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FOOT & ANKLE

Dynamic Gait Electromyography Study in Duchenne Muscular Dystrophy (DMD) Patients*

Gregory J. Melkonian,† D.V.M., M.D., Robert L. Cristofaro,‡ M.D., Jacquelin Perry,§ M.D., John D. Hsu,‖ M.D., C.M., F.A.C.S.
Muscle Disease Clinics and Pathokinesiology Service
Rancho Los Amigos Hospital
Downey, California

ABSTRACT

Preoperative and postoperative dynamic gait electromyography (EMG) was performed on 15 patients 8 to 13 years of age with Duchenne's muscular dystrophy who underwent Achilles tendon lengthening and posterior tibial tendon transfer anteriorly through the interosseous ligament for correction of equinus and equinovarus foot deformities.

The muscles tested preoperatively (anterior tibial, soleus, gastrocnemius, posterior tibial, peroneal longus, and peroneal brevis) showed phase changes. It is believed that patients with weakened leg muscles fire multiple muscle groups out of phase in an attempt to overcome the action of the stronger muscles, thus stabilizing the limb for ambulation. Postoperative EMGs, performed with the patients walking in long leg braces after the deformity had been corrected, showed litte activity in the muscles tested. As the patients became dependent on the brace, the need for the muscles to be active out of phase was eliminated. The transferred posterior tibial muscle appeared to be active both clinically and electromyographically.

Duchenne's muscular dystrophy (DMD) is a childhood neuromuscular disease with progressive degeneration of skeletal muscle affecting the male child. It is transmitted by a sex-linked, recessive inheritance. There is a high mutation rate, and a positive family history is not always elicitable.

Clinical muscular involvement begins by the manifestations of weakness in the pelvic girdle. It progresses to both upper and lower extremities. Pseudohypertrophy of the calf muscles is an early feature. Eventually, the disease involves most muscle groups. These patients progress from walking to a wheel-chair existence. Death is usually in the late teens or early twenties and is usually by cardiac arrest or respiratory infection.[9, 14]

As the disease progresses, the patient develops progressive muscular weakness and contractures.[1, 2] The children begin to fall frequently and have an associated triceps surae contracture with moderate weakness of the gluteus musculature, quadriceps, abdominals, dorsiflexors, and evertors of the ankle and foot. The triceps surae, posterior tibialis, and toe flexors generally remain strong. The patient's gait is very characteristic. They generally waddle, have difficulty with balance, and ambulate with lordosis, equinus of the ankles, inversion of the feet, and a wide base gait. Sutherland et al.[12] classify this stage as "labored walking." Eventually, their deformities and contractures create an unstable condition and they begin to fall. It is at this point that bracing and support are needed to keep them walking and standing.

Surgery has been necessary to correct ankle and foot deformities and to eliminate deforming forces in order to brace DMD children.[8, 10, 11] In a recent report of 24 cases of DMD patients in the labored stage of walking, we have been able to keep these patients further ambulatory from 12 to 52 months, with an average of 36.2 months, and thus believe that we have temporarily prevented some of the complications that result from all-day sitting and wheelchair dependence, e.g., scoliosis, obesity, and increased muscle weakness.[4]

The purposes of this study are to: (*1*) explore the possibility of extending the use of dynamic gait electromyography (EMG) to neuromuscular patients, particularly this group of DMD patients; (*2*) see if phasic

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† Orthopaedic Fellow, Children's Orthopedic Service, Rancho Los Amigos Hospital (1977–1978).

‡ Orthopaedic Fellow, Children's Orthopedic Service, Rancho Los Amigos Hospital (1976–1977).

§ Director, Pathokinesiology Service, Rancho Los Amigos Hospital.

‖ Chief, Muscle Diseases Clinics, Attending Orthopaedic Surgeon, Rancho Los Amigos Hospital. To whom requests for reprints should be addressed, at Rancho Los Amigos Hospital, 7601 E. Imperial Highway, Downey, Calif. 90242.

changes may occur when the posterior tibial tendon is transferred anteriorly; and (3) see whether the posterior tibial tendon may be active after transfer.

Clinical Material and Methods

Our study involved 13 DMD patients. Eleven of the 13 patients were members of our original group of 24 cases. The average age of the DMD patients was 10 years, and all 13 patients had surgery. However, not all patients were submitted to both pre- and postoperative walking EMG testing within 12 months of surgery. Completed pre- and postoperative walking EMG studies were done in seven patients. The preoperative walking EMGs were done within 14 days of surgery, and the postoperative EMGs were done as soon as possible, generally within 3 months after surgery.

EMG ANALYSIS

The muscles tested by EMG were the anterior tibialis, soleus, gastrocnemius, posterior tibialis, peroneus brevis, and peroneus longus.

The electromyographic evaluation consisted of the following. *1)* A 50-micrometer nylon-shielded Karina wire electrode was inserted into the muscles to be samples. 2) Placement of the electrode was then checked by both manual examination and electric stimulation. A resting EMG was recorded. 3) A foot switch was then applied to both feet, and the pattern of foot support was recorded in comparison to the EMG tracing.

This enabled the interpreter to: (*a*) differentiate between swing and stance; (*b*) demonstrate the percentage of the cycle which is in stance and swing; and (*c*) show which part of the foot contacted the ground. The areas recorded were the heel, heel-fifth metatarsal, heel-fifth metatarsal-first metatarsal, first metatarsal-fifth metatarsal, and first metatarsal-fifth metatarsal-toe.[7] The patient was then asked to stand quietly, next to walk at a normal cadence, and finally to walk at a fast cadence. All results were recorded on Visicorder paper for interpretation.

Fig. 1 indicates the phases of swing and stance in which the muscles tested (anterior tibialis, soleus, gastrocnemius, posterior tibialis, peroneus brevis, and peroneus longus) normally work.

SURGERY

In general, all 13 patients had similar surgical procedures. The contracture of the tendo Achilles was released by a subcutaneous Hoke type of lengthening.

The posterior tibial tendon causing weakly opposed foot inversion was released from its insertion and then passed through the interosseous membrane. It was then passed subcutaneously to the dorsolateral aspect of the foot, generally the third cuneiform. A suture was then placed in the end of the tendon and the suture and tendon were passed through a drill hole in the third cuneiform to the plantar surface of the foot. The wire suture was tied over a cushioned button. Pain was minimized by using small incisions.[5, 13]

A Yount release of the iliotibial band was performed for two patients who had knee flexion contractures of 20°. Postoperatively, all patients were placed in long leg casts. They stood in their casts on the first postoperative day. Walking in the casts with the walker began on the second postoperative day.

The patients were kept in their casts for 6 weeks, and at the end of this time the casts were bivalved and used for night splints. Orthoses were immediately applied for ambulation. The orthosis used was a knee ankle foot orthosis (KAFO) with a high thigh cuff. The knees could be stabilized into extension by means of a drop lock and the ankle was held at neutral.[3]

RESULTS

The dynamic EMG results in the 13 DMD patients preoperatively (Table 1) showed that the anterior tibialis was out of phase four times, the soleus four times, the gastrocnemius three times, the posterior tibialis six times, the peroneus brevis seven times, and the peroneus longus 14 times. Only seven of these patients agreed to have postoperative EMGs. This was done with ambulation in long leg braces and is recorded in Table 2. The anterior tibialis was out of

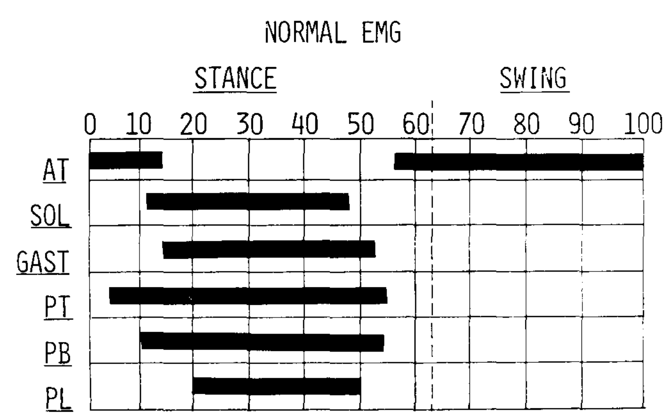

Fig. 1.

TABLE 1
Muscles Tested Preoperatively (13 Patients)

	In phase	Out of phase
Anterior tibialis	10	3
Soleus	9	4
Gastrocnemius	10	3
Posterior tibialis	8	5
Peroneus brevis	8	5
Peroneus longus	0	13

phase six times, the soleus two times, the gastrocnemius four times, the posterior tibialis five times, the peroneus brevis three times, and the peroneus longus five times. (One patient did not have the peroneus longus tested postoperatively.)

Comparison of the seven DMD patients who had both pre- and postoperative EMGs is also summarized in Table 2. The peroneus longus muscle in these seven comparison studies is persistently out of phase, both pre- and postoperatively.

CASE STUDIES

Two patients and their EMG studies will serve as examples.

Case 1

D. B. is presently an 11-year-old male with DMD. Clinically, he had a wide base gait, mild knee flexion contractures, equinus of the ankles, and intoeing of his feet. He was beginning to fall frequently, walking on his forefoot. It was felt that surgery was indicated at that time to allow for bracing. Preoperatively, walking EMG study in the Pathokinesiology Laboratory was done, and the pertinent data are illustrated by Fig. 2, *A* and *B*. In this record, the gastrocnemius, which should be active only during stance phase, was found to be active after toe-off. The peroneus longus comes on with the beginning of stance and appears to fire prematurely. The posterior tibial muscle was seen to be active only towards the end of stance.

At 9 years and 10 months, this patient had bilateral tendo Achilles lengthenings and bilateral posterior tibial tendon transfers. His knee flexion contracture was released via Yount procedures. The surgery successfully corrected the equinovarus position of the feet and allowed braces to be applied. He ambulated slower, but no longer fell. Fig. 2, *C* and *D*, shows the postoperative EMGs. Both the anterior tibial muscle and the peroneus longus are firing in both the stance and swing phase; thus, they are working out of phase. The posterior tibial muscle is now firing early in stance where this activity is expected.

Case 2

J. O. is a 9-year-old male with DMD. Clinical examination was similar to the first patient except that he did not have any knee flexion contractures. Interpreting the preoperative EMG (Fig. 3, *A* and *B*) in a manner similar to that for Case 1, the anterior tibial is active only in stance and the peroneus longus is active in both swing and stance. Thus, they are working out of phase. Posterior tibial showed activity during early stance.

This patient underwent bilateral Achilles tendon lengthenings and posterior tibial tendon transfers at 8 years and 10 months of age. Postoperatively, he had the same clinical result as Case 1. In Fig. 3, *C* and *D*, marked reduction of activity is seen. The walking EMG showed anterior tibial to be active only in stance, thus again out of phase. Activity is minimal in the peroneus longus. The posterior tibial, which was active in stance preoperatively is now active both in stance and swing. The soleus and gastrocnemius were also out of phase.

DISCUSSION

In the preoperative DMD patients, it is striking to see that the peroneus longus was out of phase in all 13 patients and the peroneus brevis and posterior tibialis in about one-half of the patients. From these findings, it is felt that the peroneus longus and in certain instances the peroneus brevis exhibit electrical activity continuously, and in cases where it is not continuous, this activity can be seen starting in stance phase and continuing to midswing. It is postulated that these muscles are trying to balance the foot in standing and walking against the relatively strong anterior and posterior tibialis. Similar such observations have been made in poliomyelitis patients where phase changes were noted in the peroneus brevis functioning against a strong anterior tibial muscle.[6]

In the seven comparison patients, the muscles most commonly out of phase were the anterior tibialis, gastrocnemius, and peroneus longus. Why muscles exhibit activity out of phase even when the higher centers are intact is not known and the scientific exploration is not within the scope of this study. In this group of patients who are able to walk despite severe muscular weakness, it is surmised by the authors that muscle activity may be going on in an attempt to stabilize the limbs for balance in ambulation.

The transferred posterior tibialis appeared to be active both clinically and electrically and thus was not just acting as a tenodesis. After transfer of the posterior tibialis, inversion is checked, thus making the peroneals less active and possibly making the anterior tibialis more efficient in acting as a dorsiflexor to maintain the corrected position.

It has also been shown that when dynamic gait EMG was done in patients in their orthosis, the electrical activity was minimal in the muscles tested. It can be surmised that the braces were eliminating the need for these muscles to be active and that the patient was almost totally dependent upon the brace for ambulation.

From this study and confirming the experience of previous observation in the DMD patients, the muscular weakness is marked and rapidly progressive. The preoperative EMG as yet has not changed our

TABLE 2
Pre- and Postoperative Dynamic EMG Studies on Selected Muscles

Case	Sex	Diagnosis	Age at operation	Surgery	Out of phase muscles											
					Preoperative						Postoperative					
					Anterior tibialis	Soleus	Gastro-cnemius	Posterior tibialis	Peroneus brevis	Peroneus longus	Anterior tibialis	Soleus	Gastro-cnemius	Posterior tibialis	Peroneus brevis	Peroneus longus
M	DMD	9 yr 8 mos.	Bilateral TALs[a] Bilateral PTTTs[b]						+	+						
M	DMD	9 yr 7 mos.	Bilateral TALs Bilateral PTTTs						+	+		+			+	
M	DMD	9 yr 8 mos.	Bilateral TALs Bilateral PTTTs	+			+		+	+			+		+	
M	DMD	9 yr 10 mos.	Bilateral TALs Bilateral PTTTs Bilateral Yount procedures			+			+	+				+	+	
M	DMD	9 yr 10 mos.	Bilateral TALs Bilateral PTTTs	+					+	+	+	+	+		NT[c]	
M	DMD	9 yr 1 mo.	Bilateral TALs Bilateral PTTTs Bilateral Yount procedures		+			+	+		+	+	+	+	+	
M	DMD	12 yr 6 mos.	Bilateral TALs Bilateral PTTs				+	+	+	+		+	+	+	+	

[a] TAL, tendo Achilles lengthening.
[b] PTTT, posterior tibial tendon transfer.
[c] NT, not tested.

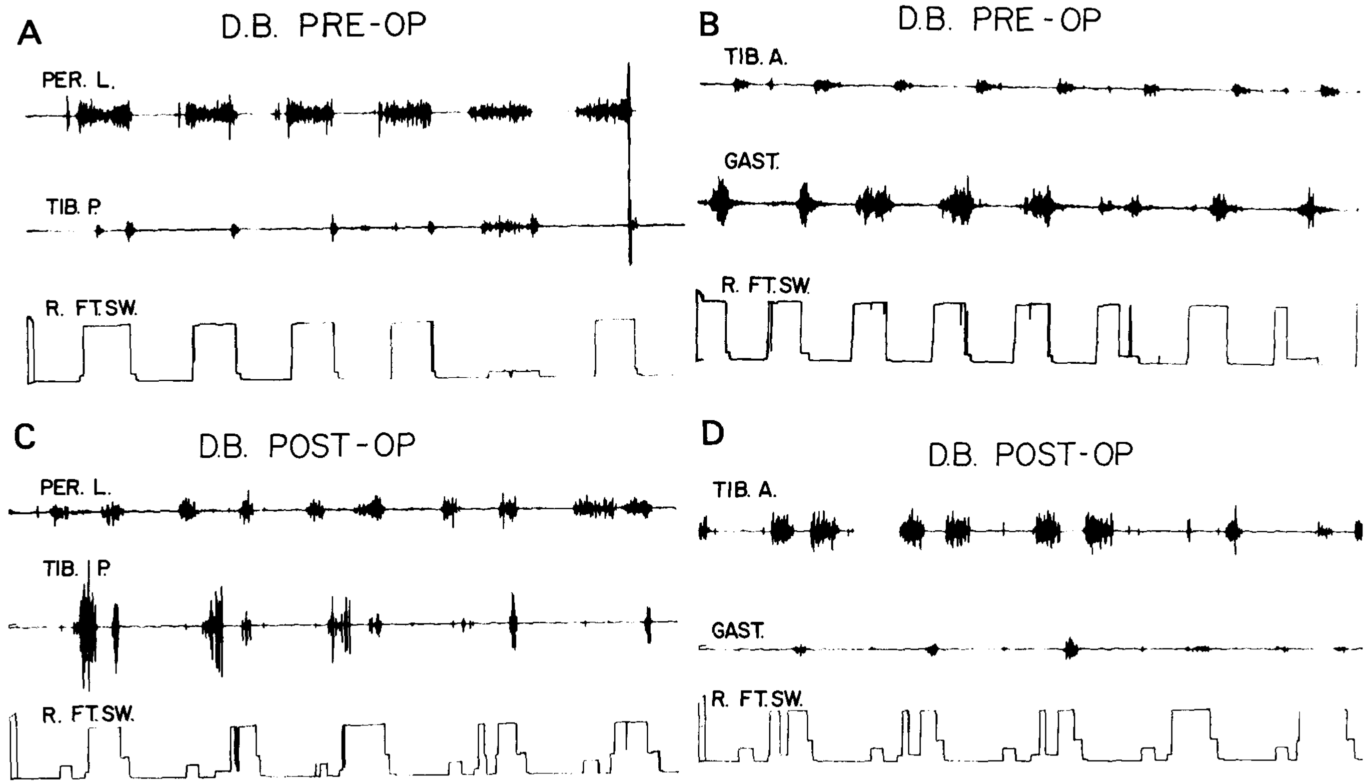

Fig. 2. Case 1. Preoperative (*A* and *B*) and postoperative (*C* and *D*) dynamic gait EMG. In the preoperative studies note premature firing of the peroneus longus which has persisted post-operatively. The posterior tibial muscle has remained in phase despite transfer anteriorly.

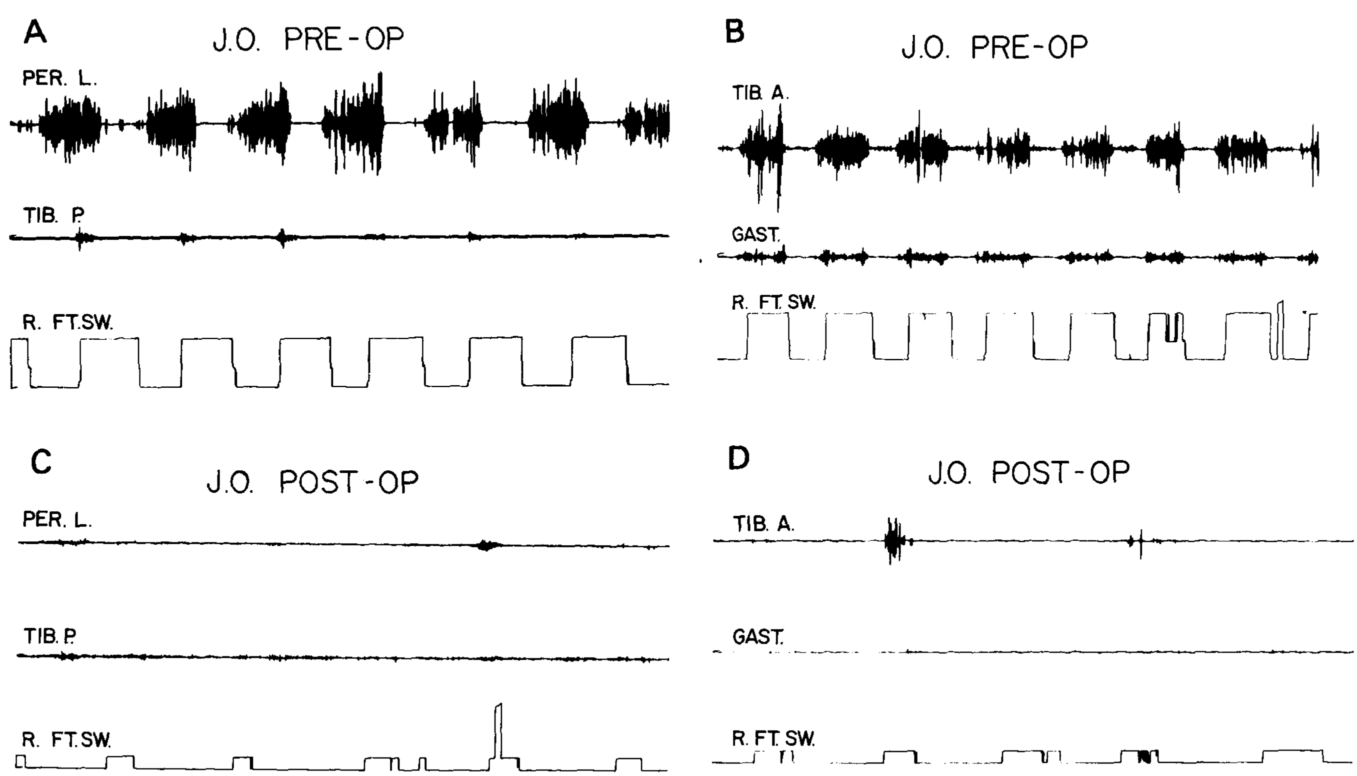

Fig. 3. Case 2. Preoperative (*A* and *B*) and postoperative (*C* and *D*) dynamic gait EMG. Activity of the peroneus longus muscle occurs in both swing and stance phase. Activity of the posterior tibial muscle occurs mostly in stance phase. Postoperatively, note minimal activity of all muscles recorded.

thoughts on the operative approach. In these patients, one must consider transferring or tenotomizing those muscles which cause persistent deformities and prevent the use of supportive orthoses.

CONCLUSIONS

1) Walking EMG studies were made in patients with DMD.

2) The surgically transferred posterior tibial tendon contracts actively and adequately corrects the varus deformity. It also shows electrical activity both pre- and posttransfer.

3) Muscle activity becomes minimal when orthoses were used.

4) In the DMD patient who has extensive lower extremity muscle wasting and weakness, walking EMG shows that multiple groups of muscles are "out of phase."

5) It is believed that the reason the muscles are out of phase is that activity is needed in all muscles to maintain balance. Thus, in this group of patients with generalized lower extremity muscle weakness, preoperative walking EMG studies do not appear to be helpful in decision-making for surgery of the lower extremity.

6) Ambulation was enhanced by surgical procedures to correct deformity and by orthoses to provide stability, although no improvement in abnormal EMG muscle patterns was found.

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