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## Original Article

# Effects of bilateral or unilateral lower body resistance exercises on markers of skeletal muscle damage

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## ABSTRACT

**Background:** It is known that different intensity exercises create skeletal muscle damage at different levels. The purpose of the study was to compare effects of bilateral or unilateral lower body resistance exercise on markers of skeletal muscle damage.

**Methods:** The Brzycki Formula was used to calculate participants' one repetition maximum strength for each movement and limb, separately. Blood samples were obtained before exercise, immediately after exercise, and 30 min after exercise for both types of exercise. Creatine Kinase (CK), Lactate Dehydrogenase (LDH), Aspartate Aminotransferase (AST), and Alanine Aminotransferase (ALT) levels were analyzed. Data was analyzed using two-way repeated measures ANOVA.

**Results:** When CK, AST, and ALT levels were compared according to time points, a statistical difference was found ( $p < 0.05$ ). Furthermore, it was revealed that LDH levels were statistically significant according to exercise types ( $p < 0.05$ ).

**Conclusion:** Unilateral lower body resistance exercise caused higher skeletal muscle damage than the bilateral lower body resistance exercise. This result suggests that unilateral lower body resistance exercise should be preferred for short preparation period as opposed to bilateral lower body resistance exercise.

Resistance exercises are widely practiced among athletes to improve performance [1]. Some of the resistance exercises variables for specific performance outcomes are: muscle action type (e.g., concentric vs eccentric), load magnitude, volume load (i.e., sets  $\times$  reps  $\times$  load), exercise selection, order, rest periods, repetition velocity, and training frequency [2]. Proper resistance exercises prescription ensure for optimal hormonal and metabolic responses [3]. Resistance exercises involve improvement in strength, power, hypertrophy, and

local muscular endurance [4]. There are many different types of resistance exercises. Bilateral variants are among the more commonly employed types of resistance exercises [5]. Bilateral exercises are performed simultaneously with two limbs of the body, whereas unilateral exercises are performed with only one limb of the body.

Unilateral resistance exercises can lead to different reactions as compared to bilateral resistance exercises. Unilateral resistance exercises activated and strengthened deep

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**At a glance of commentary****Scientific background on the subject**

Athletes use different resistance exercise protocols to increase their muscle mass and/or strength. Recently, unilateral resistance exercises are preferred by athletes to provide hypertrophy in a shorter time. Detecting the differences between unilateral and bilateral resistance exercise's skeletal muscle damage markers may reply the athletes' choice reason.

**What this study adds to the field**

Many athletes prefer unilateral exercises to provide for the recovery during the rehabilitation process and hypertrophy in the resistance training. Demonstrating biochemical differences in the organism of bilateral and unilateral exercises at the same load may help them to choose between exercise types.

muscle groups in the trunk and hip regions. Additionally, they influenced the activation of motor unit which can increase the stability for the leg muscle groups. Moreover, more load and intensive exercises are performed with more active functioning of the hip joint muscles in the single leg squat movement [6]. Exercises cause muscle damage to the organism at different levels. Exercise-induced muscle damage (EIMD) is a common occurrence following activities with high eccentric components such as plyometric training, distance and long-term running, intermittent shuttle run, and resistance exercises [7]. Moreover, depending on the changes to be made in the program of resistance exercises, different levels of muscle damage may occur in the organism.

In clinical situations, Creatine Kinase (CK), Lactate Dehydrogenase (LDH), Aspartate Aminotransferase (AST), and Alanine Aminotransferase (ALT) are widely used in the diagnosis of skeletal muscle injury and tissue damage in skeletal muscles [8]. The most important indicator of muscle damage is CK level. On the other hand, LDH level is considered as a specific indicator of muscle fatigue. A cytoplasmic and mitochondrial enzyme, AST may increase in blood in a wide range of clinical disorders. In contrast, increased level of ALT in blood reported to be a specific marker of liver damage [9]. In an exercise exceeding the limit that the muscle can lift; CK leaks out of the cell into the extracellular fluid, goes to the lymph system, and lastly into the bloodstream [10]. One of the most valid and reliable methods for evaluating EIMD is to control the increase of CK levels in blood [11]. Furthermore, observing CK and LDH levels in blood demonstrate the degree of metabolic adaptation of skeletal muscles to physical exercises [12]. Both enzyme levels are found in muscle metabolism, and both have relatively low intensities. Their values are highly risen in blood following an intensive exercise [13]. For this reason, it is important for the coaches to know the biochemical and hormonal responses to unilateral or bilateral resistance exercises.

Performance athletes in many branches work to improve muscle mass and strength during short preparation periods (2–4 week), especially. The athletes can prefer the unilateral resistance exercises, which is an alternative exercise to

improve lower body muscle strength for short preparation periods. To better understand the effects of unilateral and bilateral resistance exercises, as adaptive stimuli, it would be informative to determine the difference both exercise types. Generally, there is a difference in total load between the both exercise types. This difference can be defined as bilateral index. The bilateral index used for interpreting the bilateral deficit and facilitation. The bilateral deficit is a recognized phenomenon that occurs when the maximum voluntary strength of a simultaneous bilateral contraction is less than the sum of the strength of the right and left limbs when contracting alone. The opposite situation is also defined bilateral facilitation. Botton et al. [14] have reported that the bilateral deficit has also been observed in situations involving the lower and upper limbs, small and large muscle groups, and during exercise of maximal and submaximal intensities. The exact mechanism underpinning this phenomenon is unclear. For this reason, many athletes think that unilateral lower body resistance exercises will cause faster hypertrophy and/or muscle strength.

There are limited studies investigating the metabolic responses of bilateral and unilateral lower body resistance exercises in the literature [15,16] and there is no research comparing bilateral and unilateral lower body resistance exercises on the Turkish population. In this context, the aim of this study has been to detect the effect of bilateral and unilateral lower body resistance exercises on markers of skeletal muscle damage in blood. The hypotheses of the study are given below;

- a) Unilateral resistance exercises cause lower skeletal muscle damage as compared to bilateral resistance exercises.
- b) Unilateral resistance exercises cause lower fatigue in contrast to bilateral resistance exercises.
- c) Unilateral resistance exercises cause lower liver damage as compared to bilateral resistance exercises.

**Methods****Participants**

Fourteen healthy male athletes (age:  $21.58 \pm 3.33$ , weight:  $82.84 \pm 12.25$  kg, height:  $178.83 \pm 7.23$  cm) who had resistance exercises experiences voluntarily participated in the current research. They were not active in professional sports in the last two years. Athletes using ergogenic aids were not included in the study. Also, 72 h before the measurements, the athletes were asked not to use any anti-inflammatory drugs or to inform the researchers if consumed. Since one of the four participating athletes had used anti-inflammatory drug during the second measurements and the other three athletes were above the reference range of pre-exercise CK levels, they were not included in the study. This research was completed with 10 healthy men. The study was conducted in accordance with the guidelines of the revised Helsinki Declaration and the ethical approval with the protocol number of 2017/179 from the Faculty of Medicine, Afyon Kocatepe University.

### Experimental design

This study was a single cohort repeated measures design. In the study, the first step was familiarization session. For unilateral exercises, individual one repetition maximum (1 RM) for each movement was recorded separately for both the right and left legs at familiarization session. For bilateral exercises, individual 1 RM for each movement was recorded at familiarization session, separately. The second step was the determination of 1 RM according to Brzycki's (1993) multi-test coefficient for both types of exercise [17]. The third step was the unilateral lower body resistance exercises. The fourth step was the bilateral lower body resistance exercises. All steps were carried out with a week interval. Also, all exercises were performed at the same days and hours in a week. Olympic Leg Press, Leg Extension, Leg Curl, and Smith Machine Calf Raise were used in the study as lower body resistance exercises. Participants performed all the movements for both exercises according to the protocols and under guidance provided by the fitness professionals.

The unilateral lower body resistance exercises protocol consisted of 3 sets of 10 repetitions at 75% of the 1 RM intensity for both right and left legs without resting between the limbs with a 2-minute rest interval between exercises and sets. The same protocol was performed for the bilateral lower body resistance exercises [2].

### Experimental protocol

For bilateral and unilateral lower body resistance exercises, before exercise, immediately after exercise and 30 min after exercise, 5 cc blood was taken from the antecubital forearm vein of the dominant arm and centrifuged. The bilateral index was calculated using an equation by Botton et al. [14].

Bilateral Index

$$= \left[ 100 \times \left( \frac{\text{Total load of bilateral exercise}}{\text{Total load of (right limb + left limb)}} \right) \right] - 100$$

### Biochemical analysis

Blood samples were collected in a heparinized tube and centrifuged at 3000 rpm for 10 min using a Nuve NF-400 model centrifuge. The plasma samples were placed in Eppendorf tubes and dry ice was used during the transfer of the samples to the laboratory. The plasma samples were stored at  $-85^{\circ}\text{C}$  and solubilized at room temperature for 1 h on the day of analysis. For assay of EIMD; CK, LDH, AST and ALT levels were obtained from plasma samples via Roche Cobas C501 model biochemical autoanalyzer using Roche kits by a biochemistry specialist in a biochemical laboratory. Upper limits in blood for CK, LDH, AST and ALT are 190, 225, 40, and 40 Unit/Liter (U/L), respectively.

### Statistical analysis

Statistical analysis of the data was performed with the IBM SPSS Statistics 22.0 package program. All data are normally distributed according to Shapiro Wilk Test ( $p > 0.05$ ). Individual percent changes are calculated, especially since the

**Table 1 Comparison of CK values according to different exercise types and percent difference between time points.**

Variables	N	Immediately after exercise (U/L)	30 min after exercise (U/L)	F	p
		$\bar{X} \pm \text{SD}$	$\bar{X} \pm \text{SD}$		
Bilateral ( $\Delta$ %)	10	10.83 $\pm$ 7.67	20.67 $\pm$ 12.29	0.325	0.381
Unilateral ( $\Delta$ %)	10	18.15 $\pm$ 15.13	28.33 $\pm$ 35.60		
Total ( $\Delta$ %)		14.49 $\pm$ 12.27	24.50 $\pm$ 26.21		
F = 6.404; p = 0.021					

reference ranges for CK and LDH are wide. Analyses were performed on percent scores. The percent difference between time points was calculated using the formula  $\Delta \% = [(\text{Pretest} - \text{Posttest})/\text{Pretest}] \times 100$  [18]. The two-way repeated measures variance analysis (treatments X times) was used. The level of significance was determined as  $p < 0.05$ .

### Results

The bilateral index was found to be 7.27%. Accordingly, the bilateral lower body resistance exercises load was higher than the unilateral lower body resistance exercises and this result showed the bilateral facilitation. The average load of bilateral lower body resistance exercises was 15.980 kg while the average load of unilateral lower body resistance exercises was 14.820 kg.

When Table 1 was examined, it was seen that the percent change averages of CK levels were statistically different according to measurement times ( $p < 0.05$ ). Accordingly, it was found that the CK levels between the first and second measurements showed an average increase of 14.49% and the CK levels between the second and third measurements showed an average increase of 24.50%. Moreover, it was determined that the percent change averages of CK levels were not statistically different according to the exercise types ( $p > 0.05$ ). Furthermore, the interaction between the CK levels of the exercise types and percent changes between time points was not statistically significant ( $F = 0.002$ ;  $p = 0.966$ ).

In Table 2, it was revealed that the percent change averages of LDH levels were not statistically different according to measurement times ( $p > 0.05$ ). It was also found that the percent change of LDH levels were statistically different according to the exercise types ( $p < 0.05$ ). Accordingly, the mean percent changes of LDH in bilateral lower body resistance exercises were (11.96%) higher than the mean percent changes of LDH in unilateral lower body resistance exercises (3.96%). Furthermore, the interaction between the LDH levels of the exercise types and percent changes between time points was not statistically significant ( $F = 1.560$ ;  $p = 0.228$ ).

When Table 3 was examined, it was observed that the percent change averages of AST levels were statistically different according to measurement times ( $p < 0.001$ ). Accordingly, it was found that the AST levels increased by a mean of 12.85% between the first and second measurements, and the AST levels decreased by a mean of 8.46% between the



**Table 2 Comparison of LDH values according to different exercise types and percent difference between time points.**

Variables	N	Immediately after exercise (U/L)	30 min after exercise (U/L)	Total	F	p
		$\bar{X} \pm SD$	$\bar{X} \pm SD$	$\bar{X} \pm SD$		
Bilateral ( $\Delta$ %)	10	11.99 $\pm$ 7.20	11.73 $\pm$ 6.68	11.86 $\pm$ 2.52	6.052	0.040
Unilateral ( $\Delta$ %)	10	6.46 $\pm$ 10.52	1.46 $\pm$ 10.91	3.96 $\pm$ 2.52		
F = 1.924; p = 0.182						

**Table 3 Comparison of AST values according to different exercise types and percent difference between time points.**

Variables	N	Immediately after exercise (U/L)	30 min after exercise (U/L)	F	p
		$\bar{X} \pm SD$	$\bar{X} \pm SD$		
Bilateral ( $\Delta$ %)	10	15.91 $\pm$ 6.13	-12.05 $\pm$ 5.32	6.393	0.759
Unilateral ( $\Delta$ %)	10	9.79 $\pm$ 5.28	-4.86 $\pm$ 6.71		
Total ( $\Delta$ %)		12.85 $\pm$ 6.39	-8.46 $\pm$ 6.96	F = 115.875; p = 0.001	

**Table 4 Comparison of ALT values according to different exercise types and percent change in measurement times.**

Variables	N	Immediately after exercise (U/L)	30 min after exercise (U/L)	F	p
		$\bar{X} \pm SD$	$\bar{X} \pm SD$		
Bilateral ( $\Delta$ %)	10	32.77 $\pm$ 23.77	-25.68 $\pm$ 10.18	0.580	0.289
Unilateral ( $\Delta$ %)	10	11.12 $\pm$ 6.90	-12.34 $\pm$ 8.34		
Total ( $\Delta$ %)		21.94 $\pm$ 20.33	-19.01 $\pm$ 11.35	F = 67.492; p = 0.001	

second and third measurements. It was also detected that the percent change averages of AST levels were not statistically different according to the exercise types ( $p > 0.05$ ). Furthermore, the interaction between the AST levels of the exercise types and percent changes between time points was statistically significant ( $F = 11.308$ ;  $p = 0.003$ ). Accordingly, it was determined that a fluctuation of 27% was observed in AST measurements of bilateral lower body resistance exercises.

The percent change averages of ALT levels were statistically different according to measurement times ( $p < 0.001$ ). It was found that the mean ALT levels increased by 21.94% between the first and the second measurement and the mean ALT values decreased by 19.01% between the second and the third measurement. Moreover, it was also observed that the percent change averages of ALT levels were not statistically different according to the exercise types ( $p > 0.05$ ). Furthermore, the interaction between the ALT levels of the exercise types and percent changes between time points was statistically significant ( $F = 12.312$ ,  $p = 0.003$ ). Accordingly, it was determined that a fluctuation of 58% was observed in ALT measurements of bilateral lower body resistance exercises [Table 4].

## Discussion

The primary purpose of the current study was to assess levels of skeletal muscle damage markers in both exercise types. According to the results of current study, there was no statistical difference between CK levels when compared with bilateral and unilateral lower body resistance exercises. Moreover; CK measurements were statistically different according to measurement times. Accordingly, exercise-induced CK levels were increased by 14.49% and followed by an increase of 24.50% 30 min after exercise.

McCurdy et al. [19] reported that bilateral and unilateral lower body resistance exercises were equally effective in improving leg strength and power in untrained men and women. In contrast, Behm et al. [20] reported unilateral shoulder press produced greater activation of the back stabilizers, and unilateral chest press resulted in higher activation of all trunk stabilizers when compared with bilateral presses. Moreover, if the exercises are performed unilaterally, resistance exercises for the limbs may also cause the strengthening of the trunk. This result suggests that more muscle groups will include in activation for stabilization when unilateral exercises are performed. Vandervoort et al. [21] reported that the extent of motor unit activation of bilateral resistance exercises decreased relative to unilateral resistance exercises. Thus, more CK release will occur in the organism during unilateral exercises. However, there is no statistical difference in CK levels between unilateral and bilateral resistance exercises in our study. It means that skeletal muscle damages are equally in both exercise types.

There was no statistical difference according to time points of exercise types. However, there was statistical difference in LDH levels between bilateral and unilateral lower body resistance exercises. According to this result, bilateral lower body resistance exercises-induced LDH levels increased by 11.86% while unilateral lower body resistance exercises-induced LDH levels increased by 3.96%. This indicates that unilateral lower body resistance exercises is less fatigue than bilateral lower body resistance exercises.

There was no statistical difference in AST and ALT levels between bilateral and unilateral lower body resistance exercises types. Furthermore; it was detected that there was statistical difference according to time points of exercise types. Accordingly, exercise-induced AST levels increased by 12.85% and followed by a decrease of 8.46% 30 min after exercise. The ALT levels increased 21.94% from the exercise and followed by a decrease of 19.01% 30 min after exercise. Accordingly, it was revealed that the bilateral lower body resistance exercises-induced had a fluctuation of 28% and 58% in AST and ALT measurements, respectively. Also, the



unilateral lower body resistance exercises-induced had a fluctuation of 14% and 23% in AST and ALT measurements, respectively. This results mean that liver damage is equally in both exercise types.

## Conclusion

Skeletal muscle and liver damage markers were equal in both exercise types. Additionally, the bilateral lower body resistance exercises may cause more fatigue than the unilateral lower body resistance exercises. For this reason, bilateral lower body resistance exercises may extend the recovery times of the athletes.

Also in rehabilitation approaches, single-arm and/or leg (unilateral) exercise protocols can be used where the other arm and/or leg is not functional or used as a control. This allows the athlete to continue exercises and the performance losses are minimized during the rehabilitation process.

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## Conflicts of interest

The authors have no conflicts of interest relevant to this article.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.bj.2018.10.003>.

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