INTRODUCTION

Knee hyperextension is thought to be associated with increased stress to the posterior joint capsule of the knee [1] and anterior cruciate ligament (ACL) [2] and increased contact stress on the anterior compartment of the tibial-femoral joint [3]. Abnormal stress to these tissues can be detrimental to the knee joint [4]. Compared to men, women demonstrate greater incidences of knee hyperextension [5]. Methods to correct for knee hyperextension such as taping, bracing, muscle strengthening, and neuromuscular training [6] have shown limited success. Several studies support training, using biofeedback, to affect performance and learning of motor skills [7] and in teaching patients to regulate their movements [8]. The aim of this study was to investigate the efficacy of real-time biofeedback, provided during treadmill gait training, for correcting knee hyperextension patterns in young female subjects while walking.

METHODS

Ten healthy women, ages 18 to 39 years, with asymptomatic knee hyperextension underwent a three-week (6 sessions) treadmill gait retraining program. Clinical measures of knee hyperextension greater than 5° were used as the inclusion criteria. Participants underwent a physical and gait evaluation. The physical evaluation assessed muscular strength and passive range of motion in each subject’s lower limbs using standard techniques. The gait evaluation was conducted along an 8 m walkway using a three-dimensional motion analysis system (Optotrac, NDI; Kistler) with subjects walking at their self selected (SS) speed and at 3 mph. Gait data was processed using Visual 3D software (C-Motion). After the initial evaluation, subject participated in supervised treadmill training twice a week for three weeks. Each training session lasted one hour and consisted of three eight-minute sessions with three-minute rest periods in between training sessions. Real-time biofeedback (Visual 3D) was provided on a computer screen placed on a table (150 cm in height) about 1m in front of subject. Participants received real-time biofeedback (Fig. 1) for the knee that showed the greater knee extension (involved knee) at either initial contact or toe off. Once subjects gain proficiency controlling their more involved knee, real-time biofeedback was also provided for correction of hyperextension pattern on the less involved knee. Treadmill gait data were collected, without feedback, at the beginning (pretraining) and end (posttraining) of each training session. A final overground gait evaluation, following initial evaluation protocol, was performed at the end of the three weeks of training.

RESULTS AND DISCUSSION

Ten women (age 26.2 ± 5.4; weight 71 ± 14 Kg; height 1.6 ± 0.1 m) took part in this study. Initial muscular testing showed normal values for knee extensors (145 ± 12 N), and flexors (129 ± 25 N). The passive range of motion showed 9.7 ± 3.2°
(from 6° to 14°) of knee extension. Initial gait evaluation showed that seven subjects had greater knee extension in their right knee. Maximum knee extension occurred at initial contact in seven subjects and at toe off in 3 subjects.

A paired T-test showed significant evidence that treadmill gait training intervention reduced knee hyperextension pattern in involved (Fig. 2) and less involved knees (Fig. 3). As shown in Figure 3, the greatest reduction of knee extension pattern occurred between the third (TM3) and fourth (TM4) treadmill training sessions. Figure 3 also shows the within-session training effects (pre and posttraining) and intersession training effects (carryover in between training sessions) of the augmented type feedback provided. Data also show evidence of some loss in ability to control knee extension patterns, in the involved knee, during the final over ground gait evaluation at self selected speed ($p <0.05$) and 3 mph ($p <0.06$) walking.

**Figure 2:** Peak knee extension at initial and final gait evaluations. Treadmill gait retraining intervention, using real-time biofeedback, significantly reduced knee hyperextension patterns during over ground walking at self-selected (SS) ($p<0.01$) and 3 mph ($p<0.01$).

**SUMMARY & CONCLUSIONS**

The results of this study indicate that subjects in this study showed decreased knee hyperextension during treadmill gait retraining intervention. Subjects showed greatest improvement in decreasing knee hyperextension during the first and third treadmill training sessions. When working on correcting the knee hyperextension patterns in the involved knee, subjects demonstrated simultaneous reduction in peak knee extension in the less involved knee. Subjects demonstrated gradual improvements that continued over the three-week training program. Gained proficiency, controlling knee hyperextension patterns during treadmill training, was evident for over ground walking at and self selected speed. There was some loss in proficiency controlling knee extension between treadmill training and walking over ground at 3 mph. Improvements in decreasing knee hyperextension during walking may help to relieve constant stress in the knee joint. The present study showed that knee sagittal plane kinematics can be influenced with dynamic gait training using real-time biofeedback.

**REFERENCES**