Effect of trunk side-bend angle and shoulder abduction on arm kinetics during baseball pitching

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Introduction
Mechanism of throwing injuries has progressively elucidated for the last two decades. Atwater (1979) suggested that throwing elbow injuries were mainly due to large and repetitive valgus torque. Fleisig et al. (1995) clarified it quantitatively. Thus, some peak values of kinetics for throwing arm during pitching have been identified as parameters associating with the throwing injuries. Matsuo et al. (1999) demonstrated that these peak values of kinetics changed as a function of shoulder abduction angle during delivery phase of baseball pitching, and found that the shoulder abduction angle minimizing the kinetics was not always the same among subjects. We estimated that the inconsistency may be due to differences in trunk movement, because the shoulder abduction angles minimizing the kinetics for underhand pitchers were much different from those for overhand and three-quarter-hand pitchers (2000). In this study, therefore, we aimed to clarify the influence of trunk side-bend angle on the shoulder abduction angle minimizing the peaks of the injury-related elbow kinetics.

Methods
Data were collected from 127 healthy adult overhand and three-quarter-hand baseball pitchers (college and professional) tested at the American Sports Medicine Institute. Based upon their trunk side-bend angle at ball release, ten with the greatest were assigned to the greater side-bend group (GT) and other 10 with the least were assigned to the smaller side-bend group (ST) (Table 1).

<table>
<thead>
<tr>
<th></th>
<th>height [m]</th>
<th>mass [kg]</th>
<th>vel.[m/s]</th>
<th>side-bend [°]</th>
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</thead>
<tbody>
<tr>
<td>GT</td>
<td>1.86 (0.06)</td>
<td>87.6 (12.0)</td>
<td>35.8 (1.9)</td>
<td>30.6 (4.8)</td>
</tr>
<tr>
<td>ST</td>
<td>1.83 (0.05)</td>
<td>76.4 (9.5)</td>
<td>35.5 (1.8)</td>
<td>21.6 (6.2)</td>
</tr>
</tbody>
</table>

Table 1: Means and standard deviations (SD) of physical characteristics, ball velocity, and trunk side-bend angle at ball release for the greater trunk side-bend angle group (GT) and the smaller trunk side-bend angle group (ST). Values in ( ) are SDs.

Each subject threw between 3-8 fastball pitches, with 12 reflective markers attached onto his body. Ball velocity was measured by a radar gun. The three-dimensional location of each marker was digitally recorded and calculated using the DLT method. The fastest pitch thrown for strike by each subject was analyzed. The position data were smoothed using a fourth-order zero-lag Butterworth type digital filter, for each direction in the global reference frame for each point. The cutoff frequency was 13.4 Hz. Kinematics for the throwing arm were calculated for these data. Simulated motions were then generated by the direct kinematics method in which the shoulder abduction angle at ball release was changed from the original to a target angle, from 70 to 130 degrees in 5 degrees increments. Except the shoulder abduction angle, any kinematics including the moving direction of the throwing wrist are not altered in this approach. Resultant forces and torques on the throwing arm were calculated using the inverse dynamics of Newton equations. The inertia properties of the body segments were calculated using the previous reports. The instant of ball release and the instant of lead foot contact were identified kinematically, then the period was defined 100%; the instant of lead foot contact was 25% and the instant of ball release was 125%. Some peak parameters of the arm kinetics during the period from 50% to 130% (just before the arm acceleration phase to the end of the arm deceleration phase) were selected to compare kinetic differences between GT and ST. The shoulder abduction angles minimizing the kinetics were also compared between GT and ST. Statistical differences were tested using Mann-Whitney U tests with the p values < 0.05.
Results & Discussion

Figure 1 demonstrates an example of typical elbow medial shear force during pitching for a subject in GT. Each curves in the figure shows the elbow medial shear force for each shoulder abduction condition (half of angle conditions were omitted). Peak elbow medial force was greatest at time 105%, when the shoulder was abducted 130°. The least peak force was at time 77%, when the shoulder was abducted 90°. Thus, the time to peak was dependent on the angle condition. This tendency was observed in other kinetics.

Since many injuries may be caused by specific combinations of the magnitude of kinetics and the timing of joint movement (types of muscle contraction), it is important to know the shoulder abduction angle during delivery affects not only the magnitude of kinetics but also the time to peak.

Each peak for each angle condition in Figure 1 was selected and averaged among subjects. Figure 2 (a) and (b) show the interpolated curves of these data set; (a) for GT group and (b) for ST group. A black curve shows the mean of peak elbow medial shear force and grey curves show standard deviations from the mean. For the GT, peak elbow medial force was least (mean = 345 N, SD = 70 N) at 89° (SD = 9°) shoulder abduction. For the ST, peak elbow medial force was least (mean = 339 N, SD = 67 N) at 93° (SD = 8°) shoulder abduction. Neither the least peak force nor the angle where the least peak force appeared showed significant difference.

Similarly, figure 3 (a) and (b) show the means and SDs of the peak elbow varus torque under several angle conditions. Peak varus torque for GT was minimal (mean = 63 Nm, SD = 15 Nm) at 76° (SD = 6°). Peak varus torque for ST was minimal (mean = 66 Nm, SD = 12 Nm) at 83° (SD = 7°). Although significant difference between GT and ST was not found in the minimal peak torque, it was found in the angle where the minimal peak torque appeared (p<0.05). For the subjects in the current study, trunk side-bend angle did not affect the magnitude of the minimum of the peak elbow kinetics under several shoulder abduction conditions. It seems, however, that it affected the shoulder abduction angle minimizing injury-related elbow kinetics. Considering with the narrow range of trunk side-bend angle, this results may not be underestimated.

References
Matsuo T. et al. (submitted for publication), 2000.