# Which Time Interval Should be Used for Measuring Co-Contraction Index for Osteoarthritic Subjects: Stance Phase or Gait Cycle?

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**Introduction:** Literature has shown that people with knee Osteoarthritis (OA) tend to walk with greater muscle co-contraction to compensate for joint instability. Greater muscle co-contraction results from the alterations in muscle strategy to adjust the mechanical environment of the joint. Co-contraction can be measured during different phases or time intervals during gait. The time interval selected could play an important role when differentiating between different stages of knee OA severity

This study aims to determine if there is a trend in co-contraction index and OA severity and if this trend changes when calculating co-contraction index through the stance phase or whole gait cycle.

**Methods:** Twenty six, fully consented subjects participated in this study: ten healthy subjects, ten with medial knee OA listed for high tibial osteotomy surgery (pre-HTO), and six with late stage OA listed for total knee replacement (pre-TKR). The mean and SD of weight and height for healthy, pre-HTO and pre-TKR cohorts were (78.04±10.96 kg, 84.9±15.58 kg, 89.75±15.75 kg), (174.31±4.23 cm, 171.26±8.96 cm, 168.16±10.21 cm), respectively. The affected leg for the two OA groups and a randomly selected leg for the non-pathological group were studied. Ethical approval was obtained from the Research Ethics Committee for Wales and Cardiff and Vale University Health Board. All subjects gave their informed consent prior to data collection.

Muscle electromyographic (EMG) data were collected bilaterally, using Trigno™ Wireless EMG System (Delsys, Inc.), for six muscles: Vastus Lateralis, Vastus Medialis, Biceps Femoris, Semitendinosus, Gastrocnemius Lateralis, and Gastrocnemius Medialis. The electrodes were placed longitudinally over the muscle bellies after standard preparation of the skin.

Individuals were asked to perform different activities of daily living ADLs (i.e., walking at their comfortable speed, walking up and down stairs and finally sitting-to-standing). Meanwhile, information regarding muscle EMG, ground reaction force and three dimensional movements were collected using the synchronized movement analysis system. 6 trials of level gait, ascending/descending a four step staircase, and standing/sitting were recorded for each subject. EMG data during ADLs were used for amplitude normalization. The stance phase and gait cycle were determined using the ground reaction force measurements and foot marker positions at heel strike and toe-off.

EMG data were analysed in Matlab version R2013a. The raw EMGs were band-pass filtered by a Butterworth 4th order filter at (40_450) Hz, rectified and finally low-pass-filtered with a 4th order Butterworth filter at 6 Hz to create a linear envelope for each muscle. Then linear envelopes were normalized to peak values obtained through the ADLs by using the Peak Dynamic Method (PDM).

The EMG data were normalized to 100 data points and an average of six trials for each muscle and for each participant were created, thus representing the mean muscle activity. Finally, the co-contraction index (CCI) was calculated using the equation developed by [1], for the following muscle sets: Vastus Lateralis- Gastrocnemius Lateralis (VLLG), Vastus Lateralis-Lateral Hamstring (VLLH), Vastus Medialis- Gastrocnemius Medialis (VMMG), and Vastus Medialis-Medial Hamstring (VMMH)

CCI was calculated for each subject during stance phase and gait cycle. Group means and standard deviations are presented in Figures1 and 2. A Kruskal Wallis test of nonparametric data was performed for each index to test for significance.

**Results :** Figure 1 and 2 shows the CCI during stance-phase and gait cycle respectively for healthy, pre-HTO, and pre-TKR subjects. As expected, patients with OA have a higher CCI compared to healthy subjects. The CCI for subjects with advanced knee OA (pre-TKR subjects) is higher than for subjects Pre-HTO, with medial knee OA. Significant differences in the CCI between groups were identified.

These findings are consistent with previous literature, where patients with OA co-contracted significantly higher than that of healthy individuals. Co-contraction was higher for subjects pre-TKR compared to pre-HTO indicating an increase in CCI with increase in disease severity. A similar trend is evident for the indices measured during stance phase and during the whole gait cycle. Overall, CCIs are higher when calculated during stance.

**Significance:** CCI calculated during both the stance phase and the gait cycle can be used to differentiate between different stages of OA. Both identified an increase in CCI with increase in OA severity.

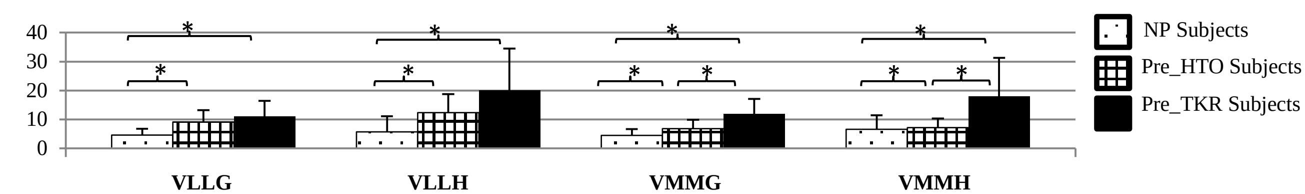


**Figure1:** Co-contraction index during stance-phase for NP subjects – n=10, pre-HTO subjects – n=10, pre-TKR subjects – n=6. Values represent mean and standard deviation. (*)means the difference is significant ($p < 0.05$). VLLG= Vastus Lateralis-Gastrocnemius Lateralis, VLLH= Vastus Lateralis-Lateral Hamstring, VMMG= Vastus Medialis-Gastrocnemius Medialis, VMMH= Vastus Lateralis-Medial Hamstring.

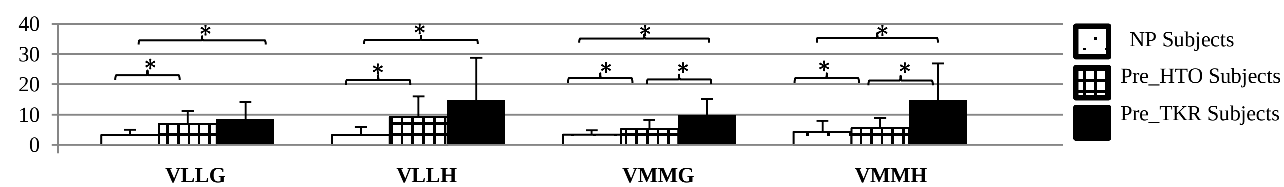


**Figure2:** Co-contraction index during Gait cycle for NP subjects – n=10, pre-HTO subject s – n=10, pre-TKR subjects – n=6. Values represent mean and standard deviation. (*)means the difference is significant ($p < 0.05$). VLLG= Vastus Lateralis-Gastrocnemius Lateralis, VLLH= Vastus Lateralis-Lateral Hamstring, VMMG= Vastus Medialis-Gastrocnemius Medialis, VMMH= Vastus Lateralis-Medial Hamstring.

**References: 1.** Rudolph KS, Axe MJ, Snyder-Mackler L. Dynamic stability after ACL injury: who can hop? Knee Surgery, Sports Traumatology, Arthroscopy. 2000;8:262-9.