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An Electromyography analysis of lower limb muscles for different locomotion activities

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Abstract

In this study, surface electromyography (EMG) signals of the Gastrocnemius, Tibialis anterior and Soleus muscles were recorded on various subject during their daily life activities such as walking and stair ascent and decent. The lower-limb muscle activities have been studied to enable power-assist robotic systems to estimate human lower-limb muscle activities based on muscle electromyographic (EMG) signals. The results from study will be used to estimate the muscle activation patterns and also be used to design the lower-limb exoskeleton assistive robotic systems for physically weak persons.

1. Introduction

The lower-limb motions are very important for the human daily activities, such as walking, stair ascent and decent. It is sometimes painful and tiring for physically weak persons (elderly, disabled, and injured persons) obese persons and women during pregnancy to perform daily activities. Previous studies show that walking speed affects the amplitude of muscle activity. Stair locomotion, being a common functional activity of daily living, has been used in the rehabilitation of the lower extremity as a motor performance test [1] Several studies were performed to investigate normal human stair ascent and descent [2][3][4]. Available literatures have shown that stair locomotion places higher loads on the joints of the lower limb than level walking does, with larger ranges of motion [5][6][7], and muscle efforts [8]. In modern society, it is important that physically weak persons are able to take care of themselves during daily activities. It is also important that such persons use their own body functions properly to keep them healthy and fit. In such cases power assisted robotic systems are very useful to assist physically weak person's daily life activities. The EMG signals are important information for power-assist robotic systems to understand how the person intends to move. [9]

Therefore, it is important to find out and establish the relationships between the human lower-limb motions and related muscles activities during daily life activities. Lower-limb muscles may adapt to changes according various locomotion activities. These adaptations are muscle-specific. The rhythmic movements of lower limb muscles during daily activities can be studied with tools like electromyography (EMG). In this study, surface electromyography (EMG) signals of the Gastrocnemius, Tibialis Anterior and Soleus muscles were recorded on various subject walked over ground with different walking speed and on stairs with normal speed. A result from this study will be helpful in developing suitable assistive devices for physically weak persons who are unable to walk like normal human subjects.

2. Methodology

Six healthy volunteers between the 20-30 years of age were participated in this study. The volunteers reported not having any kind of musculoskeletal or neuromuscular problem in lower extremity that restricts the range of lower extremity motion, which might make the walking painful. Participants were excluded if they had chronic ankle or knee problems. The subjects were instructed first to walk with their normal speed and then with two self selected speeds, i.e. slow speed and fast speed on level ground. After that subject's were asked to walk over stairs at normal speed.

Surface EMG (BIOPAC Inc., USA) was used to measure the activity of Gastrocnemious, Soleus and Tibialis Anterior muscles. The BIOPAC system comprised an MP150 data acquisition system. EMG signals were recorded, stored and analyzed offline using AcqKnowledge software version 4.1. After cleaning the skin with isopropyl alcohol, surface EMG recording electrodes were placed on Gastrocnemious, Soleus and Tibialis Anterior muscles sites. All electrodes were taped to the skin to reduce movement artifacts and remained in place throughout the study.[10] The Surface EMG data were recorded at a sampling rate of 1000 Hz. Participants carried out three repetitions of walking task under each of five conditions; normal walk, fast walk, slow walk, stair ascent and stair decent.

3. Data processing

In this study, EMG signal processing was done to determine each muscle's activation profile. As it was known that raw EMG signal is a voltage that shows both positive and negative amplitude, whereas muscle activation is expressed as a number between 0 and 1.For this EMG signal will be rectified but before rectification removal of low frequency noise should be done. The low frequency noise can be corrected by high-pass filtering the EMG signal. Once this is done, signal will be rectified where the absolute values of each point are taken and this will result in a rectified EMG signal. For each participant, the Rectified Value and Normalized value were calculated for Gastrocnemious, Soleus and Tibialis Anterior muscles in each walking repetition by dividing the EMG integral by the contraction time interval. The EMG RV values and Normalized values of Gastrocnemious, Soleus and Tibialis Anterior muscles were then averaged over the three repetitions for each condition.

4. Result

Data were collected using Bio PAC MP150 acquisition system. The max EMG ARV value, Normalized mean value, median value for GM, GL, SOL, TA are recorded. Fig. shows that as the walking speed increases EMG activity were increases in various muscles. GM, TA and SOL shows significant increase in EMG activity as walking speed increases. Data for normalized EMG value were taken and graph were plotted in MS excel 2007. Graph for gastrocnemius, soleus and Tibialis anterior muscle EMG activation shows significant differences as walking speed increases. During stair ascent and decent maximum EMG activation was seen in Tibialis anterior muscle followed by gastrocnimus and soleus muscle.

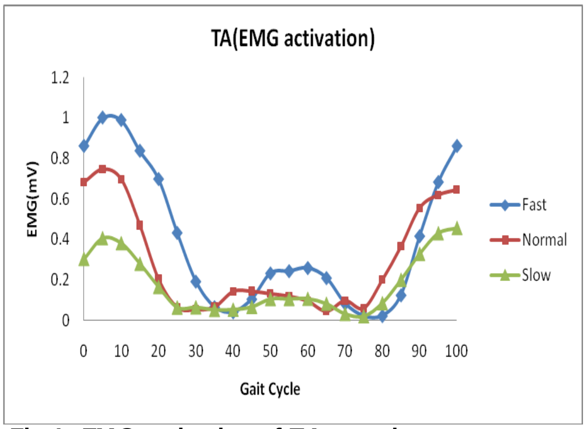

Fig-1: EMG activation of TA muscle at variable speeds

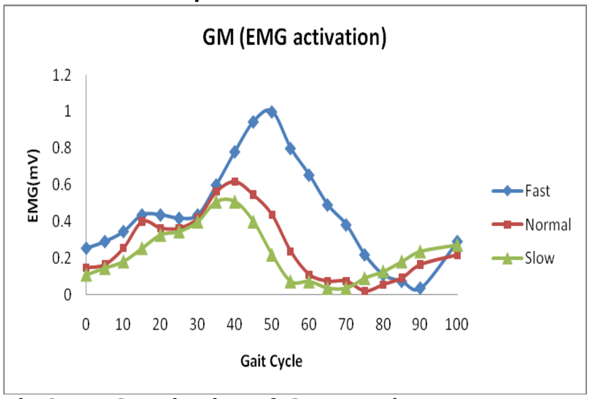

Fig-2: EMG activation of GM muscle at variable speeds

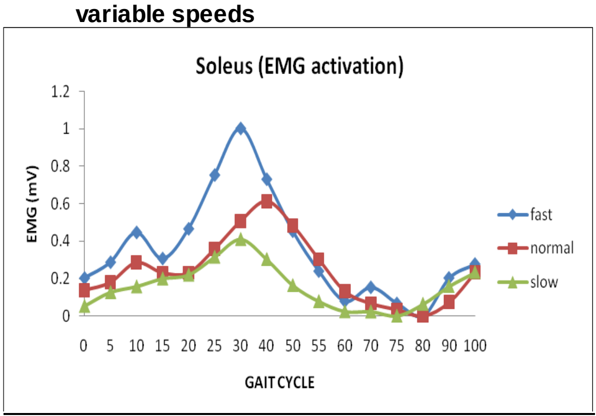

Fig-3: EMG activation of Soleus muscle at variable speeds

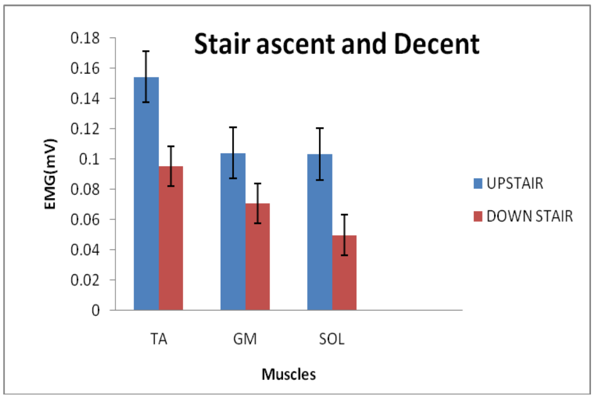

Fig-4: EMG activation of various muscle at stair ascent and decent

5. Discussion

A typical EMG trace showing raw and normalized GM, SOL and TA muscle activity during various walking conditions(normal ,slow and fast) were displayed in fig.EMG activation of GM, SOL and TA muscles during stair ascent and decent were also displayed in fig . A one-way analysis of variance test (ANOVA) with repeated measures was performed to determine the effect of changes in walking speed and stair ascent and decent on activity in the tibialis anterior, soleus and gastrocnemius muscles for each subject. Max, Mean and Median values of activity of each muscle considered for the various cases. The pair wise comparisons with revealed that for GM muscle, the difference between fast walk Vs normal walk and fast walk Vs slow walk statistically significant ($p < 0.05$). For SOL muscle, the difference between fast walk Vs slow walk was statistically significant ($p < 0.05$). For TA muscle, the difference between fast walk Vs slow walk was statistically significant ($p < 0.05$). It was seen that during gait cycle plantar flexion movement is achieved by gastrocnemius muscle and Gastrocnemius shows activity in terminal loading and in initial swing phase [11]. Dorsiflexion movement is achieved by Tibialis anterior and TA activity extended over the complete swing phase, starting slightly before toe-off, around 27%, and ending at heel contact (100%) [12] In this study, at the slower speeds, Gastrocnemius muscle EMG pattern showed a similar EMG activation during stance, but the amplitude was substantially decreased from natural speed. Similarly, at the slower speed and at faster speed, the EMG activation for Tibialis anterior muscle rises at initial contact and at toe-off. A loss of EMG amplitude of the TA and MG muscles occurred at slower speed and increase in EMG activation occurred at faster speed, which has been found in past studies. [13][14][15] [16]

When we observe changes for muscle group during stair ascent and stair decent, significant differences were seen for GM and SOL muscle. During stair ascent, Tibialis anterior muscle shows greater activation than other muscles and during stair decent, Gastrocnemius and soleus muscle shows activation higher than other muscles.

6. Conclusion

In this study, the lower-limb muscle activities during the daily lower-limb motions such as walking, stair ascending and descending motions have been studied. The relationship between the lower-limb motions and the EMG activation levels of various muscles which are mainly concerned with the daily lower-limb activities are analyzed. The biomechanical lower extremity model proposed in this study will estimate the muscle activation patterns and also be used to design the lower-limb exoskeleton assistive robotic systems for physically weak persons.

7. References

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