



Novel Analog For Muscle Deconditioning

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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 (function) 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, isokinetic knee extension (KE)/BW of 6 Nm/kg, and KE torque/BW of 1.9 Nm/kg.

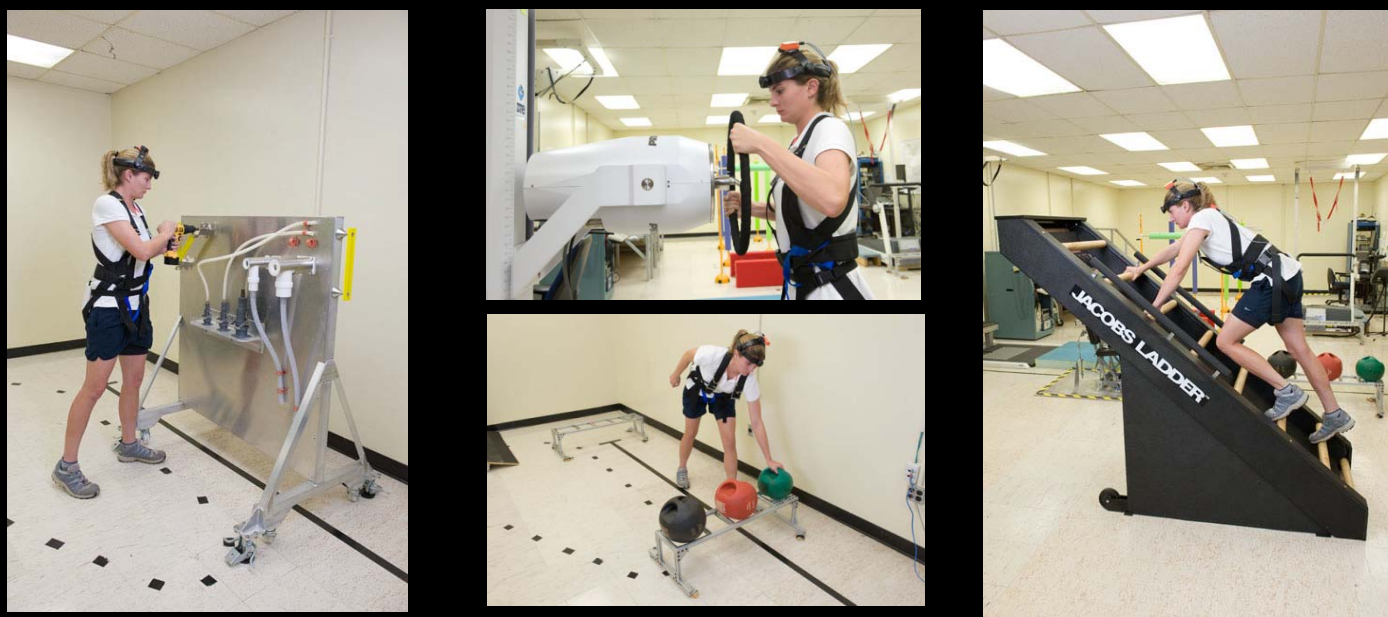
Conclusions: Laboratory manipulation of relative strength has promise as an appropriate analog for spaceflight-induced loss of muscle function, for predicting occupational task performance and establishing operationally relevant strength thresholds

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.

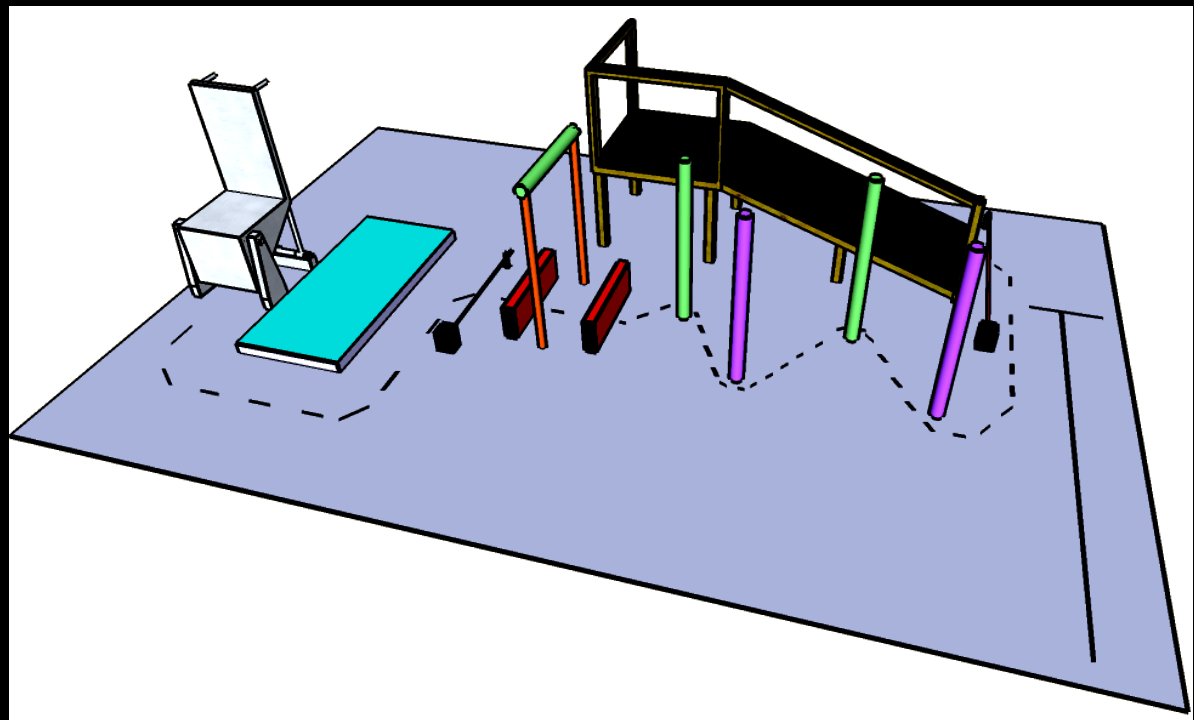


RESULTS



Weighted suit used to manipulate strength or power/body weight ratio

Spline (red line) and fractional polynomial models with 95% confidence intervals (black curve with gray shading) predicting time to completion from the seat egress and walk task from leg press power/body weight ratio. Models were estimated from weighted suit experimental subjects (open circles), with the spline model extended throughout the range of astronaut pre-flight (open triangles) and post-flight observations (filled triangles).



Seated egress and walk task

Ambulatory Tasks	Seated Egress & Walk		Supine Seated Egress & Walk		Recovery From Fall		Ladder Climb		Rock Translation	
	R ²	Threshold	R ²	Threshold	R ²	Threshold	R ²	Threshold	R ²	Threshold
LPpower:BW	0.41	17.5	0.49	14.6	0.45	6.2	0.59	8.2	0.40	6.5
LPmif:BW	0.60	17.8	0.67	13.7	0.55	13.8	0.62	13.3	0.52	13.1
LPwork:BW	0.41	78.8	0.51	72.4	0.45	71.4	0.56	34.4	0.32	71.4
KEmif:BW	0.43	5.9	0.47	5.7	0.39	5.4	0.52	5.2	0.38	4.5
KEisokinetic:BW	0.44	1.9	0.48	1.8	0.40	1.7	0.45	1.0	0.28	1.7
BPmif:BW	0.30	3.4	0.41	3.4	0.34	3.4	0.49	4.7	0.36	3.4
BPwork:BW	0.20	17.2	0.28	17.2	0.26	17.2	0.47	17.2	0.22	18.3

Upper Body Tasks	Hatch: Max Torque		Hatch: Total Work		Hatch: Distance		Construction Board	
	R ²	Threshold	R ²	Threshold	R ²	Threshold	R ²	Threshold
KEmif:BW	0.14	7.6	0.27	4.7	0.22	4.9	0.15	5.2
KEisokinetic:BW	0.07	1.0	0.09	2.4	0.15	1.6	0.06	1.0
BPpower:BW	0.36	2.3	0.63	10.8	0.23	10.6	0.05	2.3
BPmif:BW	0.32	11.6	0.62	13.0	0.24	4.0	0.07	3.1
BPwork:BW	0.45	45.9	0.74	46.0	0.22	21.0	0.06	9.9

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 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.

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

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