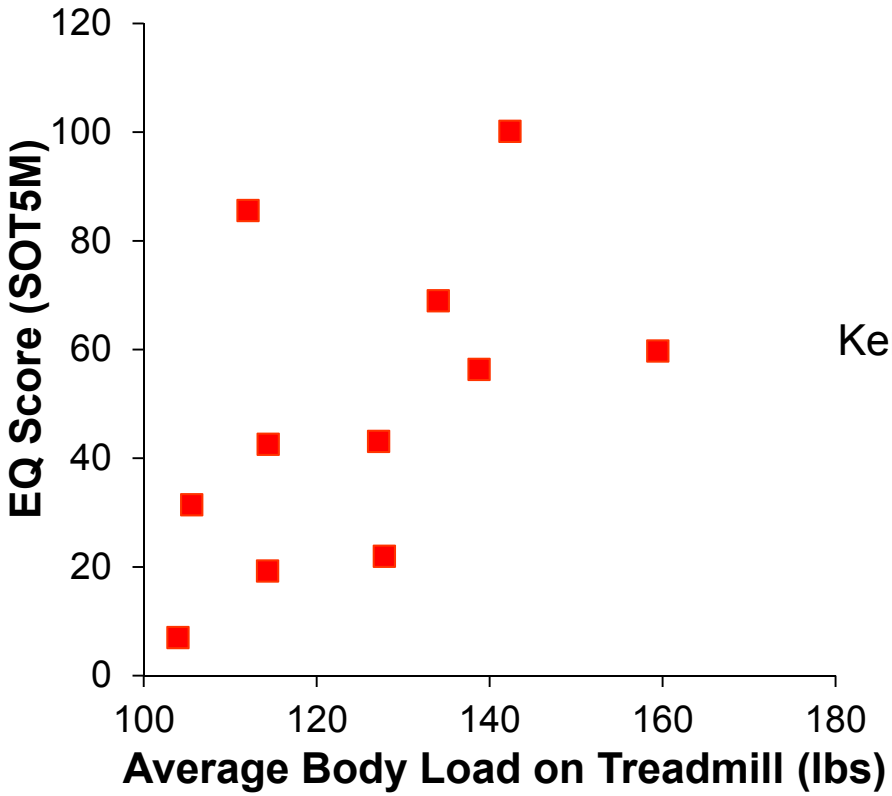
Inflight Treadmill Exercise

More time on treadmill associated with improved postflight postural stability control

Inflight Treadmill Exercise and Postflight Posture Control



Posture Test



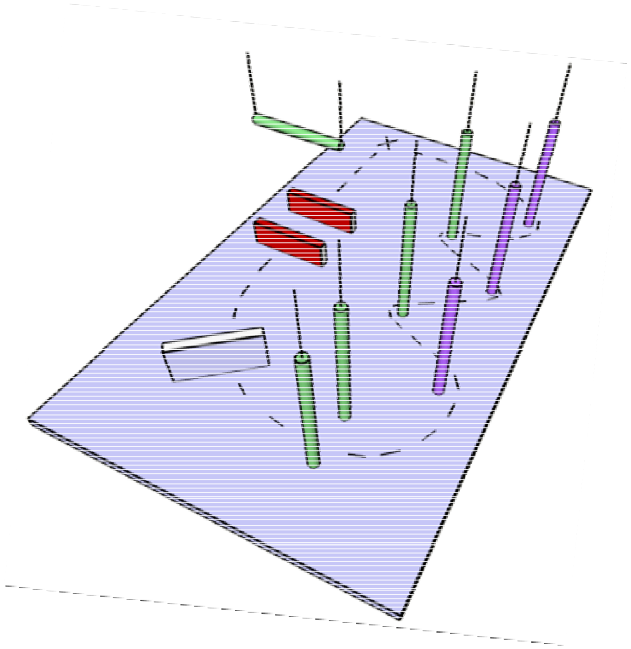
Kendalls Tau= 0.49 ($p < 0.05$)

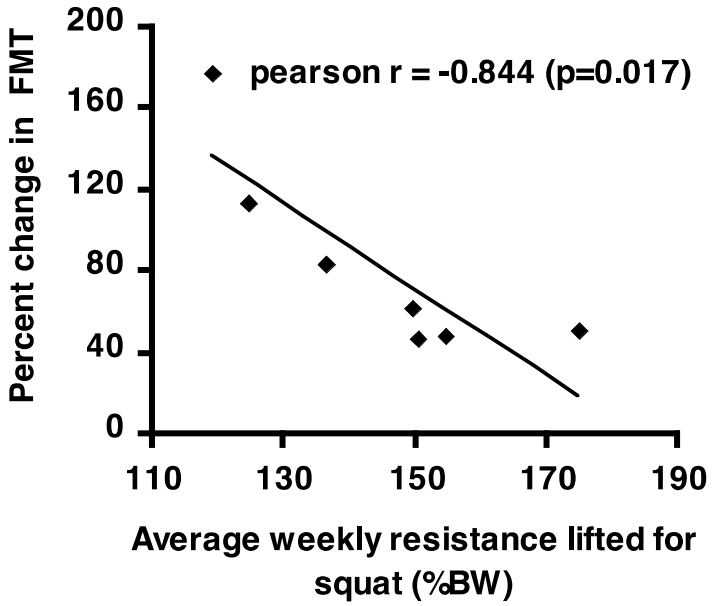
Inflight Treadmill Exercise

Increased body loading on treadmill associated with improved postflight postural stability control

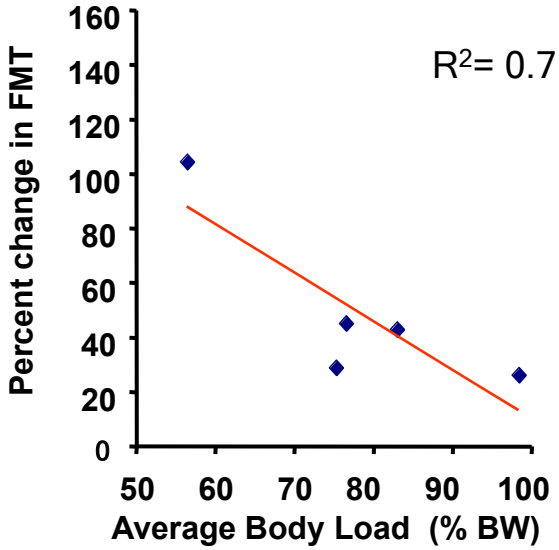
Exercising with greater loads improves postflight functional mobility (previous Mobility study)

Functional Mobility Test (FMT)





Greater loads during inflight squat exercises associated with enhanced postflight functional mobility



Increased body loading on treadmill enhanced recovery of postflight functional mobility

Integrated Countermeasure System: Requirements

1) Aerobic Exercise

2) Resistive Exercise

3) Balance training using treadmill walking

   - Support surface motion

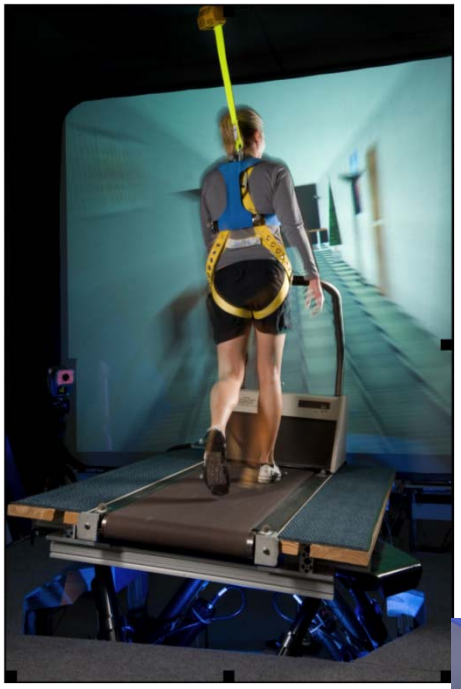
   - Modified visual flow

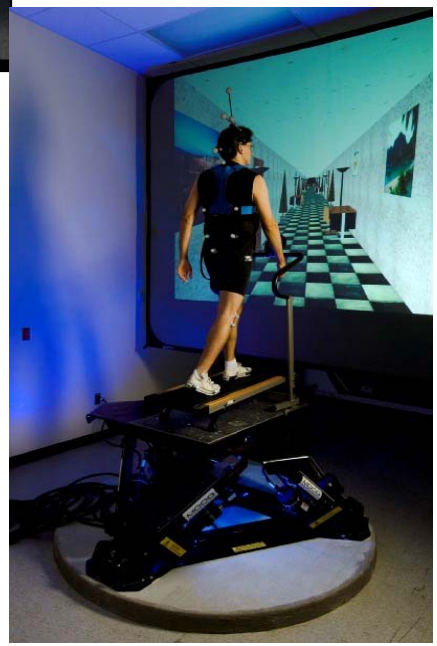
   - Axial body loading

Sensorimotor Adaptability Training System

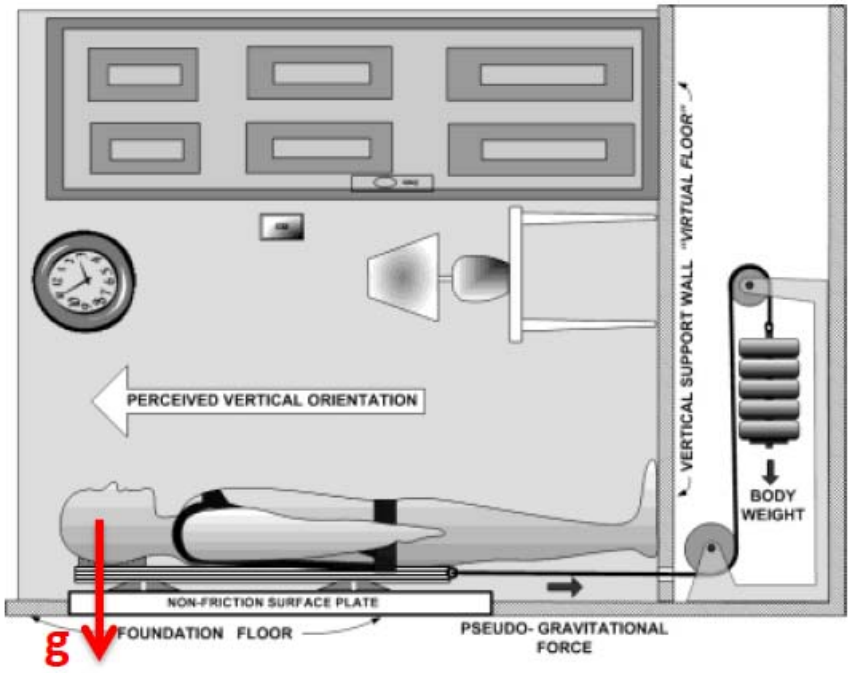
Train on a treadmill with surrogate sensory challenges:

- Altered visual information
- Support surface motion (motion base treadmill system)
- Variation in body loading





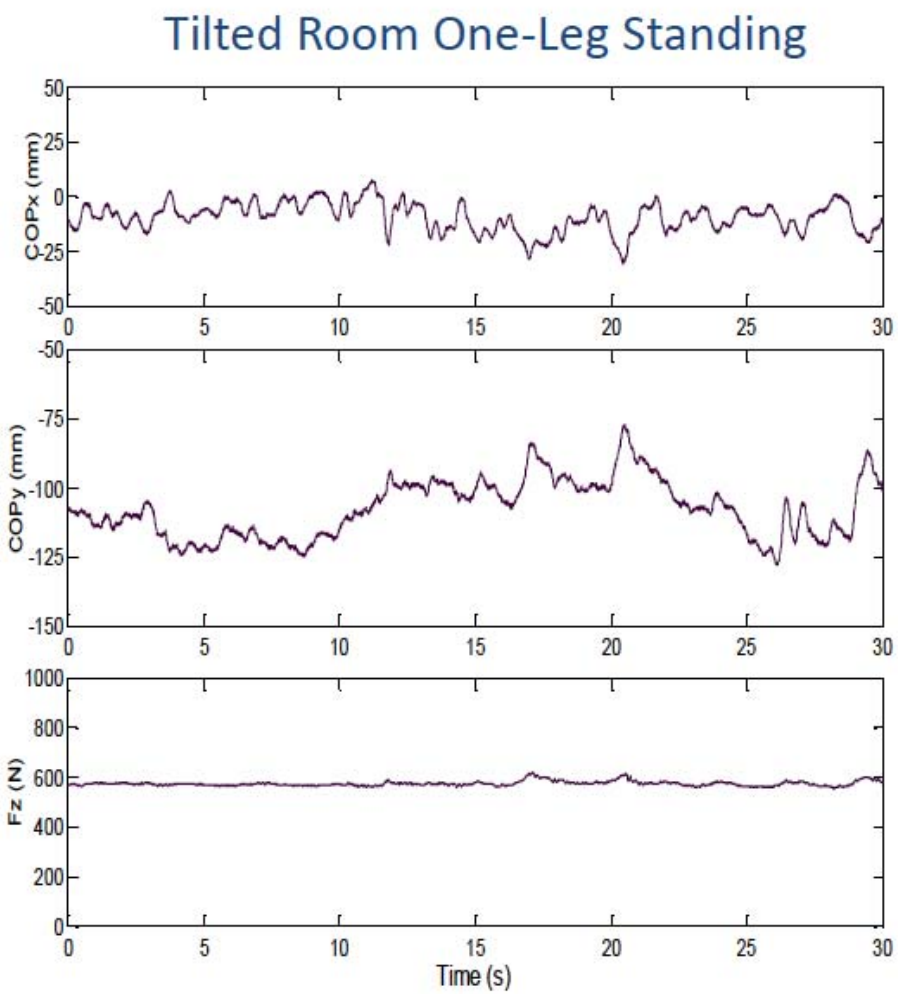
Gravity-Bed: Method to Provide Balance Training During Bed Rest

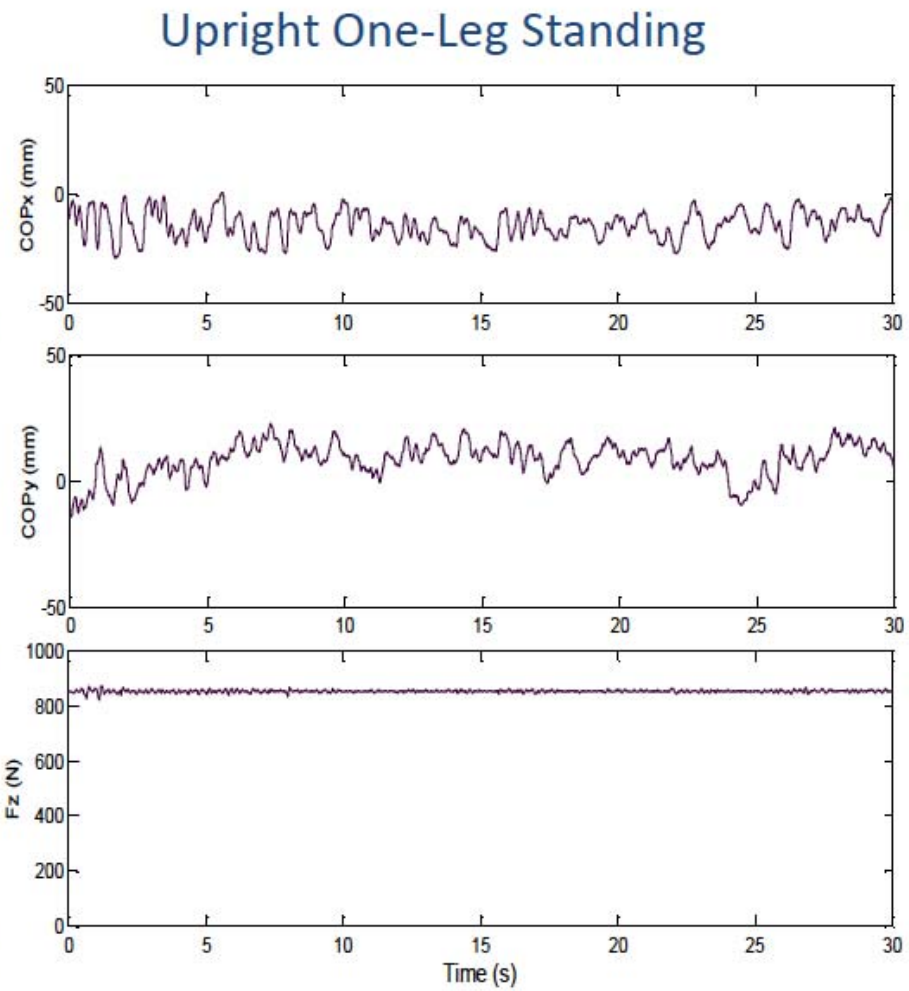


Backpack frame freely moving on air-bearings

Oddsson et al. A rehabilitation tool for functional balance using altered gravity and virtual reality *Journal of NeuroEngineering and Rehabilitation* 4:25, 2007

Sample Postural Stability Data

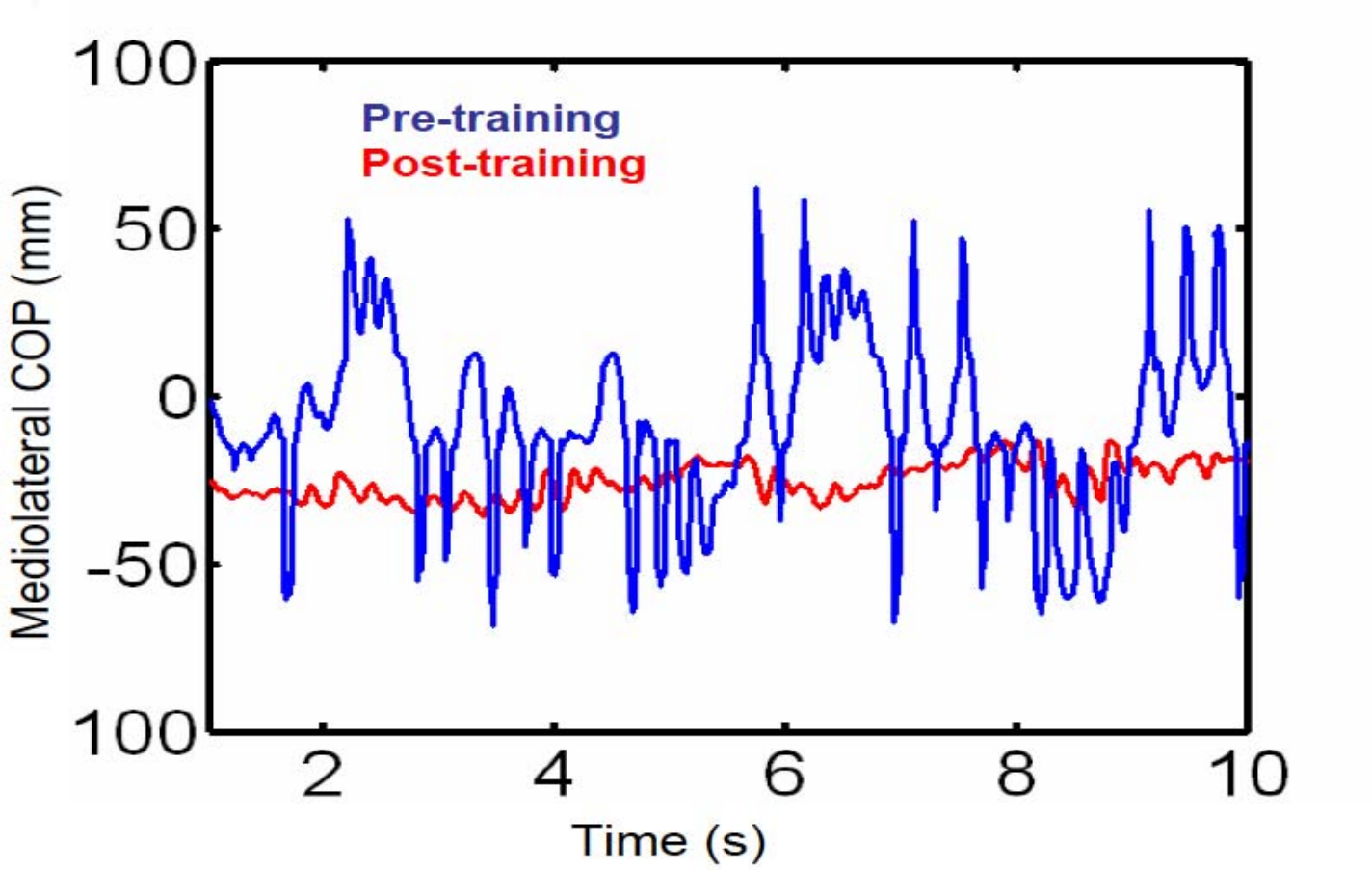




Courtesy Lars Oddsson

Gravity Bed Produces Similar Instability to Upright Standing

Sample Postural Stability Data

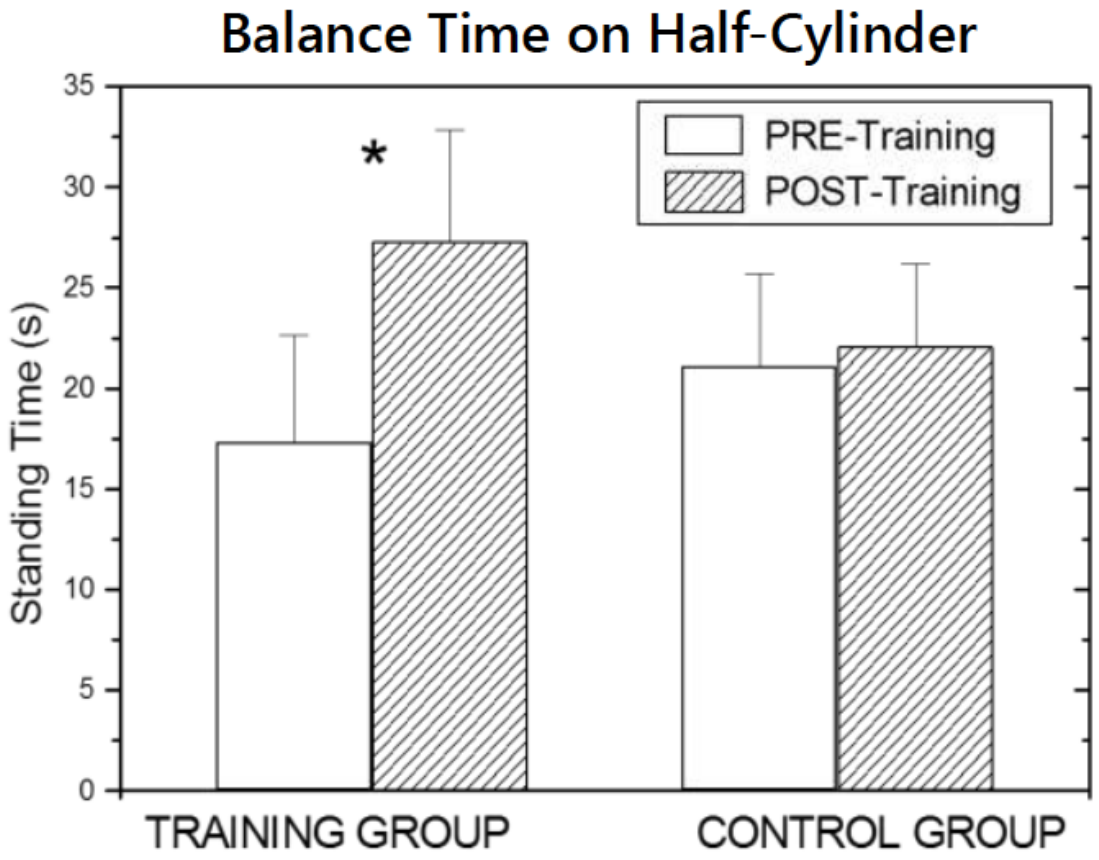


Courtesy Lars Oddsson

Gravity Bed Produces a Balance Training Effect

Gravity-Bed Training Study

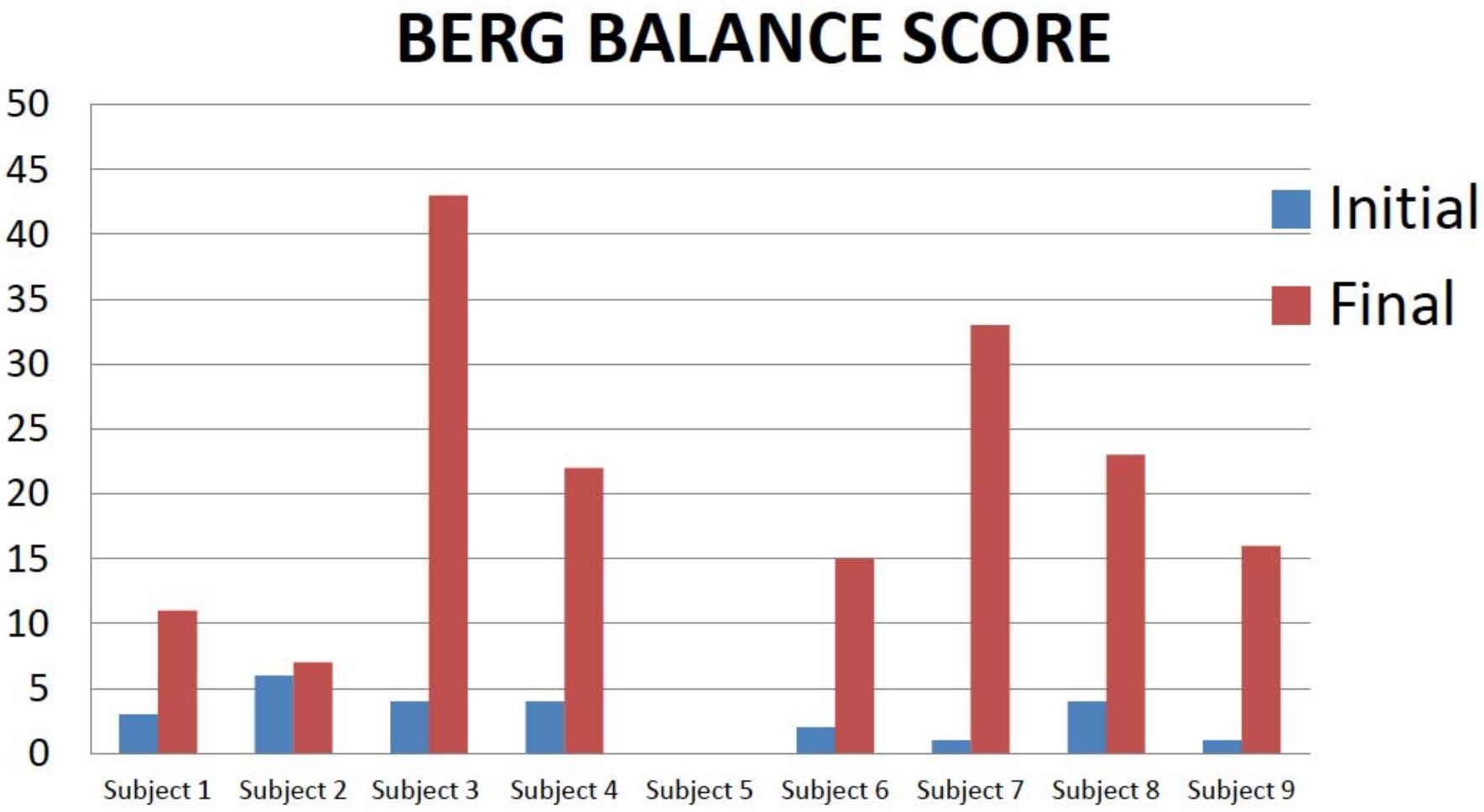
- Balance board in supine
- 10 training sessions over two weeks
- 5+5 healthy young subjects
- 10 trials 1-leg balancing for 35 s max



- Increase in Balance Time of 58% (17.3s to 27.3s, $p < 0.05$)
- No Change in Control Subjects

Oddsson & Wall 2002

Gravity-Bed Produces Improvement in Balance Control



Gravity Bed Training Improves Balance in Patients with Severe Balance Problems

Integrated Countermeasure System: Bed Rest Study

Training Group

1) Aerobic Exercise

2) Resistive Exercise

Flywheel

3) Balance training using treadmill walking

- Support surface motion
- Modified visual flow
- Axial body loading

Gravity Bed

Compare with Control and Exercise subjects from CFT70

Publication Plan

1) Combined space flight and bed rest paper

2) Multiple discipline/topic specific papers

Backup Slide

Somers D : Within Subject Significant Relationship

	Upright Egress	Supine Egress	Fall Recovery	Rock Translation	Activity Board	Torque Generation (Maximum)	Torque Generation (Work)	Ladder Climb
Sensorimotor	1. Pegboard 2. Fall Recovery (Mean Resultant Sway Speed) 3. Line Test (Torso Resultant Acceleration) 4. Treadmill (Trunk Pitch) 5. Treadmill (Step Time) 6. Line Test (Percent Correct Steps) 7. Jump (Settling Time)	1. Pegboard 2. Fall Recovery (Mean Resultant Sway Speed) 3. Line Test (Torso Resultant Acceleration) 4. Treadmill (Trunk Pitch) 5. Treadmill (Step Time) 6. Line Test (Percent Correct Steps) 7. Jump (Settling Time)	1. Pegboard 2. Fall Recovery (Mean Resultant Sway Speed) 3. Line Test (Torso Resultant Acceleration) 4. Treadmill (Trunk Pitch) 5. Line Test (Percent Correct Steps) 6. Jump (Settling Time)	1. Pegboard 2. Fall Recovery (Mean Resultant Sway Speed) 3. Line Test (Torso Resultant Acceleration) 4. Treadmill (Trunk Pitch) 5. Treadmill (Step Time) 6. Line Test (Percent Correct Steps) 7. Jump (Settling Time)	1. Pegboard 2. Line Test (Torso Resultant Acceleration) 3. Line Test (Percent Correct Steps)	1. Fall Recovery (Mean Resultant Sway Speed)	1. Pegboard 2. Line Test (Percent Correct Steps) 3. Jump (Settling Time)	1. Pegboard 2. Fall Recovery (Mean Resultant Sway Speed) 3. Line Test (Torso Resultant Acceleration) 4. Treadmill (Trunk Pitch) 5. Treadmill (Step Time) 6. Line Test (Percent Correct Steps) 7. Jump (Settling Time)
Exercise	1. Leg Press MIF 2. Leg Press Power 3. Leg Press Work 4. Upper Body Power	1. Leg Press MIF 2. Leg Press Power 3. Leg Press Work 4. Upper Body Power	1. Leg Press MIF 2. Leg Press Power 3. Leg Press Work 4. Upper Body Power	1. KnLeg Press MIF 2. Leg Press Power 3. Leg Press Work	1. Upper Body Power	1. Leg Press MIF 2. UpperBody Work	1. Leg Press MIF 2. Leg Press Power 3. Leg Press Work 4. UpperBody_ MaxIsometric Force	1. Leg Press MIF 2. Leg Press Work
Cardio	1. Plasma Volume 2. Prone Heart Rate Fall Recovery 3. Stand Heart Rate Fall Recovery	1. Plasma Volume 2. Prone Heart Rate Fall Recovery 3. Stand Heart Rate Fall Recovery	1. Plasma Volume 2. Prone Heart Rate Fall Recovery 3. Stand Heart Rate Fall Recovery	1. Plasma Volume 2. Stand Heart Rate Fall Recovery	1. Plasma Volume	1. Plasma Volume 2. Prone Heart Rate Fall Recovery 3. Stand Heart Rate Fall Recovery	1. Plasma Volume	1. Plasma Volume 2. Prone Heart Rate Fall Recovery 3. Stand Heart Rate Fall Recovery

Correlations between Functional and Physiological Tests (all data combined)