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MUSCLE INJURY RESPONSE OF TWO DIFFERENT ECCENTRIC HAMSTRING EXERCISES

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Abstract. **Aim:** This study was aimed to examine the effect of two different eccentric hamstring exercises on muscle damage in male soccer players. **Materials and methods.** Subjects were randomly divided into two groups, one group doing nordic hamstring exercise (NHE) and the other doing sliding leg curl (SLC). Lactate values were measured at the end of each test. After the first day test, the same test protocol was applied on the second exercise day with a 5-day break. Blood samples were taken from the subjects before and at the 3rd, 24th and 48th hours after exercise. The t test was used for comparisons between and within groups. **Results.** When the muscle damage responses were examined, it was seen that there was no statistically significant difference in creatine kinase (CK) and aspartate aminotransferase (AST) values between the groups. When the muscle enzyme pre-test values of the NHE group were compared at the 3rd, 24th and 48th hours after exercise, a significant difference was found in the CK values at the 3rd and 48th hours after exercise ($p < 0.05$). There was a significant difference between CK and lactate dehydrogenase (LDH) pre-test and 48th hour values in the SLC group ($p < 0.05$). There was no significant difference between all AST and LDH values ($p > 0.05$). **Conclusion.** The results of the current study indicate that muscle enzyme values continue to increase at 3, 24 and 48 hours after exercise. It was observed that SLC exercises cause more muscle damage in soccer players than NHE.

Keywords: creatine kinase, nordic hamstring, slide board, eccentric exercise

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ОЦЕНКА МЫШЕЧНОГО ОТВЕТА НА ДВА РАЗЛИЧНЫХ ЭКСЦЕНТРИЧЕСКИХ УПРАЖНЕНИЯ У ФУТБОЛИСТОВ

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Аннотация. **Цель:** изучение мышечного ответа на два различных эксцентрических упражнения у футболистов. **Материалы и методы.** Участники исследования были случайным образом поделены на две группы: первая группа выполняла скандинавские упражнения для задней группы мышц бедра (nordic hamstring exercise, NHE), вторая группа делала сгибание ног на полу (sliding leg curl, SLC).

Концентрацию лактата измеряли в конце каждого теста. После первого дня упражнений тот же протокол использовали во второй день упражнений с 5-дневным перерывом. Образцы крови у участников исследования собирали до, а также через 3, 24 и 48 часов после тренировки. Для межгруппового и внутригруппового сравнения полученных результатов использовали t-критерий Стьюдента. **Результаты.** По результатам оценки мышечного ответа установили отсутствие статистически значимых межгрупповых различий для креатинкиназы (КК) и аспартатаминотрансферазы (АСТ). В результате сравнения исходных значений показателей мышечных ферментов в группе NHE и значений, полученных через 3, 24 и 48 часов после тренировки, статистические различия обнаружили для КК через 3 и 48 часов после тренировки (p < 0,05). В группе SLC статистические различия также обнаружили между исходными значениями КК и лактатдегидрогеназы (ЛДГ) и значениями, полученными через 48 часов после тренировки (p < 0,05). Статистических различий для значений АСТ и ЛДГ не обнаружили (p > 0,05). **Заключение.** На основании полученных результатов исследования установили, что концентрация мышечных ферментов продолжает расти через 3, 24 и 48 часов после тренировки. Обнаружено, что упражнения SLC вызывают у футболистов более выраженный мышечный ответ, чем упражнения NHE.

Ключевые слова: креатинкиназа, скандинавские упражнения, сгибания ног, эксцентрические упражнения

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Introduction. Soccer performance requires a complex interaction, technical and tactical mastery within the context of well-developed physical capacities [15, 16, 38]. The physical load of soccer matches results in post-match fatigue and is linked to a combination of various factors [40, 48]; requires a high number of explosive movements such as accelerations, decelerations, changes of direction [60], jumps as well as having a powerful eccentric action, which may result in muscle injuries [31, 40].

Hamstring muscle injury is the most prevalent injury in soccer, accounting for 12 % to 16 % of all injuries. With a recognized increase in soccer, fatigue has been suggested as a risk factor for hamstring injury [11, 37]. Multiple potential risk factors for hamstring injuries have been reported, such as age, player position, previous hamstring injury, muscle architecture, fatigue, flexibility, core stability and strength [21, 22]. As muscle damage is an important limiting factor for muscle performance during the days after intense exercise [58]. Soccer requires the generation of large eccentric forces, which have frequently been associated with muscle damage that clinically presents as muscular pain developed some days post-exercise [62].

Numerous studies have been reported with eccentric exercises used in the prevention and rehabilitation of hamstring injuries [6, 42, 46]. Eccentric exercises that work the hamstring muscle groups; these are exercises that are effective in increasing hamstring eccentric muscle strength and at the same time reducing the risk of hamstring injury [4, 11, 29]. High degrees of eccentric loadings such a major cause to muscle damage [8, 10, 30]. Delayed onset muscle soreness (DOMS) is a symptom of muscle damage that occurs after eccentric exercise. The DOMS mechanism is induced by muscle contraction, especially by exercises with an eccentric component such as being highly intensive or using high-intensity movements [31, 57], longtime isometric work [37] or sustained effort [19, 44].

Muscle damage can be detected by measuring biochemical markers such as the enzymes creatine kinase (CK), lactate dehydrogenase (LDH) or aspartate aminotransferase (AST) in serum or plasma [8, 18, 26]. It has been reported that there is a significant increase in CK up until 48hr after exercise, but that CK returned to pre-exercise levels at 72h. Significant increases in CK, reaching a peak at 24 hours, have been reported [32]. AST and LDH are other enzymes that can be affected after physical activity [41, 47, 50]. LDH has been observed that muscle enzyme values increase 2 to 10 times, especially after 12 hours of eccentric exercise, and reach the highest value in 24 hours and 48 hours [8]. AST is related to the damage in the tissues where amino transferases are high or the membrane permeability that causes this enzyme to pass to muscle enzymes [33, 47].

Eccentric hamstring strengthening exercises such as the Nordic Hamstring Exercise (NHE), Sliding Leg Curl (SLC), Romanian deadlift, and hip extension exercise become popular in preventing and rehabilitating hamstring strain. NHE, one of the eccentric exercises used as a protective exercise in many sports branches, is an effective exercise in increasing hamstring muscle strength and at the same time reducing the risk of hamstring injury [4, 20, 23]. One such exercise is the sliding leg curl (SLC) can be performed without a partner and provides an alternative to the NHC, which targets the same stretched position hip extension/knee flexion moments, but in an anterior-posterior load vector; with the direction of load front to back in comparison with back to front [54].

Although previous studies have reported that eccentric contraction causes muscle damage, to the best of our knowledge, no studies have been found showing which eccentric hamstring exercises causes more damage. Thus, the aim of this study is to investigate the muscle damage responses of two different eccentric hamstring exercises. The results of this study are expected to give trainers an idea of the muscle damage that will result from different eccentric exercises, and provide positive effects on the performance determination and post-disability rehabilitation stages of athletes during the training planning.

Materials and methods. *Participants.* Nine healthy male soccer players from Pamukkale University soccer team voluntarily participated in this study. All subjects participating in the study were informed that they should not exercise and rest until at least 48 hours before starting the exercise. Subjects with a disease who reported any lower extremity injury prior to the study were not included in the study. All the players were members of the same team and trained for two hours five days per week. The subjects were informed about the possible risks and advantages of the study and gave their informed permission to participate in this study, which was approved by the Clinical Research Ethical Committee of Pamukkale University (60116787-020/59404). This study was supported by Pamukkale University Scientific Research Projects Coordination Unit (project number is 2019SABE001).

Data Collection. *Procedures.* The study was completed during a 2-week pre-season period. Participants were randomly assigned to one of the two groups, which were the intervention groups [Nordic Hamstring Exercise (NHE) and Sliding Leg Curl (SLC)]. Before the experimental period, the anthropometric data of the soccer players were taken (body weight and height). Before each exercise, all participants completed in the 15-minute warm-up (low-intensity running, stretching). Measurements were performed on two different days. The first exercise day, blood samples were taken before both exercises, 3 hours after exercise, 24 hours and 48 hours after exercise. On the second exercise day, the same procedure was applied by changing the groups. A five-day rest was given between measurements. During the rest period, the subjects were not allowed to do any physical activity or technical and tactical training. Each exercise protocol (NHE/SLC) was applied with 4 sets/8 repetitions with 2 minutes rest between sets. Lactate values were measured 3 minutes after the end of the test with the blood taken from the earlobe. The subjects were asked not to use any drugs, supplements, and alcohol 1 day before the exercise protocol and to avoid their caffeine consumption eight hours before the exercise. During the test, the subjects were asked not to change their eating habits. All the testing measurements were conducted in Pamukkale University gymnasium, at the same time of day (9:30–11:30 a.m. ± 1) to remove the effects of circadian variation on the variables. During the testing sessions, the air temperature remained between 18° and 24° C and humanity between 41% and 46.1%.

Interventions

Nordic Hamstring Exercise (NHE)

NHE is performed on the knees of the athlete, by fixing the ankles by an assistant, and falling down slowly without disturbing the position of the upper body and contracting the hamstring muscles (Fig. 1). Bending the hands and arms during the fall, pushing the chest up after touching the ground uses it to minimize the loading in the concentric phase. Before the NHE, the subjects were given preliminary information about the test and were shown how to do the test. Exercise protocol was applied with 4 sets/8 repetitions with 2 minutes rest between sets.

Sliding Leg Curl (SLC)

Flowin® friction training slide board was used in the implementation of the SLC exercise (Fig. 2). It consists of one large friction plate and two small pads. The subject rises to the bridge position with the soles of her feet on the pads, lying on her back on the slide board, knees, hips and shoulders in a straight line. Without allowing the hip to drop, the subject's feet are slid on the slide board until the feet are straight. The soles of the feet are pulled back on the pads until they return to the bridge position so that the knees, hips, and shoulders are in a straight line. Before the slide board hamstring curl exercise, the sub-

Fig. 1. Nordic hamstring exercise

Fig. 2. Sliding leg curl exercise

jects were given preliminary information about the test and how the test would be performed was shown. Exercise protocol was applied with 4 sets/ 8 repetitions with 2 minutes rest between sets.

Blood Samples and Measurements

Blood lactate values were measured with a lactate analyzer (Lactate Squat) 5μL of blood taken from the ear lobes 3 minutes after the end of the test. Blood samples were taken from the subjects before exercise, 3 hours, 24 hours and 48 hours after exercise on both days. Total creatine kinase (CK), lactate dehydrogenase (LDH) and aspartate amino transferase (AST) values were measured by taking 5 cc of blood from antecubital forearm veins into tubes with EDTA from all subjects. Measurements were made with the Rochecobas e701 auto analyzer. The reference ranges of the Rochecobas e701 auto analyzer are for the values; 712 (U/L) on day 1, < 652 (U/L) between 2–6 days for CK < 40 (IU/L) for AST, and 135–225 (U/L) for LDH are acceptable is done.

Data Analysis. All data in this study are given as mean ± standard deviation. Shapiro Wilk analysis was used to test the normality of the data, and since the normal distribution was determined, the t-test was used in groups dependent on intra- and between-group comparisons. Data were analyzed using SPSS version 21 (SPSS Inc., Chicago, IL, USA) and the level of significant differences was set at $p < 0.05$.

Results. All the subjects completed the test protocols without any problems. Changes in the participants' CK, AST, and LDH values are shown in Figs. 3–5. Descriptive characteristics of the participants are shown in Table 1.

In Table 2 there is no significant difference between the groups in the lactate values obtained immediately after the exercise ($p > 0.05$).

In Table 3 there was no significant difference between the groups in CK and AST values before exercise ($p > 0.05$), however, it was observed that they continued to increase at the 3rd, 24th and 48th hours after exercise. Similar to CK and AST values there was no significant difference between the groups in LDH values before exercise, beside that it was observed the increase similar to CK and AST values at the 3rd and 48th hours. A statistically significant difference was found in the intergroup values of LDH after 3 and 48 hours ($p < 0.05$).

In Table 4, when the muscle enzyme pre-test values of the NHE group were compared with the values 3, 24, and 48 hours after the exercise, a significant difference was found in the CK values at 3 hours and 48 hours post-exercise ($p < 0.05$). In addition, a significant difference was found between the AST pre-test value and the value after 24 hours in this group ($p < 0.05$). There was no significant difference between all values of LDH in this group ($p > 0.05$). In the SLC group, a significant difference was found between the CK and LDH pre-test values and the value only after 48 hours ($p < 0.05$). There was no significant difference between all values of AST ($p > 0.05$).

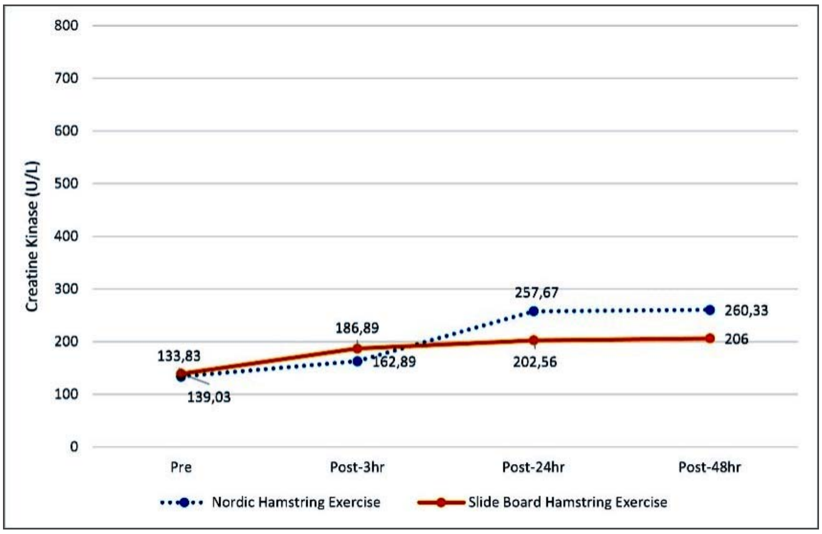

Fig. 3. Changes in participants' CK values by the time

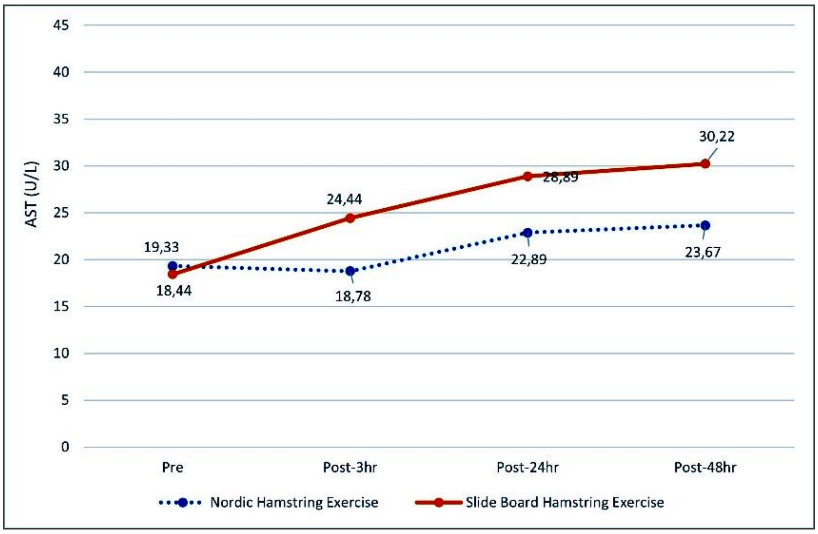

Fig. 4. Changes in participants' AST values by the time

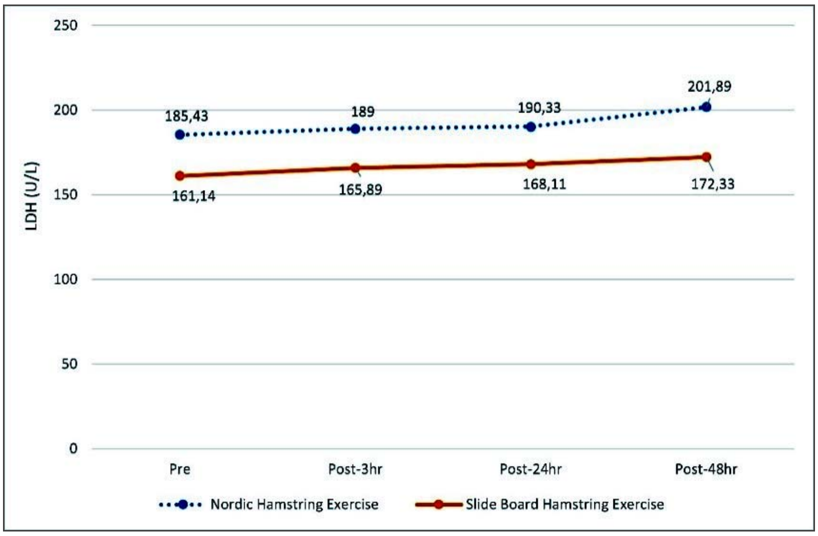

Fig. 5. Changes in participants' LDH values by the time

Table 1

Descriptive characteristics of the participants

Variables	M ± Sd	Med (min – max)
Age (years)	20.22 ± 3.80	21.00
Height (cm)	178.11 ± 4.04	177
Weight (kg)	74.33 ± 10.02	73
Training Age (years)	9.44 ± 2.4	2.07
Body Mass Index (kg/m^2)	23.36 ± 2.33	23.30

Table 2

Post-exercise lactate values

	Nordic hamstring		Slide board hamstring		p
	M ± Sd	Median	M ± Sd	Median	
Lactate (mmol/L)	2.21 ± 0.6	2.07	2.95 ± 1.26	2.8	0.066

*p < 0.05.

Table 3

Comparison of participants' muscle enzyme values between groups

	NHE				SLC				Pre	Post 3hr	Post 24hr	Post 48hr
Indicators of muscle damage	Pre M ± Sd (Med.)	Post 3hr M ± Sd (Med.)	Post 24hr M ± Sd (Med.)	Post 48hr M ± Sd (Med.)	Pre M ± Sd (Med.)	Post 3hr M ± Sd (Med.)	Post 24hr M ± Sd (Med.)	Post 48hr M ± Sd (Med.)	p	p	p	p
CK (U/L)	133.83 ± 29.30 (112)	162.89 ± 78.51 (157)	257.67 ± 264.56 (201)	260.33 ± 252.00 (160)	139.03 ± 15.59 (120)	186.89 ± 59.21 (169)	202.56 ± 103.99 (185)	206.00 ± 69.76 (190)	0.10	0.23	0.52	0.72
AST (IU/L)	19.33 ± 5.07 (18)	18.78 ± 2.28 (19)	22.89 ± 5.25 (22)	23.67 ± 3.04 (21)	18.44 ± 1.94 (19)	27.44 ± 55.75 (19)	28.89 ± 54.84 (21)	30.22 ± 2.54 (19)	0.48	0.55	0.75	0.77
LDH (U/L)	185.43 ± 11.13 (178)	189.00 ± 26.48 (186)	190.33 ± 46.36 (171)	201.89 ± 16.53 (202)	161.14 ± 26.31 (165)	165.89 ± 14.38 (168)	168.11 ± 33.69 (166)	172.33 ± 18.41 (170)	0.09	0.02*	0.12	0.02*

Note. Here and in the table 4, 5: Med.: Median, NHE: Nordic hamstring exercise, SLC: Sliding leg curl exercise, Pre: Pre-exercise, Post: Post-exercise, CK: Creatine kinase, LDH: Lactate dehydrogenase, AST: Aspartate aminotransferase, *p < 0.05.

Table 4

Comparison of participants' muscle enzyme values within groups in pre-exercise

Groups	Indicators of muscle damage	Pre M ± Sd (Med.)	Post 3hr M ± Sd (Med.)	Post 24hr M ± Sd (Med.)	Post 48hr M ± Sd (Med.)	p for Pre-Post 3hr	p for Pre-Post 24hr	p for Pre-Post 48hr
NHE (n:9)	CK (U/L)	133.22 ± 31.9 (112)	162.9 ± 78.6 (157)	257.67 ± 264.56 (201)	260.33 ± 252.00 (160)	0,03*	0.17	0.04*
	AST (IU/L)	19.33 ± 5.07 (18)	18.78 ± 2.28 (19)	22.89 ± 5.25 (22)	23.67 ± 3.04 (21)	1.00	0.04*	0.60
	LDH (U/L)	185.43 ± 11.13 (178)	189.00 ± 26.48 (186)	190.33 ± 46.36 (171)	201.89 ± 16.53 (202)	1.00	0.17	1.00
SLC (n:9)	CK (U/L)	139.03 ± 15.59 (120)	186.89 ± 59.21 (169)	202.56 ± 103.99 (169)	206.00 ± 69.76 (190)	0.06	0.22	0.02*
	AST (IU/L)	18.44 ± 1.94 (19)	27.44 ± 55.75 (19)	28.89 ± 54.84 (21)	30.22 ± 2.54 (19)	0.06	0.30	0.12
	LDH (U/L)	161.14 ± 26.31 (157)	165.89 ± 14.38 (163)	168.11 ± 33.69 (166)	172.33 ± 18.41 (170)	0.27	0.60	0.05*

Table 5

Comparison of participants' muscle enzyme values within groups in post-exercise

Groups	Indicators of muscle damage	Post 3hr M ± Sd (Med.)	Post 24hr M ± Sd (Med.)	Post 48hr M ± Sd (Med.)	Post 3hr-24hr	Post 3hr-48hr	Post 24hr-48hr
NHE (n:9)	CK (U/L)	162.89 ± 78.51 (157)	257.67 ± 264.56 (201)	260.33 ± 252.00 (160)	1.00	1.09	1.00
	AST (IU/L)	18.78 ± 2.28 (19)	22.89 ± 5.25 (22)	23.67 ± 3.04 (21)	0.01*	0.86	0.13
	LDH (U/L)	189.00 ± 26.48 (186)	190.33 ± 46.36 (171)	201.89 ± 16.53 (202)	1.00	0.27	0.02*
SLC (n:9)	CK (U/L)	186.89 ± 59.21 (169)	202.56 ± 103.99 (169)	206.00 ± 69.76 (190)	0.64	0.33	0.89
	AST (IU/L)	27.44 ± 55.75 (19)	28.89 ± 54.8 (21)	30.22 ± 2.54 (19)	0,58	0,47	0,92
	LDH (U/L)	165.89 ± 14.38 (163)	168.11 ± 33.69 (166)	172.33 ± 18.41 (170)	1.00	0.18	0.86

In within-groups comparison of muscle enzyme values in NHE; there was no significant difference in CK enzyme values all post-exercise ($p > 0.05$). AST values increased significantly at the 24th hour post-exercise compared to the 3rd hour post-exercise ($p < 0.05$). A significant difference was found in LDH values at the 48th hour post-exercise compared to the 24th hour ($p < 0.05$). In within-groups comparison of muscle enzyme values in SLC; there was no significant difference in CK enzyme, AST and LDH values ($p > 0.05$) (Table 5).

Discussion. In this study; in addition to nordic hamstring exercise, muscle damage responses of slide board hamstring curl movement with different eccentric exercises were examined. In the study, when the muscle damage responses were examined between the groups, the fact that muscle enzyme values did not differ in CK and AST values in the comparison between groups the groups at the 3rd, 24th and 48th hours after exercise before exercise. It was determined that lactate dehydrogenase (LDH) value did not show a statistically significant difference between the groups in the pre-exercise period in the comparison between the groups, but there was a statistically significant difference in the NHE group at the 3rd and 48th hours after the exercise. A training load including explosive or high intensity movements causes a decrease in strength, speed and jumping performance as well as an increase of in muscle damage markers (CK, LDH, AST, etc.) [39, 55, 57, 59].

CK and LDH are important for energy production in muscle. It has been reported that blood levels of these enzymes increase 2 or 10 times after intense training [63]. In their study, Alomar et al. [2] observed a significant increase in serum CK values at 48th and 72nd hours as a result of nordic hamstring exercise consisting of 6 sets of 12 repetitions. The results of this study are similar to the results of our study. In their study, Alexandre et al. [1] applied a plyometric training protocol consisting of eccentric contractions with high intensity and measurements were made after 24, 48 and 72 hours after exercise. As a result of these measurements, it was observed that the CK values, which started to increase immediately after the exercise, increased in the measurements after 48 hours, and a statistically significant difference was reported in the measurements after 24 hours and 48 hours.

According to LDH results in NHE group, there was a significant difference between the post 24th and post 48th hours. When the muscle enzyme pre-test values of the NHE group were compared with the values 3rd, 24th and 48th hours after the exercise, a significant difference was found in the CK values at 3rd hours and 48th hours post-exercise. In the SLC group, a significant difference was found between the CK and LDH pre-test and post 48th hours values. There was no significant difference between all values of AST and LDH.

In another study, 9 volunteer subjects had 12 eccentric maximal contractions with one arm and 100 isokinetic contractions with the non-working arm. The study was performed with an interval of two weeks, and higher creatine kinase activity was observed in the study with eccentric contraction compared to the study with isometric contraction [13]. The peak time of creatine kinase, which rises after exercise, varies depending on the intensity, type and duration of exercise. It has been reported that the CK value reaches its highest level 2 or 4 days after the exercise [45, 51]. When the literature is examined, it is seen that the CK value reaches its highest level within 1 or 5 days after exercise [7, 52].

Vincent & Vincent [61], in their study, determined that the increase in CK value reached the peak level on the 3rd and 4th days after the leg resistance training. Clarkson et al. [14], in their study, applied eccentric contraction to the leg flexors of old and young women, and their CK levels were examined. It has been reported that while CK level decreased in young women, CK level was maintained on the 5th day in older women. Clarkson et al. [13] found in their study that serum creatine kinase values increased as a result of long-term exercise and reached the highest value after 1 or 2 days. In the study conducted by Akyüz [7], it was observed that the total CK, CK-MB, CK-MM values of the subjects increased significantly between the halftime and after the match, and muscle damage occurred during the match. In the study of Güzel et al. [27] in which they had 2 different resistance exercise training with high and low intensity, it was determined that there was a significant increase in the creatine kinase value of both groups immediately after the training and this increase continued for 48 hours and returned to the level before the training after 72 hours they did. No significant difference was found between high and low intensity resistance exercises. Muscle damage is most commonly seen with microscopic tears on the sarcolemma in studies where eccentric muscle contractions are observed. As a result of microscopic ruptures, enzymes in the muscle enter the circulation. In the study conducted by Baylan [9] LDH values of all athletes were examined during the tennis tournament, regardless of group, but no significant increase was observed ($p < 0.05$). Andelkovic et al. [3] and Aquino et al. [5] in their studies on the indirect markers of muscle damage with a periodical 24-week training program in young soccer players, by emphasizing the technical tactical abilities of soccer players; They found that CK and LDH showed a great decrease in plasma activity. Wiacek et al. [62] reported that LDH and CK activity levels increased in young elite soccer players in their study on the change of physiological parameters with 12 weeks of individual training. In those who play team sports such as American football, the values 18–20 hours after the match increased by 11% compared to the pre-match LDH concentration [35]. Suzuki et al. [53] reported in their study that there was a significant increase in LDH values after the Ironman competition. In the study of Trevor et al. [56] they stated that as a result of eccentric exercise for 7 days on 22 male college students, LDH levels reached the peak level on the 4th day. When the studies in the literature are examined; it has been seen that the results of the studies looking at the chronic effect differ. In their study, Kaynar et al. [34] found that 23 volunteer athletes between the ages of 15–46 engaged in kickboxing and the ALT and AST values they applied increased statistically significantly after the training. Clarkson et al. [14] reported that when they examined LDH, CK, and ALT, AST values, which are the markers of muscle damage on the elbow flexor muscle of maximal eccentric exercise, the values increased significantly after exercise. Gabbe et al. [24] conducted a meta-analysis on the effectiveness of eccentric hamstring training on hamstring injuries in soccer and Australian football. Their study reported that eccentric hamstring training did not reduce the risk of hamstring injury.

NHE has been shown to be an effective tool for increasing eccentric hamstring strength and develops higher maximum eccentric hamstring force torques compared to normal hamstring movements [42]. Eccentric strength training interventions employing the Nordic hamstring exercise (NHE) have been shown to decrease hamstring strain rates in sport [4, 42] while low levels of Nordic eccentric strength have been reported to be associated with an increased risk of injury in some [11, 17, 25], but not all prospective studies [12, 24, 49]. Van der Horst et al. [29] conducted a randomized controlled trial to investigate the preventive effect of the NHE exercise on the incidence and severity of hamstring injuries in amateur male soccer players.

SLC provide an alternative posterior chain conditioning exercise to the nordic hamstring curls. This exercise can assist in the development of strength at the muscle lengths and under the conditions of fatigue in which hamstring injury frequently occurs, while its variations can address bilateral strength asymmetries and promote strength development at specific joint angles. The sliding leg curl (SLC), shown to generate relatively high biceps femoris and semitendinosus activity particularly during the eccentric phase, and to increase hamstring strength in a 4-week intervention study [43]. Soccer players muscle injuries, and particularly those involving the hamstring injuries, it is the most common ailment [31]. There are studies showing that NHE is compared with other exercises chosen among the exercises commonly used in post-disability rehabilitation [2, 4, 11]. In the results of this study, SLC exercises caused more muscle damage in soccer players than NHE.

There was no statistically significant difference between the lactate measurements of the NHE and SLC groups after exercise. Lactic acid continues to be produced after exercise. When taking blood measurements that may reflect metabolite accumulation in the muscle, it is important to follow a standard intermittent exercise protocol with adequate duration and minimal variation [36]. Studies emphasize that the increased blood lactate concentration is due to changes in the deformation of red blood cells after exercise [28].

Conclusion. In this study, muscle damage of NHE and SLC from eccentric exercises in soccer players responses were evaluated with muscle enzymes. Although previous studies have reported that eccentric contraction causes muscle damage, to the best of our knowledge, no studies have been found showing which eccentric hamstring exercises causes more damage. It was observed that SLC exercises caused more muscle damage in soccer players than NHE. It is thought that the use of both exercises in the training planning of the trainers and the athletes during the loading period will contribute to their evaluation of the advantages/disadvantages.

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