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The Effects of Locomotor Training on Muscle activation, Body Composition, Bone Density.

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ABSTRACT

Background/objective: To determine the effects of Locomotor Training using body weight support Treadmill Training (BWST) on kinematics, neural, muscle and bone density changes for an individual with an incomplete SCI (ASIA B), one year post injury

Method: The participant - a man with chronic ASIA B (C6 Motor, C6 Sensory) incomplete spinal cord injury, completed 2 periods of Locomotor Training. The first period was for 35 sessions. The second was for 62 sessions. Kinematic and EMG data collection occurred before each Locomotor Training period and after the completion of the second period. Bone mineral density and body composition testing occurred before any training and after completion of training.

Results: After 35 sessions of training there were alterations in mean EMG amplitude and burst duration for all muscles examined. Following the 62 sessions of training further alterations in BD and Mean EMG amplitude occurred.

Conclusion:

Locomotor training can induce musculoskeletal changes in a chronic non-ambulatory person after spinal cord injury.

Key Words

Spinal Cord Injury, Locomotor Training, Kinematic profiles, EMG profiles, Neural alterations, Bone and Muscle changes.

Introduction

Recently new approaches to facilitate locomotor recovery have been directed away from compensatory strategies and towards Locomotor Training that optimizes sensory information and facilitate activity dependent plasticity in the spinal cord to control movement ((1,2,3). The studies on Locomotor Training using body weight support treadmill training (BWST) in humans after SCI (1,3,4,5,6,7,8,9,) are based on extensive research related to animal studies (10,11,12,13).

It is well published that Locomotor Training facilitates functional walking recovery among chronic incomplete SCI with an American Spinal Injury Association (ASIA) Impairment scale C and D (1, 2, 3,4, 14, 15,17,13). However to our knowledge there is generally limited quantitative kinematic, electromyography (EMG), bone mineral density, and body composition research regarding the effect of Locomotor Training for an extended period of time on an a person with ASIA B classification in improvement of functional recovery. The objective of this case study is to determine the effects of Locomotor Training using body weight support Treadmill Training (BWST) on kinematics, neural, muscle and bone density changes for an individual with an incomplete SCI (ASIA B), one year post injury.

CASE PRESENTATION:

Materials and Methods

Institutional Review Board (IRB) approval was received for the study and the participant signed an informed consent. Clinical characteristics for the participant are given in Table 1. The participant trained for 35 sessions of Locomotor Training (T1), stopped training for 8.6 weeks, and recommenced training for another 62 sessions (21 weeks) (T2) (Figure 1). Testing procedures occurred before T1 (PRE-T1) before T2 (MID) and after T2 (POST-T2).

Training Protocol

Three trainers were involved in the Locomotor Training: one trainer at the hip/pelvis, and one trainer at each of the legs. Treadmill sidebars were not used to support the body. The participant was encouraged to swing his arms in a rhythmical motion with their lower limbs. To initiate stepping, the participants would stand with their feet straddled simulating stride length - one leg extended near mid stance and bearing most of the load. As the treadmill speed was increased the leg was moved back to terminal stance. The participant was encouraged to shift their body weight forward and laterally towards the opposite leg. Shifting the body weight forward to the front leg allowed for the posterior limb to initiate swing (and push off). During stance, assistance was given to aid in knee extension (not hyperextension) at the patella tendon and to optimally support body weight. During leg swing, assistance was given to promote knee flexion at the medial hamstring to aid in toe clearance and unloading. Assistance was given to aid in coordination between limbs i.e., simultaneous heel-strike and foot placement of one limb concurrent. When possible the trainers tried to reduce assistance at the knee during flexion. Figure 1 describes the progression of training for a total of 97 sessions. Table 2 describes the total training time.

Following each treadmill training session the participant practiced walking overground by using a Rolling Stand Up Walker (Allegromedical.com). During the overground training the participant would progressively increase the level of difficulty of the standing task. For example, initially, he would hold on to walking frame with both arms, and change his weight distribution from right to left leg. With further training, the participant would release both arms from the walker and maintain postural stability while flexing and extending at the shoulder and elbows. Total training time/session including stretching and harness setup was approximately 2 hrs. The participant was expected to complete set tasks at home such as standing or chair seated exercises.

Testing Procedure

Before T1 (PRE-T1) kinematic and EMG data were collected bilaterally for 60% and 40% body weight support (BWS), treadmill speed at 1.6 mph. The participant performed 3 independent trials for each condition. Collection time per trial was 20 sec. Before T2 (MID) the testing condition was repeated to collect PRE-T1 data. After T2 (POST-T2) was completed, POST-T2 data were collected bilaterally for 60%, 40% and 20% BWS. The additional condition after training was studied because the individual was able to bear more weight during stepping and 20% BWS was the minimum BWS trained. In between stepping bouts the treadmill was turned off and the participant stood in place with BWS or rested in a chair. Throughout the total testing period blood pressures were recorded regularly. During testing, three trainers gave assistance at the pelvis and at each knee. Overground kinematic or EMG testing did not occur. In addition, hip or total bone density measurement, (as recorded by Dual-Energy X-ray Absorptiometry, DEXA, Lunar Inc., Madison, WI) (17) scans were used before and after training. DEXA used a pencil beam X-ray to measure bone mineral density

(BMD) for regional body components including the femoral neck, lumbar spine and total body (17).

Instrumentation, Data Acquisition, and Data Analyses

A 6-camera Vicon system (sampled at 60Hz) was used to collect kinematic data for gait analyses. Spherical reflective markers were placed on right and left second and fifth metatarsal, calcaneous, tibial tuberosity, femoral epicondyle, greater trochanter, anterior inferior iliac spine, posterior inferior iliac spine. EMG was recorded using surface EMG for left and right medial gastrocnemius (below the popliteal crease on medial aspect of the aspect of the calf), tibialis anterior (below the tibial tuberosity and lateral to the tibial crest), rectus femoris and bicep femoris. EMG was collected at a bandwidth of 10-600 Hz, and sampled at 1500 or 1560 Hz. Raw EMG signals were filtered at a bandwidth of 30-150 Hz, full-wave rectified, then root mean squares (RMSs) (defined as the square root of the mean squared value of rectified amplitude) were calculated over a 120 ms window (19). We calculated RMS EMG mean amplitude as the sum of the RMS amplitudes from burst onset to burst offset divided by burst duration. Burst onset/offset was defined as time of onset/offset of EMG burst. Burst Duration (BD) was defined time between the onset of EMG burst to the offset of EMG burst of each muscle. .....EMG data was processed using MATLAB (MathWorks Inc., Version 6.1). Calculation of sagittal plane segment motion for the thigh, shank and foot was determined using MATLAB (MathWorks Inc., Version 6.1). Limb kinematics were calculated in the local moving plane with calculation of orientation angles for each segment relative to the right horizontal (18). All kinematic data are presented as segment range of motion (ROM) at the thigh, shank and foot. At least 6-8 gait cycles were analyzed for each test condition.

Results

Before training the neurological level for motor was C6 and sensory was C6. After training the neurological level for sensory changed to C7. There was no change in motor lower extremity scores. The participant (1 year post injury) was not standing, loading or standing overground before entry to the study. He was wheel chair reliant 100 % of time. Initially, with the overground training the participant (height: 1.88m, weight: 81.64kg) required assistance at pelvis, knees (to maintain knee extension), and arms to stand using the walker. After 97 BWST training sessions, the participant improved his ability to stand whereby he could stand using the walker with minimal assistance at the knees and maintain postural stability while shifting body weight medial/laterally or anterior/posteriorly. His mean total standing time at the end of the study was 20 (±2) min compared to initial standing bouts were 3 (±2) min. Furthermore, he could maintain postural control when removing his hands from the walker to flex or extend at the shoulder or elbow. Three months after completion of the study, the participant (self) reported standing (at home) for a total of 1 hour/day using the Rolling Stand Up Walker without assistance at the knees.

Trainers were able to produce consistent lower limb joint movements for each test condition (60% BWS @1.6 mph (0.71m/sec), 40%BWS at 1.6 mph) (an example is shown in Figure 2). The kinematic profiles (Figure 2) are a representative sample of the repeatability of stepping trials for the hip and the knee. The overall extension/flexion pattern of the hip and knee were similar in the two conditions, however after locomotor training more hip and knee extension were achieved for the early stance phase. Visual qualitative assessments also identified improvements in contralateral arm swing and head, neck and trunk postural control within the first few weeks of training. Significant changes were observed in EMG profiles of hip and knee flexors after Locomotor Training as shown by representative data from the left rectus femoris (LRF) and left biceps femoris (LBF) (Figure 2). Higher EMG amplitudes were observed in both muscles with firing patterns observed in late stance and swing (LRF) and late swing for the LBF post-training.

After Locomotor Training the firing patterns of the muscles during stepping were more functionally appropriate. The LRF, LBF and left tibilias anterior (LTA) EMG activity was more rhythmical and less tonic after the first series of Locomotor Training sessions (Figure 3). The left gastrocnemius LG activity was more robust and occurred appropriately in the stance phase during stepping after training. The firing patterns of the LBF and the LRF (Figure 4) were coordinated in a manner that is functionally appropriate for locomotion. These reciprocal firing patterns between the LRF and the LBF were observed at POST-T2 and MID (Figure 4 and Figure 3).

During all testing sessions, it appeared that the firing pattern of the LMG and LTA demonstrated more co-contraction rather than an agonist and antagonist coordinated activity (Figure 3 and Figure 8). The 3D positional data identified that the toe often landed before or with heel strike, and this would have compromised afferent propriocpetive sensory input to the efferent system at heel strike and during early stance.

Repetitive stepping using BWST induced changes in the EMG amplitude of several muscles.

Figure 5 presents the mean EMG RMS amplitude (uV) for 6-10 gait cycles for each test condition at PRE-T 1, MID, and POST-T2. At MID LRF (Figure 5A) had an increased mean EMG amplitude when compared to PRE-T1. At POST-T2 there was a further increase in the LRF's mean EMG amplitude. Similar results were shown for LBF and the LG (Figure 5B, 5D) where at 60%, 40% and 20% BWS the mean EMG amplitudes at POST-T2 were greater than MID and PRE –T1. The LTA did not show an increase in mean EMG RMS amplitude across time periods (PRE-T1, MID, POST-T2).

Figure 5 also demonstrates a positive linear response in mean EMG amplitude to bodyweight (BW) load. At mid, mean EMG amplitudes all muscles (LR, LBF, LTA, and LG) increased with loading from 40% to 60% BW and at POST-T2 the mean EMG amplitude for LG (at 40%, 60%, and 80% BW load) also increased. The results for LBF and LTA were more variable. Both of these muscles showed a decrement in mean EMG RMS amplitude (from 40% to 60% BW load) followed by an increase (from 60% and 80% BW load).

Burst Duration

The participant exhibited notable alterations in EMG patterns at MID compared to PRE-T1 at 60% BWS. In general, the data collected at MID (Figure 3, and Figure 6, Figure 7) illustrated increased EMG BDs during the gait cycle for the LRF, LG, LTA for the 20 second stepping duration period. Significantly, at PRE-T1 (before any Locomotor Training), the LBF was firing for most of the gait cycle (GC) [i.e., mean BD was 88.1 ± 6.1% of the GC] (Figure 3A and Figure 6) whereas at MID (after 35 sessions of repetitive stepping followed by 8.6wks of no training) the mean BD decreased to 55 ±15% of the GC and at POST-T2 its BD decreased further to 41±15%. Within testing periods, the BDs were greater at increased loading for LRF and LBF, shown by difference in duration of EMG duration for the different BWS at MID and POST-T2 (Figure 3, Figure 6 and Figure 7). Importantly, the increase in BD for both muscles occurred while still maintaining reciprocal firing patterns (Figure 3 and Figure 7). In general, the BD for the LTA and LG at MID and POST-T2 decreased with increasing load (except for LG from 60% BW load to 80% BW load)

Figure 6, Figure 7, and Figure 8 demonstrate the increased BD for both LTA and LG after training sessions (both MID and POST-T2). After BWST training the LG was active during stance and the onset of LMG EMG activity consistently preceded the onset of loading. After the first 35 sessions of locomotor training co-contraction of the LTA with the plantarflexors was often observed in SCI participant (Figure 3, Figure 4, and Figure 8). This co-contraction of LTA and LG still existed at POST-T2 (after 97 training sessions). There is a decrease in BD for the same load (for 40% and 60% load) at POST-T2 compared to MID for the LRF, LBF, and LG.

Detraining Effect and EMG Activity after BWST

After 35 sessions of training (and 8.6 weeks of no training) the LRF, LBF, and LG muscles at mid had greater mean EMG amplitudes compared to pre. BDs also were greater at MID (than PRE-T1) for all except the LBF. The decrease in the BD of LBF at MID (and at POST-T2) promoted a coordinated firing pattern at mid that was not present at pre. Since we did not test immediately following the first 35 sessions of BWST training it is difficult to determine what if any detraining occurred during the 8.6 weeks of no training. However, it can be said that certain aspects related to EMG amplitude, duration and reciprocal firing patterns were maintained even with 8.6 weeks of no BWST training.

After the second training session there is an increase in mean EMG amplitude for the LR, LB, LG (Figure 4) compared PRE-T1 and MID. Reciprocal alterations in BD for the LRF and the LBF were consistent with the stepping movement (Figure 2, and Figure 4).

Bone Mineral Density (BMD) Values and Body Composition

Bone mineral density and bone mineral content for pre and post training are presented in Table 3a and Table 3b. Table 3a presents the bone mineral density at the hip (femoral neck, wards triangle, trochanter and femoral shaft) and the T score which represents the standard deviation from the mean peak bone mass of gender-matched young adults in Lunar database. After 97 training sessions, his total body BMD decreased .01% (presented at the bottom of Table 3). From pre to post training there was a change in his T score from -0.5 to –1.9 and a reduction in femoral neck BMD was 77% of the normal aged matched BMD values (Table 3a). Table 3b presents the bone mineral content (BMC) and the area for each region. The femoral neck decreased its bone mineral content by approx. 21% (with a 4.2% decrease in area). Data are currently being analyzed from all participants that underwent step training with BWST to look at the effect of Locomotor Training on body composition and BMD.

Overall, the participant increased weight (Table 4). He gained both lean body mass and fat over the training period. He gained fat and lean body mass in the arms and trunk and gained lean body mass and decreased fat in the legs (Table 4). Additionally, the shank circumference increased from 2.6 cm . This preliminary data raises the possibility that load-bearing training might increase the torque potential of these muscles as well as the level of activation as shown by EMG activity.

Discussion

This case study involves a participant (ASIA B) who was one-year post a spinal cord injury. The most significant quantitative aspect of this case study is the alteration of generated efferent EMG firing patterns for all muscles studied after locomotor training using BWST for this participant (without any improvement in his ASIA motor score). After training, EMG firing patterns for muscles studied were consistent to kinematic profiles at the hip and knee. Certainly, before training the EMG firing profiles were not. Specifically, the increases in mean EMG amplitude and changes in burst durations (particularly for the LBF and LR and to a certain extent the LG) reflected a stepping pattern that was functionally more appropriate to locomotion. Importantly, even after 35 sessions of training there was a coordinated EMG burst response from the LBF and LRF during walking at all BW loads that was not present before training. During additional training with increased limb loading stimulus, the agonist and antagonist activation patterns for the LBF and LRF were further enhanced.

After training, often the ankle joint plantarflexed on foot landing where the LTA had to concentrically contract against gravity to promote ankle dorsiflexion. Continued stepping with ankle plantarflexion at heel strike compromised afferent propriocpetive sensory input to the efferent system at heel strike. This probably contributed to the co-

contraction (for the LTA and the LG) that was determined at mid and POST-T2 for most if not all test conditions.

The literature (20) has established that an increase in afferent loading stimulus and kinematics associated with repetitive stepping will elicit more activation (i.e., increased amplitude and improved timing of BD per gait cycle) of motor pools and more reciprocal patterns of activity between agonists and antagonists within one training bout (for ASIA levels A, C, D). It is suggested that stepping with knee and hip extension/ flexion combined with loading and unloading provided more propriocpetive afferent input to the spinal cord to facilitate the motor unit recruitment. Other studies (5, 23) have found significant differences in EMG activity with increased BW load within a single stepping session with BWST. Our case study, for an individual who is classified as ASIA B, is consistent with the literature. Specifically, mean EMG RMS amplitude increased with increased loading during MID and at POST-T2 (for LRF, LBF and LG) and there was an increase in BD at MID and POST-T2.

Additionally, BD at POST-T2 60% BWS (for the LRF, LBF and LG) and BD at POST-T2 40% (for LBF and LG) were less than BD at MID (for same BWS). This could suggest that after training, to get the same BD response the participant required more loading stimulus. All of these results highlight that specific motor task, loading and repetition provided the sensory inputs to promote training effects or changes or plasticity and motor learning of spinal cord neural circuitry.

After 35 sessions of training (and 8.6 weeks of no BWST training), there were synchronized rhythmic EMG bursting and importantly, there were gains in Mean EMG amplitude and BD at MID that were not seen before training. This would suggest that there is some retention of neural gains after training has stopped (at least for 2 months). This would have advantages within the clinical environment. For example, if a participant needs to stop Locomotor Training/therapy for a short time because of cost or medical issues, then it appears that some training response may exist (for at least 2 months). Unfortunately we did not collect kinematic and EMG data immediately following the 35 training sessions, to effectively address neural retention after training has stopped. However, for these participants there were improvements at MID those were not present at pre.

After repetitively loading for 97 sessions there was very little change in total body BMD. There was a decrease in femur neck BMC of approx. 21 % from pre to post study. This represented a reduction to 79% of normal BMC values. This value is still higher than what is reported in the literature for the decrease in femoral neck BMC, 2 years post injury (based on 8 spinal cord injured patients) (21). Biering-Sorensen (21) has shown that after two years the femoral neck seems to reach steady state of approximately 60-70% of Normal BMC values (21). This may suggest the significance of Locomotor Training (with the associated agonist/antagonist muscle activity and dynamic unloading/loading) as a potential therapy for the slowing down the decrement of bone loss. Further investigation into possible effect is continuing for a larger sample size.

For this participant, an increase in muscle mass for the arms, trunk and legs was recorded after the completion of training. This may be an overall training response to the exercise. Additionally, there was an increase in fat in the trunk and arms but a decrease in fat in the legs. Overall, these skeletal muscle adaptations would have contributed to the alterations in the participant's ambulatory capacity and postural control on the treadmill and overground. These results concur with another study that completed Locomotor Training for ASIA C participants only (n=9) to show that BWST is able to produce an increase in fiber size (22). Potentially, Locomotor Training (and the reduction of BWS to provide a mechanically loading stimulus) may induce relative muscle hypertrophy that would serve to reverse the injury-induced atrophy.

Qualitatively, an improvement in upper body strength and/or control was observed whereby the participant developed more dynamic and postural stability for the head, neck and trunk so as to maintain a more erect "top down" system when loading at the beginning of stance on the treadmill. Prior to entry into the study, the participant had very little arm/hand control and could not stand. Progressively, the participant's tolerance for standing using a walker (and with assistance at the pelvis and knees) overground on a flat surface improved. At the end of training standing was documented to be 20 min (± 5.3 min). On follow-up (three months following the completion of the study) the participant was able to stand in a walker at home for one hour with the help of one assistant. The participant was 1year post injury, and prior to entry into the study he was wheelchair reliant for at least 100 % of the day. Being able to stand with the aid of a walker were functional gains for this participant. He had not been able to achieve this since his injury.

Conclusion

Locomotor Training allows for over head harness support, progressive loading of body weight and treadmill speed to promote repetitive stepping. The results in this case study provide evidence related to the positive neuromuscular and bone changes that occur after Locomotor Training with repetitive stepping for a an individual with an incomplete

SCI (ASIA B, 1 year post injury). Furthermore, these gains in neural activation were shown to transfer to functional outcomes.

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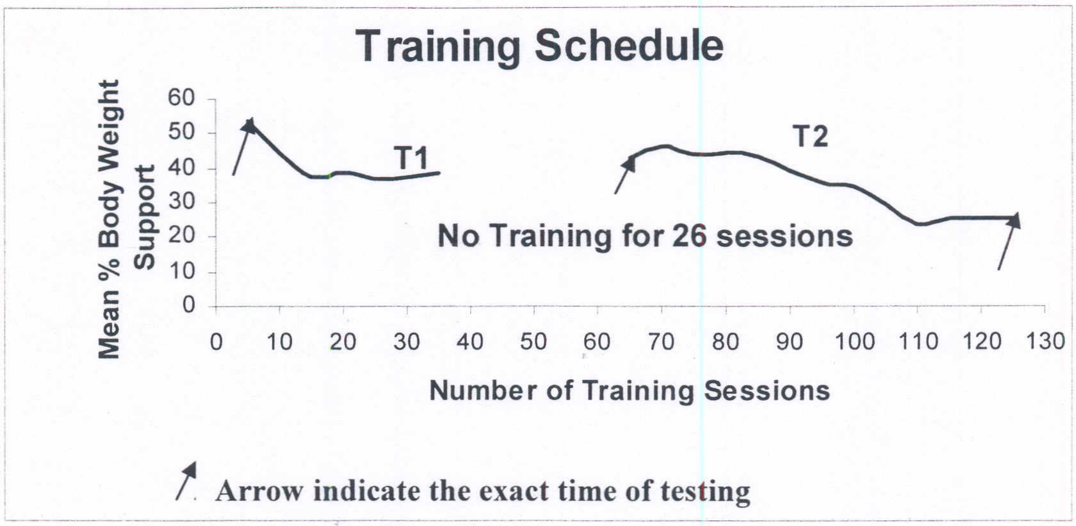

Figure 1. Training Progression with Decrease with BWS. Mean % Body Weight support/per session/5 sessions. T1 represented 35 training sessions followed by 8.6 wk. (26 sessions) of no BWST. T2 represented 62 training sessions.

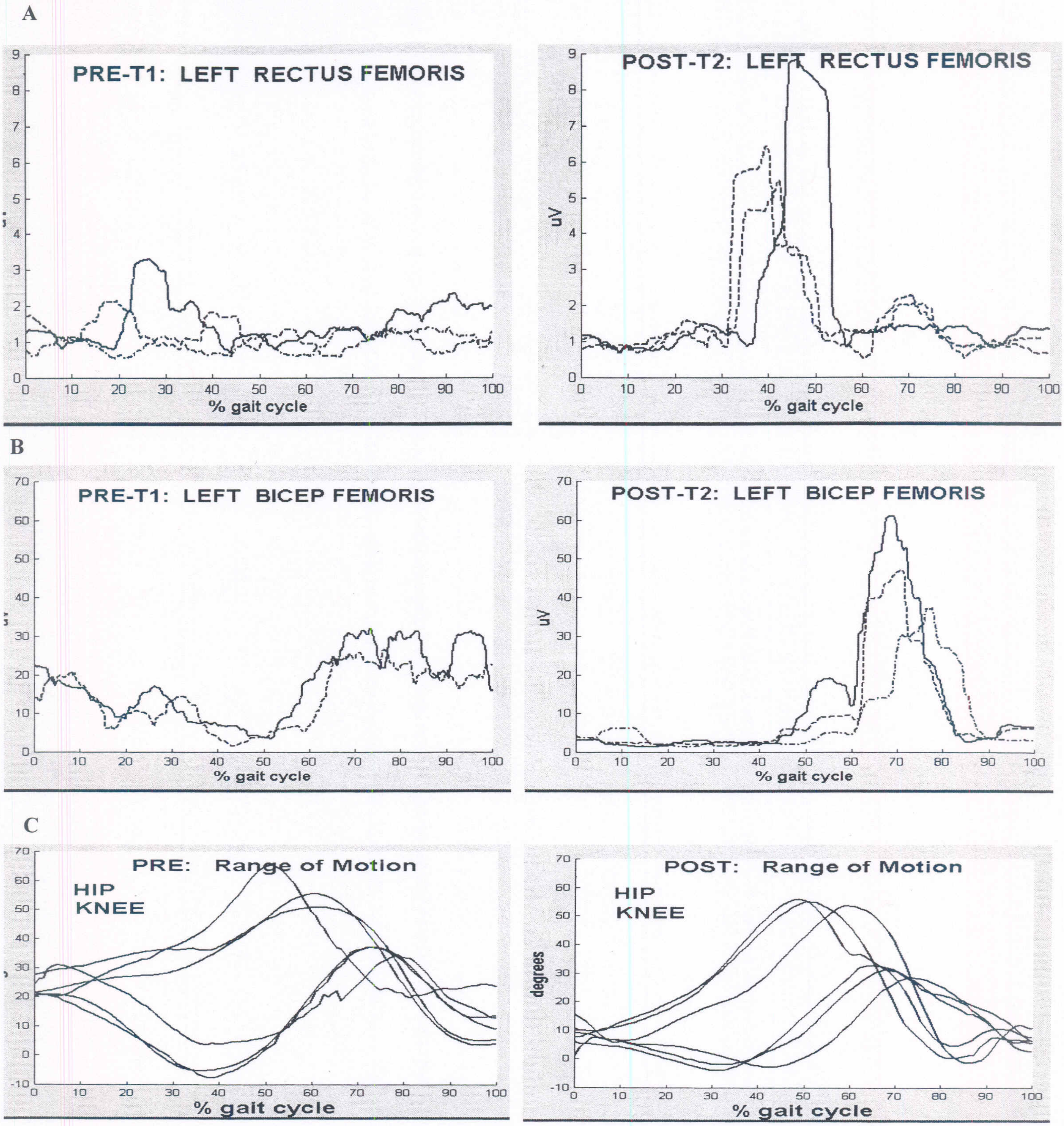

Figure2 A, B, C: EMG (2A, 2B) and kinematics (2C) for LRF and LBF before and after the locomotor training (60% BWS, 1.6 mph, n=3 repeated trials for both kinematics and EMG activity profiles). **Abscissa:** Percent Gait cycle **Ordinate**: MicroVolts RMS

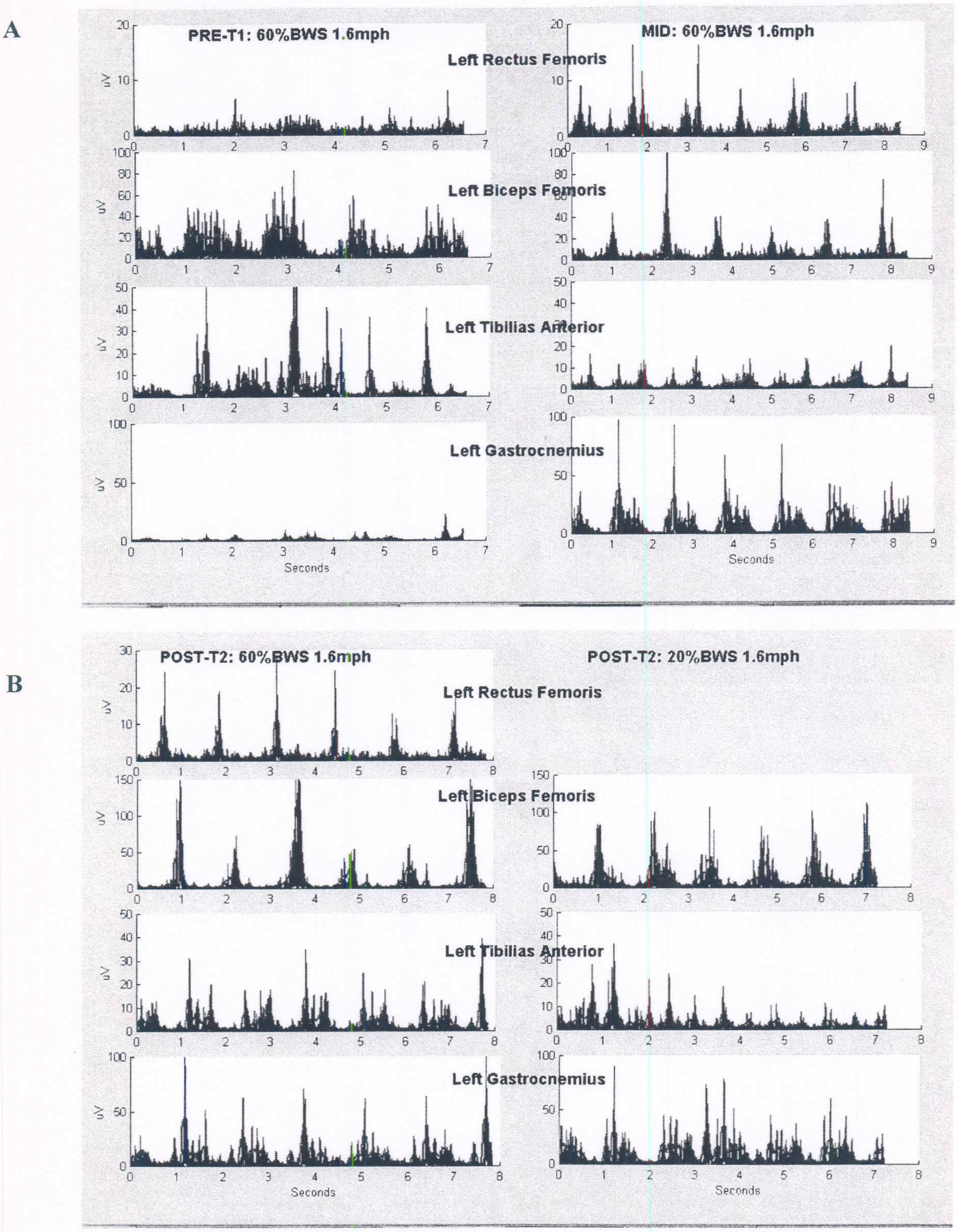

Figure 3. Ordinate: Rectified EMG and EMG RMS amplitude for 5 gait cycles (heel strike to heel strike) for Left Rectus Femoris, Left Bicep Femoris, Left Tibilias Anterior, Left Gastrocnemius. Abscissa: seconds. Data were collected for 20 seconds of continuous stepping. **(A)** Activity recorded at PRE-T1 and MID (after 35 sessions of training and 26 sessions of no training) and (Activity in uV; raw EMG signals were filtered at a bandwidth of 30-150 Hz, full-wave rectified, then root mean square (RMS) were calculated over a 120 ms window. **(B)** EMG Activity (LR, LB, LTA, LG respectively) recorded after training, POST-T2, was completed for different BWS at 1.6 mph. Note: no data recorded for Left Rectus at 20%BWS at 1.6 mph

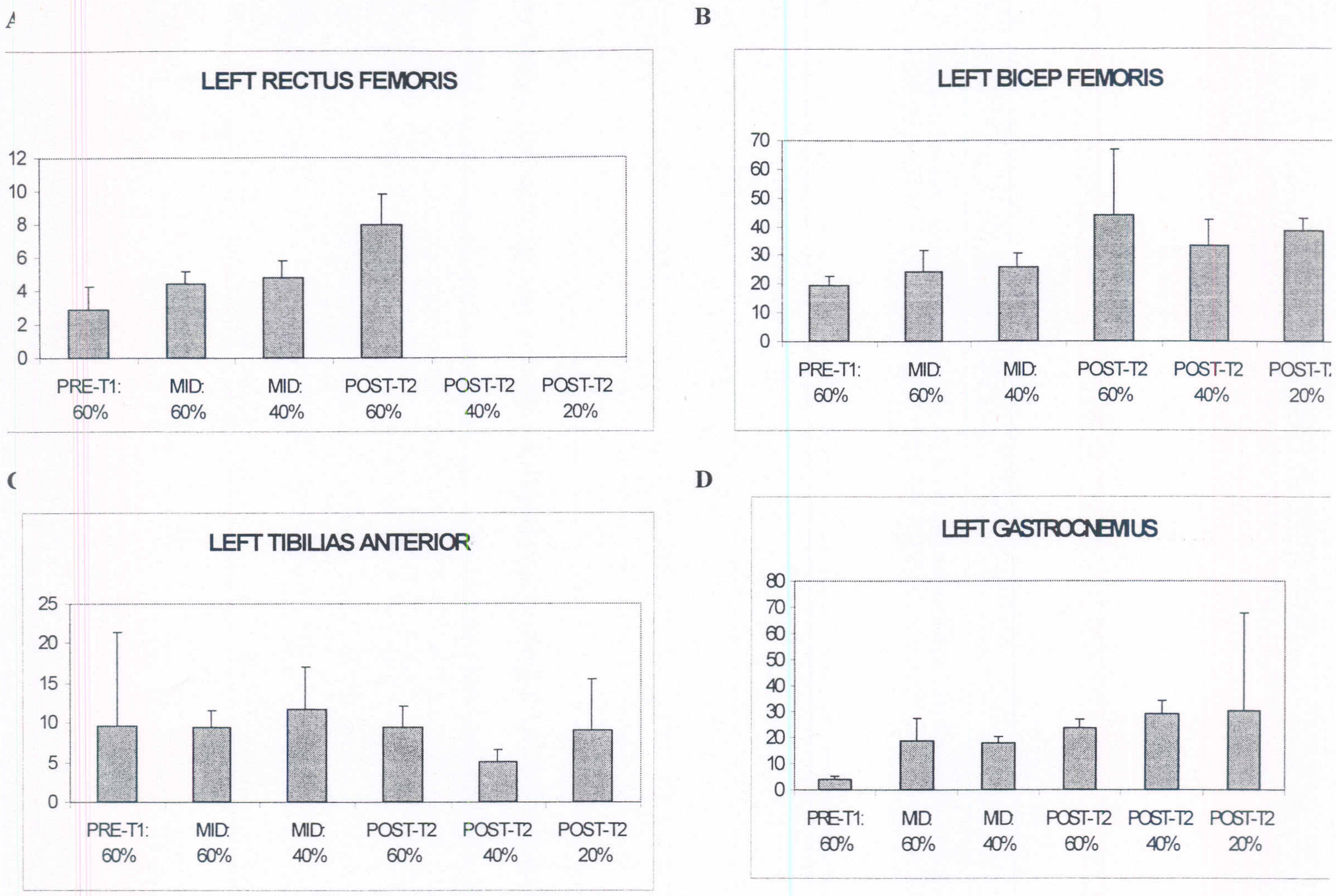

Figure 4. Ordinate: Mean EMG RMS amplitude (uV) for 6-10 gait cycles. Abscissa PRE-T1, MID and Post-T2 at 60%, 40% and 20 % BWS. PRE-T1: before any training had commenced. MID: Participant trained for 35 sessions and stopped training for 26 sessions (8.6 weeks) and before the participant had recommenced training for another 62 sessions. Post-T2: after the completion of 107 sessions of training. Mean EMG RMS amplitude: calculated as the sum of the RMS amplitudes from burst onset to burst offset divided by burst duration (ms).

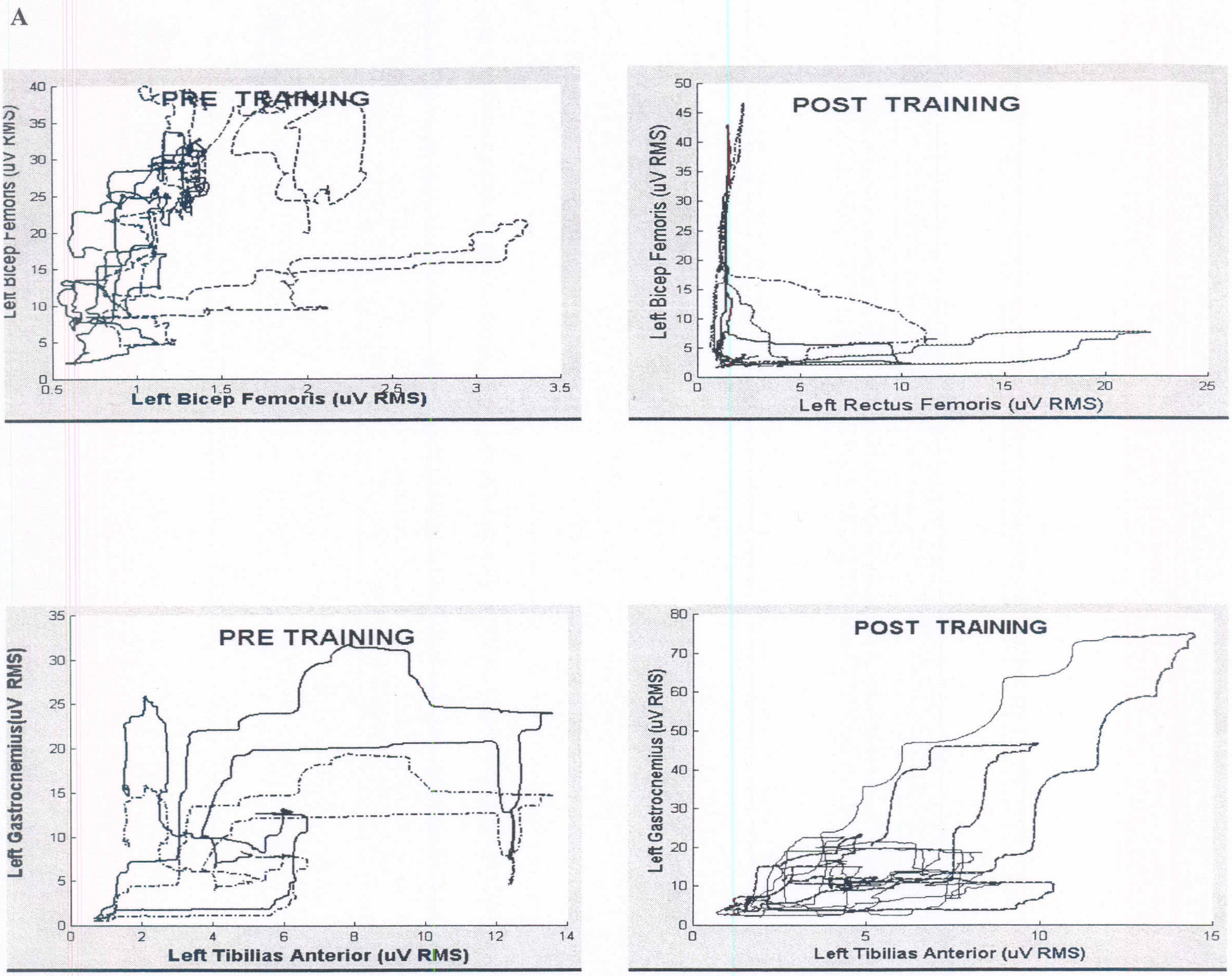

Figure 5. Coordination profiles for the LRF, LBF, LTA, and the LMG for 3 gait cycles (A) Coordination Profile for the agonist and antagonist for 40% 1.6mph. Before training (PRE –T1) the LRF and LBF EMG amplitudes are increasing/decreasing at the same time. After training (POST-T2), there is a reciprocal firing pattern of the LRF and the LBF. **(B)** After training (POST-T2), the amplitudes of the LG increased however both the LTA and LG were firing together, there was no reciprocal-firing pattern between the LTA and the LG.

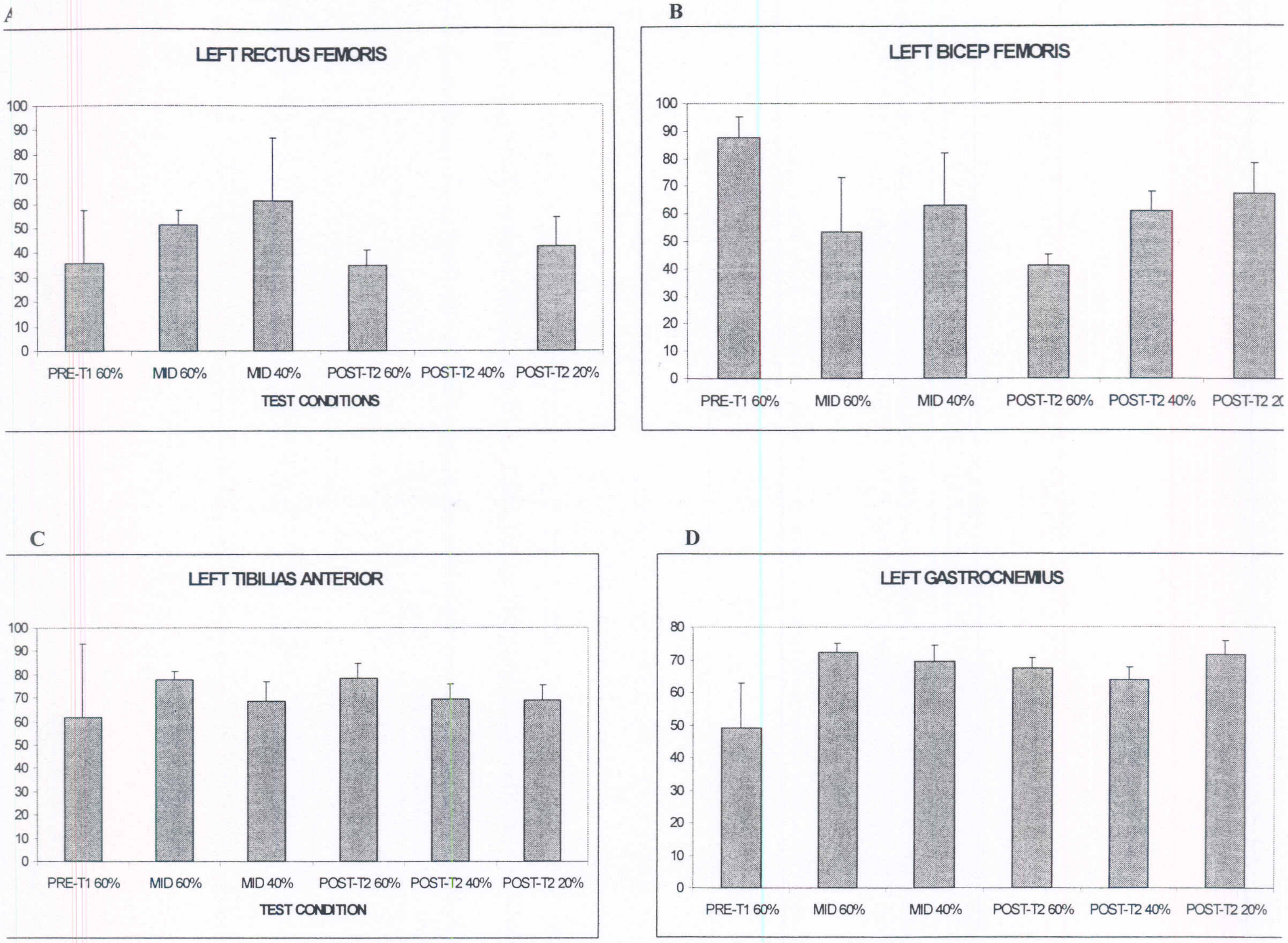

Figure 6. Ordinate: Burst Duration for 6-10 gait cycles. Abscissa PRE-T1, MID and Post-T2 at 60%, 40% and 20 % percent BWS. PRE-T1: before any training had commenced. MID: Participant trained for 35 sessions and stopped training for 26 sessions (8.6 weeks) and before the participant had recommenced training for another 62 sessions. Post-T2: after the completion of 97 sessions of training.

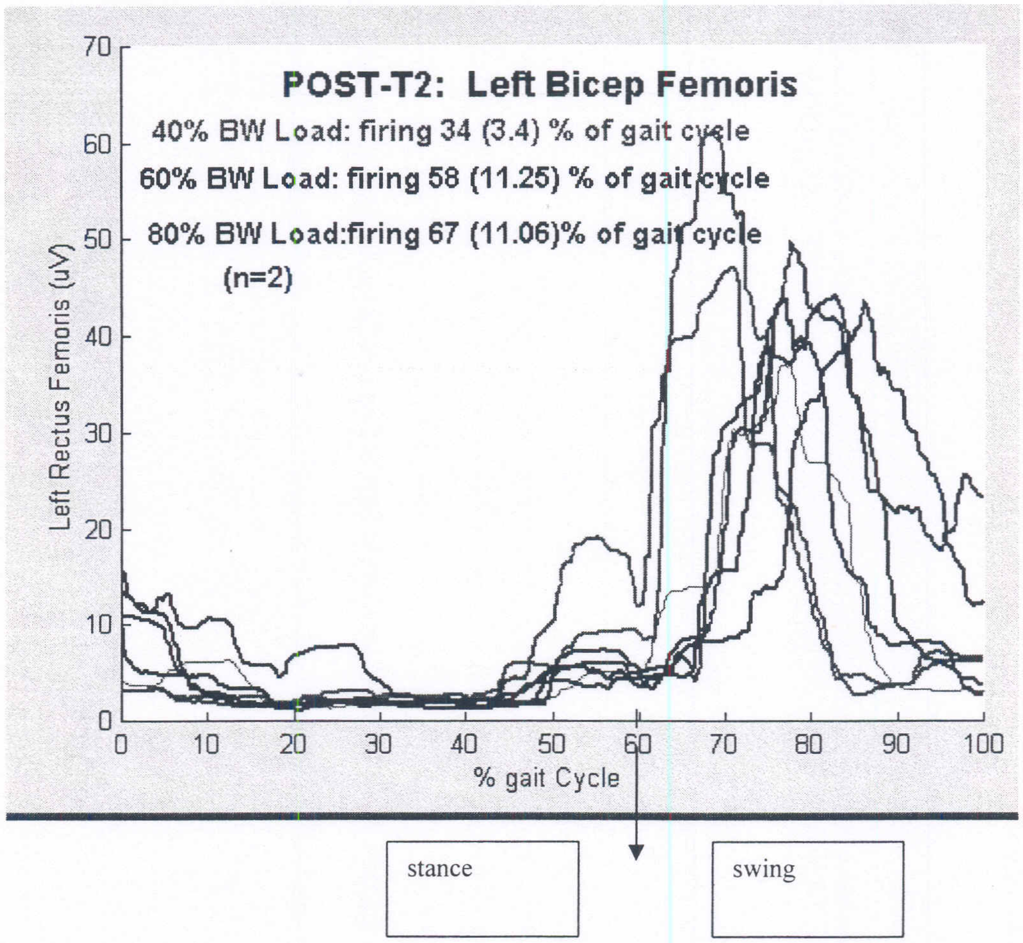

Figure 7. An example to show the effect of Limb Loading on burst duration in SCI participant. At POST-T2: LBF EMG profiles for each BW load (40%, 60%, and 80% BW load). Two gait cycles are presented for each BW. After 97 sessions of training there was an increase in burst duration (as percent of gait cycle) for the increase in load. Mean and Std (n=2) are presented in Figure. Ordinate: EMG amplitude RMS amplitude (uV). Abscissa: % gait cycle.

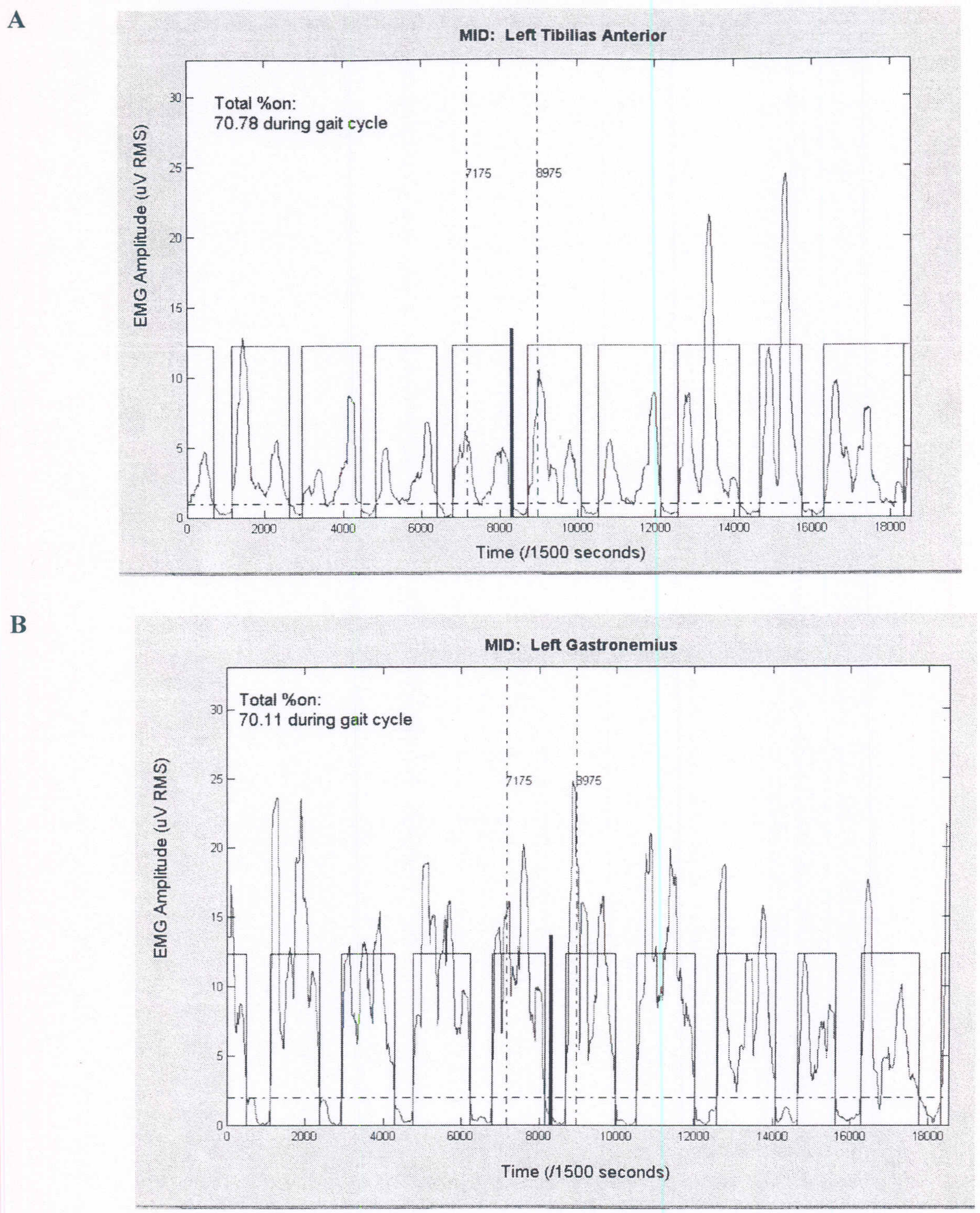

Figure8. A and B: EMG Amplitudes for the LTA and LG at MID: 40% BWS, 1.6 mph, 20 **Abscissa:** Percent Gait cycle **Ordinate**: uV RMS. Dotted Vertical lines represent one gait cycle (heel strike to heel strike) and solid vertical line represents toe off. Co-contraction during stance and swing is occurring for LG and LTA.

Gender	Male
Weight pre Locomomotor Training	81.64kg
Weight post Locomomotor Training	91.17kg
Height	1.88m
Months post Injury	12 months
Percent time reliant on wheelchair	100 %
Level of lesion	C6
ASIA Score pre Locomomotor Training:	ASIA B (with sacral sensation):
Motor Level	C6
Motor Score	16/100
Sensory Level	C6
Sensory Score	45/224
Lower Motor Extremity Score (LME)	0
ASIA Score pre Locomomotor Training:	ASIA B:
Motor Level	C6
Motor Score	17/100 (increase in finger flexors)
Sensory Level	C7
Sensory Level	51/224
LME	
Antispasmodic medications	None

Table 2. Training Profile for the participant

Duration of training (sessions)	97 sessions
Average time for Treadmill training Average walking time Average standing time	54.45 (±13.03) min 19.43 (± 4.52) min 35.03 (± 9.94) min
Average decrement of BWS/session	See Figure 2.
Average training speed	1.78 (±0.19) mph
Average time standing over ground using a platform rolling walker	
• Beginning of study (over first n=4 sessions)	3 (±2) min
• During study (for n=97 sessions)	15 (±8) min
• End of study/session (for final n=4 sessions)	20 (±2) min
• Three months after study completion	60 minutes (10 min without using arms)

Table 3a. BMD Values

Pre	BMD (gm/cm$^{2)}$	T Score	%	Post	T Score	%	BMD (gm/cm$^{2)}$
neck	1.009	-0.5	94	0.827	-1.9	77	18.04
wards	1.016	0.4	106	0.739	-1.7	77	27.26
trochanter	0.896	-0.3	96	0.651	-2.5	70	27.34
shaft	1.207			1			17.15
total	1.046	-0.3	96	0.83	-2	76	20.6

* Statistically 68% of repeat scans will fall within ±0. 01 g/cm^2 of error
* 1.9% loss of BMD for total body (over one year period)
* 20.6% loss of BMD in the Total L Hip (compared to pre)
T Score and % compared to Young Adult Ages (20-45)

Table 3b. BMC Values with cross sectional Area

	BMC	Area (cm^2)	BMC	Area (cm^2)	% Decrease BMC	% Decrease Area
neck	5.73	5.68	4.5	5.44	21.46	4.22
wards	3.64	3.58	2.43	3.29	33.24	8.10
trochanter	14.43	16.11	10.05	15.43	30.35	4.22
shaft	19.76	16.37	16.26	16.26	17.71	0.67
total	39.92	38.16	30.8	37.13	22.84	2.69

Table 4. Body Composition Values
Pre Weight: 81.64kg. Post weight: 91.17kg
Shank Diameter: PRE-T1: 37.4cm; MID: 38.3cm; POST-T2: 40cm

Body Composition	Pre: Lean mass (g)	Pre: Fat (g)	Post: Lean mass(g)	Post: Fat (g)
Arms	4930	2416	5025	3392
Legs	**17329**	**11097**	**19948**	**10398**
Trunk	27435	10165	31581	12029
Total	54548	24629	60984	26,858