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EMG Signals Analysis of BF and RF Muscles In Autism Spectrum Disorder (ASD) During Walking

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***Abstract*— This paper presents the analysis of Electromyography (EMG) signals at lower limb muscles during walking. The muscles of Biceps Femoris (BF) and Rectus Femoris (RF) were examined between ASD and TD children. The EMG signals pattern will be observed over one gait cycle and the statistical analysis will be used to compare the significant difference of two muscles between ASD and TD children. The result shows that there are significant differences in RF muscle for both ASD and TD children at 70% of gait cycle (p value is equal to 0.007) and at 90% of gait cycle (p value is equal to 0.023). From this result, the RF muscle shall be considered as the vital muscle for rehabilitation plan.**

***Keywords*— Electromyography (EMG); Autism Spectrum Disorder (ASD); Biceps Femoris (BF) muscle; Rectus Femoris (RF) muscle**

I. INTRODUCTION

Autism Spectrum Disorder (ASD) is the nerve problems on gross motor behavior including motor coordination, gait postural stability, arm movement and muscle tone [1], [2]. Generally, the ASD children had suffered an unusual gait. Several studies on gait activity in ASD children show that their body posture is odd and unnatural such as floppy and rigid. The abnormalities in trunk postural which the reductions in motion range at the hips and knees haves led to difficulty to maintain a straight line during gait 3. Previous findings also show that there was impairment of movement planning in ASD children compare to Typical Development (TD) children in different level walking [1], [4].

During walking, the mechanical energy was transferred from leg to trunk as support provider and the whole body muscle actively involved [5]. The muscular system of the legs and foot are for propelling, supporting and balancing the body of human. Tremendous power can be produced by these muscles while making small amendment continuously for balance whether the body is at rest or in motion [6]. Rectus femoris is one of the powerful muscles in quadriceps. It is connected to hip and helps in extending the knee and also used to contract the thigh. The rectus femoris is the only muscle that can flex the hip. Biceps femoris muscle works in conjunction with multiple thighs and hip muscles. These muscles assist to stabilize the pelvis in standing position and support the rotation of the thigh away from body. Hence, rectus femoris and biceps femoris will be examined in this study as both of them greatly affect the gait in an individual.

Electromyography (EMG) is an electrical activity that will be generated when instances of contraction in body muscle. Numerous applications regarding EMG in various fields have been used such as in areas of human movements and clinical neurophysiology. EMG is also useful for the diagnosis of muscle weakness in ASD children [7]. Muscle weakness is a lack of muscle strength. Since the surface electromyography (SEMG) is non-invasive, therefore it is the most common method that has been used by previous researchers, as it is easy to conduct. SEMG can be conducted without any medical supervision and with minimal risk to the subject gait.

In this study, two phases of gait cycle were observed; midstance (10% to 30% of gait cycle) and midswing (70% to 90% of gait cycle) as these two phases were associated with muscles activation of BF and RF during walking in healthy children [8]. Therefore, the objective of this study is to analyze the EMG signals of BF and RF muscles activation pattern between ASD and TD children during walking. This paper will organise in the following manners. Section II is the methodology for this study, which describing about the data collection and data analysis. Section III will presents on results and discussion. Finally, Section IV is the conclusion of the analysis.

II. Methodology

In this section the data collection will be described and methods for the analysis will be explained in details. The data has been obtained from 8 ASD children and 10 TD children age ranges between 6 to 13 years old with no orthopedic surgery. All parents or guardians of the subjects were provided with printed consent form to confirm the children's health condition. The data were collected at Human Motion and Gait Analysis Laboratory, UiTM Shah Alam.

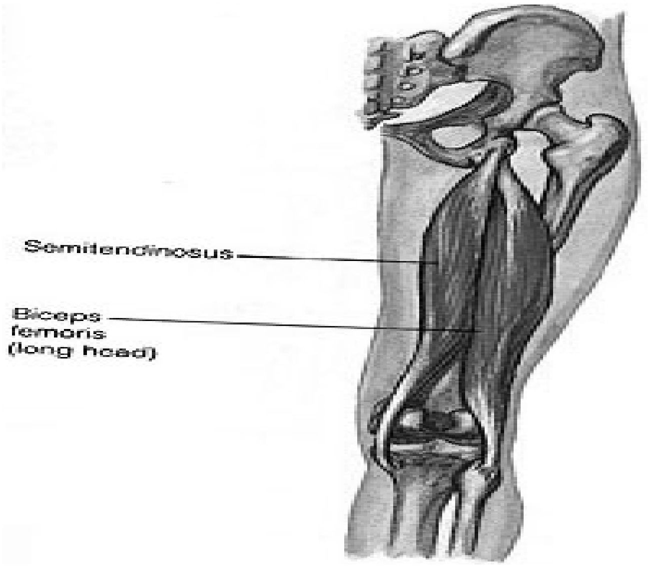


Fig. 1 Biceps Femoris (BF) muscle

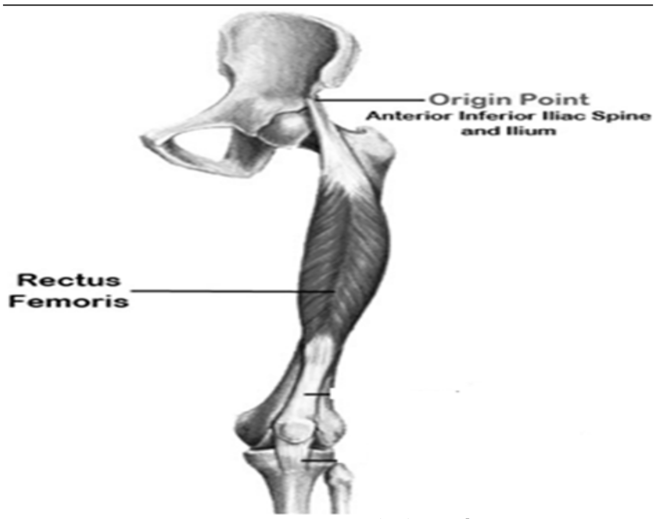


Fig. 2 Rectus Femoris (RF) muscle

During walking, the BF muscle is a muscle of thigh that positioned at the posterior as shown in Fig. 1. The BF muscle has two parts which one of them called long head. The three posterior thigh muscles (biceps femoris, semitendinosus and semimembranosus) form part of hamstrings muscle group. Throughout stance phase, the BF muscle acts as hip extensor. While at the swing phase, this muscle acts as knee flexor.

Meanwhile, RF muscle is situated in the middle of the front of the thigh as shown in Fig. 2. The RF muscle and another three muscles (vastus medialis, vastus intermedius and vastus lateralis) form quadriceps muscles of the human body. The muscle of RF acts as knee extensor throughout stance phase and hip flexor at swing phase.

A. Data Collection

The experiments were conducted using Trigno Wireless Systems and Smart Sensors. The Trigno Wireless EMG System is a high-performing device designed to make EMG signal detection reliable and easy. Each EMG sensor has a built-in triaxial accelerometer, a transmission range of 40 m and a rechargeable battery lasting a minimum of 8 hours. The system is capable of streaming data to EMGworks 4 Acquisition and Analysis software for generating 16 EMG sensors (37mm x 26mm x 15mm) and 48 accelerometer analog channels for integration with motion capture and other 3rd party data acquisition systems. Full triggering features further expand the possibility for integration with additional measurement technologies. The sensors used were capable to react instantaneously to disturbances detected on the surface of the skin.

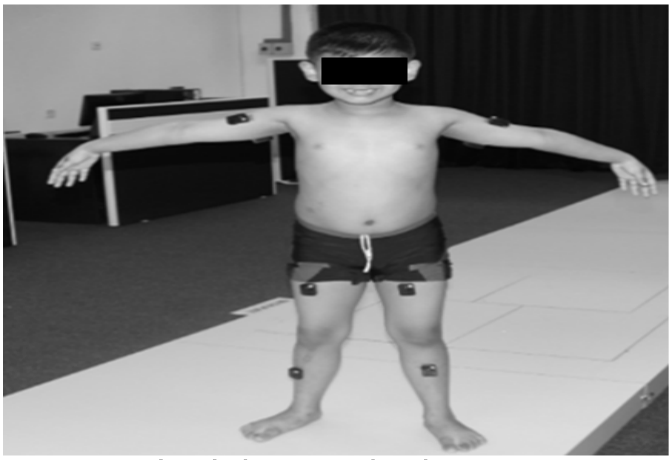


Fig. 3 Electrode placement on subject during experiment

In this study, 2 electrodes have been used to capture EMG signals from Biceps Femoris (BF) and Rectus Femoris (RF) muscles of ASD and TD children. All subjects were asked to walk without assistance in normal pace. Tapes were used to prevent the electrodes from being displaced from their fixed location during experiment. The SENIAM guidelines for electrode placement were followed as shown in Fig. 3. The data will be acquired from EMG signals by using EMGWorks 4 Acquisition software. A video camera was fixed and synchronized with the EMGWorks 4 Acquisition software so that the time of video camera and EMGWorks 4 Acquisition software is recorded simultaneously. The desired sample rate used for this recording purpose is 2000 samples per second, which this sample rate achievable by all devices used in this configuration.

The EMG data for one gait cycle will be extracted and time to complete one gait cycle will be normalized as percentage of one complete gait cycle. One gait cycle in this study is the period between heel stride in the same leg. Therefore, for this study, only EMG signals of BF and RF muscles on the left leg will be considered.

B. Data Analysis

In this study, the normality test is used to check the data distribution of BF and RF muscles in ASD and TD children. Then the EMG signals pattern for BF and RF muscles are observed and the analysis are inspected based on the duration taken to complete one gait cycle. The boxplot will be plotted to compare the result obtained during midstance and midswing for ASD and TD children. For this study, the midstance phase is considered during 10%, 20% and 30% of gait cycle while the midswing phase is considered during 70%, 80% and 90% of gait cycle. Finally, the independent sample t-test will be used to compare the significant of these two muscles. Results and discussion obtained from this experiment will be observed and discussed in the next section.

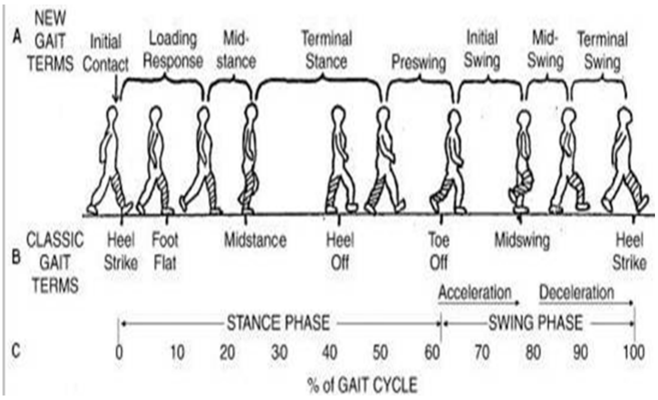


Fig. 4 Phase of gait cycle

Fig. 4 describes the complex activity in walking which it considers the motions from initial placement of the supporting heel on the ground to when the same heel contacts the ground for a second time. The phase of gait can be divided into stance phase and swing phase. At 60% of gait cycle are consist of stance phase, while swing phase consist 40% of the gait cycle. Stance phase is defined as the interval in which the foot is on the ground. There are five sections in stance phase, consists of heel contact, foot flat, mid-stance, heel off and toe off. While swing phase is defined as the phase when all foot portions are in forward motion.

During walking, the muscles of BF and RF are activated simultaneously. In the stance phase, the foot stays in contact with the ground surface and the body is fully supported by the leg. In stance phase, the muscle of RF is mostly activated for knee joint extension while BF muscle acts on the hip joint extension. The BF muscle aid in stabilizing the pelvis and propel the body forward by extending the hip backward.

Whereas, swing phase is the behavior that the foot leaves ground surface. In the swing phase, the RF muscle is mainly activated for hip joint flexion. At the same time, the knee joint is varying from extension to flexion thus the BF muscle acts as the knee joint flexion.

III. Results and Discussion

This section presents and discusses the results obtained from this study. 18 children consist of 8 ASD children and 10 TD children are involved in this study. Firstly, the data distribution obtained from this study will be checked using normality test. Upon examining the data normality, 7 subjects (3 ASD and 4 TD) out of 18 subjects were involved in this test. Another 11 subjects were omitted from the analysis because the data had fallen outside of the extreme value range and this had been presented as the outliers of the data. All data were normally distributed during midstance and midswing. Then the boxplot were plotted to show the differences of mean amplitude of EMG signals of BF and RF muscles during midstance and midswing in ASD and TD children.

TABLE I
DEMOGRAPHIC DATA

	Mean Age (year)	**Height (cm)**	**Weight (kg)**
ASD children	8.75	129.10	30.55
TD children	11.30	133.95	34.76

Table I shows the demographic data of ASD and TD children. The mean age for ASD and TD children has slight differences which are 8.75 years and 11.30 years respectively. In this study, TD children have a greater mean of height and weight compared to the ASD children, which are 133.95cm and 34.76kg respectively. This is linearly dependent on their age as TD children age range is larger than ASD children.

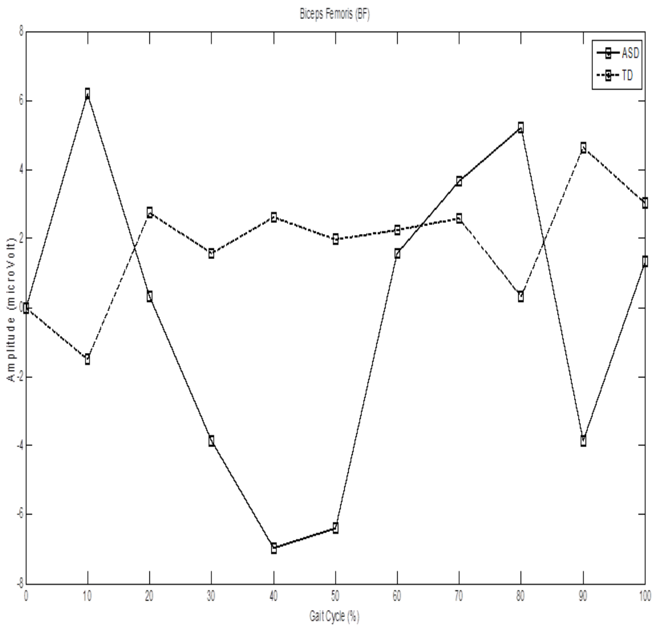
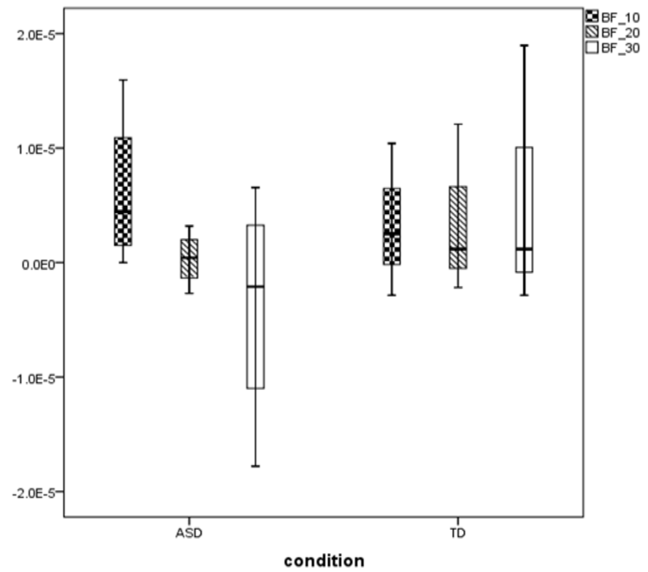
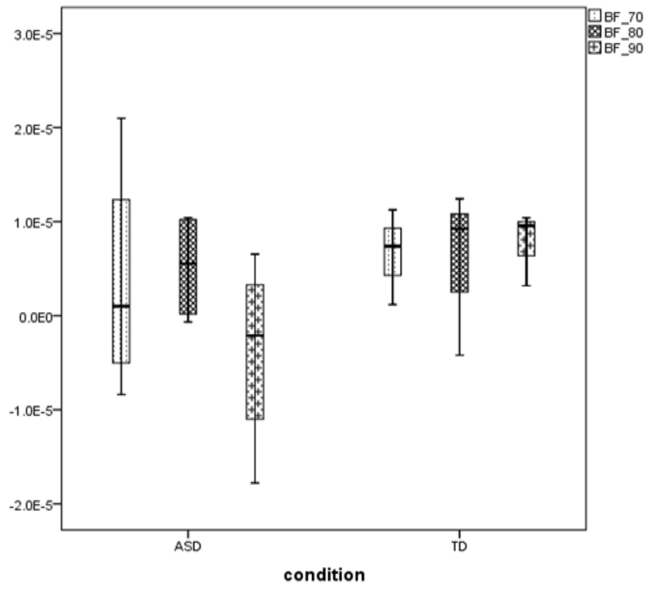


Fig. 5 Mean amplitude of EMG signals from BF muscle for one gait cycle

Fig. 5 shows the mean amplitude of EMG signals from BF muscle in one gait cycle for ASD and TD children. At 20% of the gait cycle which is during the stance phase, the BF muscle was extended in TD children which the mean amplitude of EMG signals was at maximum point. Compared to the ASD children the BF muscle was in flexed position, which at this point the mean amplitude of EMG signals was decreased. Meanwhile, during swing phase, the muscles of BF for both ASD and TD children were in position of flexion. However, the mean amplitude of EMG signals for TD children was at minimum point at 80% of the gait cycle compared to ASD children, the minimum EMG signals was at 90% of the gait cycle. The result that obtained during stance phase in this study was similar with some previous findings. The BF muscle was extended during stance phase, as it worked as extending of hip joint for healthy children [8], [9]. The flexion condition during swing phase in ASD and TD children occur at different stage of gait cycle may come from few factors such as subject's age and walking cadence. From the demographic data obtained in this study had obviously shown that the range of age between ASD and TD children is slightly large. This difference may influence the stride length in ASD and TD children. As stated in [10]-[12] the age factors also may influence the difference result of kinematic angle and gait features between genders.



(a)



(b)

Fig. 6 Boxplot of BF muscle for ASD and TD children (a) during midstance; (b) during midswing

Fig. 6(a) shows boxplot of mean amplitude of EMG signals of BF muscle for ASD and TD children during midstance. At 20% of gait cycle, there are slight differences of EMG signals activity between ASD and TD children. At this phase, the body is supported by one single leg. From the figure, TD children have higher hip extension compared to ASD children during the phase of foot in the flat condition, which the mean of EMG signals for TD children is 4μV and for ASD children is 0V. Meanwhile, at 30% of gait cycle, the EMG signals for ASD children is more likely to be negative that caused by the flexion condition of BF muscle which the mean value is -4μV compared to TD children which the mean value is 6μV.

Fig. 6(b) shows boxplot of mean amplitude of EMG signals of BF muscle for ASD and TD children during midswing. From the figure above, it is generally seen that the BF muscle for ASD children shows wide ranges of EMG signals compared to TD children. Throughout the toe off stage (midswing), ASD children have a higher knee flexion compared to TD children thus the mean amplitude of EMG signals for ASD children at 70%, 80% and 90% of gait cycle is 4μV, 5μV and -4μV respectively. For TD children the mean amplitude of EMG signals is 7μV, 6μV and 8μV respectively. The BF muscle for TD children showed less range of muscle contraction compared to ASD children.

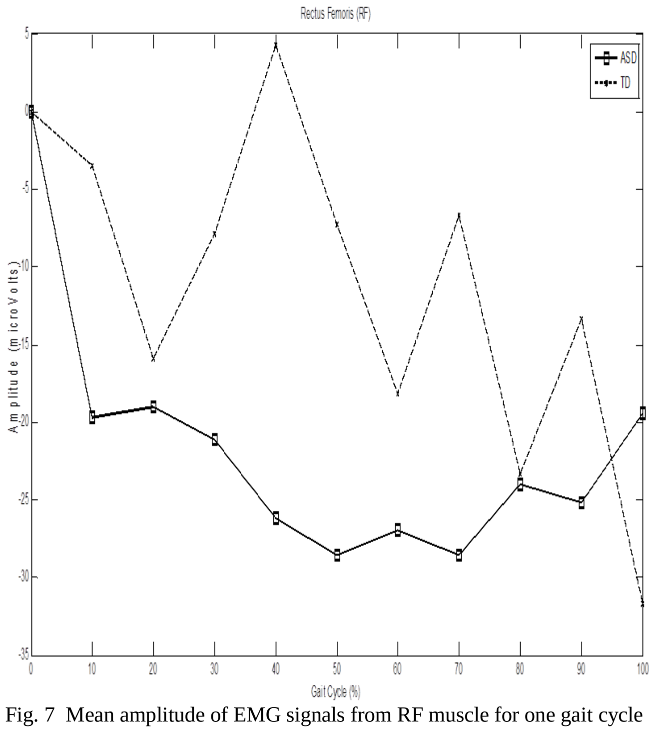
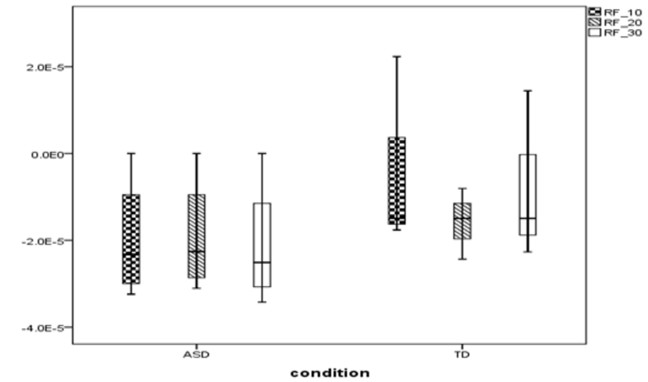


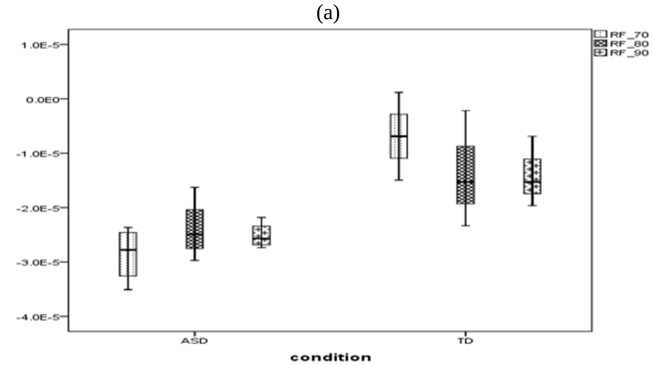
Fig. 7 Mean amplitude of EMG signals from RF muscle for one gait cycle

Fig. 7 shows the mean amplitude of EMG signals from RF muscle during walking for ASD and TD children. Throughout stance phase (20% to 40% of the gait cycle) which at this phase, the condition of foot was vary from flat condition to heel off while RF muscle for ASD children was in flexion condition which the mean amplitude of EMG signals was at the minimum point at 20% of gait cycle. In contrast with TD children, the RF muscle was extended at 20% of gait cycle thus the mean amplitude of EMG signals were at the minimum point. Similar result was reported in

[13] where the RF muscle of healthy person was extended during midstance (20% of gait cycle) and terminal stance (30% to 50% of gait cycle) phase. Meanwhile, throughout swing phase, the RF muscle in ASD children was flexed which the mean amplitude of EMG signals was at minimum point at 80% of gait cycle. In contrast with TD children, the mean amplitude of EMG signals was at minimum point at 70% of gait cycle.



(a)



(b)

Fig. 8 Boxplot of RF muscle for ASD and TD children (a) during midstance; (b) during midswing

Boxplot of mean amplitude of EMG signals of RF muscle for ASD and TD children during midstance is shown in Fig. 8(a). From the figure, the TD children show greater extension compared to ASD children notably at 10% of gait cycle, which the foot was in the flat condition. The mean amplitude of EMG signals are -3μV and -20μV respectively. Meanwhile, at 20% of gait cycle (midstance phase), there are only slight differences of mean amplitude of EMG signals range between ASD and TD children.

Fig. 8(b) shows the boxplot of mean amplitude of EMG signals of RF muscle for ASD and TD children during midswing. At 70%, 80% and 90% of gait cycle, there are notably differences of RF muscle contraction for ASD and TD children. The RF muscle for ASD shows higher flexion compared to TD children during the variation of foot condition from toe off to heel strike condition.

During the stance phase (heel strike to heel off condition), the active muscles act to prevent buckling of the support limb. From the analysis of EMG signals pattern of two lower limb muscles above, it shows that the active muscle which the amplitude has increased during walking in TD children is BF as stated by [8]. However, for ASD children, these two muscles show the opposite activity during stance phase.

In the swing phase (heel off to heel strike condition), the limb is not in weight bearing condition. There have seen that during mid-swing, the BF muscle has a short burst of activity (increased amplitude of EMG signals) in both TD and ASD children. Contrary with the amplitude of EMG signals of RF muscle had decreased in both TD and ASD children during this phase.

TABLE II
INDEPENDENT SAMPLE T-TEST FOR BF AND RF MUSCLES

		Midstance			**Midswing**		
		10%	**20%**	**30%**	**70%**	**80%**	**90%**
t-test	BF	0.607	0.426	0.297	0.722	0.915	0.129
	RF	0.287	0.730	0.347	*0.007	0.152	*0.023

*Significant difference (t-test, $p < 0.05$)

Finally, the statistical analysis using Independent t-test was examined. From Table II shows that there is a significant difference in RF muscle for both ASD and TD children at 70% of gait cycle (p value is equal to 0.007) and 90% of gait cycle (p value is equal to 0.023) during walking. These muscles can be used to discriminate the difference between ASD and TD children. Previous study in [14] also found that RF muscle might influence the activity of stiff-knee gait of a person during pre-swing phase, which support the result obtained in this study.

IV. CONCLUSIONS

The EMG pattern of lower limb muscles between ASD and TD children aged 6 to 13 years old has been presented in this paper. Two muscles that considered in this study are Biceps Femoris (BF) and Rectus Femoris (RF). The EMG signal activities have been discussed for these two lower limb muscles during walking. From the results, there is a significant difference in RF muscle between ASD and TD children at two stages of gait cycle where the p value at 70% and 90% of gait cycle are equal to 0.007 and 0.023 respectively. It is shown that the amount of EMG signals of RF muscles is clearly related to walking, as it shows the significant difference between ASD and TD children during swing phase.

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