DALT : Detection Algorithm of Throwing Form Changing to Prevent the Baseball Players' Throwing Related Injuries

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Abstract. Baseball players are susceptible to shoulder and elbow injuries due to having an inappropriate throwing form and overload. Fielders has to manage the amount of practice by himself. Thus, it is important to provide objective feedbacks to those fielders to prevent shoulder and elbow injuries. In this research, we achieved creating the algorithm(DALT) to detect the change in throwing form by using wearable gyroscope sensor. In the end, we designed three experiments to measure fatigue state through consecutive throw. DALT could detect throwing form changing.

1 Introduction

In baseball, the injury of shoulder and elbows which is caused by throwing is one of the grave issues for many baseball players. In this paper, the injury is defined as **Throwing Injury**. According to the questionnaire survey about throwing injury [1], 72% of high school baseball players at Kagoshima Prefecture in Japan experience the injury. Throwing injury are caused by overwork or unsuitable throwing form[2]. To prevent throwing injury, it is important for players to recognize their fatigue status. However, it is also difficult for them to understand the fatigue precisely. Since there are fewer numbers of coaches than baseball players in a team, the player must manage their condition by themselves. Fatigue state is influenced by the mental condition.

The most simple way to prevent throwing injury is to limit the number of throwing. However, since physical ability such as throwing skills depend on the person, it is difficult to set a certain number of throwing as the limitation. Therefore, it is necessary to recognize each player's physical fatigue for judging whether they continue to throw or not. There are two ways to recognize fatigue, direct and indirect recognition. The direct fatigue recognition is to observe blood lactate level. However, it is impractical to execute blood test while players are in practice. Therefore, indirect fatigue recognition such as monitoring changes of throwing form[3] is considered as the best way. However, past research to monitor throwing form such as using motion capture also does not fit to actual practice.

In this paper, we propose a system to recognize changes of throwing form by more practical way. The system uses only one gyro sensor and recognizes throwing form by our proposed algorithm called DALT. We describe the details of the system and its evaluation with actual baseball players.

2 Problem Statement

In this section, we describes problem of past approach as to detect physical fatigue. Firstly, we explain the details of throwing form. Then, we describe system requirements for daily fatigue measurement.

2.1 Model of throwing motion

Throwing motion are divided into five phases as shown in Fig.1. In this paper, we name each seperate **motion points** as **Takeback**, **Cock**, **Top**, **Maxout** and **Release**. The position of elbow falls according to the increasing number of throwing count. The phenomenon is caused by fatigue of the muscles of around the shoulder joint. Especially, it is reported that angle of elbow changes at cock, top and maxout point[3]. Thus, we can recognize physical fatigue as form of fallen elbow (**FFE**).

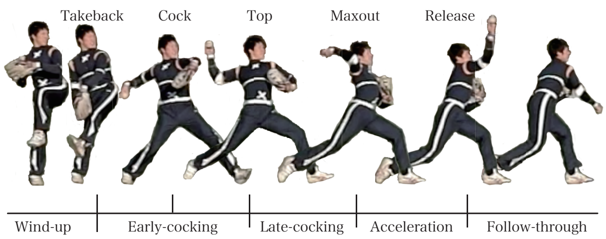

Fig. 1. Throwing Phases & Motion Points

2.2 System requirements for daily measurement

There are three methods to measure the change in throwing form. The first method is motion-capture system. This system force users to use a lot of big equipments, wearing special clothing. Therefore, this system is unavailable in daily practices. The second method is DLT-method. It is three dimensional(3D) analysis system using multiple high-speed cameras. This system can be used in the field. However, this method takes long analysis time, because this system require to check markers manually. The third method is to use sensors. Lapinski[4] had proposed 3D analysis system using by acceleration and gyro sensors. The accuracy of this system is almost as high as the motion-capture system. However, wearing many sensors demands high physical load. Sagawa[5] had proposed calculation method of throwing arm's path. This system can be used in field and has low physical load. However, this system needs to be calibrated every time. Therefore, it can not be used in real baseball practice.

The system must not affect the practical activities, to measure objective fatigue state from a natural movement. A major factor of the throwing injuries are overwork and unsuitable throwing form[2]. To prevent the throwing injuries, it is essential that the system is always used doing the practice. To satisfy the requirements, it is neccesary that the system minimizes the impact of measuring process of the players.

3 Detection Algorithm of Throwing Form Changing

In this section, we propose Detection Agorithm of Throwing Form Changing called **DALT**. Firsty, overview of DALT. Then, we explain details of by DALTs' three steps.

3.1 Overview of DALT

In DALT, we use gyro sensor to measure the change of throwing form. The sensor was put on the lower part of upper arm to the measure the change of the upper arm movement according to fatigue(Fig.3).

In order to correspond differences of each palyer, DALT uses base throwing data (*BaseData*) which is collected from each player preliminarily. *BaseData* is created from average of 10 throwing angular velocity. *BaseData* consisted of *NormalData* and *FatigueData*. *NormalData* was measured from no-fatigue condition and *FatigueData* was measured from Intentional FFE.

3.2 Detection of the Throwing Motion

In first step, DALT detects of the throwing motion during routine practice. This step is composed of two phases. First phase, DALT detects Release point from two thresholds for the Y-axis value. Throwing motion has the radical shoulder external and internal rotation. Similarly, data of a gyro sensor usually had sharp increase and decrease of Y-axis. Y-axis value become 0 deg/sec at near Release point[6]. In DALT, we suppose the value of Y-axis to be 0 deg/sec on Release. Thresholds were adjusted to -350 and 0 deg/sec(Fig.2). Release is the position that became more than 0 after having become smaller than -350deg/sec.

There is many detection failure in the judgment by the threshold. Second step, DALT judges throwing motion using correlation coefficient (Correlation). DALT calculates X, Y and Z-axis Correlation from *NormalData*. At that time, analysis is performed from the end(Release) to the beginning. When X-axis and Z-axis Correlation are over 0.5 and Y-axis is over 0.9, the DALT judged it as throwing motion. We conduct the preliminary experiment that ten players throw 100 balls. As a result, DALT could judge of all throwing motions.

3.3 Decomposition of Throwing Form

In second stop, DALT decomposeds the throwing form into five throwing phases (Fig.2). DALT detecteds feature motion points. *Release* is detected after releasing ball. *Maxout* is position of changeover from radical external rotation to internal rotation:Y<0. *Top* is position of changeover from horizontal abduction to horizontal adduction:Z>0. *Cock* is position of starting external rotation:Y>0. *Takeback* is point of starting throwing motion and shoulder abduction:X>0.

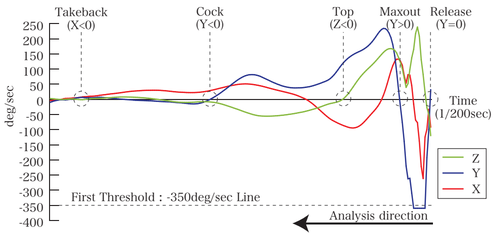

Fig. 2. Motion points on gyro sensors' data

Fig. 3. Sensor position

3.4 Calculating Rate of Throwing Form Change

In third stage, DALT calculats the rate of throwing form changing (**Rtc**) from motion throwing phases and *BaseData*. A difference is seen from *Maxout* to *Top* when we compared *NormalData* with *FatigueData*. Wherein, the DALT calculates Correlation during *Maxout* and *Top*. In addition *Rtc* consists of the average value of X-axis, Y-axis and Z-axis Correlations. First, DALT calculates Correlation (*NowR*) of current measurement data (*NowData*) and *NormalData*. Second, DALT calculates Correlation (*BaseR*) of *NormalData* and *FatigueData*. At the end, DALT calculates *Rtc* from *NowR* and *BaseR* using expression (1).

$$Rtc = NowR/BaseR \times 100 \tag{1}$$

4 Evaluation

We designed three experiments to measure fatigue state through consecutive throws. Methods of measurement were used three methods that are light load for player. First experiment was ability of ball control in fatigue state: **Ball control ability**. This method is used in routine practice. Second experiment is **DLT-method**. DLT-method measures the maximum angle of shoulder abduction (Max-SA) at early-cocking phase. Third method was **DALT**. DALT measures Rtc.

4.1 Evaluation Methodology and Purpose

Participants of the evaluations were 5 baseball players from a Keio university baseball club. Participants throw 100 balls to the net where placed 90ft(27.431m) away from participant at Keio university baseball club's ground. We set targets to the net with 50cm interval between each targets. In DLT-method experiment, we used two high speed cameras (CASIO EXILIM PRO EX-F1). Participants placed markers on the *ensiform process* and *dominant arms' shoulder* and *elbow*. And, we used *Frame-DIAS IV* (DKH company) for analysis. Three experiments were conducted at the same time.

We divided result of 100 throws into three Terms[7]. **Term1** is 1-10 throws, **Term2** is 46-55 throws and **Term3** is 91-100 throws. This study did analysis of variance(**ANOVA**) at each three terms. The level of significance set as 5% (p). If there is significant difference in the whole three terms, this study does analysis of **Dunnett's test** as the multiple comparisons. This study does multiple comparisons that assumed **Term1** control term. Finally the results were inspected to which pair had diffence significantly. As a result, if Ball control ability was not different significantly and result of DLT-method and DALT differ significantly between same term, DALT could prove degree of fatiguability during throwing.

4.2 Results

Ball control ability had no significant difference whether the player was fatigue or not (Table1:F=0.23, p=0.8). Ball control ability could not be a barometer of fatigue state. DLT-method was significantly different(Table1:F=8.7928, p=0.0002). And DALT was also significantly different (Table1:F=20.38, p=0.0001). Subsequently, we examined Dunnett's test. As a result, DALT (Fig.4) was significantly different between Term1 and Term2, and Term2 and Term3. DLT-method(Fig.5) was significantly different between Term1 and Term2. However, it was not significantly different between Term2 and Term3. Accordingly, DALT was able to measure the throwing form changing with the increase of the number of the throws. However, DALT detected the throwing form changing between Term1 and Term2. DALT was used to the *FatigueData* to calculate Rtc. Therefore, Rtc 100% was often measured in Term3. DALT could learn Rtc reference value and improrve its recognition rate by using in daily practice.

DLT-method took more than 45 minutes to do analysis of one throwing motion. On the other hand, DALT took only 22.5 seconds. DALT has predominantly more advantages on analysis time.

Techniques	Average (±Standard Deviation)			F	p	Sign
	Term1	Term2	Term3			
Ball Control Ability	3.44(±1.24)	3.46(±1.36)	3.3(±1.28)	0.23	0.8	n.s
DLT-technique	11.41(±3.95)	12.43(±4.48)	15.36(±5.99)	8.7928	0.0002	∗∗
DALT	40.71(±22.21)	70.64(±29.9)	73.04(±32.12)	20.38	0.0001	∗∗

F:F-distribution Sign:significance ∗:p<0.05 ∗∗:p<0.01 n.s:not significant

Table 1. Result of ANOVA

5 Conclusion & Future work

We proposed DALT, which is an algorithm to detect throwing form changing. DALT analyzes state in much shorter time than the DLT-method does. The

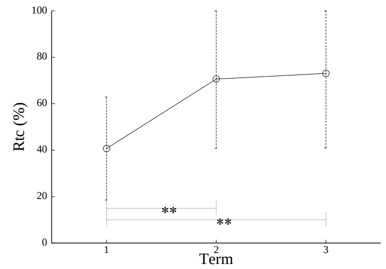

Fig. 4. DALT Result

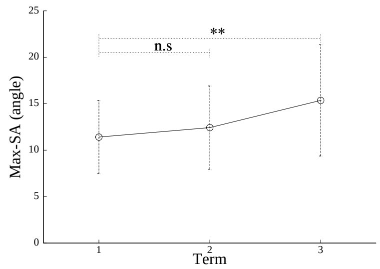

Fig. 5. DLT-method Result

analysis process of DALT is executed automatically against manual analysis process of DLT-method.

The implementation of the learning system was necessary for algorithmic precision improvement. In this experiment, throwing distance was the same. However, in practice, since the fielder was performing throwing practice in various distance, and it is necessary to conduct the experiment with various distance. Throw fatigue varies among individuals. An experiment using physiological and motion capture system are necessary to evaluate individual difference. Even if the fatigue state is detectable, if not transmitted to the suitable timing for the player during practice,the player will overwork after all. Therefore, we are currently working on the portion which decides when to notify the player.

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