CO-CONTRACTION INDEX DURING GAIT AND RELATIONSHIP TO QUADRICEPS STRENGTH IN INDIVIDUALS WITH FOCAL CARTILAGE DEFECTS IN THE KNEE

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INTRODUCTION

Greater muscle co-contraction about the knee has been commonly reported in individuals with knee pathology such as anterior cruciate ligament injury and osteoarthritis. Previous work indicates co-contraction is higher in individuals with more severe osteoarthritis [1], and increases potentially injurious compressive forces in the knee. [5] Despite being younger in age, individuals with focal cartilage defects (FCD), or isolated articular cartilage lesions, of the knee present with impairments similar to osteoarthritis, including considerable quadriceps weakness. [2] To our knowledge, there are no reports of muscle activation strategies in individuals with FCDs during dynamic activity. The primary purpose of this exploratory study in individuals with FCDs was to test the hypotheses that (1) co-contraction index (CCI) is higher on the involved limb than the uninvolved limb during gait and (2) weaker quadriceps strength is correlated with greater CCI during gait. We also explored when during the gait cycle CCI is the highest, to inform future research questions.

METHODS

Fourteen individuals (7F:7M, 29.5±6.0 years old, 25.8±3.5 kg/m²) with FCDs in the knee (Grade 3-4) provided IRB-approved informed consent prior to participation. Defect location varied per participant: 5 patellofemoral only, 6 tibiofemoral only, 3 mixed.

Quadriceps strength was quantified as the peak torque produced during 3 maximal isometric knee extensions at 60° knee flexion (Biodex System 3, Shirley, NY), normalized to mass and height.

Five gait trials at each subject’s self-selected speed were captured with three-dimensional motion capture (10-camera, Vicon MX-F40, Oxford, UK) and electromyography (EMG) concurrently. Ground reaction force data were collected for two consecutive foot strikes by independent force plates (Bertec FP4060, Columbus, OH). Motion capture and forces plate data were used to identify initial contact and toe-off to define the stance phase.

A 16-channel telemetric surface EMG system (Noraxon Telemyo DTS, Scottsdale, AZ) measured muscle activation of the right and left vastus lateralis (VL), vastus medialis (VM), biceps femoris (BF), and semitendinosus (ST). EMG signals were filtered using a 50-500Hz 4th order band-pass Butterworth filter and rectified. A 50 millisecond running average was used to create a linear envelope and normalized to the highest signal amplitude during a maximal volitional isometric contraction (MVIC). The normalized linear envelopes for VL and VM, and for BF and ST, were summed to create a single activation curve for the quadriceps and hamstrings respectively.[5] CCI was calculated for each time point during stance phase with Equation 1.[3,4]

\[ CCI_i = \frac{\text{lower } EMG_i}{\text{higher } EMG_i} \times (\text{lower } EMG_i + \text{higher } EMG_i) \]

The stance phase of gait was divided into ten 10% epochs (ie. subdivision of stance phase) for analysis (Epoch 1-10 consecutively, with Epoch 1 beginning at heel strike, and Epoch 10 ending at toe off). The average CCI was calculated over each Epoch. We evaluated the average CCI with a 2x10 repeated measures analysis of variance, with Limb (involved, uninvolved) and Epoch (Epochs 1-10) as within-subject factors (α=0.05). Limb, Epoch, and the Limb*Epoch interaction violated the sphericity assumption (Mauchly’s test), thus the Greenhouse-Geisser correction was used. Significant interactions or main effects were evaluated post-hoc with pairwise comparisons and a Bonferroni correction. Spearman’s Rank Order Correlation was used to
evaluate the relationship between quadriceps strength and the average CCI for the stance phase, as quadriceps strength was non-normal.

RESULTS AND DISCUSSION

There was a main effect for limb (Figure 1, p = 0.013). CCI was higher in the involved than the uninvolved limb, supporting the first hypothesis. There was also a main effect for epoch (p < 0.0005). Post-hoc pairwise comparisons between phases indicated CCI was highest in early stance. Phase 1 was significantly different than Phases 2-9 (p = 0.000-0.005) and Phase 2 was different than Phases 1, 4, 5, 9, and 10 (p = 0.005-0.042). All other phases were similar to each other. There was no interaction effect of between limb and phase (p = 0.065).

Figure 1: Average CCI per epoch during the stance phase of gait for the involved and uninvolved limb

Our second hypothesis was also supported. Involved limb quadriceps strength was negatively correlated to average CCI during the stance phase (Figure 2, $\rho = -0.73$, p = 0.003). There was no relationship on the uninvolved side ($\rho = -0.27$, p = 0.4).

With future studies, we will investigate if the high CCIs resulted in increased joint compressive forces, or were over-estimated resulting in minimal impact on compressive forces. This study was limited by a small sample size and heterogeneous FCD location.

Figure 2: Scatterplot of involved quadriceps strength vs. involved CCI

CONCLUSIONS

Individuals with FCDs demonstrate higher CCI on the involved compared to the uninvolved limb. Given the inverse relationship between quadriceps strength and CCI, future work considering the detrimental effect of higher CCI, especially in early stance, on compressive joint forces must consider the potential over-estimation of CCI in individuals with quadriceps strength deficits.

REFERENCES


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