GROUND REACTION FORCE OF BASEBALL FLAT GROUND PITCHING

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The purpose of this study was to describe the characteristics of the ground reaction force (GRF) of baseball flat ground pitching, and compares the characters with previous research which pitched on pitching mound. Fourteen division I college pitchers participated in this study. A VICON Motion capture system (10 cameras) and two force platforms were used to collect 3-D kinematic data (500Hz) and GRF data (1000Hz). Three successful trials for each subject were analyzed. The result shows the pivot foot anterior/posterior (AP) propulsive force was larger on flat ground, and the leading foot AP force was larger on pitching mound. The other two components GRF were similar in these two ground situations. The three components of GRF had low correlation with ball velocities. Comparing the peak GRF in three components between pitcher with fast and slow ball velocity groups, the fast velocity group produced a larger leading AP braking force. The leading foot AP breaking force may be an important variable for identify the fast and slow pitching ball velocities.

KEY WORDS: pitching, baseball, biomechanics

INTRODUCTION: Pitcher plays an important role in a baseball game. The game result was often affected by pitcher performance, so the pitching training is very important. Pitching on flat ground is a common practice for training. This method is thought to be a training method with less pressure. But we don't really know why it is less pressure. MacWilliams et al. (1998) measure GRF from 6 collegiate and 1 high school pitcher. They found that when pitcher throw on the mound, ball velocity have high correlation with three components of peak ground reaction forces (GRF). (pivot foot AP forces r^2=.82, ML forces r^2=.74, vertical r^2=0.76. leading foot AP forces r^2=0.86, ML force r^2=0.70, vertical r^2=0.88). However, there was lack of research focus on flat ground pitching. Gottschall et al. (2004) in their research in running found when running from flat to downhill, the AP braking force increased, the AP propulsive force decreased. According to these two researches, we made two hypotheses. First, pitching on flat ground, the three components of GRF will have high correction with ball velocity. Second, when pitching on flat ground, the pivot foot AP propulsive force would be larger, but the leading foot AP breaking force would be smaller than pitching on the mound.

METHODS: 14 healthy collegiate (12 right hand, 2 left hand) who plays in Chinese Taipei university baseball division I volunteered to participate in present research (age 19±1.1yr; height 172.8±6.6cm; body mass 74.2±8.0kg). All subjects were informed of the experimental procedures and gave their consent before participating. This study was approved by the local medical ethics committee. A VICON Motion capture system (Vicon Peak, Lake Forest, CA) with ten digital cameras (MX13) and two force platforms (Kistler model 9281, 9287) were used to collect 3-D kinematics data (500Hz) and force data (1000Hz). Thirty eight markers (8 mm in radius) were attached to the subject according VICON Plug-in model. Four markers were attached on the ball to compute ball velocity (resultant velocity). The anatomical nature position data were collected in the first trial. Subjects threw to a target (40*60cm,80cm high from ground.) attached to the safety net which is 3 m in front of the force platforms. The succeed trial was defined as the ball hit the target. Ten successful trials were collected. Kinematic data were computed by Visual3d. The GRF data were transformed into the frequency domain by Fourier transform and the first 32 harmonics coefficients were used for analysis (MacWilliams et al., 1998). The mean result of three trials with fastest ball velocity of each subject was used to compute correlations and t test. The correlations between GRF and ball velocities and t test were computed with SPSS 11.

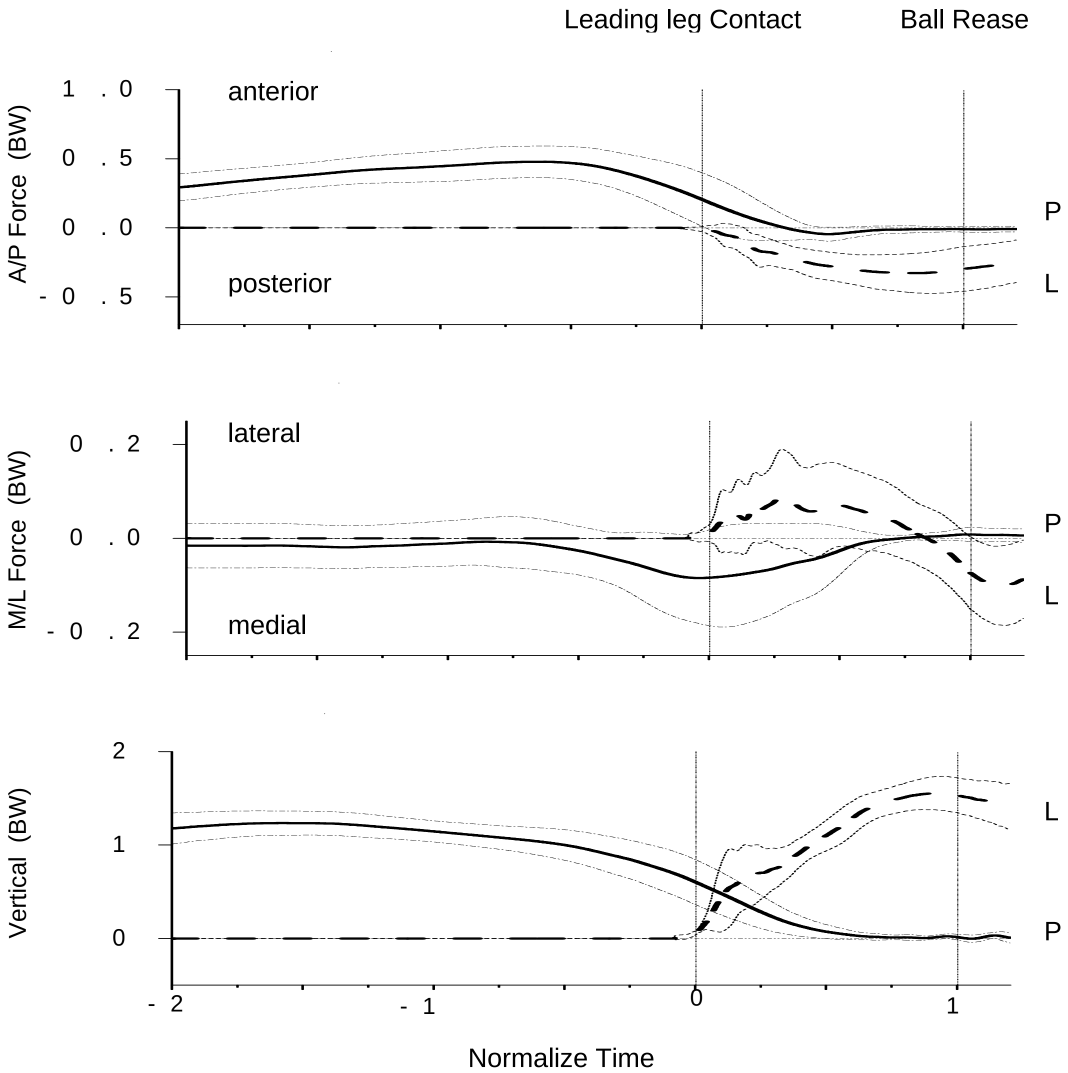

Figure 1. Pivot and leading foot mean GRF and standard deviation of 14 subjects (pivot foot ___ , leading foot _ _). Every subject's data were computed for mean of three trails. Force data are normalized with body weight.

Table 1. Comparison of GRF on fast and slow ball velocity groups

	Fast Speed (BW) (n=6)		Low Speed (BW) (n=6)			
	Mean	Std	Mean	Std	t	p
Pivot Foot						
A/P Force	0.49	0.12	0.55	0.10	-1.01	0.34
M/L Force	-0.19	0.04	-0.16	0.04	-1.59	0.14
Vertical	1.28	0.12	1.33	0.09	-0.91	0.38
Leading Foot						
A/P Force	-0.27	0.11	-0.43	0.15	2.26	0.05*
M/L Force	0.22	0.06	0.14	0.03	2.92	0.02*
Vertical	1.60	0.16	1.60	0.15	0.05	0.96

*p<.05

RESULTS: The mean ball velocity was 31.1±3.1m/s. The mean peak wrist velocity before ball release was 17.9±1.9m/s, maximum is 21.7 m/s, and minimum is 19.2m /s.

The pitcher produced pivot foot AP propulsive force when the leading leg started to stride, and AP propulsive force reached a peak 0.5BW before leading leg contact the ground. After contact, the pivot foot AP force rapidly decreased. The leading foot AP force appeared and increased after foot contact and reached a peak 0.3 BW just before ball release.

In medial/lateral (ML) direction, right side is lateral side for right-handed pitchers. For left-handed pitchers, it is opposite. The ML forces of the two feet were all small. Pivot foot medial force reached a peak 0.1BW just about leading leg contact. After the leading leg contact, the leading foot produced a lateral force, then switch to medial force after weight transfer and reached a peak 0.1BW after ball release.

The pivot vertical force maintained about 1.2BW, and decreased just before leading leg contact. Then the weight started to transform to the leading foot. The vertical force of leading foot appeared after it contact to the ground and increased to a peak 1.6BW just before ball release.

In this research, the coefficient of correlation between GRF and ball velocity were very weak. (pivot foot AP forces r^2=.14, ML forces r^2=.00, vertical r^2=0.20. leading foot AP forces r^2=0.15, ML force r^2=0.10, vertical r^2=0.00). For making the relationship between GRF and ball speed more clear, we took 2 subject of mid ball velocity out and compared the GRF peaks between the 6 pitchers with faster ball velocity and 6 with slower ball velocity. Only the leading foot AP and ML forces had significant difference. The result shows the pitcher with faster ball velocity produced more AP braking force.

DISCUSSION: Compare this result with previous research (MacWilliams et al., 1998), The wrist velocity was similar. The MP and vertical forces have similar value. But the AP forces were different. The pivot foot AP force in this study was larger but the leading AP force was smaller than the previous research. When compare with level running, Gottschall et al. (2004) found the result AP braking peak force was greater for downhill running, but AP propulsive peak force was greater for flat. The same phenomenon appeared on baseball pitching. Pivot foot produce more AP propulsive force when pitching on flat ground and leading foot produced more AP braking force on the mound.

MacWilliams et al. (1998) found that pitchers should train to develop powerful pivot leg drives as a normal part of the throwing motion, but they should not attempt to overpush to gain extra velocity. In their study pitching on the mound need more AP braking force than propulsive force. If pitchers overpush, they will not have enough AP braking force to maintain balance. So control propulsive force is an important factor. But on flat ground, the parallel braking force is smaller than propulsive force. No matter how hard the pitcher pushed off, he can produce enough force to braking. So it is easy to pitch on the flat ground and the pitcher can focus on other parts of the mechanic. The weak correlation between GRF and ball velocity might come from subjects' variation. The large different of AP forces show when faster ball was pitched greater braking force produced. The different correlation in this study and previous might reflect that pitching on the mound and flat ground is using different way to transferred the

Table 2 GRF data of previous study and present study. (The mean and standard of previous study are measure from paper's figure.)

	MacWilliams et al (BW)	present study (BW)
A/P force		
Pivot foot	0.35±0.07	0.48±0.10
Leading foot	0.72±0.08	0.33±0.14
M/L force		
Pivot foot	0.10±0.02	0.85±0.10
Leading foot	0.10±0.02	0.86±0.10
Pivot Force		
Pivot foot	1.00±0.03	1.2±0.14
Leading foot	1.50±0.05	1.6±0.21

energy to trunk and upper limbs. required further research to clarify the mechanic sequences of how energy produced and transferred.

CONCLUSION: when pitching on flat ground, the pivot foot AP propulsive force is larger, but the leading foot AP braking force is smaller. That makes the pitcher easy to balance. This study finds low correlation between GRF and ball velocity, and the leading foot produces greater braking force when faster ball was pitched. According this, pitching on flat ground can develop upper limb mechanic with less chance of injure. It is a better practice for rehabilitated pitcher for develop upper limb mechanic. When move from ground to the mound, they should pay attention to control their pivot foot force to avoid overpush. If pitcher loses balance in pitching process, the force produced from lower limb might hurt their arm or trunk again.

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