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Title

Biomechanics during quadriceps resistance exercise – effects of the direction of the gravity vector

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Introduction

During conventional strength training, musculoskeletal loading is commonly provided both by the body weight and by externally added load. In microgravity, the entire load during resistance exercise (RE) will be imposed by external resistance. Hence, when an astronaut performs a squat exercise in space, an extra load corresponding to 70% of the body weight is typically added to the shoulder-mounted bar, resulting in a different regional load distribution than in the 1-G condition. Information is scarce regarding biomechanical effects of body position in relation to the gravity vector during traditional resistance exercise, and particularly during resistance exercise developed for astronauts. Accordingly, this study aimed at comparing the internal load distribution on the musculoskeletal system during two corresponding quadriceps resistance exercises performed in the direction of, and perpendicular to, the gravity vector.

Methods

16 healthy subjects (8 women, 8 men, age: 24 ± 2 years) performed knee flexions/extensions with horizontal (H; i.e. leg press) and vertical (V; squat) movements using an inertia-dependent flywheel exercise device. Motion capture and external force data were recorded and used as input in a musculoskeletal modelling software (AnyBody Modeling System), in which joint angles and moments were calculated. Total load was expressed as the sum of foot reaction forces, measured by force plates. External resistance was measured by a traction force sensor in the harness pulley, connecting the subject to the flywheel. The subjects performed an isometric maximum quadriceps contraction in a restricted H position and the measured total load was used to calculate the target value for the dynamic trials, where 10 repetitions of each exercise were completed.

Results

For a total load of 80% of the isometric maximum reference value, the external resistance was twice as high in H (1.99 ± 0.41 BW) as in V (1.03 ± 0.37 BW, $p < 0.001$). Peak ankle- and hip-joint moments were greater in H than in V, whereas the peak knee-joint moments were similar in both positions (table 1).

Table 1. Peak joint moments in H and V at 80% of isometric maximum. Moments are plantar flexion (ankle) or extension (knee and hip).

Joint	H [BW BH] (M ± SD)	V [BW BH] (M ± SD)	p
Ankle	0.062 ± 0.019	0.043 ± 0.014	0.001
Knee	0.092 ± 0.019	0.098 ± 0.016	0.09
Hip	0.108 ± 0.031	0.085 ± 0.026	0.001

Discussion

Resistance exercise performed perpendicular to the gravity vector required twice as much external load, and induced higher peak plantar flexion and extension moments in the ankle and hip joints, respectively, compared to exercise performed at the same reference load in the direction of the gravity vector. This indicates that the gravitational direction impacts the regional load distribution and should be considered when prescribing exercise regimens for astronauts.