Introduction: Proprioception is the conscious and unconscious perception of joint position and movement. Deficits in knee proprioception are known to occur after specific knee injuries (1) and may increase the risk of acute knee injuries or falls. In addition, deficits in proprioception are believed to have a role in the progression of knee osteoarthritis (2). Stochastic resonance (SR) electrical stimulation is a novel means for increasing the output of sensory systems (3) and may provide a means of enhancing knee proprioception. The objective of this study was to determine if SR stimulation applied with a neoprene sleeve could improve knee proprioception relative to a no-stimulation/no-sleeve condition (control) or a sleeve alone condition in the normal knee. We hypothesized that SR stimulation when applied with a sleeve would provide enhanced proprioception relative to the control and sleeve alone conditions.

Materials and Methods: After approval by the IRB, 24 healthy, physically active subjects (12 females, 12 males; Age: 18-35) were recruited. Proprioceptive tests were carried out under the following 4 conditions: no electrical stimulation/no sleeve (NE/NS), electrical stimulation/no sleeve (E/NS), no electrical stimulation/sleeve (NE/S), and electrical stimulation/sleeve (E/S). The sequence of the conditions assigned to each subject was applied using a counterbalance design. Stimulation was applied with an electrical stimulator device (Afferent Corp.) by two pairs of self-adhesive surface electrodes placed 2cm above and below the joint line on the medial and lateral aspects of the knee. Stimulation consisted of a 50uA Gaussian white noise signal (zero mean, s.d.=0.05mA, 0-1000Hz bandwidth). This stimulation was below the subject’s threshold of detection. Proprioceptive tests determined the subject’s ability to actively reproduce a target knee flexion angle of 30° and were conducted during both a partial-weight bearing (PWB) and non-weight bearing (NWB) task. An electrogoniometer strapped to the lateral side of the knee and interfaced with a PC data acquisition board was used to acquire the knee flexion angle in real-time (100Hz) during the proprioceptive tests. During the NWB task, the subject’s knee was passively moved from 90° flexion to the target position, returned to the starting position, and then the subject actively attempted to reposition the limb to the target. For the PWB task the subject was on a sliding reclined (20° relative to the horizontal) platform that was relatively frictionless. The subject actively moved from full extension to the target angle, returned to the starting position, and then attempted to actively reposition to the target. For each task the real and absolute value of the difference (error) between the target and reposition angle was computed for each of the 3 trials for each condition and averaged. A two-way (stimulus and sleeve status) repeated measures ANOVA and one-way (4 conditions) ANOVA were conducted to determine differences in the measured variables with the testing conditions for each task (NWB or PWB). The Holm-Sidak posthoc tests were used to determine statistical differences (p<0.05) between the conditions. To ascertain if improvements in proprioception with the test conditions were dependent on the absolute error of the control condition (NE/NS), a regression analysis was performed. For the control condition revealed a significant correlation (R=0.78, R=0.62, respectively). For the NWB task no differences were found with the testing conditions for both the one-way and two-way ANOVA. On average the subjects tended to overshoot the target angle for all conditions for each task.

Results: For the PWB task the one-way ANOVA revealed that the absolute error of the E/S condition displayed improved proprioception relative to the control (NE/NS) and E/NS conditions (Fig. 1). The absolute error of the NE/S condition was not found to differ from the control (NE/NS). The two-ANOVA revealed a main effect of the sleeve, though there was no main effect of the stimulation or interaction of these main effects. Regression analysis of the improvement in absolute error with the E/S or NE/S conditions versus the absolute error of the control condition revealed a significant correlation (R=0.78, R=0.62, respectively).

Discussion: Our findings were only partially supportive of our hypothesis that SR stimulation applied with a knee sleeve could improve proprioception beyond that of the control condition as no improvement was observed in the NWB task. However, our finding that proprioception could be enhanced in the more physiological PWB task is encouraging for the potential clinical use of SR stimulation to improve knee proprioception. Our regression analysis is suggestive that the improvements in proprioception with the E/S condition may be greater in a population with a proprioceptive deficit. Our findings coincide with previous reports that SR stimulation of the knee can enhance balance in the elderly (4). Our one-way results for the effect of the sleeve alone on proprioception in the PWB task are in agreement with past studies (5) that have shown no significant improvement in proprioception in the loaded knee, and the level of improvement observed with the sleeve alone (0.9°) in the NWB task was similar to past reports though it did not reach significance in our study. Our study is limited by the smaller sample size, the use of a single target angle, and the reduced potential to observe proprioceptive improvements in a normal population. Overall, we believe these results suggest the need for further study of the potential of SR stimulation to correct proprioceptive deficits in a clinical population with knee injury/ pathology or in subjects at risk of injury because of their deficit.

Acknowledgements: We thank Afferent Corp. for the use of their stimulation equipment and the UNC Injury Prevention Research Center for funding.