THE RELATIONSHIP BETWEEN THE STAIR CLIMBING TEST, KNEE EXTENSION STRENGTH, AND PEAK EXTERNAL KNEE FLEXION MOMENT IN PATIENTS AWAITING TOTAL KNEE ARTHROPLASTY

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INTRODUCTION

Stair climbing is one of the most challenging activities of daily living for an individual with severe osteoarthritis. Clinicians test leg strength and often use the stair climbing test (ascend and descend a flight of stairs as fast as possible) to track the progress of patients [1], with the presumption that patients with a faster stair climbing test (SCT) time have better knee function. Biomechanical studies of stair climbing often focus on the peak external knee flexion moment (pEKFMs), which provides an estimate of the demand placed on the quadriceps to climb stairs [2-4]. Previous analyses of lower limb kinematics and kinetics during stair climbing have shown that osteoarthritic patients have lower pEKFMs when compared to healthy controls due to quadriceps avoidance mechanisms such as a forward trunk lean [5]. Although the poor knee extension strength, slow SCT times and low pEKFMs have been linked to patients with severe osteoarthritis, to our knowledge no one has ever investigated the relationship between standard clinical tests and knee biomechanics. Therefore, the purpose of this study was to test the hypothesis that faster SCT time will be positively associated with greater knee extension strength and greater pEKFMs during stair ascent in individuals with knee osteoarthritis.

METHODS

Twelve subjects (4 males age=60.5±8.0y, ht=1.77±0.03m, wt=95.6±14.0kg; 8 females age=60.5±4.7y, ht=1.61±0.06m, wt=87.1±9.1kg) awaiting a total knee arthroplasty provided IRB to participate.

Each subject performed the clinical SCT (climb and descend a 12-step staircase as fast as possible (seconds), using a handrail if necessary), an isometric knee extension strength test at 60° of flexion (peak torque normalized by body mass)(System 3; Biodex, Inc.; Shirley, NY), and 8 stair ascent trials in our movement analysis laboratory.

Reflective markers were placed using a modified point cluster technique [6] on the femur and tibia segments to determine knee kinematics. 3D marker data were captured with 10 cameras at 150 Hz (Vicon MX-F40; OMG plc; Oxford, UK) and kinetic data from a three-step instrumented stair case (tread width: 10”, step height: 8”), custom designed with two steps attached to force plates (FP-4060; Bertec, Inc.; Columbus, OH) embedded in the floor, were collected at 1500 Hz.

Marker and force data were filtered with fourth order low-pass Butterworth filters at a cutoff frequency of 6 Hz and 12 Hz, respectively, to minimize skin artifact and artifacts due to resonance of the staircase structure. Inverse dynamics were calculated using custom Bodybuilder (Vicon; OMG plc; Oxford, UK) and Matlab scripts. pEKFMs was normalized to a percentage of body weight times height..

The Spearman rank-order correlation coefficient was used to test the association between the pEKFMs of the involved limb, the SCT time and knee extension strength of the involved limb.

RESULTS AND DISCUSSION

The average SCT times, peak external knee flexion moments during ascent of the involved limb and knee extension strength of the involved limb are shown in Table 1. The results supported the hypothesis in that individuals with a faster SCT time had greater knee extension strength (-0.81,
However, there was no association between pEKFM with SCT time or knee extension strength (Table 2), which did not support the hypothesis.

<table>
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<th>Variable Average ± Standard Deviation</th>
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<td>SCT (seconds)</td>
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<td>24.69 ± 12.763</td>
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<th>Table 2: Spearman Rank-Order Correlation Coefficients between the variables</th>
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<td>SCT time vs. pEKFM</td>
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* P < 0.05

The association between the SCT time and the knee extension strength suggests that more knee extension strength is needed to climb stairs faster. The lack of an association between pEKFM and extension strength suggests that in this population with end-stage osteoarthritis of the knee, pEKFM is not limited by quadriceps strength. However, this is consistent with our previous observation that pEKFM does not increase with increasing stair climbing speed [7], which is different from level ground walking [8].

We did not test uninjured individuals in this study, but compared to values in the literature, participants in this study had lower knee extension strength, lower pEKFM values and slower SCT times compared to healthy individuals, which is consistent with previous studies [2,5]. The lack of relationship between pEKFM and the other variables may be related to differences in task demands. These subjects may be employing a compensation strategy to reduce demand on the quadriceps during the short three-step climb in the laboratory, while they cannot avoid using the quadriceps during the isometric extension strength test or the timed SCT. Also, some patients used the handrail to climb and descend stairs, so they may be using more upper body strength to pull themselves up and lower themselves down the staircase.

There were several limitations to this study. The SCT time includes ascending as well as descending a full flight of stairs, and this was compared to the pEKFM during just ascent on a three-step staircase. Also, during the SCT, the patients are allowed to step one stair at a time, using only their uninvolved leg, while they are forced to go stair-over-stair when climbing the 3-step staircase in the motion capture volume. The lack of relationship may also be due to other biomechanical factors such as knee flexion angle, ground reaction force, or muscle activation patterns that were not analyzed in this analysis.

**CONCLUSIONS**

The results of this study suggest the necessity to reevaluate the relevance and meaning of estimating pEKFM in osteoarthritic patients during stair climbing, as it does not seem to change with stair climbing speed and was not correlated with knee extension strength. Further investigation of muscle activations, and other biomechanical variables such as knee flexion angle and ground reaction forces is necessary to make conclusive correlations between clinical tests and biomechanical measurements.

**REFERENCES**


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