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MINIMAL CHANGES IN INDIRECT MARKERS OF MUSCLE DAMAGE AFTER AN ACUTE BOUT OF INDOOR PRE-SEASON FAST BOWLING

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ABSTRACT

The aim of the study was to determine the effect of pre-season indoor fast bowling on indirect markers of muscle damage. Ten elite male, fast bowlers (22±1 yrs) participated in the study. Each participant bowled 48 balls off a full run up during a practice session. The bowling load was eight overs with six balls bowled/over. The overs were separated by a three-minute standing rest period. Creatine kinase (CK) activity, Visual Analogue Scale (VAS) muscle pain ratings, hip, knee and ankle joint range of motion and maximal quadriceps and hamstring isometric strength were measured 24 hours before, one hour and 24 hours after bowling and analysed using a one way ANOVA. Significance was set at $p\leq0.05$. Maximal isometric strength of the quadriceps and hamstrings for both legs was unchanged. CK activity was significantly elevated at one hour and 24 hours. Pain rating for quadriceps (trailing leg) and gastrocnemius (leading leg) were elevated at one hour and at 24 hours. Ankle range of motion was significantly reduced at 24 hours for the trailing and leading legs. The indoor pre-season fast bowling had no effect on maximal isometric strength and a minimal effect on other indirect markers.

Key words: Cricket; Eccentric; Creatine kinase; Delayed Onset Muscle Soreness (DOMS); Injury.

INTRODUCTION

The prevalence, nature and aetiology of cricket related injuries are important to understand in order to ensure the optimal health and performance of cricketers. Research conducted on first class cricketers in Australia from 1995/96 to 2000/01, reported that injury rates varied from 19.0 per 10 000 playing hours in domestic first class matches to 38.5 per 10 000 playing hours in one-day internationals (Orchard *et al.*, 2002). It was also found that the average seasonal incidence was around 19.2 per 25 players per 20 matches played (Orchard *et al*., 2002). Furthermore, the research identified that fast bowlers have a higher injury rate (14%) compared to other cricketers (Orchard *et al*., 2002; Dennis *et al*., 2005; Davies *et al*., 2008).

Fast bowlers are predisposed to higher injury rates due to the biomechanical and physical demands they are exposed to during bowling (Dennis *et al.*, 2005). Fast bowlers who bowl more than 20 overs (>120 balls bowled) in the week leading up to a match have an increased risk of sustaining a bowling related injury (Orchard *et al*., 2002). A further risk is seen in bowlers bowling second in a match (Orchard *et al*., 2002). Recently, it was reported that fast bowling accounts for 41% of all injuries that occur in cricket, with 47% of these injuries occurring in young up and coming bowlers (Davies *et al.*, 2008). The researchers found that the majority (41%) of injuries occurred at the knee, followed by lower back (37%) and shoulder (16%) (Davies *et al*., 2008).

Factors associated with the increased incidence of fast bowling related injuries include: poor bowling mechanics and inappropriate bowling technique that are associated with an increase in rotational forces in the lumber spine; inappropriate strength and conditioning regimes; inadequately rehabilitated injuries; and over-bowling (bowling too many balls/overs) and under-bowling (not bowling enough balls/overs, and therefore, being inadequately prepared/conditioned) (Dennis *et al*., 2005; Davies *et al*., 2008).

Guidelines have been developed in an attempt to reduce the rate of injuries in fast bowlers (Davies *et al*., 2008). These guidelines specify that senior players (≥19 yrs) must be limited to three spells of eight overs per match (total of 24 overs or 144 deliveries) with a minimum of an hour's rest between each spell (Davies *et al*., 2008). It is also recommended that a senior bowler should bowl no fewer than 123 deliveries and no more than 188 deliveries per week between games (Dennis *et al*., 2005). These guidelines were developed to ensure that bowlers are not predisposed to overuse injuries and that they are adequately conditioned for fast bowling (Dennis *et al*., 2005). Further research, however, is required to examine the link between injury rate and the number of deliveries per season/ week/match.

An important factor that may contribute to lower leg injuries in fast bowling is the high ground reaction forces experienced with each delivery. Ground reaction forces can be four to nine times that of gravity for back and front foot landing respectively (Noakes & Durandt, 2000). Studies have suggested that the human musculoskeletal system is poorly designed to deal with the repetitive nature of fast bowling, as well as the increased forces placed on the body during the landing phase (Noakes & Durandt, 2000).

Fast bowlers are also exposed to repeated, elevated eccentric muscle contraction forces during the bowling landing phase or delivery stride that may result in lower limb muscle or tissue damage. The stability of the knee joint and of the back and front leg during the landing and delivery phases is maintained through powerful eccentric contractions of the quadriceps femoris muscles (Noakes & Durandt, 2000). Research in other sport has demonstrated that unaccustomed or strenuous, eccentric muscle contractions increased indirect markers of skeletal muscle damage (Tiidus, 2008).

Exercise-induced muscle damage has been examined in humans (Ebbeling & Clarkson, 1989; Hoffman *et al*., 2002) with plasma creatine kinase (CK) activity commonly reported as an indirect marker of skeletal-muscle damage (Takarada, 2003; Peake *et al*., 2005). While elevated CK has been reported after competitive match play in contact sport (Takarada, 2003; Suzuki *et al*., 2004; Kraemer *et al*., 2009), suggesting that significant skeletal muscle damage occurs during such contact sport, there is limited information available relating the impact of cricket fast bowling on skeletal-muscle damage or CK. Importantly, although eccentric muscular contractions have traditionally been considered the predominant contributor to increased CK after exercise (Brancaccio *et al*., 2007), recent evidence suggests that significant increases in CK may also occur as a result of physical collisions and blunt force trauma (Hoffman *et al*., 2002; Smart *et al*., 2008). It is the view of the authors that the high ground reaction forces experienced during fast bowling may also be considered a physical collision or blunt force trauma that starts at the foot and travels upwards through the lower limbs of a bowler. These forces together with the eccentric contractions may increase the level of skeletal-muscle damage and together contribute to increasing CK levels, as well as other indirect markers of muscle damage.

Therefore, despite the existence of bowling guidelines, currently there is limited information regarding the effects of a single spell of fast bowling on indirect markers of muscle damage or the subsequent recovery thereof. Due to the high incidence of injury in fast bowlers, additional information relating to muscle damage and recovery may aid in the planning of conditioning and injury prevention programmes and possibly prolonging the careers of fast bowlers. Therefore, the aim of this study was to determine the effect of a recommended match spell of eight overs (48 balls bowled) of fast bowling on indirect markers of muscle damage in elite senior players. It was hypothesised that there would be an increase in the indirect markers of muscle damage immediately after bowling and that these would be further elevated at 24 hours post.

METHODOLOGY

Subjects

Ten male, elite (defined as a member of a professional provincial squad), fast bowlers participated in the study. The demographics of the fast bowlers were: seven right hand and three left hand bowlers; age 22±1 years; stature181±6.1 cm; mass 87.3±12.9 kg; with a body fat percentage of 13.1±6.0. A fast bowler was defined as any bowler to which the wicket keeper stands back (and not close to the wickets) and bowls between 120 to 135 km/h. The participants were tested approximately 3 months into the cricket off-season (July, 2009) and 3 months prior to the start of the 2009/2010-season. The mean and standard deviation for last time bowled was 1.24±0.80 months at pre-testing. An attempt was made to reduce the effect of training on baseline readings by performing the bowling intervention and pre- and post-data collection during a rest week of the strength and conditioning mesocycle. Prior to commencement of the study, participants read and signed an informed consent form and completed medical and cricket history questionnaires approved by the Institution’s Research Ethics Committee. All participants were asymptomatic of any diseases or injuries and were not on any pain or anti-inflammatory medication.

Testing protocol

Baseline testing (Day 1) was performed in the Discipline of Sport Sciences, Human Performance Laboratory (HPL) (22^{o}C, 50% humidity) between 09h00 and11h00 with stature, body mass, per cent body fat (chest, abdomen and thigh skinfolds) (Jackson & Pollock, 1985) and flexibility assessed after a 15-minute seated resting period. Capillary blood creatine kinase (CK) activity levels were then measured, followed by Visual Analogue Scale (VAS) muscle pain ratings, range of motion (ROM) and maximal isometric strength testing. Day 2 and Day 3 were designated rest days with the participants performing limited physical activity to reduce the impact on the dependant variables.

The bowling spell was performed on Day 4 between 08h30 and 11h30. Resting CK levels were measured immediately prior to a standardised 15-minute warm up (dynamic, bowling specific warm-up) to ensure that they were similar to the baseline levels measured on Day 1. A paired t-test indicated that the CK levels of Day 4 were not statistically different from Day 1 and were, therefore, used in the final statistical analysis. The intervention took place in an indoor cricket centre. Participants were required to wear non-spiked cricket shoes due to the indoor surface. They were asked to treat the bowling spell as a match situation. Each player bowled 8, 6-ball overs (48 balls in total) with an average rest time between each over bowled of 3 minutes (calculated by averaging the rest time between 10 overs during a live international limited overs match).

After each delivery the participants returned to their full-length run up and performed each delivery with maximal effort for the duration of the testing protocol. Within an hour following completion of the bowling spell, participants were transported to the HPL where the same testing protocol as Day 1 was performed. During this time the bowlers did not perform any recovery interventions such as stretching but were permitted to continue with their normal dietary and hydration practices. The bowlers then returned to the HPL 24 hours later and measurements were repeated (Day 5). During this time the players were requested to avoid any pain or anti-inflammatory medication, participate in any recovery sessions using modalities/techniques, for example, massage, which could impact on the variables measured in the study.

CK activity was determined using a Reflotron blood analyser, which uses, a colorometric assay procedure (Boehringer Mannheim GmbH, Germany). The within-series precision (CV) of the Reflotron ranges from 1.8 to 3.0%, while the day-to-day precision ranges from 2.2 to 3.0%. Capillary blood (32ul) was pipetted onto a Reflotron CK strip (Roche Diagnostics, Indianapolis, USA). The strip was inserted into the Reflotron analyser for 180 seconds. Results were recorded from the value seen on the Reflotron blood analyser digital display.

The VAS was used to assess the severity of skeletal muscle pain. Players were asked to gently palpate and move various muscle groups through a comfortable range of motion. They were then asked to rate each muscle group individually, by placing an 'X' along a visual analogue scale (VAS) of 100 mm. The verbal anchors on this scale were: '1=normal'; and '100=very, very sore' (Grant *et al.*, 1999). The distance in centimetres, from the beginning of the scale to their mark, was measured and this represented the muscle soreness score for that particular muscle group. Palpation occurred at the followings sites: 10 and 15cm above the superior pole of the patellae, as well as 5cm laterally and medially from the 15cm mark, on the quadriceps. In addition, they were palpated along the midline of the calf muscle 15cm from the joint margin of the tibiofemoral joint. The same investigator administered the VAS measurements to ensure standardisation of the palpation of the muscle groups. Range of motion was determined using a goniometer (Lafayette Guymon). Hamstring and hip flexor flexibility was assessed using the supine straight-leg flexion test (Davis, 2008) and ROM of the ankle was assessed using the plantar- and dorsiflexion tests (Moseley *et al.*, 2001).

All participants completed strength testing on the Biodex System 3 (Biodex Medical Systems, New York, USA). To obtain bilateral maximal isometric strength of the quadriceps and hamstrings, participants performed a maximal knee extension and flexion at 45˚ for a period of 5 seconds. All participants completed 2 trial repetitions, 1 at a submaximal level and the other maximal (for 2 seconds), per leg before each testing protocol. These 2 practice trials per leg were used to improve the reliability of the maximal 5-second effort. The order of testing of the legs (trail or leading leg first) was randomised.

Statistical analysis

The statistical analysis was performed using GraphPad Prism version 5.00 for Windows, (GraphPad Software, San Diego, California, USA). The data were analysed with a 1-sample nonparametric test (Kolmogorov-Smirnov test) to determine whether the data distribution was normal. A one-way analysis of variance (ANOVA) was used to analyse the following dependant variables: CK, VAS muscle pain ratings, ROM, as well as maximal isometric torque. The levels of each variable at 1 hour and 24 hours after the bout of bowling were compared to pre-bowling levels. Post hoc testing was performed using Tukey's multiple comparison test. Significance was set a $p \leq 0.05$.

RESULTS

Range of motion

There were significant differences at 24 hours for trailing ($p=0.004$) and leading ($p=0.0008$) leg ankle dorsiflexion (Table 1) representing a relative decrease in range of motion from baseline of -29.8 and -27.2% respectively.

Pain ratings (Visual Analogue Scale)

Significant differences in VAS pain ratings were found at various palpation points on the trailing leg quadriceps group (Table 1). At 1 hour ($p=0.02$) and 24 hours ($p=0.03$) post intervention, there were significant increases at 15cm above the superior pole and 5cm lateral of the patella. The VAS score at 1 hour increased from baseline by 177%, while the score at 24 hours represented an increase of 59%. At 1 hour post intervention there was a significant difference ($p=0.01$) for the quadriceps 10cm above the superior pole. The VAS score at 1 hour was 35% higher than baseline. A significant difference was found at 1 hour ($p=0.04$) post intervention for 15cm above the superior pole of the trailing leg with an increase of 130%. There was a significant difference ($p=0.03$) in the VAS scores at 1 hour and 24 hours for the gastrocnemius of the leading leg (Table 1), with increases from baseline of 168 and 122% respectively.

Creatine kinase activity

Significant differences in CK activity were found at 1 hour ($p=0.03$) and 24 hours ($p=0.04$) post intervention compared to baseline (Figure 1), with relative increases from baseline at 1 hour and 24 hours of 108.6 and 77.2% respectively.

Maximal isometric torques

Compared to baseline there were no changes in the leading or trailing limb maximal isometric torques after the spell of fast bowling (Table 1).

TABLE 1: **RANGE OF MOTION, VAS SCORES, LIMB CIRCUMFERENCES, MAXIMAL ISOMETRIC TORQUE**

Variable	Pre Mean (SE)	1-h post Mean (SE)	24-h post Mean (SE)
Dorsiflexion ROM (degrees)			
Trailing leg	20.4(1.1)	20.0(1.1)	*14.9(1.3)
Leading leg	21.2 (1.3)	21.6(0.9)	*15.2(1.3)
Plantarflexion ROM (degrees)			
Trailing leg	35.6 (4.1)	42.1 (2.2)	38.9 (1.8)
Leading leg	38.7 (3.8)	42.2 (2.3)	38.8 (1.9)
Hamstring ROM (degrees)			
Trailing leg	63.2 (3.9)	65.6 (3.1)	65.3 (2.6)
Leading leg	60.3 (4.2)	64.0 (2.3)	66.6 (3.5)
VAS Quadriceps (mm)			
Trailing leg			
5cm above superior pole of patella	22.7 (5.5)	36.8 (7.7)	27.6 (6.3)
10cm above superior pole of patella	13.2 (3.3)	#24.4 (4.8)	8.2 (2.2)
15cm above superior pole of patella	9.9 (1.9)	#26.0 (7.4)	13.2 (3.4)
15cm above superior pole and 5cm lateral of patella	11.4 (4.7)	#31.6 (6.2)	#18.1 (3.6)
Leading leg			
5cm above superior pole of patella	17.4 (4.3)	35.9 (6.5)	22.9 (5.5)
10cm above superior pole of patella	14.2 (4.0)	24.0 (5.6)	8.8 (1.9)
15cm above superior pole of patella	10.9 (3.9)	24.3 (5.7)	13.8 (3.3)
15cm above superior pole and 5cm lateral of patella	14.6 (6.2)	32.3 (8.2)	18.7 (4.5)
VAS Gastrocnemius (mm)			
Trailing Leg	37.9 (0.7)	38.0 (0.7)	38.2 (0.9)
Leading Leg	12.6 (3.9)	#33.8 (6.81)	#28.0(5.8)
Isometric Torque (N.m)			
Trailing leg			
quadriceps extension	180 (8.7)	198 (19)	206 (12)
hamstring flexion	143 (11)	142 (15)	147 (10)
Leading Leg			
quadriceps extension	201 (10)	185 (13)	207 (7.3)
hamstring flexion	146 (14)	147 (17)	157 (14)

* $p<0.01$ # <0.05

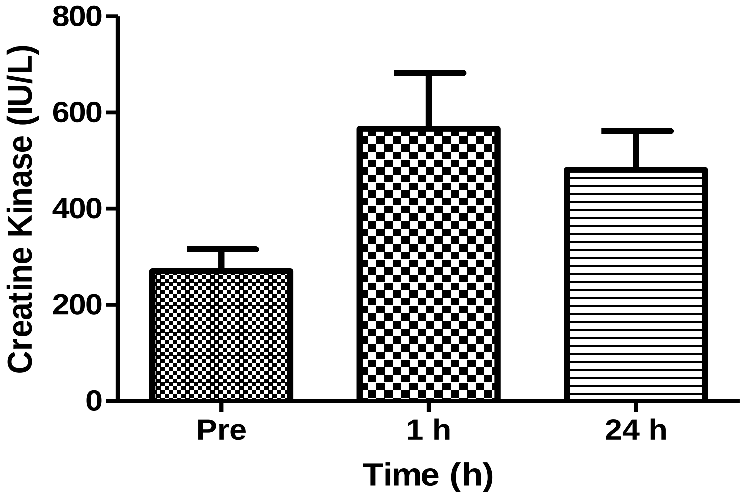

FIGURE 1: **TOTAL CREATINE KINASE ACTIVITY**
*Significantly elevated at 1-h (p=0.03) and 24-h (p=0.04) compared to pre-measure.

DISCUSSION

The main finding of this study was that a recommended match spell of pre-season, indoor fast bowling had a significant effect on some indirect markers of muscle damage at 1 hour and 24 hours post intervention, while it had no effect on others. The alterations possibly reflect the physiological load of a spell of fast bowling rather than excessive, exercise-induced muscle or tissue damage that would inhibit performance or prolong recovery. This is the first study to provide information regarding the acute effect of recommended fast bowling guidelines (Davies *et al*., 2008) on indirect markers of muscle damage (muscle pain as measured by the VAS, ROM and isometric strength). In addition, it provides an indication of the possible CK reference limits that could be expected after a spell of fast bowling in professional cricketers.

The increases in CK at 1 hour and 24 hours after the bowling spell were within the normal reference CK limits (82–1083 U/L) reported for well trained and elite male athletes (Mougios, 2007). However, comparison with baseline (normal) male reference intervals for the general non-athlete population (upper reference limit <350U/L) (Wong *et al*., 1983), could be interpreted as reflecting the existence of exercise-induced muscle or tissue damage. Although even higher baseline CK levels (upper reference limit of 532U/L) (Lev *et al*., 1999), and 491U/L (Mougios, 2007) have been reported in the non-athlete male population. This result highlights the importance of sports medicine physicians, coaches and conditioning specialists having access to sports specific reference intervals for CK, as sport have quite different demands in terms of strength, speed, endurance, flexibility and technique, which all impact CK levels (Mougios, 2007).

Creatine kinase usually peaks between 24 to 48 hours post exercise-induced muscle damage (Tiidus, 2008). However, the results in the present study indicate that CK activity was returning to baseline levels by 24 hours. It is generally agreed that the CK response to exercise induced muscle damage is due to variability in the susceptibility of muscles to injury (Warren *et al.*, 2006). In addition, the time of CK release into and clearance (Warren *et al*., 2006) from the circulation depends on the level of training and conditioning, and the type, intensity and duration of exercise (Brancaccio *et al*., 2007). These factors may have contributed to the results in the present study.

There were significant decreases in dorsiflexion ROM for both the leading and trailing legs at 24 hours which suggests that muscle damage may have occurred in either or all of the lower leg muscles of the shin and calf. Although the VAS was not used to assess pain in the tibialis anterior, the participants experienced a significant increase in pain in the gastrocnemius of the leading leg at 1 hour and 24 hours post bowling. The associated muscle damage may have increased muscle tightness in the gastrocnemius (antagonist) that manifested at 24 hours, which would have played a role in limiting dorsiflexion ROM at 24-h.

Eccentrically induced muscle contractions or the ground reaction forces may have been the contributing factor to the muscle pain experienced post intervention in specific muscle groups of the leading and trailing legs. The pain reported in the thigh, however, does not correlate with the finding of no change in maximal extension isometric strength. There was a significant increase in pain of the gastrocnemius of the leading leg at 1 hour; yet the trailing leg seemed to experience a greater amount of pain. Possible reasons for increased pain in the trailing leg include increased rotational forces (Hurrion *et al*., 2000), landing position (Davies *et al*., 2008), knee angle, as well as eccentric muscle contractions (Noakes & Durandt, 2000), compared to the leading leg, although further research is required in this area.

Eccentric muscle actions can disrupt cytoskeletal elements involved in force transmission, damage the muscle cell membrane and impair excitation-contraction coupling together resulting in a loss of force production (Tiidus, 2008). However, in the present study there were no significant changes in the maximal isometric strength of both the trail and leading leg at any time point after the bowling spell, which indicates no disruption of excitation-coupling. This provides further evidence that the bowling spell caused minimal muscle or tissue damage, specifically in the quadriceps and hamstrings.

Damage related eccentric muscle actions could alter the pattern of lower limb muscle fibre recruitment (Noakes & Durandt, 2000). In addition, research has indicated that damaged muscles of the lower limb become less able to store the energy of the ground reaction forces upon landing, and therefore, are less able to maintain the same level of energy output for the subsequent toe off (Noakes & Durandt, 2000). Although there was an increase in muscle pain and stiffness in the lower limb in the present study that could reflect the existence of muscle damage, it is believed that this was not severe enough to alter recruitment patterns or energy output of the lower limb muscles. The role that exercise-induced muscle damage plays in altering muscle fibre recruitment patterns and reducing muscle energy output in fast bowlers needs to be examined further, particularly after multiple spells of fast bowling over a day or consecutive days. Understanding this relationship could help clarify whether fatigue, reduced performance and susceptibility to injury are associated with the eccentric muscle contractions that occur in the lower limbs during the fast bowling action.

CONCLUSION

The results indicate that a fast bowling spell of eight six-ball overs produces significant changes in various indirect markers of muscle damage. However, these alterations, specifically the small elevation in CK, if interpreted together with the maintenance of maximal isometric strength, possibly reflect the physiological load of the bowling spell rather than eccentrically induced muscle damage. A recommended spell of eight six-ball overs for fast bowlers, therefore, seems to be safe and does not result in a reduction in subsequent performance. Further research is required to examine the effects of multiple spells of fast bowling on indirect markers of muscle damage over a single day, as well as over consecutive days.

The practical implication is that an eight-over spell of indoor, fast bowling, performed pre-season will result in a small increase in muscle stiffness, muscle pain and CK that lasts up to at least 24 hours after the spell. However, maximal isometric strength does not change, suggesting that an eight-over spell does not induce muscle damage that would inhibit subsequent performance.

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