FINGER FORCES DURING BASEBALL PITCHING

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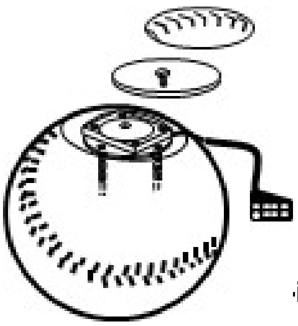
A 3D force transducer was installed in an official baseball to make a direct measurement of finger force imparting on the ball during pitching. Eight collegiate pitchers threw a 4-seam fastball at their maximal speed. Force was measured separately from each of the index, middle, and ring fingers, and the thumb. Peaks and peak occurrence time of computed resultant and shear forces were evaluated. Index and middle finger forces generally had a bimodal pattern with the first and second peaks appeared at about 80, and 96% of the stride foot contact period, respectively. Their force magnitude reached 90 N. and above. Magnitude of shear force was about half of the resultant force. Forces by the thumb and ring finger were less than those by the index and middle fingers. The findings indicated that the fingers were applying considerably large magnitude of force during pitching.

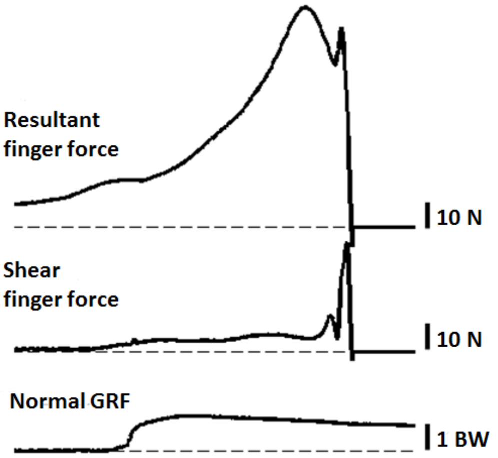
KEY WORDS: fastball, 3D force transducer, ball velocity, overarm throw, resultant force

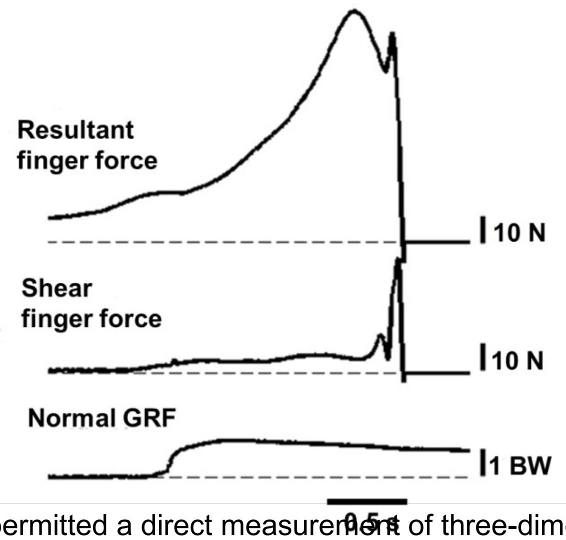
INTRODUCTION: Although much has been investigated on biomechanics of baseball pitching, limited information is available on force imparted by each finger on a baseball during pitching. Finger force data provides fundamental information on kinetics of baseball pitching. It is essential when understanding mechanical stress of pitching on the finger(s). The information can also be useful for baseball coaches or players to understand the habits of ball gripping and releasing. Hore et al. (1999; 2001) taped small force pressure sensors on the distal and middle phalanges of the middle finger to investigate finger force during ball throws. The balls used were tennis balls, or plastic balls of different weights, and sizes, and throwing speeds tested were clearly slower than those for ordinary baseball pitch. Nevertheless, they provided valuable information on finger force during actual ball throws. The force at the distal phalange showed a bimodal pattern regardless of weight, size, and surface texture of the ball used. Force magnitude was dependent on throwing speed and ball weight. Peak force resulted at the distal phalange during throwing a standard tennis ball (55 g) was around 15N at fast throwing speeds (>16 m/s), and 5 N at slow speeds (<12 m/s). When throwing a weighed tennis ball (196 g), the peak force at fast speeds reached 30 N. The present study was, to our knowledge, the first investigation of force imparted by the fingers on a baseball during maximum speed overhand pitching. To this end, we developed a 3D force-transducer-installed baseball allowing direct measurement of ball reaction force.

METHODS: Six right-hand and two left-hand overhand pitchers from the baseball teams of the Japanese university's top western league were tested. Their mean fastest pitch velocity during games was 39.2 m/s. (range = 37.5 – 40.2 m/s.). This study was approved by the university ethics committee. For the force transducer-equipped baseball (mass = 156 g), a miniature 3D USL06-H5-500N-C force transducer (Tec-Gihan co, Japan) was mounted on a duralumin plate, which was then firmly fixed inside an official baseball after removing a portion for the transducer placement (Figure 1). From the transducer in the ball to a strain amplifier, there was a 10-m long light-weighed electric wire. After ball release, this wire could be easily separated in two portions at a miniature electric connector placed at 7 cm from the ball. The wire in the hand side was taped to the back of the throwing arm, shoulder, back and hip of the subject. The experiment took place at the biomechanics lab, where a pitcher's plate, a force plate, and a ball receiving cage were placed on the floor. The cage was located 4 m in front of the pitcher's plate, and it had 6 layers of hanging cloths as impact shock absorbers. A 20-cm circle drawn in the middle of the front cloth served as a target for pitching. All electric signals were stored on a PC via a 12-bit A/D converter sampling at a frequency of 1 kHz for each channel. Ball speed after release in every throw was assessed using a SRA3000 speed radar tracer. The subjects pitched a four-seam fastball 4 times at his maximum speed for each of the index, middle, ring and thumb conditions. For each finger condition, the phalange of the designated finger was placed on the leather with seams located above the force transducer. For the index and middle fingers, four subjects also pitched an additional 9-10 times at varied ball speeds to examine the effect of speed. Resultant and shear forces were computed from the 3D force data for each pitch. The peak amplitude of the forces, and their occurrence time relative to the instant of ball release as well as to stride foot contact period were computed. Stride foot contact period was the time from the instant of normal ground reaction force (GRF) increase assessed by the force plate to the instant of ball release. ANOVA with repeated measures was conducted to test the effect of finger with statistical significance at $p < 0.05$.

Figure  **install** 

RESULTS & DISCUSSION: The mean ball speed across all experimental trials for all subjects was 32.5 + 1.6 m/s. This slower ball speed than their mound pitched speed was due possible to the 10% increase of the current ball mass, a need of extra force to disconnect the electric connector (2.6 N), pitching on a flat wooden floor, and indoor rubber soled shoes. Typical resultant, and shear forces of the middle finger during the four-seam fastball pitch are shown in Figure 2. The resultant force showed a bimodal pattern in many throws, which agreed with the findings of a study by Hore et al. (1999). The forces started to increase clearly from the moment of the stride foot contact, and peaked at around 37 ms (79.4% of the stride foot contact period) before the instant of ball release, which coincided with the relative time of maximum shoulder external rotation reported by Fleisig et al.(1999). The mean value of this first peak force was 100.5 ± 16.2 N (SD). The second peak (89.6 ± 18.5 N) appeared at 8 ms (95.5% of the stride foot contact period) before the instant of ball release. These force values were more than three times of those reported by Hore et al. (1999; 2001) due most likely to higher pitching speed by the present pitchers. The middle finger's shear force commonly had a distinct peak at about 5 ms before the instant of ball release, and this tangentially generated force clearly contributed to the development of the second peak in resultant force. The mean magnitude of the shear force peak was 47.3 ± 16.4 N. Peak time and amplitude of the resultant and shear forces for the index finger were similar to those observed for the middle finger. That is, the first and second peaks of the index resultant force appeared at 6, and 38 ms before the instant of ball release, respectively, and with magnitude of 93.1 ± 11.6 N, and 95.6 ± 14.5 N, respectively. Forces by the thumb and ring finger also developed in a similar manner to the index and middle fingers. Their magnitude was, however, less than the index and middle fingers, and often the second peak was absent. The first peak resultant force for the thumb was 75.3 ± 19.5N, and that for the ring finger was 56.0 ± 16.2 N. Testing the effect of pitching speed revealed that the peaks of the resultant and shear forces all increased nearly in proportion to pitched speed. Regression analysis indicated that with 10-20% increase in ball speed and an ordinary 145 g baseball during pitching a fastball from the mound, force imparts on each of the index and middle fingers can exceed 110 N. A future work should be made to design a wireless type of a similar instrumented ball with the standard weight, and with force sensors for multiple fingers. Studies are also needed to investigate finger forces during pitching with two-seam fastballs, and other pitch types, and to coordinate finger force data with full body motion analysis data.





and stride leg ground reaction force (Normal GRF)

d baseball developed in this study successfully permitted a direct measurement of three-dimensional forces generated between the finger and ball during pitching. During maximum fastball pitch, resultant force on each of the index, and middle fingertips exceeding 90 N, and tangential shear force exceeding 45 N. Substantial magnitude of force by the thumb and ring finger were also contributing to fastball pitching.

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