Impact of Exercise Induced Muscle Damage on Target Shooting Performance

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Abstract: The purpose of this study was to investigate the impact of exercise induced muscle damage created by upper arm on target shooting performance. Eleven healthy and moderately active males [(mean±SD) age: 21.91±2.66 years; stature: 175.33±4.83cm; body mass: 70.12± 6.83kg; body fat %: 11.20±3.83], who did not perform any high intensity physical training towards upper body extremities during last 3 months, volunteered to participate in this study. Target shooting performance for both arms were measured, following assessment of serum CK activity and muscle soreness level using visual analogue scale, before (baseline) and at 5th minute, 24th, 48th, 72nd, 96th and 120th hours after muscle damaging exercise protocol. Two sets of 25 repetitions, totally 50 maximal eccentric contractions were performed with forearm flexors, as muscle damage exercise protocol. Repeated measure ANOVA and Friedman test was used for statistical analysis. Repeated measures ANOVA showed significant changes in serum CK activity [$F_{(5\text{-}50)}$= 40.028, p<0.01] and in target shooting performance for both dominant [$F_{(6\text{-}60)}$= 3.271, p<0.01] and non-dominant [$F_{(6\text{-}60)}$= 3.136, p<0.01] arms, relevant with time intervals. According to Friedman test, muscle soreness for both arms changed significantly (p<0.01) within time intervals. Compared to baseline values significant (p<0.05) changes were recorded following muscle damaging exercise protocol regarding to serum CK activity, muscle soreness and shooting performance. Consequently, the results of this study revealed that exercise induced muscle damage affect target shooting performance negatively. The respondents should be careful while adding unaccustomed exercises including intense eccentric contractions during the process of training planning, in sports which target shooting skills are important features.

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1. Introduction

Exercise induced muscle damage is defined as temporary cellular damage occurring in the skeletal muscle after unaccustomed exercises (Simith & Miles, 2000). Muscle damage is a common situation after high intensity exercises including excessive eccentric contractions (Hazar, 2004; Twist & Eston, 2007; Highton et al., 2009). In previous studies, delayed onset muscle soreness (Howell et al., 1993), inflammation (Cleak & Eston, 1992), rise of muscle proteins in blood (Howatson & Milak, 2009), and deterioration of muscle function (Rawson et al., 2001) have been reported together with the creation of muscle damage.

Over time, the impact of exercise induced muscle damage on athletic performance has become a subject of curiosity among sport scientists. In these studies, effects of exercise induced muscle damage on various athletic performance components were investigated following high intensity unaccustomed exercises including eccentric contractions. In the preliminary studies conducted on the effects of muscle damage, athletic performance was determined mainly by isometric strength measurements. The unfavourable effects of muscle damage on isometric strength were confirmed in various studies (Byrne & Eston, 2002; Sayers & Clarkson, 2001; Cleak & Eston, 1992).

Although, isometric strength measurements were widely used in most experimental studies to evaluate the strength performance; it is thought that the characteristics of this type of contractions do not reflect the actual athletic performance including dynamic contractions. Therefore, researchers who aim to keep athletic performance forefront, preferred the tests including dynamic movements to evaluate the influence of muscle damage on performance. Researches done in this respect showed significant decrease in isokinetic strength performance after muscle damage exercise protocols and this reduction reached to the maximum level at 24th and 48th hours (Twist & Eston, 2007; Burt & Twist, 2011; Highton et al., 2009). Furthermore, studies examining endurance performance showed significant decrease in running distance following muscle damage exercise, especially at 48th hour (Burt & Twist, 2011; Twist & Eston, 2009; Marcora & Bosio, 2007). In addition to this, significant degradation was reported in vertical jump (Marginson et al., 2005; Byrne & Eston, 2002), sprint running (Twist & Eston, 2005; Highton et al., 2009; Semark et al., 1999; Akdeniz et al., 2012) and agility performance (Highton et al., 2009; Akdeniz et al., 2012), and in peak power values recorded by cycle ergometer (Twist & Eston, 2005; Nottle & Nosaka, 2007; Byrne & Eston, 2002) following eccentric exercise protocols in various studies. Moreover, significant deterioration was investigated in the balance of dominant leg following muscle damage exercise protocol (Twist et al., 2008).

Shooting is an important skill that affects directly the results of the competitions of the sports such as archery, tennis, basketball and volleyball. In order to develop shooting performance coaches are creating special training programmes to their athletes. As mentioned before muscle damage has detrimental effect in various athletic performance components, there is only one study conducted on the effect of exercise induced muscle damage created by lower body extremities to soccer based skill performance (Draganidis et al., 2013). However, there has been no reported recent study in the literature, which examined specifically the effect of upper arm eccentric exercise induced muscle damage on target shooting performance. Therefore, the purpose of this study was to investigate the impact of exercise induced muscle damage created by upper arm on target shooting performance.

2. Material and Methods

2.1. Participants

Eleven healthy and moderately active males [(mean±SD) age: 21.91±2.66 years; stature: 175.33±4.83cm; body mass: 70.12± 6.83kg; body fat %: 11.20±3.83], who did not perform any high intensity physical training towards upper body extremities during last 3 months, volunteered to participate in this study. At the beginning of the study before the applications, written informed consent was obtained from each participant, following detailed explanation about the purpose, methods, contributions and possible risks.

2.2. Experimental Design

During the two weeks before the beginning of the experiment, the participants were familiarized with the test battery to avoid the learning effect during the testing period of the study. Each participant had repeated the target shooting test protocol (10 sets x 3 reps dart throwing both with dominant and non-dominant arms) twice a day for ten days, before the baseline values were taken. At the first day of the study, anthropometric and body composition measurements were taken and then blood samples were collected from each athlete to set the baseline creatine kinase (CK) values. Later, muscle soreness of upper arms was determined by visual analogue scale and target shooting tests were completed as pre-test. After the participants completed muscle damaging exercise protocol, determination of muscle soreness and target shooting tests were repeated immediately at 5th minute. Afterwards, blood sampling, muscle soreness assessment and target shooting tests were repeated at 24th, 48th, 72nd, 96th and 120th hours following exercise. All measurements were taken in Abant Izzet Baysal University, Sport and Exercise Physiology Laboratory at 22-24^{o}C temperature, between 14:00-17:00 hours. Participants were asked to not to do any physical activity during last 24 hours before the test and were asked to come to tests with full rest. Also, they were asked to eat at least 2 hours before tests and were allowed to drink only water between test and last meal. Experimental design of the study was shown in table 1.

Table 1. Experimental Design of The Study.

Pre-Test (Baseline)	Exercise Protocol	Post-Exercise					
		5th min	24th hour	48th hour	72nd hour	96th hour	120th hour
CK - Blood sampling	2 sets x 25 repetitions Maximum Eccentric Contraction	-	CK - Blood sampling	CK - Blood sampling	CK - Blood sampling	CK - Blood sampling	CK - Blood sampling
Muscle soreness assessment		Muscle soreness assessment	Muscle soreness assessment	Muscle soreness assessment	Muscle soreness assessment	Muscle soreness assessment	Muscle soreness assessment
10 sets x 3 reps. dart throwing		10 sets x 3 reps. dart throwing	10 sets x 3 reps. dart throwing	10 sets x 3 reps. dart throwing	10 sets x 3 reps. dart throwing	10 sets x 3 reps. dart throwing	10 sets x 3 reps. dart throwing

2.3. Anthropometric and Body Composition Measurements

Stature was measured to the nearest 0.1cm via a Stadiometer (Seca 700, Germany). Body mass (± 0.1kg) and body fat percentage were assessed by using foot to foot bioelectrical impedance analyser (BIA) (TanitaBC-418 MA; Tanita Corp., Japan). Participants were asked to remove all clothing, shoes, jewellers and other accessories except a light shorts for the BIA measurement. BIA measurements were performed in accordance with the manufacturer’s specified procedures.

2.4. Blood Sampling and CK Assessment

Blood samples were taken before the muscle damaging exercise protocol and at 24th, 48th, 72nd, 96th and 120th hours thereafter. Venous blood samples (2ml) were taken from the antecubital vein and centrifuged immediately at 3000 rpm for 10 minutes before the analysis. Serum CK was measured spectrophotometrically using CK-NAC kits (Shimadzu Spectrophotometer UV 1201V, Kyoto, Japan).

2.5. Assessment of Muscle Soreness

Visual analogue scale of a 50mm continuous line was used to assess perceived muscle soreness. The beginning of the line represents “no muscle soreness” and the end represents “too sore”. The distance between the beginning (no muscle soreness point) and the point where the participant marked a line was used as muscle soreness level. Pain was rated by the participant when the researcher palpated over the biceps muscle, while flexed and extended position of the elbow joint. The application of this measurement was done by the same experienced researcher. This technique was created as a useful method for assessing pain (Revill et al., 1976) and used successfully in previous studies (Nosaka & Newton, 2002; Lavender & Nosaka, 2008).

2.6. Target Shooting Test

Dart throwing game set up was used for target shooting test. The size of the target was same as a standard dartboard and composed of a nested 9 rings centred with a bull's eye ring. The diameter of the centre was 5cm and the rings were lined up with 2.5cm width. The dartboard was hung so that the bull’s eye was173cm from the floor and the line (oche) behind which the throwing participant must stand was237cm from the face of the dartboard measured horizontally. Participants could get 9, 8, 7, 6, 5, 4, 3, 2 or 1 point, according to the accuracy of the throws. The application set up of the test is shown in figure 1. Each participant performed 10 sets of 3 repetitions dart throwing with dominant and non-dominant arms, separately. Missing shoots were not repeated. Means of 30 throwing scores was used in statistical analysis. In order to keep concentration, target shooting tests were done in an isolated environment away from the other participants.

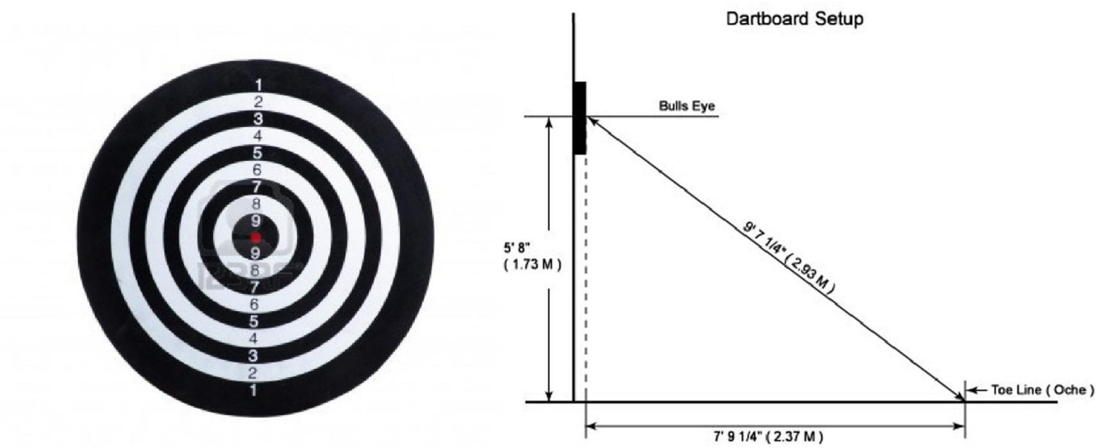

Figure 1: Target Shooting Setup Dimensions

2.7. Muscle Damaging Exercise Protocol

After a standard warm up, participants underwent a high-force eccentric exercise protocol of the forearm flexors on a preacher curl machine. The exercise protocol was consisted of 2 sets of 25 repetitions totally 50 maximal eccentric contractions, with each repetition lasting 5 seconds. Resting intervals between repetitions and sets were 15 seconds and 5 minutes, respectively. The investigator provided resistance manually by pulling downward on a lever arm attached to the preacher bench machine. Subjects resisted the downward force by pulling upward maximally on each repetition; thus each subject produced his maximal voluntary force on each repetition. After each repetition the investigator returns the machine lever arm to the starting position. Thus, only the eccentric contraction is realized without the concentric contraction. This protocol has been used before successfully by Rawson et al. (2001).

2.8. Statistical Analysis

First, mean and standard deviations were calculated for all variables. Repeated measures ANOVA were used for the determination of the difference between consecutive measurements taken before and after muscle damaging exercise protocol. Bonferroni and LSD (Least Significant Difference) tests were defined as post hoc test for pair wise comparison between baseline measurement and post-exercise measurements. Friedman and Wilcoxon Signed Rank tests were used in non-parametric situations. The significance level was accepted as p≤0.05 and all analyses were performed on SPSS version 16.0.

3. Results

The changes on serum CK activity, muscle soreness and target shooting performance at baseline, 5th minute 24th, 48th, 72nd, 96th and 120th hour are presented in table 2.

Table 2. CK, muscle soreness and target shooting scores at pre (baseline) and post muscle damaging exercise protocol. Data are means (±SD)

Variables		Baseline	5th min	24th hr	48th hr	72nd hr	96th hr	120th hr
CK (IU/L)		111.91 (13.20)	-	445.73* (205.60)	535.36* (171.59)	279.36* (72.51)	186.45* (19.17)	118.36* (11.43)
Muscle Soreness (mm)	Dom	1.91 (2.91)	5.10* (4.28)	7.27* (4.47)	9.54* (6.41)	7.27* (6.97)	4.45 (4.78)	2.18 (2.09)
	Non-dom	2.10 (2.21)	5.73* (6.31)	8.55* (6.65)	9.64* (6.23)	9.18* (10.06)	6.91 (9.47)	3.82 (4.04)
Target Shooting Scores (Point)	Dom	7.11 (0.48)	6.34* (0.43)	6.79* (0.50)	6.64* (0.59)	6.62* (0.51)	6.65* (0.45)	6.78 (0.60)
	Non-dom	6.03 (0.52)	5.09* (0.76)	5.53* (0.40)	5.55* (0.50)	5.07* (0.85)	5.52* (0.78)	5.64 (0.63)

* Significantly different than baseline.

3.1. Serum CK Level

Results of repeated measures ANOVA on the serum CK activity showed statistically significant main effect for time [$F_{(5-50)}$= 40.028, p<0.01]. Post-exercise values were significantly (p<0.05) higher than the baseline serum CK value (mean±SD= 111.91±13.20 IU/L) (Table 2). CK values started to increase following muscle damaging exercise and peaked at 48th hour. Along with 72nd hour decline has started, but even at the end of the 120th hour still it did not return to baseline value. This situation was shown graphically in figure 2.

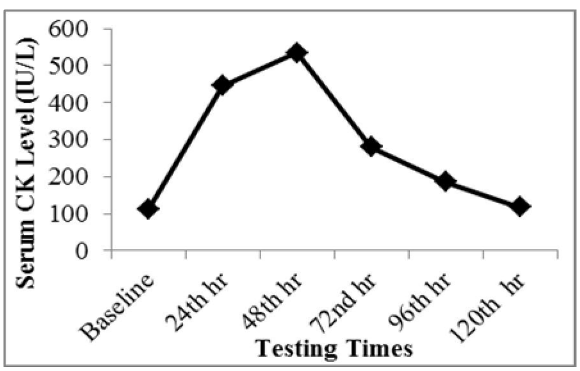

Figure 2. Changes in serum CK level immediately before and for 5 days following muscle damage exercise protocol

3.2. Muscle Soreness

Friedman test showed significant main effect for time regarding to muscle soreness level, for both dominant (p<0.01) and non-dominant (p<0.01) arms. Muscle soreness levels were significantly high, following exercise protocol at 5th minute, 24th, 48th and 72nd hours, compared to baseline values for both arms (Figure 3).

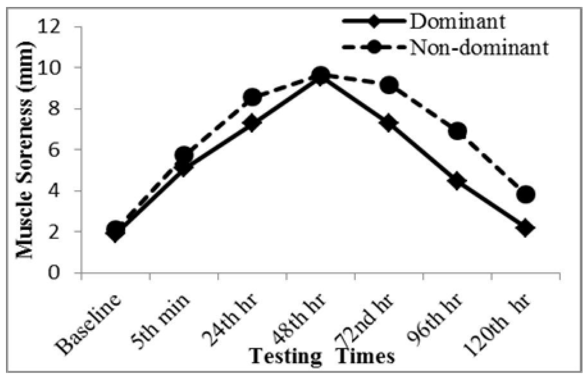

Figure 3. Changes in muscle soreness level immediately before and for 5 days following muscle damage exercise protocol

3.3. Target Shooting Performance

According to repeated measures ANOVA, there was significant main effect for time regarding to dominant [$F_{(6-60)}$= 3.271, p<0.01] and non-dominant [$F_{(6-60)}$= 3.136, p<0.01] arm target shooting performance. In accordance with baseline values mean target shooting scores of both dominant and non-dominant arms declined significantly at 5th minute, 24th, 48th, 72nd and 96th hours after the exercise protocol (Table 2). As shown in figure 4, dramatic decrease was observed at 5th minute immediately after muscle damaging exercise. After the 5th minute, shooting scores were started to increase and complete return to baseline was seen at 120th hour.

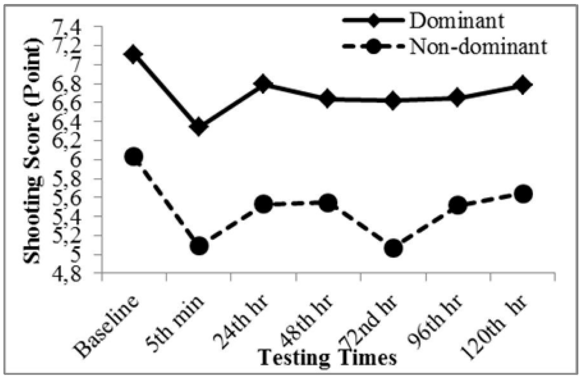

Figure 4. Changes in target shooting scores immediately before and for 5 days following muscle damage exercise protocol

4. Discussions

In this study, the impact of exercise induced muscle damage on target shooting performance was investigated to make contribution to the process of creating work out prescription and planning the training and competition periods by considering the exercises which can generate muscle damage. The main finding of this study was the existence of the impact of muscle damage on target shooting performance. It was found that muscle damaging exercises will lead to decrease in shooting accuracy in parallel of the increase of serum CK activity and muscle soreness. In this section the impact of exercise induced muscle damage on target shooting performance will be discussed and interpreted.

Muscle damage could be determined directly by muscle biopsy or magnetic resonance imaging; or indirectly by degradation of muscle power, increase of edema and muscle soreness, changes of serum levels of muscle enzymes (CK, LDH, AST etc.) and increase of some inflammation indicators (Harbili et al., 2008). In the present study, exercise induced muscle damage was assessed indirectly both by serum CK activity (Chen & Nosaka, 2006; Chen et al., 2011; Nosaka & Newton, 2002; Rawson et al., 2001) and perceived muscle soreness level (Lavender & Nosaka, 2008; Nosaka & Newton, 2002). The results of the present study showed that the participants' serum CK activity (at 24th, 48th, 72nd, 96th and 120th hours) and perceived muscle soreness levels (at 5th minute, 24th, 48th and 72ndhours) following the eccentric exercise induced muscle damaging protocol were significantly higher than the baseline values. Increase in the serum CK activity and perceived muscle soreness, following exercises including maximal eccentric contractions of elbow flexion muscles, was the indicator of the effectiveness of the muscle damaging exercise protocol. As it is presented in figure 2, following the exercise protocol serum CK level of participants showed gradual increase and peaked at 48th hour. Then, in the following time periods, it started to decline, however, at the last measurement (120th hour) significant difference was still present and the serum CK activity did not return completely to the baseline. Perceived muscle soreness data showed similar reaction to the muscle damaging exercise like serum CK activity. Soreness level of participants showed gradual increase and peaked at 48th hour for both arms. After 48th hour, it started to decrease and complete return to baseline was seen at 96th hour (Figure 3). Parallel to the results of the present study, Chen et al. (2011), Chen & Nosaka (2006), Lavender & Nosaka (2006; 2008), and Nosaka & Newton (2002) reported significant increase in serum CK activity and muscle soreness, after similar upper arm eccentric exercise protocols as in this present study.

Results of the present study demonstrated that target shooting scores obtained following upper arm eccentric exercise protocol (at 5th minute, 24th, 48th, 72nd and 96th hours) were lower than baseline scores for both arms. Following the eccentric exercise; %10.8, %4.5, %6.6, %6.9 and %6.5 decline for dominant arm and %15.6, %8.3, %8.0, %15.9 and %8.46 decline for non-dominant arm was identified in target shooting scores respectively at 5th minute, 24th, 48th, 72nd and 96th hours compared to baseline value. Significant difference has disappeared at 120th hour in the last measurement time. These changes were graphically shown in figure 4. In the literature, there is no reported previous study on investigating the impact of eccentric exercise induced muscle damage specifically created by upper arm on target shooting performance. By the way, there is only one study conducted on the effect of muscle damage to skill performance (Draganidis et al., 2013). Different than the present study, the participants of this study were highly active athletes (soccer players), the skill tests were soccer based and generated mainly towards measurement of leg skills. Similar to the present study, the results of this study stated significant decline in passing and shooting performance immediately after the resistance exercise compared to baseline values. However, different than the results of the present study the comeback of the passing and shooting performance in the study of Draganidis et al., (2013) was faster. In this study, compared to baseline values, significant difference has disappeared at 24th hour. However, as mentioned before, the complete return of the target shooting performance in the present study was seen at 120th hour. Possible explanation for this difference could be the dissimilar content of the muscle damaging exercise and the characteristics of the participants and skill tests. The effectiveness of the muscle damaging exercise protocol of the present study was proven before by various studies (Rawson et al., 2001; Nosaka & Newton, 2002). On the other hand, the exercise protocol of the study of Draganidis et al., (2013) was a standard strength training work out probably with limited eccentric component. In addition to this, the participants of their study were highly active elite soccer players probably familiar to strength training work outs because of their training regimen. However, it is known that the formation of exercise induced muscle damage is mainly a common situation following high intensity unaccustomed exercises including eccentric contractions (Hazar, 2004; Twist & Eston, 2007; Highton et al., 2009).

5. Conclusion

It could be concluded that target shooting performance is sensitive to the negative effects of muscle damage. Since, similar changes were shown in serum CK activity, muscle soreness and target shooting performance within time, following muscle damaging exercise. So, the respondents should be careful while adding unaccustomed exercises including intense eccentric contractions during the process of training planning, in sports which target shooting skills are important features, such as archery, tennis, basketball and volleyball.

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