ABSTRACT

Existing models (such as bed rest) of muscle deconditioning are cumbersome and expensive. We propose a new model utilizing a weighted suit to manipulate strength, power, or endurance relative to body weight (BW).

Methods: 20 subjects performed 7 occupational astronaut tasks while wearing a suit weighted with 0-120% of BW. Models of the full relationship between muscle function/BW and task completion time were developed using fractional polynomial regression and verified by the addition of pre- and postflight astronaut performance data for the same tasks. Spline regression was used to identify muscle function thresholds below which task performance was impaired.

Results: Thresholds of performance decline were identified for each task. Seated egress & walk (most difficult task) showed thresholds of leg press (LP) isometric peak force/BW of 18 N/kg, LP power/BW of 18 W/kg, LP work/BW of 79 J/kg, and KE torque/BW of 1.9 Nm/kg.

Conclusions: Laboratory manipulation of relative strength has promise as an appropriate analog for spaceflight-induced loss of muscle function, for predicting occupational task performance and establishing operationally relevant strength thresholds.

INTRODUCTION AND PURPOSE

• Lower body muscle strength and power is related to performance of ambulatory tasks of daily living in older adults (1-4).
• Minimal strength / power requirements to perform ambulatory activities of daily living are related to body mass (4).
• Greater body mass requires more strength / power.
• Develop and validate a methodology for evaluation leg strength / power requirements of occupational astronaut tasks.

METHODS

• Subjects were tested for leg press (LP) maximal isometric force (MIF), power and work (21 reps at 40% MIF) as well as knee extension MIF and isokinetic peak torque at 60 deg/sec.
• Subjects performed a series of occupational tasks including seated egress & walk, ladder climb, rock translation, hatch opening, recover y from fall, and construction board.
• Tasks were performed wearing a weighted garment loaded with 0, 20, 40, 60, 80, 100 or 120% of body weight distributed over the body according to limb weight segments to minimize changes in the center of gravity.

STATISTICAL MODELING

Spline Regression
• Extension of OLS regression that estimates the relationship between outcome and predictor as a piecewise linear function composed of two or more linear segments.
• Used to model a single-knot/two-slope linear association between all strength/body weight predictors and the time to completion for each task.
• Modeled a two-slope association, where the intersection of the two segments (knot) represents the threshold where the association between strength/body weight and performance changes. Separate models were estimated varying the knot location by percentile increments throughout the range of X including a no-spline (linear) model. The model of best-fit was chosen based on the highest multiple R2 coefficient of determination.

Fractional Polynomial Regression
• Generalization of polynomial regression that allows fractional powers and/or powers of the natural log of X in the estimation of a curvilinear relationship.
• Used to estimate the full curvilinear association between individual strength/body weight predictors and time to completion.
• Consistent with our threshold-hypothesis we restricted our models to include, at most, three terms including the Y-intercept.

RESULTS

Table: Muscle Function Thresholds

<table>
<thead>
<tr>
<th>Task</th>
<th>Thresholds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg Press</td>
<td>18 N/kg</td>
</tr>
<tr>
<td>LP Power</td>
<td>18 W/kg</td>
</tr>
<tr>
<td>LP Work</td>
<td>79 J/kg</td>
</tr>
<tr>
<td>Knee Extension</td>
<td>1.9 Nm/kg</td>
</tr>
</tbody>
</table>

DISCUSSION

• Laboratory manipulation of relative strength has promise as an appropriate analog for spaceflight-induced loss of muscle function, for predicting occupational task performance and establishing operationally relevant strength thresholds.
• Addition of astronaut data appears to confirm the models established using the weighted suit.
• Future work should focus on optimization of both predictors and tasks.

REFERENCES