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original research

Joint Kinetics and Kinematics During Common Lower Limb Rehabilitation Exercises

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Context: Unilateral body-weight exercises are commonly used to strengthen the lower limbs during rehabilitation after injury, but data comparing the loading of the limbs during these tasks are limited.

Objective: To compare joint kinetics and kinematics during 3 commonly used rehabilitation exercises.

Design: Descriptive laboratory study.

Setting: Laboratory.

Patients or Other Participants: A total of 9 men (age = 22.1 ± 1.3 years, height = 1.76 ± 0.08 m, mass = 80.1 ± 12.2 kg) participated.

Intervention(s): Participants performed the single-legged squat, forward lunge, and reverse lunge with kinetic data captured via 2 force plates and 3-dimensional kinematic data collected using a motion-capture system.

Main Outcome Measure(s): Peak ground reaction forces, maximum joint angles, and peak sagittal-joint moments.

Results: We observed greater eccentric and concentric peak vertical ground reaction forces during the single-legged squat than during both lunge variations ($P \leq .001$). Both lunge variations demonstrated greater knee and hip angles than did the single-legged squat ($P < .001$), but we observed no differences between lunges ($P > .05$). Greater dorsiflexion occurred during the single-legged squat than during both lunge variations ($P < .05$), but we noted no differences between lunge variations ($P = .70$). Hip-joint moments were greater during the forward lunge than during the reverse lunge ($P = .003$) and the single-legged squat ($P = .011$). Knee-joint moments were greater in the single-legged squat than in the reverse lunge ($P < .001$) but not greater in the single-legged squat than in the forward lunge ($P = .41$). Ankle-joint moments were greater during the single-legged squat than during the forward lunge ($P = .002$) and reverse lunge ($P < .001$).

Conclusions: Appropriate loading progressions for the hip should begin with the single-legged squat and progress to the reverse lunge and then the forward lunge. In contrast, loading progressions for the knee and ankle should begin with the reverse lunge and progress to the forward lunge and then the single-legged squat.

Key Words: joint moment, peak force, lunge, single-legged squat, loading

Key Points

- Concentric and eccentric peak vertical ground reaction forces were greater during the single-legged squat than during the reverse and forward lunges because of an increased base of support during the lunges and greater ankle- and knee-joint moments.
- Hip-joint moments were greater in the forward lunge.
- Peak joint angles were greater in the lunge variations than in the single-legged squat.
- Practitioners can use this information to develop a progressive loading paradigm for the hip, knee, and ankle during rehabilitation after injury.

Factors determining the progression of exercise loads during rehabilitation after injury currently follow 1 of 2 general approaches: (1) a progression according to tissue-healing time frames based on histologic studies and (2) an evaluation-based protocol in which the patient passes specific criteria before progression. Both approaches have several advantages and disadvantages.[1]

During the first approach, progressive loading may be applied, but it is often applied based on time-since-injury criteria rather than tissue-capability criteria. The resultant lack of progressive loading based on tissue capability may provide insufficient stimulus for optimal tissue development and has been proposed to increase the likelihood of disorganized scar formation, passive muscle and joint stiffness, muscle atrophy, and prolonged rehabilitation times.[2] The second approach potentially applies controlled stresses on the injured body part, which is likely to promote tissue healing that enhances the mechanical properties of the injured tissues. The problem with the second approach is that limited objective criteria of when and how to progress exercises for the magnitude of mechanical load are available within the research literature, especially when this involves the selection of different exercises.[3] If the level of loading is unknown, then a logical progressive schema of tissue loading cannot be applied. Musculoskeletal modeling has described the internal forces, including a patellofemoral-joint force range from 2.5 to 7.6 times body mass and a tibiofemoral joint force range from 2.5 to 7.3 times body mass during body-weight squatting.[4–17] Such force results in increased stress on the joint articular surfaces and muscle tendons and increased force production that the muscles require to arrest movement, especially during the eccentric