INTRODUCTION

The shoulder and elbow joint of baseball pitchers were frequently overused by the repetition of throwing. The overuse caused throwing injuries of the shoulder or the elbow joint (Meister, 2000). To prevent the injuries or find it as soon as possible at the early stage, it is important to understand and evaluate each individual's baseball pitching motion exactly. Therefore, we have been developing the analysis system of the baseball pitching motion for clinical use (Nakamura, 2001). In the long-term clinical experience in our hospital, we have expected that one of the causes of throwing injuries is related to the pitch styles. The pitching motion is classified into four major pitch styles, as follows: over-arm, three-quarter, side-arm, and under-arm (Figure 1). The differences of pitch styles are mainly the posture of trunk, upper arm and forearm of throwing arm relative to the ground at the ball release. The classification has been performed by baseball experienced person qualitatively up to now. There is no standard method to classify the pitch styles quantitatively. Different pitch styles have different kinematic and kinetic results of pitching motion analysis (Matsuo, 2000). Therefore, it is important to classify pitch style quantitatively. The aim of this study was to classify various levels baseball pitchers into four pitch styles quantitatively.

METHODS

We measured pitching motions including four pitch styles, with regard to the whole body movement. The positions of 34 markers on subject’s skin (Figure 2) were recorded at 500Hz, using a motion capture system (ProReflex MCU-500, Qualisys, Sweden). We determined the coordinate systems using the subset of the markers on each body segment (Nakamura, 2001). In order to reduce noise on the measured data, the data were filtered using the cubic spline function.

Fifty physiologically normal amateur pitchers served as the volunteers in this study. Their mean age was 19.6 ± 6.62 years old (10-12 years old: 6/50, 13-15 yo: 8/50, 16-18 yo: 13/50, 19-22 yo: 8/50, 23-35 yo: 15/50), and their average height and weight were 171.1 ± 11.23cm and 65.3 ± 13.29kg, respectively. Their pitch styles were classified into the following four control groups as reference by a baseball experienced person: E1: over-arm (20/50), E2: three-quarter (23/50), E3: side-arm (4/50), E4: under-arm (3/50). Under 16 years old youth pitcher were classified into the following: E1: 9/20, E2: 10/23, E3: 2/4, E4: 0/3.

Next, in order to classify the pitch styles quantitatively, we selected following three kinematic parameters: upper arm elevation ($\theta_U$), trunk tilt ($\theta_C$), and the inclination ($\theta_F$) of a plane $S_{fa}$ relative to the ground. The $S_{fa}$ was an approximated plane along the tracing of the forearm of throwing arm, around the time of the ball release. $r_{ua}$: longitudinal axis of the humerus, $r_{tr}$: thoracic axis, $t_{BR}$: the timing of ball release.

Figure 1: Pitch styles: (a) over-arm, (b) three-quarter, (c) side-arm, (d) under-arm.

Figure 2: Bony landmarks to measure pitching motion.

Figure 3: The definition of kinematic parameters at the ball release. ($a=0.01[sec.]$, $S_{fa}$: approximated plane of forearm tracing, $l_{fa}$: normal vector of plane $S_{fa}$, $r_{ua}$: longitudinal axis of the humerus, $r_{tr}$: thoracic axis, $t_{BR}$: the timing of ball release.)
projected onto $ZG\ YG$ plane. The projected vector of $r_{ua}$ and $r_{tr}$ were represented by $p_{ua}$ and $p_{tr}$, respectively. $\theta_U$ was calculated by inner product of $p_{ua}$ and $z_G$. $\theta_C$ was calculated by inner product of $p_{tr}$ and $z_G$. $\theta_F$ was calculated from inner product of normal vector $l_{fa}$ and $z_G$.

These three kinematic parameters were assessed to classify into the four pitch styles. We employed MANOVA to investigate significant differences among the control group E1, E2, E3 and E4. Box’s M test was used to evaluate the equality of covariance matrix. Multivariate discriminant analysis was applied to classify four groups.

**RESULTS**

Figure 4 shows relationship between the pitch styles and kinematic parameters. Table 1 described the average and standard deviation of the three kinematic parameters of the control group. The result of MANOVA showed significant differences among the control group ($P < 0.01$). The result of Box’s M test suggested applying a linear discriminant function for the discriminant analysis. Using the discriminant analysis, the pitching motions of fifty pitchers were classified into four predicted group. The correct answer rate was 82% (Table 2). Table 3 shows that the contribution of each kinematic parameter to classify into 4 pitch styles. Table 4 is the canonical discriminant function coefficients that were used in this study.

Figure 4: Distribution of four pitch styles with regard to three kinematic parameters.

**DISCUSSION**

The results of kinematic and kinetic analysis were calculated using body weight, height and segment movements, which were measured by camera system quantitatively. Previous studies have reported that the differences of age and skill showed some differences of analysis results (Fleisig, 1996, 1999). However, the pitch styles were not classified quantitatively. The difference of pitch styles will influence to analysis result. The pitch styles also have to be classified quantitatively to investigate various factors of injuries. Therefore, we classified the pitch styles using three kinematic parameters. Fifty subjects with wide range of age from 10 to 34 yr served in this study could be classified into four pitch styles with 82% correctly. This result showed that the set of three kinematic parameters have a capability of classifying the pitch styles without relationship between age or skill differences. Our next work is to increase the number of subject, especially side-arm and under-arm pitchers.

**SUMMARY**

We suggested three kinematic parameters in order to classify the baseball pitch styles. The pitching motions of fifty baseball pitchers were classified into four pitch styles using multivariate discriminant analysis. The result showed that our method was able to classify the pitch styles reasonably.

**REFERENCES**