A Better ARED Squat

E. E. Caldwell[1], N. J. Newby[1], L. Ploutz-Snyder[2]
[1]Wyle Science, Technology & Engineering Group, 1290 Hercules Drive, Houston, TX 77058
[2]NASA Glenn Research Center, 21000 Brookpark Rd., Cleveland, OH 44135
[2]Universities Space Research Association, 3600 Bay Area Blvd., Houston, TX 77058

Background: The 0-G ARED squat under loads the legs relative to the 1g ARED squat. In 1g the knee extensor/flexor muscles are primarily engaged due to the body's center of gravity is behind the knees during the motion of the squat. As body weight does not play a sufficient role 0 G, a crewmember's load exposure is limited by the load delivered by ARED through the exercise bar. Prescription loads for lower-body resistance exercise in microgravity aim to include 1-G exercise bar load in addition to the crewmember's Earth body weight (BW); however, pressure points from the bar and the 1BW increased load at the shoulders translating to higher loads on the back have been a historical limitation for shoulders, requiring a decrease in exercise load at the start of the mission. Analogous to crewmembers, bed rest subjects report limitations of exercising with high loads on the back while performing squats on the horizontal exercise fixture (HEF), a custom exercise device that serves as an analog to 0-G ARED. Improvements for increasing loads on the HEF squat were suggested by distributing total exercise load between the hips and the bar[1]. The same is recommended for the 0-G ARED squat, with using current equipment on the ISS, which include the T2 running harness and T2 bungees. Quantification of this improvement has been accessed through computational modeling.

The purpose of this study is to characterize joint torque during a squat with a distribution in exercise load on the ARED in 0 G. The analysis used existing models from NASA's Digital Astronaut Project. The biomechanics squat model was integrated with the ARED model and T2 bungees. The spring constant for the bungees were derived from ground testing. Forward dynamic simulation was performed for various conditions including anchor point attachments on the footplate of the ARED, bar load, hip load, and gravitational environment.

Table1. Simulation Conditions Completed in LifeMod

Environment	Body Weight (kg)	Hip Load (kg)	Anchor Point	Bar Load (kg)	Total Load (kg)
1-G Ground	76	0	N/A	86	162
0-G Start of Mission	0	0	N/A	122	122
0-G End of Mission	0	0	N/A	162	162
0-G w/bungee	0	38	Fore/Mid/Aft	124	162
0-G w/bungee	0	57	Fore/Mid/Aft	105	162
0-G w/bungee	0	76	Fore/Mid/Aft	86	162

Results: The model confirms joint torques at knees is lower relative to 1G conditions primarily because the load delivery system is just with the exercise bar in 0 G. By distributing partial loads through use of the bungees to the hips joint-torque profiles were altered during a squat and provided options to enhance targeting lower-body loading in aims as for an improved countermeasure.

Future Work: Distributing the load at the hips and shoulders can be used to develop an enhanced prescription by targeting specific muscle groups, thereby allowing for increased total loads as well as providing a hybrid of lower-body exercises on the ARED. While applications on the ISS are important, it is critical to think about the future of exercise hardware in smaller space vehicles. Current requirements for exercise hardware must be able to deliver 600 lb.; however, implementation of dividing the load could provide increased design options for volume, power, and mass.

1. Newby N, Leach M, Fincke R, Sharp C. Hardware Evaluation of the Horizontal Exercise Fixture with Weight Stack, NASA Technical Report, 2009, http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100017350_2009036319.pdf