A comparison of squatting exercise on a centrifuge and with earth gravity

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Abstract

Purpose: Long-duration space missions require countermeasures against the muscular wasting and cardiovascular deconditioning associated with microgravity. Replacing gravitational acceleration by means of centrifugation is a promising alternative as it challenges all physiological systems at once.

The aim of this study is to examine the metabolic energy costs of squatting on a centrifuge in comparison with squatting in upright standing posture under natural gravity. On the centrifuge a potential impact of the Coriolis-effect on the energy cost was test by squatting at two different radii.

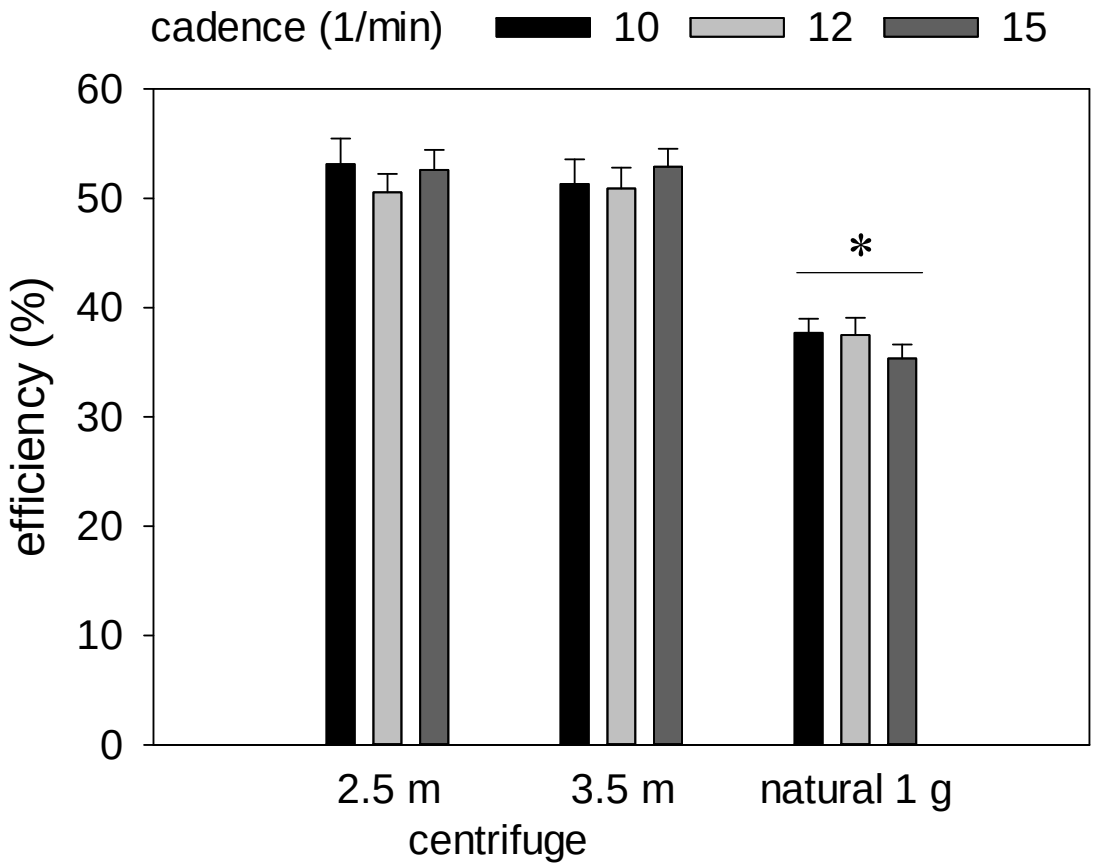
Methods: 24 subjects (11 male, 13 female) performed continuous squatting exercise for 9 minutes with increasing cadence (10, 12, 15 squats·min^{-1}, each 3 min). This procedure was repeated under three conditions: Upright standing and guided by a sledge, under natural gravity and lying supine on a centrifuge with the foot plate fixated at 2.5 and 3.5 m distance from the rotation axis, respectively. A centrifugal acceleration of 1g was set by the angular velocity, which was adjusted when the subject reached the body weight measured at the foot plate in the mid position of a squat. Oxygen consumption rate ($V'O_2$) during exercise was determined by subtracting the consumption at rest 1 min before exercise. $V'O_2$ was normalized to body mass. The metabolic efficiency was calculated assuming a constant caloric equivalent of 20.9 Ws per ml O2 and a total power calculated as concentric power + 0.3 x eccentric power.

Efficiency = 100 x (concentric power + 0.3 x eccentric power) / (V'O2 x 20.9/60)

Results: Generally, subjects did not suffer from motion sickness. Training under natural gravity led to a higher $V'O_2$/body mass (7.1±2.0, ml·min^{-1}·kg^{-1}, mean ± SD,) compared with training on the centrifuge (6.1 ±1.6). The metabolic efficiency was lower under natural gravity (37±7, %) than on the centrifuge (52±9, %). As expected, oxygen consumption increased with increasing cadences. The Coriolis-effect had a negligible impact as there was no significant difference in $V'O_2$ between the two radii. However, during centrifugation and upwards movement the right leg was more loaded than the leg left and versus visa during downwards movement.

Conclusions: The lower $V'O_2$ on the centrifuge may be attributed to the improved stabilization of the torso which had to be provided by the subjects themselves while in the upright condition. Subjects tolerated high rotational rates combined with exercise very well.

Figure legend: Additional oxygen consumption rate normalized on mean power (concentric power + 0.3 x eccentric power) during squatting with almost body weight on a centrifuge and under natural 1g. *: P<0.01.


cadence (1/min)
10
12
15
60
50
40
30
20
10
0
efficiency (%)
*
2.5 m
3.5 m
natural 1 g
centrifuge