Electromyographic Analysis and Energy Expenditure of Harness Supported Treadmill Walking: Implications for Knee Rehabilitation

1 Scott M. Colby ME*
2 2Donald T. Kirkendall, Ph.D.
3 Robert F. Bruzga, MPT, ATC

2Department of Orthopaedic Surgery, University of North Carolina, Chapel Hill, NC 27599
3Department of Physical and Occupational Therapy, Duke University, Durham, NC 27710

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Work performed at Coach Krzyzewski Human Performance Laboratory, Department of Orthopaedic Surgery, Duke University Medical Center, Durham, NC 277 1 0

Corresponding author
1 Scott Colby
Texas Scottish Rite Hospital Movement Science Lab 2222 Welborn St. Dallas, TX 75219

Abstract

Harness supported treadmill ambulation has been recommended for patients as a way of decreasing loads on the healing tissues, conserving energy and reducing pain. We quantified muscle activation levels around the knee and metabolic responses during harness supported treadmill walking. Ten healthy recreational athletes (age 28.9 ± 7.8 years) walked on the treadmill (1.34 n-dsec) for five minutes each at full weight bearing (FV@B), 20% and 40% body weight support (BWS). EMG was monitored for vastus lateralis, vastus medialis, rectus femoris, biceps femoris, medial hamstrings and gastrocnemius. Oxygen consumption was collected by open circuit spirometry and heart rate was collected by a heartwatch. Statistically significant reduction of EMG was found at 40%33WS for the quadriceps. Oxygen consumption decreased by 6% (20% BWS) and by 12% (40% BWS) from FWB ($p<0.05$). I-leart rate was unchanged. BWS ambulation reduces energy cost, but does not significantly alter muscle activation, except for quadriceps at 40% BWS.

The goal of rehabilitation is to return a patient to the preinjury state (13). This is achieved during knee rehabilitation in part by strengthening muscles around the affected joint while avoiding further damage to the knee (8). This study was undertaken to determine the muscular activity and cardiovascular response of a normal population during harness supported treadmill walking. The results will provide information as to whether or not harness supported treadmill walking can help achieve these rehabilitation

Electromyography (EMG) of the quadriceps, hamstrings, and gastrocnemius

during walking has been documented previously (1, 2, 4, 5, 12). During full weight-bearing level walking, the quadriceps achieve peak activity level at heel strike and are relatively inactive at midstance until the next heel strike. The hamstrings are active just prior to heel strike, decelerating the leg, and remain active (along with the quadriceps) during early stance phase to stabilize the knee. And finally, in the gastrocnemius, there is a single peak of activity during push off (5), Harness supported treadmill ambulation is defined as "decreasing an individual's effective body weight by a given amount using a supporting harness and counterbalance system that accommodates the rise and fall of the body during treadmill ambulation" (14). This method of gait retraining has frequently been recommended for patients as a way of decreasing loads on the healing tissues, conserving energy and reducing pain

(9). However, before harness-supported treadmill ambulation can be prescribed as an effective tool for knee rehabilitation, one needs to know if lower extremity muscle activation changes with increasing removal of body weight. In other words, can muscle activation be preserved while the tissues are healing. Documentation of lower extremity muscular activation during barness supported treadmill ambulation has not been thoroughly investigated. Finch et al. (6) investigated a normal population walking on a treadmill while a harness supported 0%, 30%, 50%, and 70% of their body weight. They reported that with the removal of body weight, vastus lateralis muscle burst amplitude was not significantly affected, and attributed this to a' large between-subject variability. They also noted that there were no changes in medial hamstring muscle burst amplitude at 30% and 50% of body W'eight support, but decreased significantly at 70% of body weight support, while medial gastrocnemius activity decreased significantly with increasing body weight support This is the only study in the literature documenting quadriceps, hamstring, and gastrocnemius activity during harness treadmill walking. However it didn't assess the vastus medialis obliquus, rectus femoris, and lateral hamstring musculature. Another concern for patients undergoing rehabilitation is cardiovascular endurance. It has been shown that harness-supported treadmill ambulation reduces heart rate, oxygen consumption, and caloric expenditure of both below knee amputees and able bodied subjects (9). This evidence has been used by physical therapists who have recommended this type of rehabilitation when energy, expenditure savings would be advantageous. As the patients improve, they should theoretically be able to participate in longer rehabilitation sessions, and return to activities of daily living and recreation at an earlier time. Other than Finch et al. (6), the authors are unaware of any published research on muscular activity during harness supported treadmill ambulation. In addition, no investigators have evaluated electromyography and respiratory response of the harness supported treadmill device, Pneu Weight (Quinton Instruments). Therefore, the objectives of the current study were to quantify not only muscle activation levels and timing of various muscles (quadriceps, hamstrings and gastrocnemius), but also cardiovascular response during harness supported treadmill walking. The results will establish a baseline for comparison to patients with various knee injuries, Materials and Methods

Subjects Preparation

Ten healthy recreational athletes (9 males, I female, age = 28.9 -4- 7.8 years, stature = 178.8 ± 8.8 cm, mass = 75.7 ± 12.2 kg) who reported no prior knee injury or history of knee pathology gave their written consent to participate in the study Pre-gelled silver/silver chloride 3M Red Dot surface electrodes (St. Paul, NIN) were placed over the following muscles on the subjects' dominant side: vastus lateralis, vastus medialis obliquus, rectus femoris, biceps femoris, medial hamstrings (semimembranosus/semitendinosus), and medial gastrocnemius according to Perotto et al. (I 5). Prior to application of the surface electrodes, the subjects' skin was shaved and cleaned with alcohol. Two electrodes were then placed over each muscle with an interelectrode distance of approximately 4 cm. A. single ground electrode was placed on the dorsum of the hand.

Experimental Protocol

During the testing session, the subjects walked on a treadmill, Pneu Weight, (Quinton, Inc) at 1.34 ra/sec (3.0 mph) with 0% grade during each of the following harness supported ambulation situations: full body weight (FVTB), 20% body weight supported (BWS), and 40% body weight supported (13WS). This speed was felt to be representative of exercise during the beginning of a gait rehabilitation session. EMG activity, oxygen consumption and heart rate were recorded as the subjects exercised oh the treadmill. Walking trials lasted 5 minutes each in order to allow for vital sign stabilization and the attainment of steady-state exercise (3, 1 1). Five seconds of EMG data (1000 Hz) were recorded at 4 minutes of exercise for each condition. Raw EMO was collected using Myosoft software (Noraxon, USA, Inc., Scottsdale, AZ). An analog signal was recorded using the Myosoft software to define heel strike and toe off. Oxygen consumption and heart rate data were recorded during the last minute of the 5-minute exercise period. Oxygen consumption was collected by open circuit spirometry and heart rate was collected by a heartwatch throughout the five-minute trial.

Data Analysis

The average amplitude of the integrated EMG signals was determined from the "on-time" of each muscle during the stance phase of the gait cycle (dominant leg heel strike to dominant leg toe off). Onset of a muscle contraction was defined as when EMG amplitude exceeded IO pV for longer than I 00 msec. Offset occurred when the F-MG amplitude fell below 10 @tV for longer than 20 msec (10). Three complete stance phases were analyzed from each 5-second collection period. The EMG activity of the three