HIP LOADING DURING THE SQUAT EXERCISE

Gabe Haberly¹ and Michael Pavol²

¹Department of Health and Human Performance, George Fox University, Newberg, OR USA
²School of Biological and Population Health Sciences, Oregon State University, Corvallis, OR USA

email: ghaberly@georgefox.edu, web: http://www.georgefox.edu/academics/undergrad/departments/performance/

INTRODUCTION

Hip fractures have high mortality and morbidity rates [1], and a major risk factor for these fractures is a loss of bone at the hip in older age [2]. Lower-body resistance exercises that apply large forces to the femur at the hip may be able to slow this bone loss, however. The squat appears to be one such exercise, as bone density of the femoral neck increased in postmenopausal women with low bone density after a program of squats [3]. The effectiveness of the squat exercise in preventing bone loss at the hip may depend on how it is performed, however. This study thus determined the peak force on the femur at the hip as a function of squat depth and the extent to which this relationship is affected by adding static resistance to the upper body.

METHODS

Twenty healthy, physically active women, aged 35-49 years (mean ± SD: 43 ± 5 yrs) gave informed consent to participate. Participants performed a task-specific warm-up, and then two sets of squat trials, one without and one with a 5.4 kg weighted vest. Within each set, participants performed 3-4 squats to each of four depths, at about 2 s per repetition, with a pause between. Shallow squats corresponded to a position in which the knees were above the toes and the hips above the heels. During deep squats, participants lowered their hips as low as they felt they safely could without touching a chair behind them. Depths for the medium-shallow and medium-deep squats corresponded to knee flexion angles that were approximately one-third and two-thirds of the way, respectively, between the peak knee flexion seen in the warm-up during shallow and deep squats. During each squat, kinematic data were recorded at 60 Hz by a motion capture system and the ground reactions under each foot were recorded at 360 Hz by a pair of force plates.

For each correct squat, the peak magnitude of the contact force on the femur at the hip joint was estimated from the filtered kinematic and ground reaction data using a biomechanical model, scaled to each participant, in the AnyBody Modeling System (Aalborg, Denmark). Inverse dynamics solutions were found that minimized the sum of the cubed forces, normalized to maximum, in 169 Hill-type muscle fascicles in each limb. Peak trunk and knee flexion angles were also extracted. Values were averaged between limbs and forces normalized to body weight. Mixed-model linear regression determined the effects of peak knee angle, peak trunk angle, weighted vest use, and their two-way interactions on the peak contact force at the hip. Random effects of participant on the intercept and on the effect of knee angle were included. Effects were considered significant at p<.05. Data from one participant were excluded.

RESULTS AND DISCUSSION

The magnitude of the peak contact force on the femur at the hip joint was influenced by the peak knee flexion angle, peak trunk flexion angle, and weighted vest use, with the effects of knee angle interacting with both trunk angle and vest use (all p<.001). Peak contact force at the hip increased with increasing knee flexion and/or trunk flexion, and the extent to which weighted vest use increased this peak contact force increased with greater knee flexion (Figure 1). Effects of increased knee flexion decreased with greater trunk flexion. The regression model explained 94% of the variance in peak contact force.

The main contributors to the contact force on the femur at the hip are upper body weight and forces from muscles acting across the hip. As squat depth increases, so does the activity, and presumably force output, of the hip extensors [4]. This can be explained by a decrease in moment arm with increased hip flexion [5] and an increase in the hip extension moment needed to support the more flexed trunk, as peak knee and trunk flexion during a squat are correlated. The weighted vest will increase the weight of the upper body, but also the hip extension moment needed to support the flexed trunk, leading to a greater effect of the vest at greater squat depths. The results thus make sense.

CONCLUSIONS

Squatting to deeper depths, with increased trunk flexion, and while wearing a weighted vest may increase the effectiveness of the squat exercise in preventing bone loss at the hip in older age.

REFERENCES


Figure 1: Peak magnitude of the contact force acting on the femur at the hip as a function of peak knee flexion angle for squats performed without and with a 5.4 kg weighted vest.