Effects of Varying Recovery Periods on Muscle Enzymes, Soreness, and Performance in Baseball Pitchers

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ABSTRACT: In this study we examined the effects of varied recovery time on serum creatine kinase (CK), serum lactate dehydrogenase (LDH), muscle soreness, and pitch velocity in baseball pitchers. Ten males who had pitching experience participated in the study. After an 18-day training period, subjects pitched three simulated games. Game A and Game B were separated by four days of rest, while Game B and Game C were separated by two days of rest. CK, LDH, and muscle soreness were evaluated at the following times: before and immediately after exercise, and six, 24, 48, and 72 hours after exercise. Muscle performance was evaluated by measuring pitch velocity during the games. The CK level was elevated after each game (Game A - 249 U/l; Game B - 243 U/l; and Game C - 240 U/l); then it dropped toward baseline ($p \leq 0.01$). CK post-exercise values were not different among games A, B, and C. LDH displayed a response similar to CK; however, there was a reduction over the span of the games ($p \leq 0.05$). Muscle soreness was significantly elevated immediately after exercise ($p \leq 0.01$) compared to all other measurement times. Pitch velocity was not different among games A, B, and C. Results indicate that muscle damage, as evidenced by CK release, occurs in response to baseball pitching. However CK values, muscle soreness, and pitch velocity are not significantly affected by changes in the amount of recovery time typically scheduled between games.

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The appearance of intramuscular enzymes in the blood following strenuous exercise provides evidence of skeletal muscle fiber damage (5,7,13,14,18). Creatine kinase (CK) and lactate dehydrogenase (LDH) are two physiological markers that have been used as indicators of skeletal muscle damage. The efflux of CK and LDH into the blood has been attributed to structural damage of the muscle fibers (1,4,8,9).

It has been reported that eccentric muscular contractions result in a greater CK and LDH efflux than concentric muscular contractions (11,15,16,18,20). The increased enzyme efflux is attributed to the generation of higher tensions by active muscle fibers during the eccentric contractions. The higher tension is thought to initiate some form of mechanical damage to the muscle that allows enzyme efflux into the blood.

The enzyme efflux that occurs after exercise may be modified by training (7,19) or repeated bouts of eccentric exercise (5,12). In these studies, previous training or eccentric exercise by the subjects reduced the amount of enzyme efflux during subsequent exercise bouts. Conversely, several studies show that a significant enzyme efflux still may occur following acute strenuous exercise, even when previous bouts of exercise have been performed (2,3,22).

The role of prior eccentric exercise on muscle enzyme release and performance is still unclear and deserves further study. The majority of past research has examined muscle enzyme release, muscle soreness, and performance in response to running, stepping, and isometric exercise bouts. The effect of other types of sport and exercise on these variables needs investigation. The purpose of this study was to examine the effects of varied recovery periods between games of baseball pitching on serum enzyme levels, muscle soreness, and performance.

Methods

Ten males, who had prior experience as baseball pitchers, participated in the study. Age, height, and weight were (mean $\pm$ SE) 22.6 $\pm$ 1 yr, 173.0 $\pm$ 2 cm, and 72.9 $\pm$ 4 kg, respectively. As outlined by the American College of Sports Medicine, the experimental procedures were explained in detail, and the subjects signed an informed consent prior to participation in the study.

Subjects were required to report to the laboratory to participate in an 18-day training program. On alternating days, each subject threw a specified number of pitches at a predetermined percentage of their maximum velocity. The starting number of pitches for the training program was established at 55 and then increased by five pitches per workout until training was completed. By the end of the training program, subjects were throwing 100 pitches per workout. The beginning percentage of maximum velocity was 50% and was periodically increased to 100% for the last six days of the training program. During each training session, the subjects were given a warm-up similar to that employed before

participation in a typical game situation. After warm-up, they threw 14 pitches per inning, with a six minute rest between innings, until they threw the predetermined number of pitches.

Subjects did not pitch for three days following training. They then pitched three simulated games with four days rest between Games A and B and two days rest between Games B and C (Table). The four-day recovery period was selected because it is an established routine for baseball pitchers. The two-day recovery period was selected in an effort to reflect the unusual strategies used in post-season play and the recovery periods employed by relief pitchers. Randomization of the protocols within subjects did not occur because we felt that the two-day recovery period would have a carry over effect on the subsequent pitching performance.

During the time between the pitching performances, the subjects were instructed to refrain from participating in any physical activity. There were no instructions given regarding the use of any therapuetic measures between games.

We attempted to establish a pitching protocol similar to a game situation. Subjects were allowed 45 warm-up pitches prior to the game and five warm-up pitches prior to each inning. Warm-up pitches were thrown at the rate of one pitch every 12 seconds. Subjects then threw 14 pitches per inning at a rate of one pitch every 20 seconds. At the end of 14 pitches (one inning), they rested six minutes and then threw during the next inning. Testing was complete when the subjects finished seven innings of pitching. The total number of pitches thrown, excluding warm-ups, was 98. The protocol for the number of pitches and the between-inning rest was developed from previously recorded experimental data dealing with competitive collegiate games lasting seven innings.

Blood for CK and LDH was collected from the non-pitching arm via venipuncture. Six samples (5 ml each) were collected at the following times: (a) before exercise; (b) immediately after exercise; and (c) six, 24, 48, 72 hours after exercise (Table). The blood was allowed to clot and then was spun at 3000 rpm for 20 minutes in an IEC Centra-7R refrigerated centrifuge A visual examination was performed to ensure that no hemolysis was present. The serum was divided into two separate storage tubes. The serum to be used for a CK level was frozen (-10 to -15° C) and analyzed within 72 hours. The serum for the LDH level was stored at room temperature (21° C) and analyzed within 72 hours. Creatine kinase was analyzed using Sigma procedure No. 16-UV and LDH was analyzed using Sigma procedure No. 47-UV (Sigma Diagnostics, St. Louis MO).

Experimental Protocol

Pitching Assignment	Day	Blood Collection Before & after exercise
Game - A	1	Before, immediately after, 6 hr after
	2	24 hr after
	3	48 hr after
	4	72 hr after
	5	rest - no collection
Game - B	6	Before, immediately after, 6 hr after
	7	24 hr after
	8	48 hr after
Game - C	9	72 hr after, before, immediately after, 6 hr after*
	10	24 hr after
	11	48 hr after
	12	72 hr after

* 72 hr after Game B and before exercise Game C are the same sample.

During each game, pitch velocity was monitored as a measure of performance. Each pitch was measured with a calibrated radar gun (RA-GUN G 1, Decatur Electronics, Decatur GA). On all pitches, subjects were instructed to maintain a velocity equal to or greater than 95% of their maximum velocity. Maintenance of near maximal pitching velocity was enforced to ensure that each subject was performing with a close to maximal effort on each pitch. Subjects were instructed to throw pitches eight, nine, and ten with their maximal effort, and these values were recorded as maximal pitch velocity.

Subjects were asked to rate their perception of soreness in the muscles of the pitching arm and muscles of the legs at all blood collection times. The Abraham (1) scale for muscle soreness was used to evaluate general soreness as follows: 0 - complete absence of soreness; 1 - light pain felt only by palpation; 2 - moderate soreness, some stiffness and/or weakness, especially during movement; and 3 - severe soreness, distressing pain that limits the range of motion.

A repeated measures analysis of variance (ANOVA) (treatment x time) was used to examine the results. Orthogonal polynomial comparison tests were employed to determine where the differences occurred. Significance was established at the $p \leq 0.05$ level.

Results

Creatine kinase response to the three pitching performances are shown in Fig 1. The response to each game was very similar; all three games elicited a significant increase in CK level ($F(2,12)=23.61$, $p=.0001$). Peak CK values occurred at 24 hours after exercise for Game A (249 U/l) and Game B (243 U/l), but at six hours after exercise for Game C (240 U/l). Following

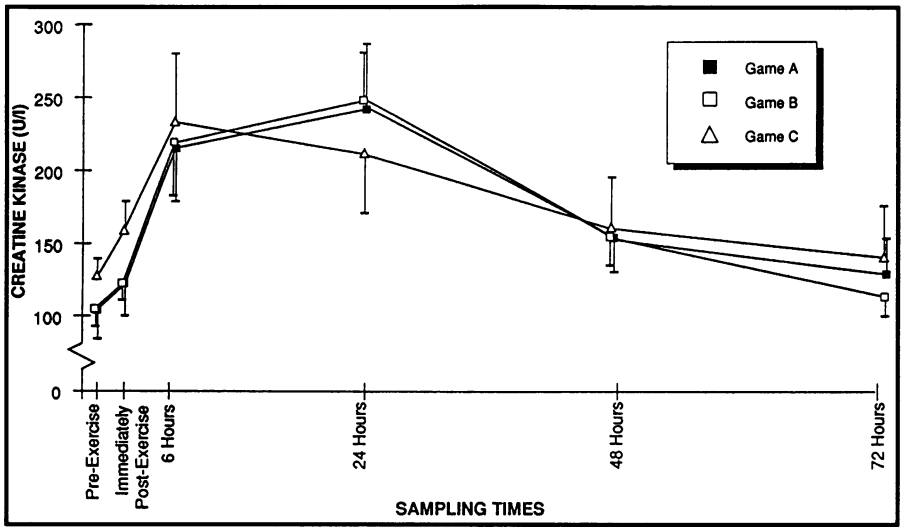

Fig 1.—Creatine kinase response prior to and following a game (mean ± SE); * Significant quadratic effect within games A, B, and C ($p \leq 0.01$)

each game, the enzyme levels then decreased, approaching baseline values at 72 hours after exercise. There were no significant differences between the three games at any of the sampling times ($F(2,12)=0.52$, $p=.87$).

Fig 2 shows the LDH response to the games. As with CK, the LDH profile exhibited a significant LDH increase after each game ($F(2,12)=17.29$, $p=.0001$). Peak values for LDH occurred at six hours after exercise in each case. There appeared to be a change in the response of LDH to the repeated games. In general, the LDH values for Game B ($F(2,12)=3.87$, $p=.05$) and Game C ($F(2,12)=10.99$, $p=.002$) were lower than for Game A ($p \leq .05$).

Data for muscle soreness in the pitching arm are exhibited in Fig 3. In each protocol, the subjects reported the greatest soreness immediately after exercise, and this value was significantly different from all other values ($F(2,12)=21.00$, $p=.0001$). Subjects reported no muscle soreness in the legs in response to any of the pitching performances.

The effects of the varied recovery periods did not significantly change the pitching velocity among games (Fig 4), although there was a slight trend toward decreased velocity in Game C ($F(2,21)=2.65$, $p=.11$). Subjects were able to maintain their pitching velocity throughout the entire game, and there were no significant differences within games for any inning ($F(2,29)=0.34$, $p=.70$).

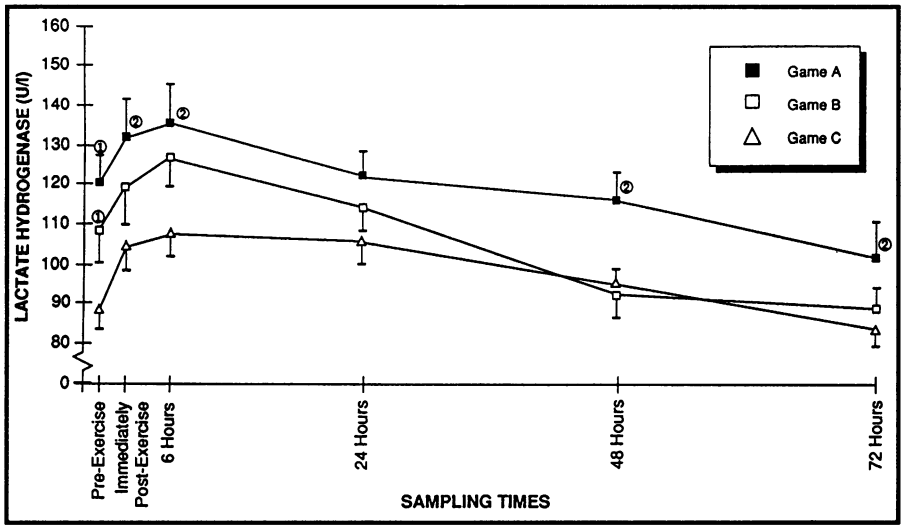

Fig 2.—Lactate dehydrogenase response prior to and following a game (mean ± SE); 1-pre-exercise games A and B different from game C ($p \leq 0.05$); 2-game A different from games B and C ($p \leq 0.05$); * Significant quadratic effect within games A, B, and C ($p \leq 0.01$)

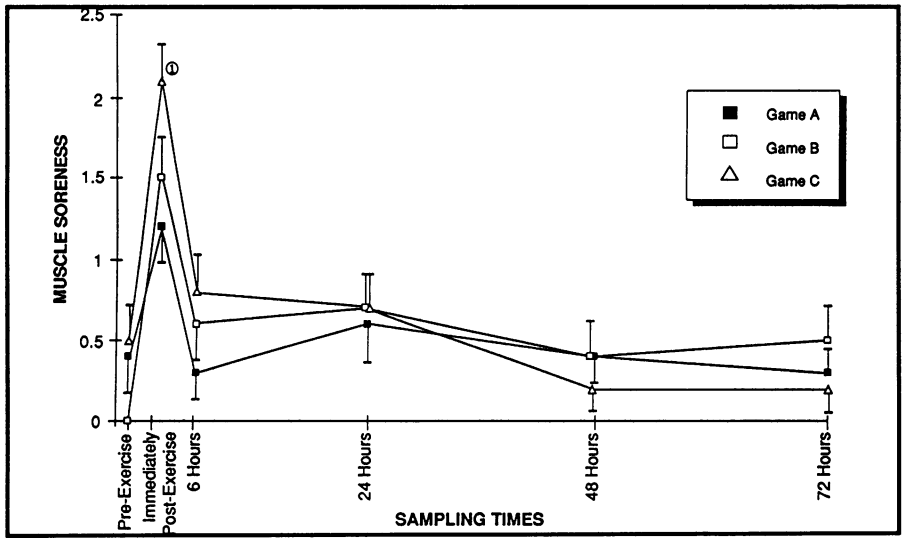

Fig 3.—Muscle soreness in the arm prior to and following a game (mean ± SE); 1-immediate post-exercise different from all other values within games A, B, and C ($p \leq 0.01$)

Discussion

It is commonly believed that the appearance of intramuscular enzymes in the blood is an indicator of skeletal muscle damage (5,7,13,14,18). It has been shown that enzyme efflux occurs in response to unaccustomed eccentric work or long duration strenuous exercise (11,15,16,18,20); however, previous training or prior participation in exercise may modify or provide a protective effect to subsequent enzyme release (5,7,10,17,21).

The CK and LDH post-exercise profiles for the individual pitching performances are similar to those reported in other studies using trained subjects (5,7). There was no significant modification of CK release among the pitching performances in our study. We believe that the

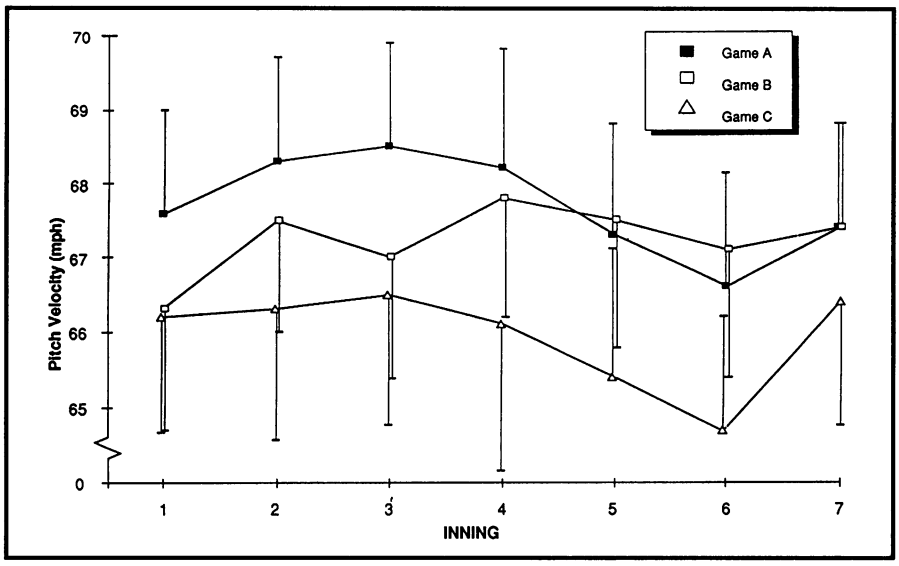

Fig 4.—Pitch velocity during a seven inning game (mean ± SE); * No significant difference within or between games

modification of enzyme release occurred during the 18-day training program. Other studies have demonstrated that the majority of the protective effect against enzyme release may occur after only one acute bout of exercise (6,21).

The high intensity levels required during pitching made it impossible to examine enzyme levels without prior training. In an effort to protect our subjects from injury, they participated in an 18-day training program prior to testing. If previous studies dealing with trained and untrained subjects are accurate, then we conclude that the modification of enzyme release occurred during the training program. Therefore, it appears that the CK and LDH response shown in this study is a normal occurrence in trained pitchers and is not significantly affected by either four days or two days of recovery.

While there was an increase in muscle enzyme efflux following pitching, the measurement of enzymes in the general circulation does not allow conclusions to be made about which muscle groups are involved with enzyme release and possible muscle damage. If determination of enzyme release from specific muscle groups can be made, then there exists the possibility of using enzyme levels following pitching as a clinical marker of arm overuse or arm injuries. Future research in this area is needed in an effort to make these determinations.

The majority of studies examining muscle soreness have found peak soreness levels to occur between 24 and 48 hours after exercise (1,5,6,8,13,18). Our subjects experienced the greatest arm soreness immediately after exercise (Fig 3). Arm soreness then decreased over the next 72 hours. The profile for muscle soreness was similar following all three games. Past studies have demonstrated that muscle soreness is reduced in response to training (5,12). There were no significant differences in muscle soreness levels among games, and we believe that a reduction in delayed muscle soreness occurred during the training program. The subjects reported no soreness in the muscles of the legs before or after any of the pitching performances.

Maximal pitching velocity was recorded as a measure of muscle performance during each game (Fig 4). There were no significant differences in velocity among games, although there was a trend ($F(2,21)=2.65$, $p=0.11$) for velocity to be lower in Game C. Examination of the data reveals that for every inning of Game C, the mean velocity was lower (although not significantly) than in either Game A or Game B. Pitch velocity for Game C was 2.7% lower than Game A and 1.9% lower than Game B. While the percentage decrease may seem rather small, in game competition, the decrease in pitch velocity may be a determining factor in successful performance. It is quite possible that subjects were not able to generate the same amount of force following a two-day rest as they did following a normal four-day rest. These observations are supported by Newham et al. (12) who observed a decrease in maximal force production for as long as two weeks following exercise-induced CK release. In addition, Clarkson and Tremblay (6) saw force production decrease following maximal eccentric exercise, then take as long as five days to recover to pre-exercise levels.

Baseball pitching appears to cause a release of the intramuscular enzymes CK and LDH that is similar to that seen in other forms of exercise. The difference between four-day and two-day recovery periods for baseball pitching does not significantly change CK release, although it may result in a modification of LDH release. The difference in recovery periods also has no significant effect on muscle soreness or pitch velocity, although it is interesting to note the trend for pitch velocity to be slightly lower following the two-day recovery period. We believe that elevated CK levels may indicate muscle damage, which could compromise pitching performance. It appears that further research is needed in an effort to determine if monitoring CK release from muscle tissue following pitching is related to subsequent baseball pitching performance.

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