A BIOMECHANICAL COMPARISON OF THE CROSSOVER STEP AND JAB STEP TECHNIQUES IN THE PUSHOFF OF BASE STEALING STARTS IN BASEBALL

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The aim of this study was to compare the effectiveness of the crossover step (CS) and jab step (JS) start techniques in baseball base stealing. Fourteen varsity fielders participated in the study. An automatic motion capture system and synchronized force platforms were used to analyze the two start techniques, performed at full effort by each individual. No statistical difference was found in the start time (duration of the start phase) between the two techniques. However, the start velocity (forward velocity of the body CG at the end of right leg push-off phase) was significantly larger in JS than in CS. It was found that the difference in the start velocity between the two step techniques comes from the difference in the forward impulse generated by the left leg push-off.

KEY WORDS: start velocity, start time, joint kinetics of lower limb

INTRODUCTION: The ability to steal bases is one of the most important aspects of offensive baseball (Johnson, Leggett & McMahon, 2001). Good base stealing performance gives a team many scoring opportunities. The execution of a base steal can be separated into several distinct phases, including lead, start (push-off), acceleration, and sliding. An explosive start is essential for reaching a high level of sprint performance in Track and Field (Mero, 1988). In baseball, due to the shorter distance run (approximately 27.4 m from base to base), the start phase is still more critical for the achievement of a high level of base stealing performance.

In baseball coaching textbooks, two kinds of step techniques are recommended for the start phase of base stealing: the crossover step (CS) technique (Russo, Landolphi & Gershberg, 1985; Kindall, 1993; Johnson, Leggett & McMahon, 2001) and the jab step (JS) technique (Lopez, 1996). In the crossover step technique the base runner pivots on the ground-supported right foot, and subsequently crosses over with the left foot directly toward the target (i.e., second base, third base, or homeplate). In the jab step technique, the right foot is briefly lifted off the ground and re-planted before the left foot crosses over directly toward the target (Figure 1). Thus, the main difference between the two techniques is whether the base runner lifts the right foot off the ground in the initial step or not.

The purpose of the present study was to compare the effectiveness of the crossover step and jab step start techniques. Since start performance could be evaluated by the start time (duration of the start phase) and by the start velocity (forward velocity of the body center of gravity at the end of the start phase), we measured these critical parameters and the factors that produced them. In addition, we analyzed the work exerted at the lower leg joints. It was hypothesized that the start velocity of the jab step technique would be larger than that of the crossover step technique due to an increased forward impulse generated by the left leg push-off, resulting from larger leg muscle forces.

METHODS: Fourteen varsity baseball fielders (age 19.6±1.0 yrs, athletic career 10.4±1.2 yrs, standing height 1.73±0.46 m, mass 71.9±5.7 kg) participated in this study. Informed written consent was obtained from all participants. All fielders normally used the JS start, but practiced the two starts until they could execute both satisfactorily. After this practice, they performed five CS starts and five JS starts at maximum effort to steal a second base, starting from an initial static position with evenly distributed body weight. Sufficient time was given for recovery between trials.

Three-dimensional positions of 43 passive reflective markers (14 mm diameter) attached to the body were recorded at 250 Hz using nine MX-T20 cameras with an automatic motion capture system (VICON, Vicon Motion Systems Ltd., UK). Ground reaction force (GRF) data synchronized with the motion capture system were collected at 1,000 Hz using two force platforms (type 9287B, Kistler Instruments, Switzeland), one for each leg, and then smoothed at 40 Hz using quintic spline functions (Woltring, 1986). An LED set in front of the fielder was used for the start (steal) signal. For each fielder, the trial with the shortest duration of the start phase in each type of start was selected for further analysis.

The coordinates of the reflective markers were smoothed using quintic spline functions (Woltring, 1986) with optimal cutoff frequencies (ranges: 7.5-15 Hz) determined by the residual analysis method (Winter, 1990). Anthropometric segmental data for the fielders were estimated from the standing height and body mass of each fielder using de Leva's (1996) adjustments of the values reported by Zatsiorsky, Seluyanov & Chugunova (1990).

The start phase was defined as the period of time from the start signal to the instant of the second toe-off of the right foot (ROFF2). It was divided into a left leg push-off phase (start signal to toe-off of the left foot (LOFF)), and a right leg push-off phase (LOFF to ROFF2) (Figure 1). Note that the instants of ROFF1 (first toe-off of the right foot) and RON (toe-on of the right foot) did not exist in the crossover step technique.

To assess the start performance, start time, defined as the duration of the start phase, was measured from the GRF data. Start velocity, defined as the forward velocity (i.e., velocity toward second base) of the body center of gravity (CG) at the end of start phase, was calculated from the GRF data by dividing the summed horizontal impulses of the two platforms by the fielder's body mass. The initial velocity of the fielder was set at 0 m/s.

Based on inverse dynamics analysis of a 16-link segment model, joint angular velocity (ω_j), joint torque (T_j) and joint power ($P_j=T_j\,\omega_j$) at the hip (h), knee (k), and ankle (a) were calculated from the kinematic, GRF, and anthropometric segmental data. Mechanical work values (absolute, W_a; positive, W_p; negative, W_n) at each joint were calculated by integration of the joint power with respect to time. To facilitate the interpretation of the results, these parameters were expressed in anatomically-relevant components about the three axes of each joint. Only kinetics of the left leg joints are reported in the present study. All force and work values were normalized for the subject's body weight (BW).

Paired Student's t-tests were performed using SPSS version 20 (SPSS Inc., Chicago, IL) to assess the differences in the calculated parameters between the two techniques. Significance levels were set at $p < .05$ for each test.

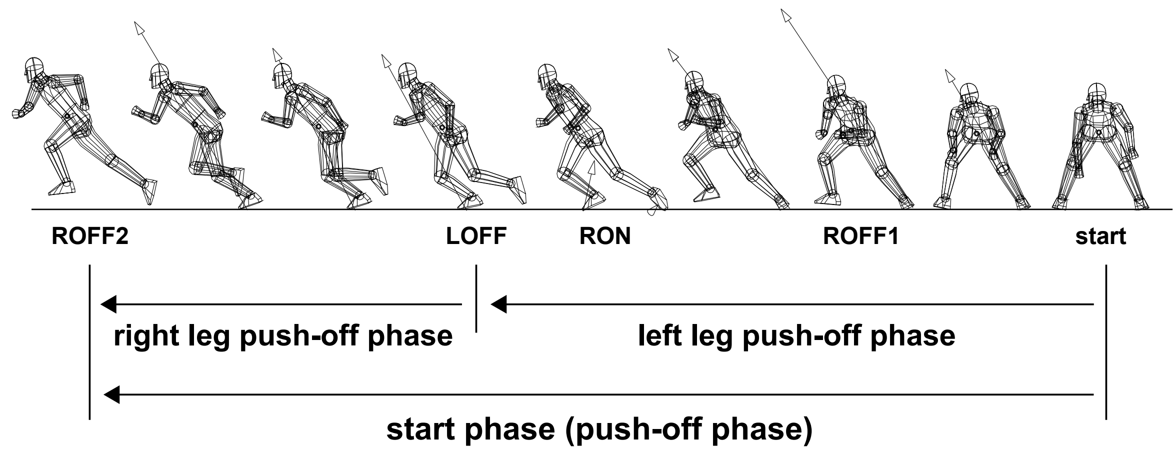

Figure 1: A sequence of the jab step technique drawn with the GRF vector acting on each foot from the ground, and definitions of phases. (See text.)

RESULTS: The start velocities and the mean forward forces generated by the left leg push-off and by the combined push-offs of the two legs were significantly larger for JS than for CS, as shown in Table 1. No significant differences were found between the two techniques in regard to start time, left leg push-off time, right leg push-off time, mean forward force generated by the right leg push-off, peak forward forces by the left leg push-off and by the right leg push-off, and start velocity generated by the right leg push-off.

As shown in Table 2, significant differences were found in mechanical work (J/BW) at the left leg joints as follows: flexion/extension at hip, inversion/eversion and flexion/extension at knee, and abduction/adduction at ankle for absolute work; extension and abduction at hip, and extension at ankle for positive work; and inversion (integration of the product of inversion torque by eversion angular velocity) at knee, and adduction (integration of the product of adduction torque by abduction angular velocity) at ankle for negative work. All these values of mechanical work were significantly larger for JS than for CS.

Table 1: Critical parameters for start performance

parameters	**Crossover Step**	**Jab Step**	sig.diffs
Duration of Phase (units: s)			
Start time [T_{LR}]	0.804 ± 0.046	0.808 ± 0.054	
┌ Left leg push-off time [T_L]	0.559 ± 0.047	0.562 ± 0.053	
└ Right leg push-off time [T_R]	0.245 ± 0.022	0.246 ± 0.023	
Mean Forward Force (N/BW)			
Legs [F_{LR_mean}]	0.43 ± 0.04	0.45 ± 0.04	*
┌ Left leg [F_{L_mean}]	0.30 ± 0.03	0.32 ± 0.02	***
└ Right leg [F_{R_mean}]	0.13 ± 0.02	0.13 ± 0.03	
Peak Forward Force (N/BW)			
┌ Left leg [F_{L_peak}]	0.96 ± 0.10	0.96 ± 0.11	
└ Right leg [F_{R_peak}]	0.72 ± 0.10	0.73 ± 0.14	
Forward Velocity of Body CG (m/s)			
Start velocity [V_{LR}]	3.40 ± 0.35	3.52 ± 0.28	*
┌ Left leg [V_L]	2.38 ± 0.24	2.52 ± 0.19	**
└ Right leg [V_R]	1.02 ± 0.15	1.00 ± 0.19	

significant differences: * $p < .05$; ** $p < .01$; *** $p < .001$

Table 2: Mechanical works of left hip, knee, and ankle joints during left leg push-off phase

parameters	**Crossover Step**	**Jab Step**	sig.diffs
Absolute Work (units: J/BW)			
Flexion/Extension at hip [W_{a_FE-h}]	0.95 ± 0.33	1.39 ± 0.50	**
Inversion/Eversion at knee [W_{a_IV-k}]	0.39 ± 0.17	0.58 ± 0.29	*
Flexion/Extension at ankle [W_{a_FE-a}]	0.25 ± 0.11	0.33 ± 0.16	*
Abduction/Adduction at ankle [W_{a_AA-a}]	0.84 ± 0.34	1.12 ± 0.44	*
Positive Work (J/BW)			
Extension at hip [W_{p_ext-h}]	0.87 ± 0.39	1.35 ± 0.51	***
Abduction at hip [W_{p_abd-h}]	0.30 ± 0.18	0.42 ± 0.27	*
Extension at ankle [W_{p_ext-a}]	0.38 ± 0.33	0.60 ± 0.38	**
Negative Work (J/BW)			
Inversion at knee [W_{n_inv-k}]	0.33 ± 0.17	0.52 ± 0.28	**
Adduction at ankle [W_{n_add-a}]	0.23 ± 0.11	0.31 ± 0.17	*

significant differences: * $p < .05$; ** $p < .01$; *** $p < .001$

DISCUSSION: Success in the base stealing start relies on the achievement of a shorter start time and a larger start velocity. That is to say, the base runner needs to receive maximum forward impulse from the ground in the shortest time possible.

The present study showed that the start velocity was significantly larger in JS than in CS, while no significant difference in the start time was found between the two techniques (Table 1). Since the start velocity was caused by the resultant forward impulse generated by pushing backward against the ground with both legs, we divided the start velocity into fractions generated separately by the left leg and right leg push-offs. This showed that only the start velocity produced by the left leg push-off was significantly larger in JS than in CS, while there was no significant difference in the left leg push-off time between the two techniques (Table 1). These results indicate that the difference in the start velocity between the two techniques resulted only from the difference in the mean forward force generated by the left leg.

Mechanical work about a joint reflects the activities of the muscles that cross the joint (Winter, 1990). Since the performance difference between the two techniques was in the start velocity produced by the left leg push-off, we calculated nine work values for absolute, positive and negative work at the hip, knee and ankle joints of the left side leg. The above-mentioned differences (Table 2) in the joint work values between the two techniques indicated increases in the muscle activities of JS in relation to CS. It seems that concentric activities of the hip and ankle extensors and eccentric activity of the knee invertors, all of which showed highly significant ($p < .01$) increases from CS to JS, may have contributed to the increase of the mean backward force exerted by the left leg against the ground in JS.

CONCLUSION: No significant difference was found in the start time between the crossover step and jab step techniques. The start velocity of the jab step technique was larger than that of the crossover step technique. The difference between the start velocities of the two techniques resulted from the difference in the mean backward force exerted by the left leg against the ground. This increase in the mean force generated by the left leg could be caused by increases in the joint work values, resulting mainly from the extensors and abductors at the hip, invertors at the knee, and extensors and adductors at the ankle. It can be concluded that the jab step technique is more effective than the crossover step technique in increasing velocity in the start of baseball base stealing.

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