PATELLOFEMORAL JOINT KINETICS DURING FORWARD STEP-UP, LATERAL STEP-UP AND FORWARD STEP-DOWN EXERCISES

1 Chatchada Chinkulprasert, 2 Roongtiwa Vachalathiti, 3 Christopher M Powers

1, 2 Faculty of Physical Therapy and Applied Movement Science, Mahidol University, Salaya, Phuttamonthon, Nakhon Pathom, THAILAND, 3 Jacquelin Perry Musculoskeletal Biomechanics Research Laboratory, Division of Biokinesiology and Physical Therapy, University of Southern California, Los Angeles, CA, USA

email: chatcha@swu.ac.th, chinkulp@usc.edu

INTRODUCTION

Stepping exercises are commonly prescribed exercises for persons with patellofemoral pain (PFP) [1,2,3]. Appropriate rehabilitation exercises for persons with PFP should emphasize appropriate lower extremity muscle training without increasing symptoms. To that end, specific exercises for PFP should minimize patellofemoral joint loading and stress.[2, 4] To date, few studies [5-7] have investigated patellofemoral stress during various rehabilitation exercises (i.e. squatting and non-weight bearing knee extension). The purpose of this study was to characterize patellofemoral joint kinetics during forward step-up (FSU), lateral step-up (LSU) and forward step-down (FSD) exercises in healthy individuals.

METHODS

Three-dimensional lower extremity kinematics and electromyographic (EMG) activity of the knee muscles were obtained from 19 healthy young adults while they performed forward step-up, lateral step-up and forward step-down exercises with the same step height. The step height for each subject was standardized allowing a knee flexion angle of 45° for each condition. Each subject randomly performed each stepping exercise (3 trials of 5 repetitions) at a fixed rate using a metronome (1 second up and 1 second down). Knee joint moments were computed using visual 3D software and normalized by body mass. Data obtained from the 3 trials were averaged. Muscle EMG and joint kinematics were used as input variables into a musculoskeletal model (SIMM) to estimate the net knee extensor moment.

A previously described biomechanical model was used to estimate patellofemoral joint stress [8]. Briefly this model uses subject input variables (i.e. knee joint kinematics, net knee joint moment) as well as variables from the literature (i.e. knee moment arms, quadriceps force/patella ligament force ratios and joint contact area). Model output was the patellofemoral reaction force and patellofemoral joint stress followed as figure 1.

![Figure 1. Flow chart of patellofemoral joint model.](image)

Differences in peak patellofemoral joint reaction force and stress were compared across stepping exercises using a one-way ANOVA with repeated measures. Separate ANOVA’s were conducted for the concentric and eccentric phases of each exercise. The Bonferroni adjustment was used in post hoc multiple comparisons for both phases. All significance levels were set at p<0.05.

RESULTS

**Patellofemoral Joint Reaction Force (PFJRF):** For both concentric and eccentric phases, peak PFJRF was significantly different among 3 stepping exercises (p=0.004 and p=0.028 respectively). Post hoc analysis indicated that peak PFJRF during FSD was significantly greater than LSU (p=0.006) during the concentric phase (Fig. 2A). During the...
eccentric phase, peak PFJRF during FSD was greater than LSU \( (p= 0.019) \).

**Patellofemoral Joint Stress (PFJS):** For both concentric and eccentric phases, peak PFJS was significantly different among the 3 stepping exercises \( (p=0.001, p=0.004) \). Post hoc analysis indicated that peak PFJS produced during the FSD was greater than LSU \( (p=0.001) \) and FSU \( (p=0.004) \) during the concentric phase (Fig. 2B). During the eccentric phase, peak PFJS during FSD was greater than LSU \( (p= 0.007) \) and FSU \( (p=0.02) \).

![PFJRF Graph](image)

**Figure 2.** PFJRF for both concentric and eccentric (A), PFJS for both concentric and eccentric (B) among FSU, LSU and FSD \( *) \) Indicates significant differences \( (P\leq0.05) \) between FSD and LSU for both phases. \( \dagger \) Indicates significant differences \( (P\leq0.05) \) between FSD and FSU for both phases.

**DISCUSSION**

Our data revealed that peak PFJS during the FSD was greater significantly than the LSU and FSU. The increased peak PFJS during the FSD was the direct result of an increase in the PFJRF. The fact that the PFJRF is mainly driven by the knee extensor moment, suggests that there is a greater quadriceps demand during FSD than LSU and FSU activities. This finding was consistent for both the concentric and eccentric phases.

**CONCLUSIONS**

FSD places increasing stress on patellofemoral joint when compared to LSU and FSU. Clinicians may want to avoid using the FSD exercises to minimize patellofemoral joint loading during the rehabilitation of persons with PFP.

**REFERENCES**


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