© 2016 IJSRSET | Volume 2 | Issue 3 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Comparative Analysis of Clubfoot and Normal Calf Muscle Activity Using Electromyography- A Case Study

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ABSTRACT

In this paper we analysed the signals of Gastrocnemius (GST) and Soleus (SOL) calf muscles from a unilateral clubfoot patient (right leg normal and left clubfoot) during different stages (resting, flexion and extension) using EMG. The Raw and filtered [Root Mean Square (RMS) and Integrated EMG (IEMG)] signals acquired from the subject were quantified using (AcqKnowledge 3.9, BIOPAC MP-100 systems Inc.), for 120 seconds and the output was analysed using paired sample T-test. Significant differences were observed between the Root Mean Square (RMS) EMG and Integrated EMG (IEMG) muscle activity of normal and clubfoot leg during the three conditions for both GST and SOL muscles. With the mathematical modelling tools, the results were studied and was found that the calf muscle activity of affected leg varies from the normal leg during resting, flexion and extension stages. It was also studied and proved that relapses can occur even after surgical correction (Achilles tenotomy) on these patients with the accuracy of 80%.

Keywords: Achilles Tenotomy, Clubfoot, EMG, Gastrocnemius (GST), Soleus (SOL)

I. INTRODUCTION

Club foot, also known as Congenital Talipes Equino-varus (CTEV), is the most common congenital structural deformity of lower limbs, involving one (unilateral), or both (bilateral) feet. Idiopathic clubfoot is as isolated deformity of one or both limbs consisting of four components: equines, hind foot varus, forefoot adductus, and cavus [1, 2]. The weight is shifted to the lateral side of the forefoot due to the fact that the foot is plantar flexed and the heel turned inwards which cannot bear the weight of the body. Clubfoot may be either primary (idiopathic) or secondary. The etiology of clubfoot is still unknown. Maternal smoking during pregnancy can lead to CTEV [3]. Risk of clubfoot is more (25%) in case a first degree family member (parent, siblings) is affected. First-born children are also more likely to have TEV than children from subsequent pregnancies. The effects of TEV on the infant are limited to the lower limbs and do not involve the other body systems or the mental ability of the affected infant. Clubfoot is usually diagnosed immediately after birth simply by looking at the foot. The heel of the foot turns inwards, the foot and toes pointing down and curve inwards. The bones are abnormally shaped with tight tendons, muscles, and ligaments. The foot and calf muscles are usually smaller than normal. The calf and peroneal muscles are poorly developed in the affected limb [4]. Diagnosis is confirmed by radiographic assessment of the foot and ankle. Ultrasonography (USG) and Magnetic Resonance Imaging (MRI) are other diagnostic methods. Two methods for correcting clubfoot include: Non-Surgical Treatment: Ponseti method**,** Manipulation method, Functional/ French/ Physiotherapy method and Botox method. Surgical Treatment: Achilles tenotomy. The Golden standard method of treatment for idiopathic club foot deformity is serial casting (Ponseti method) [5]. Ponseti method and the French functional method are both effective in reducing the need for surgery [6].

Perspective of the Study

1) To study the impact of surgical correction on the calf muscle activity by EMG analysis.
2) To identify any sort of muscular imbalance or abnormality and relapses in clubfoot patients treated with Achilles Tenotomy.

Comparative analysis of calf muscle activity between the normal and the surgically treated leg in unilateral clubfoot patient using EMG

II. METHODS AND MATERIAL

This portion of the work describes the study design used in this research as well as the measurement instruments and methods used. This also involves the study sample, size, settings, and selection of the study group and data collections. The methodology followed for carrying out the study is shown in Figure 1.

Figure 1. EMG recording of selected calf muscle activity in unilateral clubfoot patient

2.1 Subject Details

Due to the paucity of clubfoot patients in the age group of above three years it was not possible to perform EMG analysis on new born CTEV babies as they won't respond to this test, therefore the study is conducted on one subject, who had attended the age of 27 years and was born with unilateral clubfoot (right leg normal and left clubfoot).The patient's medical history revealed that he had been operated for Congenital Talpies Equinovarus (CTEV) of the left foot at an age of 6 months. Mean (± SD) age, height and weight calculated is shown in Table-1: Characteristics of Subject.

Category	Age (Years)	Height (Cm)	Weight (Kg)
Male	25 ±2	152±3	54.5±5.5

2.2 Equipments Used in Study

The equipment used during the study was Wireless EMG Systems for data acquisition shown in the figure 2.

Figure 2. BIOPAC-MP 100 System

The BIOPAC MP-100 System was used in the study because it allows nearly unlimited freedom of movement and unsurpassed comfort, enabling subjects to easily relax while performing selected tasks as per approved protocol.The basic components of the MP System are shown in fig 1.Acq*Knowledge* is extremely flexible, giving full control over data collection. Data can be analysed either while it is being acquired or after the fact. Main User Interface of AcqKnowledge 3.9 is shown in figure 3.

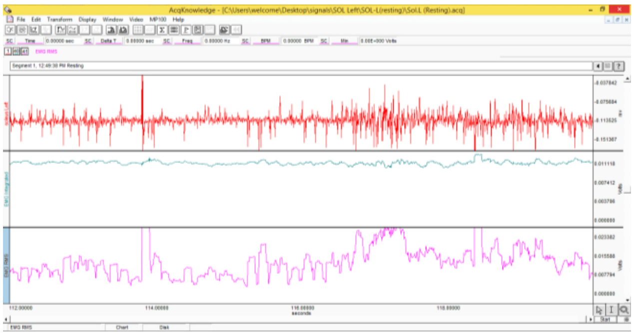

Figure 3. Main User Interface of AcqKnowledge 3.9

2.3 Hypothesis of the study

2.3.1 There will be a non-significant difference in EMG activity of normal (right) and clubfoot (left) leg of unilateral clubfoot patient.
2.3.2 There will be a non-significant difference in EMG activity of Gastrocnemius (GST) and soleus (SOL) muscles of unilateral clubfoot patient during resting, flexion and extension conditions.

2.4 Data Acquisition

EMG analysis of selected calf muscles [Gastrocnemius (GST) and Soleus (SOL)] was carried out for 2 minutes using disposable gel electrodes shown in Fig 4. Normal

(Right) and abnormal (Left) calf muscle activity was recorded during resting, flexion and extension stages.

Figure 4. Disposable Gel electrodes

The Raw and filtered [Root Mean Square (RMS) and Integrated EMG (IEMG)] signals acquired from the subject were quantified using AcqKnowledge 3.9 software. The data acquisition software (AcqKnowledge 3.9, BIOPAC systems Inc.) was set to sample rate of 200 samples per second and acquisition duration was set for 120 seconds. Scaling parameters were set as default value (Cal1= 10) and (Cal 2= -10) and their units were set in millivolts. All acquisition parameters and window positions are saved along with the data when the Save command is chosen. The subject preparation were carried out following standard protocols for placing electrodes on subject's pre identified muscles to acquire EMG simultaneously from both the legs. After data acquisition, EMG signal was recorded for 120 seconds to better understand the influence of resting, flexion and extension conditions on EMG signal of selected calf muscles of clubfoot and normal leg. The schematic placement of electrodes is shown in Fig 5.

Right (Normal) Left (Clubfoot)

Figure 5. Experimental Setup

III. RESULTS AND DISCUSSION

In case of Raw EMG, Significant difference between GST.R and GST.L muscle activity was recorded at resting state. Non-significant difference was observed between GST.R and GST.L muscle activity in flexion condition. Non-significant difference was observed between GST.R and GST.L muscle activity in extension condition (table2). Raw EMG analysis showed non-significant difference for SOL muscles at all three conditions (resting, flexion and extension) between the clubfoot and the normal leg. Significant difference was observed between the Root Mean Square (RMS) EMG and Integrated EMG (IEMG) muscle activity of normal and clubfoot leg during resting, flexion and extension conditions for both GST and SOL muscles as shown in (tables 3-4) respectively. SPSS software (version 17) was used to carry out Paired t test to compare the results obtained from the normal (Right) leg and the treated clubfoot (Left) leg of the patient.

Raw EMG recorded for GST and SOL muscles for 28, 58 and 120 seconds under three different positions (resting, flexion and extension). (GST R + SOL R: Normal; GST L+ SOL L: Abnormal)

Paired Samples Test

		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	95% Confidence Interval of the Difference: Upper	T	Df	Sig. (2-tailed)
Pair 1	GSTR.rest GSTL.rest	0.000767	0.028506	0.000265	0.000248	0.001285	2.897	11601	0.004
Pair 1	GSTR.flexion GSTL.flexion	0.000570	0.064547	0.000456	-0.000323	0.001464	1.251	20045	0.211
Pair 1	GSTR.Ext GSTL.Ext	0.000060	0.038131	0.000268	-0.000466	0.000586	0.224	20186	0.822

Paired Samples Test

		Paired Differences					T	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	SOLR.rest SOLL.rest	0.000328	0.016898	0.000218	-0.000100	0.000756	1.501	5991	0.133
Pair 1	SOLR.flexionSOLL.flexion	-0.000166	0.035773	0.000231	-0.000618	0.000287	-0.718	23994	0.473
Pair 1	SOLR.Ext SOLL.Ext	-0.000389	0.047960	0.000310	-0.000996	0.000217	-1.258	23989	0.209

95% CI value indicates 5% level of Significance ($p<0.05$)

Table no: 2

Integrated EMG recorded for GST and SOL muscles for 28, 58 and 120 seconds under three different positions (resting, flexion and extension). (GST R + SOL R: Normal; GST L+ SOL L: Abnormal)

Paired Samples Test

		Paired Differences					T	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	GSTR.rest-GSTL.rest	-0.000077	0.000963	0.000009	-0.000094	-0.000059	-8.560	11598	0.000
Pair 1	GSTR.flexion GSTL.flexion	0.000207	0.001399	0.000010	0.000187	0.000227	20.437	19062	0.000
Pair 1	GSTR.Ext GSTL.Ext	0.000040	0.000814	0.000006	0.000029	0.000051	7.128	21355	0.000

Paired Samples Test

		Paired Differences					T	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	SOLR.rest SOLL.rest	0.000006	0.000164	0.000002	0.000002	0.000010	2.843	5989	0.004
Pair 1	SOLR.flexion SOLL.flexion	0.000039	0.001389	0.000010	0.000020	0.000057	4.067	21239	0.000
Pair 1	SOLR. Ext SOLL. Ext	-0.000068	0.001101	0.000008	-0.000083	-0.000053	-8.990	21329	0.000

95% CI value indicates 5% level of Significance ($p<0.05$)

Table no: 3

Root Mean Square EMG recorded for GST and SOL muscles for 28, 58 and 120 seconds under three different positions (resting, flexion and extension). (GST R + SOL R: Normal; GST L+ SOL L: Abnormal)

Paired Samples Test

		Paired Differences					T	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	GSTR.rest GSTL.rest	-0.002820	0.007412	0.000069	-0.002955	-0.002685	-40.986	11604	0.000
Pair 1	GSTR.flexion GSTL.flexion	0.029251	0.018488	0.000133	0.028990	0.029513	219.235	19200	0.000
Pair 1	GSTR. Ext GSTL. Ext	0.002708	0.013057	0.000122	0.002469	0.002946	22.276	11539	0.000

Paired Samples Test

		Paired Differences					T	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	SOLR.rest SOLL.rest	-0.001206	0.002451	0.000032	-0.001268	-0.001144	-38.083	5993	0.000
Pair 1	SOLR.flexion SOLL.flexion	0.026560	0.010492	0.000068	0.026428	0.026693	392.152	23994	0.000
Pair 1	SOLR. Ext SOLL. Ext	-0.024326	0.017378	0.000112	-0.024546	-0.024106	-216.837	23993	0.000

95% CI value indicates 5% level of Significance ($p<0.05$)

Table no: 4

IV. CONCLUSION

It is concluded from the present study that calf muscle activity of affected leg varies from the normal leg during resting, flexion and extension conditions in a unilateral clubfoot patient even after surgical correction and can be efficiently analysed using electromyography (EMG). The study also helps in understanding the muscular imbalance among clubfoot patients. The results of the present study are in favour of abnormal innervations as the prime factor in the development of such deformity. The findings support the theory that muscle imbalance is an etiological factor in congenital clubfoot & electrophysiological studies are useful in idiopathic clubfoot with residual deformities after conservative or operative treatment. In future Biosensors can be used in clubfoot patients that show relapses or resistance even after conservative or operative treatment. Pre-treatment and post treatment assessment of muscles in clubfoot patients during gait analysis can be a guiding tool in treatment as well as recurrence cases. Electromyography is one of the prognostic factors to analyse such deformity. EMG analysis provide information to surgeon as well as to parents about the expected results and indicates the need for more extensive operation or further surgical corrections depending upon the severity of the condition, rather than limited procedures which may prove inadequate.

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