INTRODUCTION
Chronic neck pain affects approximately one-third of the population in the course of 1 year and 5-10% of these will result in a significant disabling neck problem. Often diagnosis relies on planar motion, typically flexion/extension, however this does not effectively examine the complex coupled motion of the cervical spine. Previous groups have aimed to quantify the kinematics and helical axes of healthy individuals and those suffering from neck pain. However, many of these investigate motion only in the anatomic planes and the few that look at off-axis or coupled motion are still planar, but at an oblique angle. Kinematic analysis of neck circumduction, Figure 1, allows us to explore how helical axes are affected by the coupling nature of the cervical spine.

Figure 1 A: Linkage System Set-up  B: Head Circumduction.

There are no reliable functional mechanical exams to diagnosis, differentiate, or assess progress of individuals with chronic neck pain. Therefore, the purpose of this study was to investigate neck function/motion in subjects suffering from chronic neck pain while they perform a circumduction exercise with their head using an instantaneous helical axis (IHA) approach.

METHODS
Head-to-torso kinematic data was collected on 22 subjects (age: 45.2±9.5 years, 14 female) with chronic neck pain twice prior to and following a treatment intervention. The two baseline measurements were taken 1-2 weeks apart. These subjects, a subset of the complete 270 patient sample, were used to examine a motion anomaly algorithm in the current study. Pain intensity, range from 0-10, and neck disability index (NDI), range from 0-50, values were recorded before each session. Pain was categorized into three equally distributed bins ‘low’ (n=20), ‘medium’ (n=37), ‘high’ (n=12). NDI was categorized in a similar way: ‘low’ (n=13), ‘medium’ (n=38), ‘high’ (n=15). Relative position and orientation of the head with respect to the torso was computed via a CA-6000 Linkage system (OSI, CA) at a frequency of 100 Hz. The inferior end of the linkage system, located over the spinous process of T1, was secured to a harness that was snugly strapped around the torso. The superior end was connected to a helmet (Figure 1A).
Subjects were instructed to perform a circumduction exercise while standing with their arms by their side. Beginning from neutral position the subjects went into full flexion rolled their head to the left and around back to full flexion before returning to neutral position (Figure 1B). IHA were calculated for each time step between the subject’s initial full flexion position and their final full flexion position. Figure 2 illustrates the head position and IHA at each step. The IHA vector tips were fit to a three-dimensional plane and transformed into spherical coordinates, where theta is the azimuthal angle. Aberrant motion was defined when the numerical derivative of theta was negative, indicating where the IHA folds back upon itself. This is displayed in Figure 3 as red vectors and markings on head position plot. The number of folds, location of folds with respect to head position, as well as percent range of motion and percent time the subject was in the midst of aberrant motion were also analyzed. In an effort to identify if aberrant motion is correlated with pain intensity and NDI, ANOVA techniques were performed with an alpha acceptance of 0.05.

RESULTS AND DISCUSSION
IHA computation for neck circumduction was found to be correlated with patient outcome measures. Specifically, number of folds (p=0.049) and percent time in folds (p=0.014) showed a significant increase as pain intensity increased, but percent range of motion did not. NDI was not indicative of any changes with any of the metrics. Observationally, the smoothness of the IHA seems to be related to pain intensity. Even distribution of IHA vectors as indicative of a more constant velocity of motion. Also, the range of motion of the head seems to increase following treatment. Limitations of this approach include no a priori knowledge of how IHA relate to neck dysfunction. This coupled with the lack of a healthy control dataset does not allow us to determine a causal relationship between aberrant motion and patient outcome measures. Further analysis of the 270 patients in this dataset will enable us to draw generalizable conclusions regarding the IHA and chronic neck pain.

CONCLUSIONS
The circumduction activity is robust for similar pain ratings within an individual, but distinct when the pain levels are different. This analysis allows for the detection of subtle changes in the path of motion that are not detectable by eye or any classic metrics. Thus, this methodology represents a new way to examine neck pain patients with respect to their aberrant motion so as to develop an assessment and tracking measure for care of these patients.

REFERENCES