Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 41 (2012) 32 – 36

Engineering Procedia

www.elsevier.com/locate/procedia

International Symposium on Robotics and Intelligent Sensors 2012 (IRIS 2012)

EMG Analysis of Lower Limb Muscles for Developing Robotic Exoskeleton Orthotic Device

Ashish Kumar Mishra[a*], Amit Srivastava[a], R. P. Tewari[a], Rakesh Mathur[a,]

[a]*Applied Mechanics Department, Motilal Nehru National Institute of Technology, Allahabad-211004, India*

Abstract

Human walking is a complex and rhythmic activity. It is well integrated effort of brain, nerves and muscles. It relies on the coordinated action of various muscles to control the jointed trunk and limbs and to generate the forces needed to counter gravity and propel the body forward. In this study, surface electromyography (EMG) signals of the gluteus maximus, gluteus medius, adductor longus, hamstrings, tibialis anterior, Tricep surae, rectus femoris and erector spine muscles were recorded on various subject walked over ground at normal walking speeds. Comparative study of the normal gait with clinical gait exhibited greater activation of the hamstring and tricep surae during mid-stance phase. The complete lack of triceps surae signal during the pushoff phase was also seen. Tibialis anterior showed activation throughout most of the gait cycle in clinical gait. During the walking, EMG activity of Adductor Longus, Hamstrings, Tibialis Anterior, Tricep Surae and Erector Spine muscles were significantly augmented ($p<0.05$) in both normal and clinical gait. There were no significant differences ($p < 0.050$) shown for muscle EMG for the gluteus maximus, gluteus medius and rectus femoris muscle. The biomechanical lower extremity model proposed in this study will estimate the muscle activation patterns and also be used to design the lower-limb exoskeltal assistive robotic systems for physically challenged persons.

Keywords: *Human GAIT, Electromyography, Muscles, annova*

1. Introduction

During normal walking muscles produce forces which act directly on the musculoskeletal system. In recent years, musculoskeletal models have been used to generate simulations of normal and pathological gait patterns. [1] Musculoskeletal models consist of a set of body segments connected by joints with specified degrees-of-freedom (dof) spanned by muscles and ligaments[2] Joint or segmental motions and external forces are specified and an optimization routine is employed to determine muscle and ligament forces [3,4,5]. Proposed Model outcomes can be used to study specific muscles contribution to movement coordination, assess difference between normal and pathological gait and also suggest interventions to correct pathologic walking patterns. In this study, electromyographically (EMG)-driven biomechanical models is developed to estimate muscle forces and joint moments. Since these models determine muscle forces based on recorded EMG data, they can be used to determine how different muscle activation patterns influence joint moments, and thus can be used to study normal and clinical gait analysis. The biomechanical lower extremity model proposed in this paper will be used to estimate the muscle activation patterns that would enable clinically disabled patients to walk with a similar joint kinematics to that of an unimpaired person. Outcomes from this study will be used to design the lower-limb exoskeltal assistive robotic systems for physically challenged persons. A result from this study suggests that models have considerable potential to improve understanding and hence help in developing suitable assistive devices for physically challenged persons who are unable to walk like normal human subjects.

1877-7058 © 2012 Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
doi:10.1016/j.proeng.2012.07.139

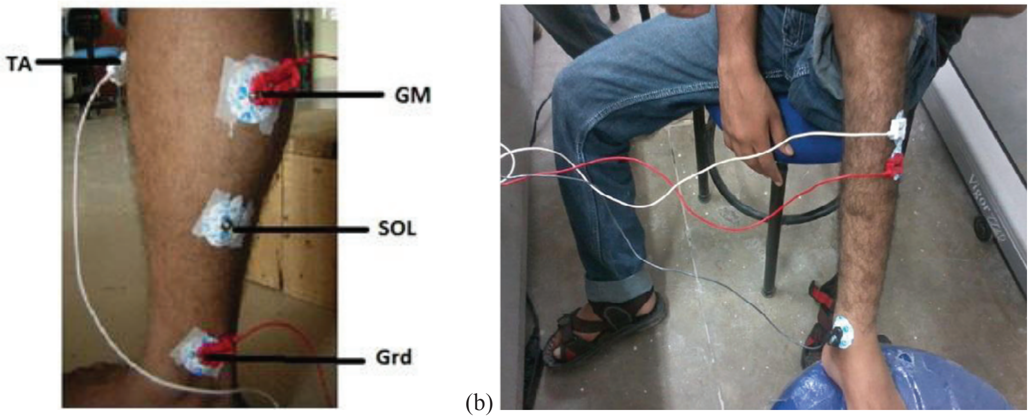
2. Materials and Methodology:

Six healthy volunteers and two cerebral palsy volunteers between the ages of 18-24 years of age were chosen for this study. In this study participants with cerebral palsy were very functional ambulator. For the patient suffering from cerebral palsy, walking upstairs and downstairs is a painful and tiring due to calf muscles.

2.1. Instrumentation and Procedure:

Surface EMG (BIOPAC Inc., USA) was used to measure the activity of gluteus maximus, gluteus medius, adductor longus, hamstrings, tibialis anterior, Tricep surae, rectus femoris and erector spine muscles of the subject. The BIOPAC system comprised an MP150 data acquisition unit and EMG signals were digitized, stored and analyzed using acqKnowledge software version 4.1. After cleaning the skin with isopropyl alcohol, active surface EMG recording electrodes (BIOPAC Inc., USA, Ag/Ag Cl, diameter 11.4 mm, electrode spacing 20 mm centre to centre, with a built in 350× amplification and a 3 dB band pass of 12 to 500 Hz) were placed on gluteus maximus, gluteus medius, adductor longus, hamstrings, tibialis anterior, Tricep surae, rectus femoris and erector spine muscles of the dominant leg of the subject at standardized sites on the dominant leg.[6] A good quality tape were used to tighten the electrodes so that their position will not changed during experiment and to avoid movement artifacts also. The EMG data were recorded at a sampling rate of 1000 Hz. In this study, EMG normalization was not required because the participants acted as their own control and all procedures were performed in the same session, without the electrode positions being altered. [7]

.

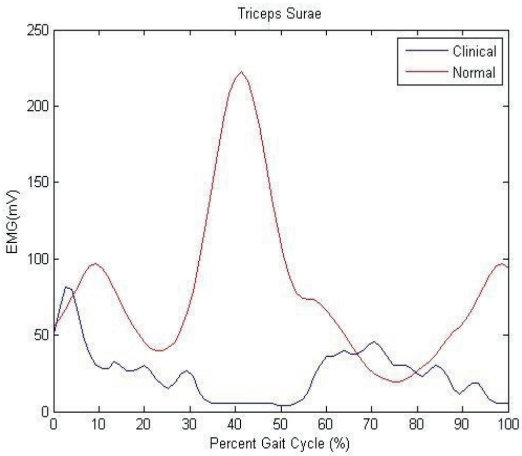


(a) (b)

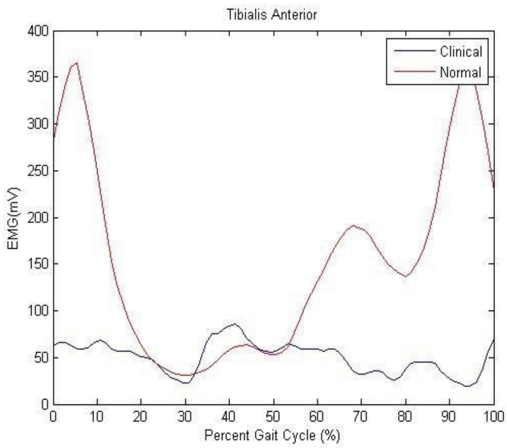
Fig1 - Electrode placement on Subject during experiment

2.2. Data Processing:

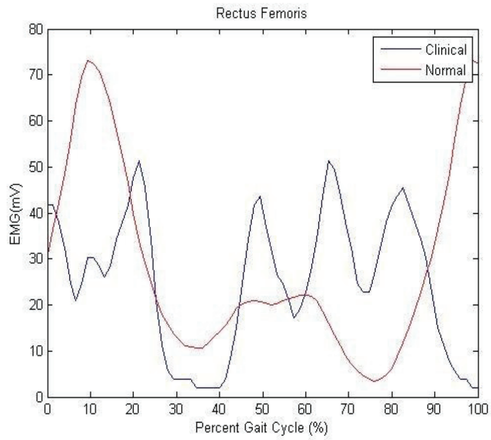
All The EMG signals were processed using MATLAB software. A Band pass filter was applied to the raw data to remove any movement artifacts. For each participant, the average rectified value (ARV) was calculated for gluteus maximus, gluteus medius, adductor longus, hamstrings, tibialis anterior, Tricep surae, rectus femoris and erector spine muscles in each walking repetition by dividing the EMG integral by the contraction time interval. The data were checked to ensure artifacts were not incorrectly identified as onsets. Graphs for various muscles were plotted for both normal and clinical gait.


Triceps Surae
Clinical
Normal
EMG(mV)
Percent Gait Cycle (%)

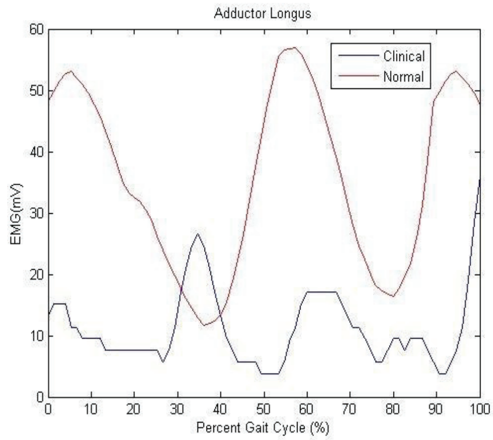
(a)


Tibialis Anterior
Clinical
Normal
EMG(mV)
Percent Gait Cycle (%)

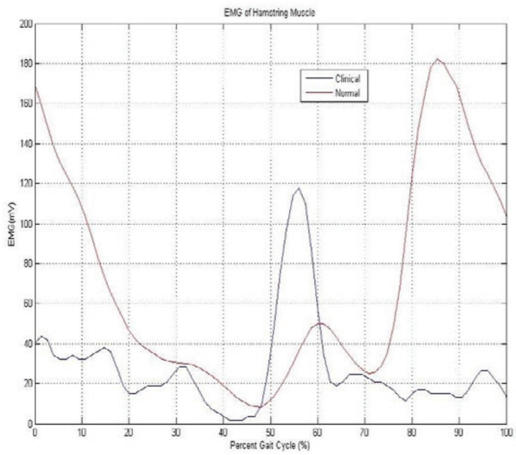
(b)


Rectus Femoris
Clinical
Normal
EMG(mV)
Percent Gait Cycle (%)

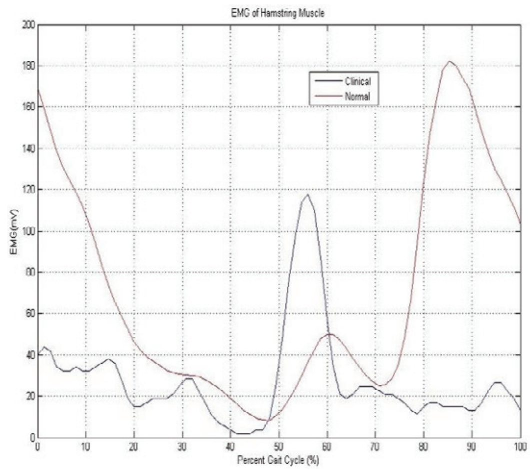
(c)


Adductor Longus
Clinical
Normal
EMG(mV)
Percent Gait Cycle (%)

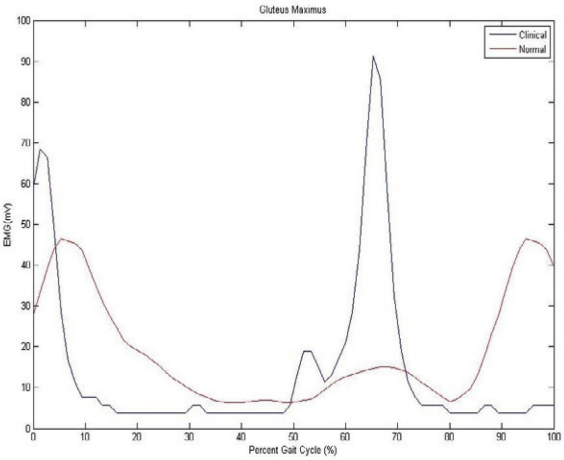
(d)


EMG of Hamstring Muscle
Clinical
Normal
EMG(mV)
Percent Gait Cycle (%)

(e)


EMG of Hamstring Muscle
Clinical
Normal
EMG(mV)
Percent Gait Cycle (%)

(f)

(g) 

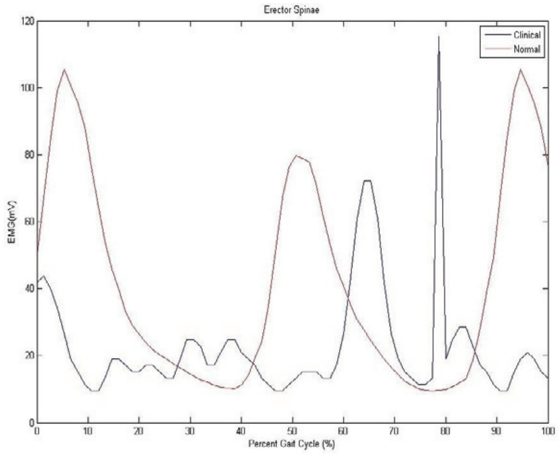
(h) 

Fig 2. EMG in µV for various muscles for normal and clinical gait

3. Result & Discussion

In this work, EMG activities of lower limb muscles have been acquired for normal and pathological gait. An one-way analysis of variance test (ANOVA) with repeated measures was performed to determine the effect of activity in gluteus maximus, gluteus medius, adductor longus, hamstrings, tibialis anterior, Tricep surae, rectus femoris and erector spine muscles for each subject. There were significant differences ($p < 0.050$) shown for muscle EMG for adductor longus, hamstrings, tibialis anterior, Tricep surae and erector spine muscles. There were no significant differences ($p < 0.050$) shown for muscle EMG for the gluteus maximus, gluteus medius and rectus femoris muscle.

The calf muscle, gluteus maximus, gluteus medius, adductor longus, hamstrings, tibialis anterior, Tricep surae, rectus femoris and erector spine were shows activation during beginning and end of stance and swing phase of gait cycle. During midstance and midswing calf muscle, gluteus maximus, hamstrings, rectus femoris and erector spine muscles were showing very less activity. During midstance, gluteus medius acts as a hip abductor to stabilise the pelvis as the contralateral leg swings through, while the triceps surae prevents excessive dorsiflexion of the ankle and then prepares to drive the person forward [8] . Muscles of the lower leg of clinical person showed major discrepancies in activity when compared to normal person. It is seen that the EMG for a normal man's Tibialis Anterior shows greater activity just after heel strike. In contrast, clinical man's Tibialis Anterior is active throughout most of the gait cycle. Similar kinds of results were seen in literature available in which TA muscle shows a greater activity during swing phase compared to stance phase.[9] A literature also reported that during midswing, the tibialis anterior provides active dorsiflexion and thus prevents the toes from dragging on the ground.[10] Triceps Surae muscle shows a very less activity during the pushoff phase. Although lacking this pushoff function, which is characteristic of normal gait, clinical man's triceps surae are active before and after heel strike. In this study, comparison of lower limb muscles for normal and clinical person were done using EMG analysis and results were weakness in the Tibialis Anterior and this will affect the plantar flexion movement of leg that occurs just after heel strike.

4. Conclusion & Proposed Future Work:

In this work, EMG activities of lower limb muscles have been acquired for normal and pathological gait. It has been observed that Tibialis Anterior and Tricep Surae muscles are showing most significant activities in comparison to other muscle groups. This study will also helpful in automatically detecting various phase of gait cycle for normal and pathological gait based on EMG data of significant muscle group only. This study will be helpful to minimize mechanical complexity of lower limb exoskeletal system. In future the lower limb exoskeleton robotic system will be developed by designing mechanical link and joint system, taking into consideration only significant muscle group. The work is in progress to develop lower limb exoskeleton system based on this research, with minimum mechanical link and joint system. The EMG data is also correlated to various joint angles for normal and pathological gait. In case of pathological gait the difference of joint angle (hip, knee and ankle) will helpful in designing lower limb exoskeleton assistive device.

References

[1] Caroline Stewart, Adam P. Shortland, 2010 "The biomechanics of pathological gait– from muscle to movement", Acta of Bioengineering and Biomechanics, Vol. 12, No. 3
[2] Damsgaard, M., Rasmussen, J., Christensen, S.T., Surma, E., de Zee, M., 2006 "Analysis of musculoskeletal systems in the anybody modeling system". Simulation Modeling Practice and Theory, 14 (8), pp 1100–1111.
[3] Erdemir, A., McLean, S., Herzog, W., van den Bogert, A.J., 2007 "Model based estimation of muscle forces exerted during movement", Clinical Biomechanics 22, pp 131–154
[4] Praagman, M., Chadwick, E.K., van der Helm, F.C., Veeger, H.E., 2006 "The relationship between two different mechanical cost functions and muscle oxygen consumption", Journal of Biomechanics 39, pp 758–765
[5] Rasmussen, J., Damsgaard, M., Voigt, M., 2001 "Muscle recruitment by the min/max criterion—a comparative numerical study", Journal of Biomechanics 34, pp 409–415
[6] Edwards L., Dixon J., Kent J.R., Hodgson D. and Whittaker V.J., 2008 "Effect of shoe heel height on vastus medialis and vastus lateralis electromyographic activity during sit to stand", The Journal of Orthopaedic Surgery, 10:3:2
[7] Soderberg GL, Knutson LM, 2000 "A guide for use and interpretation of kinesiologic electromyographic data", Physical Therapy, 80: pp 485- 498
[8] Vaughan Christopher L, Davis Brian L, O'Connor Jeremy C, "Dynamics of human gait", 2nd edition, Kiboho Publishers, Cape Town, South Africa.
[9] Semple Ruth, Murley George S, Woodburn James and Turner Deborah E, 2009 "Tibialis posterior in health and disease: a review of structure and function with specific reference to electromyographic studies", Journal of Foot and Ankle Research, 2:24
[10] Inman, V.T., Ralston, H.J., & Todd, F, 1981 "Human walking". Baltimore, Williams & Wilkins