

# EMG Analysis of the Lower Extremities During Pitching in High-School Baseball

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**Summary:** I evaluated the contractions of the muscles of the lower extremities during baseball pitching using video imaging and simultaneous surface EMG. The subjects were 10 members of a high school baseball club and, for contrast, 10 students without any baseball club experience. I divided their pitching movements into two phases determined with respect to the landing of the non-pivot leg. The EMG signal intensities over the 2 seconds prior to landing, and over the 2 seconds after landing, were then integrated to give an EMG value to each phase. I then computed this value as the % MMT. The abductor and adductor of the hip muscles of both lower extremities in the players were strongly contracted, especially the adductor. This finding was consistent with the observation that pitching tends to lead to adductor muscle disorders. Strengthening the adductor and its antagonist abductor can therefore directly influence the capability for pitching, and can reduce the risk for the adductor disorders.

**Key words** baseball, EMG, pitching, lower extremities, adductor of the hip

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## INTRODUCTION

Many baseball players have been playing baseball since they were very young, frequently suffering from physical disorders without adequate treatment [1]. Orthopaedically, not only treatment but also preventive therapy is important. The disorders typically occur in the upper limbs and also in the body trunk or lower limbs. A stable pitching form is indispensable for ideal pitching, and intensive running has been generally recommended for strengthening the muscles of the lower extremities. Intensive running has also been recommended as effective for strengthening the endurance of the respiratory system and of the circulatory organ. However, only a few reports which have analyzed pitching substantiate that strengthening the lower extremities is beneficial for improving pitching and preventing related disorders. The purpose of this study was to examine the activities of muscle contractions during pitching using EMG and video image analysis, in order to help prevent disorders in high school baseball players.

## SUBJECTS AND METHODS

### *Subjects*

The subjects consisted of two groups. One group consisted of 10 players who had participated in the Japan National High-School Baseball Competition; 9 were right-hand dominant, and one was left-hand dominant. The other group for control was made up of 10 students who had played baseball at a lower, less formal level of competition. Their mean age was 20.2 years, ranging from 18 to 23 years. All these controls were right-hand dominant. The pitching form was all overhand. I examined the muscles which could be measured clearly on EMG, consisting of the main muscles of the lower extremities for the pitching movement. These involved the abductor, adductor, quadriceps, biceps, tibialis anterior, and gastrocnemius.

### *Installation*

I fixed bipolar electrodes, from a 6-channel

electromyograph, with paste, onto the skin surface of the observed muscle of both legs. The positions of fixation were as reported by Tajima et al. [2]. I fixed the electrodes on the legs at the motor point for muscles.

### Measurements

I collected and delivered codes from the electrodes to a terminal box, held on the lumbar, and relayed them to an input terminal of the electromyograph by cable, the length of which was sufficient so as not to disturb pitching. I recorded the data on a personal computer connected to the output terminal at 10V absolute. I connected a terminal from a video camera to the input terminal of a video timer, and the output terminal to a video recorder to record images of the pitcher from the side view simultaneously with the measurements on EMG. I could identify the position every 1/100 second on the recorded image. Each set of data was synchronized (Fig. 1). I repeated rehearsing experiments and removed noise as much as possible before the actual take.

### Pitching

The subjects pitched with all their power by wind-up motion, after sufficient warm-up exercising. I measured the pitching movement over 8 seconds after the subject's hands were raised.

### Classification

For analysis, the motion was divided into two phases depending on the activity of the lower limbs. Several different phases have been employed to

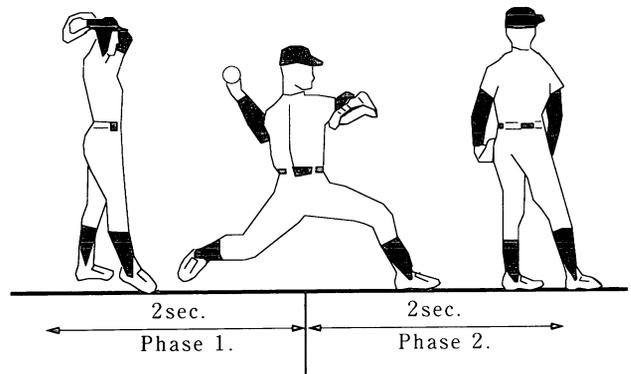


Fig. 2. Phases of the pitch.

analyze the upper limbs [3-6]. In this study, the first phase covered the 2 seconds immediately prior to the landing of the non-pivot leg. The second phase covered the following two seconds immediately after the landing of the non-pivot leg (Fig. 2). I could analyze the activity of the lower limbs in units of 1/100 second, since the activity of the lower limbs was not faster than that of the upper limbs.

### Data analysis

I evaluated the results according to % MMT, (integration value of each phase/integration value of maximum muscle force by manual muscle test for two seconds  $\times 100$ ) using analyzing software [3].

## RESULTS

### Pivot-leg, phase 1

The abductor, adductor, biceps and gastrocnemius of the player group showed higher activity than those of the control group. In these muscles, the biceps contraction was highest in significance. The biceps showed 71% MMT (Table 1, Fig. 3A).

### Pivot leg, phase 2

The abductor, adductor, biceps and gastrocnemius of the player group showed higher activity than those of the control group. The adductor, biceps and tibialis anterior were highest in significance. The adductor showed 83% MMT. The biceps showed 60% MMT. The tibialis anterior of the control group showed 29% MMT (Table 1, Fig. 3B).

### Non-pivot leg, phase 1

The abductor, adductor and quadriceps showed

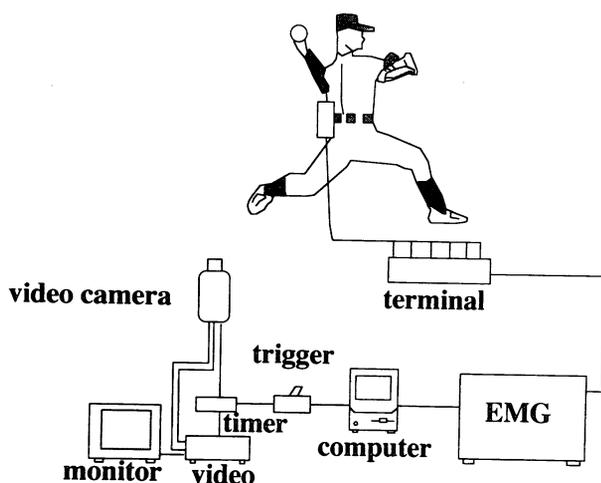


Fig. 1. Measurements.

TABLE 1.  
Mean and standard deviations of muscle activity during pitching

Muscles (Player vs. Control)	Pivot Leg		Non-Pivot Leg	
	Phase 1	Phase 2	Phase 1	Phase 2
Abductor				
Player	73±19	53±21	48±19	47±25
Control	49±21	46±20	32±13	34±17
Adductor				
Player	63±15	83±12*	84± 8*	84±12*
Control	57±23	61±21	53±15	56±14
Quadriceps				
Player	14± 3	17±14	48±14*	24± 8
Control	27±18	28±14	27±15	22±13
Biceps				
Player	71±23*	60±24*	30±10	50±15
Control	35±16	37±17	36±24	41±16
Tibialis-anterior				
Player	26±10	11± 6	13± 9	14± 8
Control	29±10	29±21*	15± 9	20± 6
Gastrocnemius				
Player	38±13	33±15	32±10	42±16
Control	35±23	32±24	25±12	40±25

Mean ± standard deviation Numbers are in % MMT  
\* Significantly different at p<.05

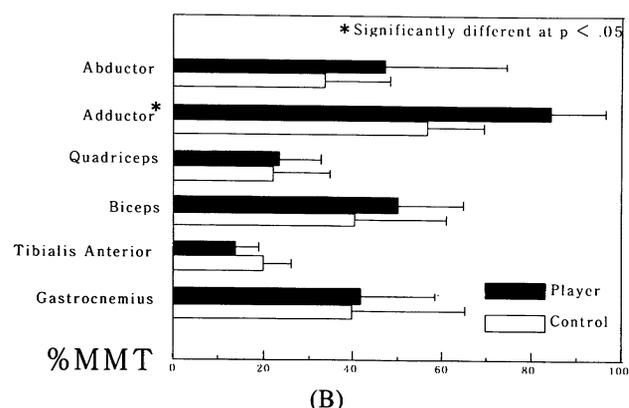
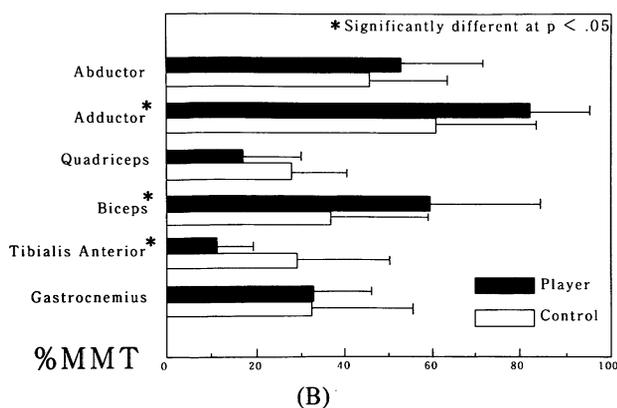
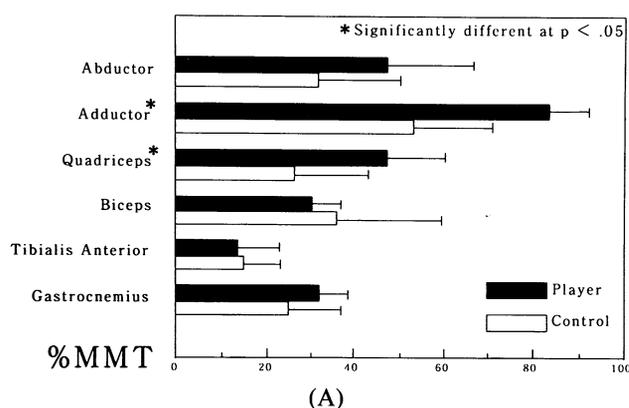
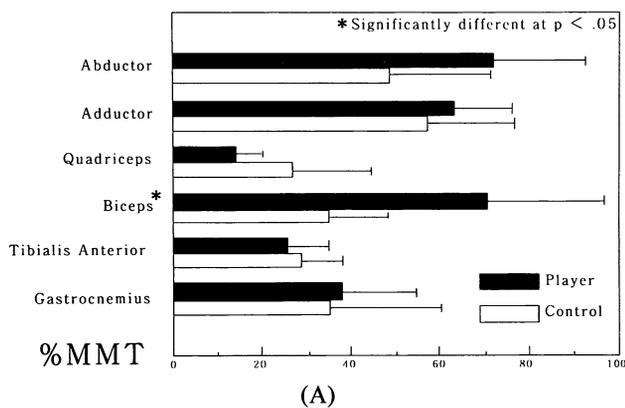


Fig. 3. Percent manual muscle test (% MMT) of the lower extremities of pivot leg during phase 1 (A) and during phase 2 (B) (mean ± standard deviations).

Fig. 4. Percent manual muscle test (% MMT) of the lower extremities of non-pivot leg during phase 1 (A) and during phase 2 (B) (mean ± standard deviations).

higher activity than those of the control group. The adductor and quadriceps were highest in significance. The adductor showed 84% MMT. The quadriceps showed 48% MMT (Table 1, Fig. 4A).

#### *Non-pivot leg, phase 2*

The abductor, adductor and biceps of the player group showed higher activity than those of the control group. The adductor of the player group was highest in significance. The adductor showed 84% MMT (Table 1, Fig. 4B).

### DISCUSSION

Surface EMG is effective for analyzing muscle contraction. However, this method has the limitation of being able to evaluate only the comparatively larger muscles near the cutis surface where the electrode is attached. There are many studies which used EMG on pitching, but they focused mainly on the upper extremities, especially on the shoulder joints. The muscles of the shoulder are much smaller than those of the lower extremities, so needle electrodes were used in those studies. In this study, I have focused my attention on using EMG to discover the out-put character of the larger leg muscles, and so surface EMG was applicable.

It is recognized that pitching movements are a compound exercise of the whole body, and that the strength of the body trunk and the lower extremities are extremely important to assure effective and consistent pitching [6]. The key roles of the lower extremities in pitching movements are to preserve energy, control sway of the body trunk, and decelerate the upper part of the body to help prevent disorder to the shoulder [7,8], especially in junior players, involving the humeral proximal epiphysis [9-11]. However, exercises for strengthening these muscles for pitching continue to be recommended even though numerical data on the muscle strengths and requirements have not yet been gathered. The present study is the first to provide a numerical assessment of muscle strength in pitching.

The adductor showed over 80% MMT in both phases for the bilateral lower extremities of the player group. This indicated that the adductor was the main source of pitching energy to the upper extremities, and the adductor contributed to the stability of the body trunk and to the deceleration of the upper part of the body in the latter phase of pitching. The adductor and quadriceps in phase 1 of the non-pivot leg were strongly active to preserve

energy for pitching. In phase 2, the adductor, biceps and tibialis anterior of the pivot leg and the adductor of the non-pivot leg may contribute to prevent burden to the upper extremities.

From a questionnaire survey of baseball players, I found many self-reported cases of a damaged adductor. Not only the adductor but also the abductor takes on a considerable burden during pitching with reference to the leading muscles and antagonist, and augmentation of the abductor is required in addition to adductor augmentation. Therefore, I recommend three kinds of player training as follows: muscle force augmentation for the adductor and abductor using a physical therapist's manual as before, training with a machine like KIN-COM, and an exercise called "closed kinetic." One such exercise involves standing up with a single crus and pulling up the pelvis, and moving right and left like skating on the sliding board.

The results of this study show that the abductor and adductor muscles play an important role in pitching, and sufficient strengthening and stretching of these muscles is obviously important to prevent disorders. Strengthening these muscles may enhance the stability of pitching and also reduce the incidence of other disorders caused by unstable pitching. Furthermore, such strengthening is important for high-school baseball players, who are still developing physically, meaning that any disorders could involve the risk of serious long-term consequences.

**ACKNOWLEDGMENTS:** The author thanks Professor Akio Inoue and Dr. Naoto Shiba (Department of Orthopaedic Surgery, Kurume University School of Medicine) for their kind advice.

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