Research Article

Comparison the effect of TRX and traditional resistance training on responses some indices of muscle damage of soccer player

Mohsen Akbarpour Beni[1*], Ghasem Maleki[2], Zahra Samari[2]

Abstract

The purpose of this study was to compare the effect of two methods of resistance training TRX and traditional resistance on the response of some indicators of muscle damage in soccer players. The present study was a semi-experimental; therefore, 36 participants with mean age of 19/36±1/4 were voluntarily selected and assigned to two groups of TRX and traditional resistance training. The training program for both groups consisted of several joint movements, these movements in 2 sets, with 8 repetitions in to isometric form, and the duration of muscle tension in each movement was 20 seconds. Both groups were evaluated by biochemical, physical and anthropometric measurements in two stages of pre-test and post-test. Data analysis was done using independent sample t-test and paired sample t-test with the significant level of 0.05 ($p\leq0.05$). Serum creatine kinase levels showed a significant increase in traditional resistance training group 54.01% ($p=0.001$) and in the TRX training group 58.19% ($p=0.003$). Serum lactate dehydrogenase levels increased significantly as the result of traditional resistance training ($p=0.033$) while Aspartate aminotransferase did not show any significant changes from pre-test to post-test in the experimental groups. Moreover, the results of the present study showed that there was no significant difference in the changes observed in the indices of muscle damage between a traditional training and TRX training. Therefore, performing TRX or traditional training is not improving muscle injury during training.

Key Words: **Resistance training, TRX training, Muscle damage, Creatine kinase, Lactate dehydrogenase, Soccer player**

1. Association Professor, Department of Sport science, Faculty of Literature and Human Sciences, University of Qom, Qom, I.R. Iran. 2. Expert Physical Education and Sports Sciences, Department of Sport science, University of Qom, Qom, I.R. Iran.

*Author for correspondence: akbarpour.mohsen@gmail.com

M A B: 0000-0002-3565-4851; G M: 0000-0003-1883-2705; Z S: 0000-0001-9164-2145

Received 17 June 2021; Accepted 31 August 2021

Introduction

In addition to technique, tactics and mental readiness, soccer players need physical fitness. Soccer players need a lot of power due to the nature of the various explosive moves, the quick change of direction and the control of the ball against the pressure of the opponent. For this reason, resistance training today is an important part of soccer team training (Helgerud, Engen, Wisloff, & Hoff, 2001). Performing resistance training reduces injury and improves moving performance and has no adverse effect on soccer players' technique (Helgerud et al., 2007). To this purpose, various sport equipment has been designed to perform different types of resistance training, which are generally divided into three groups: resistance training with free weights, resistance training with sport equipment, and body weight resistance training (Bompa & Buzzichelli, 2015). The most important drawback of using free weights is the risk of injury resulting from improper use of weights. To reduce this risk, resistance exercises were developed with the machine based on the resistance created by a variety of mechanical machines which are more secure in the risk of injury than free weight exercises (Melrose & Dawes, 2015).

However, due to the principle of exercise specificity, the muscles involved in specific exercises and movements of sports activities cannot be performed by mechanical machines, and the performed pattern in resistance exercises is also different from the pattern of motions required to perform soccer techniques. Furthermore, considering the enhancement of ever increasing importance of physical fitness among soccer players and the increased damage caused by reduced strength and imbalance, special attention should be paid to the use of different methods of resistance training; the most prominent of which can be noted as TRX or suspended resistance exercise with body weight (Janot et al., 2013). The most important feature of this device, besides focusing on the target muscle, is disturbing the balance to the muscles of the central body for which the athlete needs help to maintain balance. The central muscles are the muscles that control the spine, abdomen, waist

, and pelvic girdle and make transfer of the force from the organs to the trunk better. Therefore, by strengthening these muscles, TRX can be expected to enhance athletic performance more than traditional resistance training (Fong et al., 2015). Therefore, TRX exercises are one of the equipment used today for a variety of purposes, which can range from general fitness for athletes to injury rehabilitation (Melrose & Dawes, 2015). On the other hand, researchers believe that exercise, especially intense exercise, causes muscle damage and plays a role in the release of various substances such as intracellular proteins and enzymes (Andring, 2006); in other words, one of the consequences of resistance training, especially in the early stages of exercise, is delayed congestion that indicates an increase in inflammatory markers (Uchida et al., 2009). Since most sport players, including soccer, use resistance training to increase their performance, which in turn, may increase the risk of injury factors by factor aggregation while playing soccer, in fact, vigorous activities such as resistance training due to high metabolic and mechanical stress cause rupture and disruption of the normal structure of muscle proteins and increase the extracellular calcium concentration (Lowe, Warren, Hayes, Farmer, & Armstrong, 1994). Muscle biopsy on the day after intense exercise indicates bleeding and disconnection of muscle filaments responsible for maintaining muscle fibers, which is the result of being worn during muscle contraction and causes muscle pain. Researchers have suggested that late muscle soreness is associated with the release of keratin kinase, lactate dehydrogenase and aspartate amino transferase enzymes and is measured by their release into the blood (Marcora & Bosio, 2007). In fact, the destruction of the muscle fibers that causes muscle pain is observed up to 72 hours after the increase in keratin kinase levels due to exercise or competition, hence keratin kinase as a primary indicator of athlete's fatigue, damage and rate of return to their original state are to be considered (Hunkin, Fahrner, & Gastin, 2014). Creatine kinase is a key enzyme that is involved in muscle cell metabolism and accelerates the process of converting creatine to phosphocreatine or vice versa. It is found in healthy individuals within the cell membrane and has been suggested as a reliable indicator of muscle membrane permeability. Thus, destruction of the Z-lines and damage to the sarcoma makes the release of soluble enzymes such as creatine kinase into interstitial water possible (Nieman et al., 2002). There is also a significant relationship between the decrease in peak muscle tension and the increase in lactic acid in the muscle. Lactate dehydrogenase (LDH) is an enzyme that is abundantly found in the cytoplasm of all body tissues at varying concentrations and in the conversion of pyruvic acid to lactic acid or vice versa in the anaerobic glycolysis pathway. LDH increases between the third to the fifth day and sometimes even to the seventh day after exercise (Nameni, Kashef, & Lari, 2004). Moreover, aspartate aminotransferase (AST) is another enzyme that is normally restr--icted to the cytoplasm of cells and is abundant in the liver. This enzyme catalyzes the transfer of the amino group of aspartate amino acid to ketoglutarate to produce oxalate and pyruvic acid, and its release into the extracellular medium occurs only with cell death, and therefore the increase in this enzyme can be considered as an indicator of cell death (Nissen et al., 1996).

Therefore, researchers have paid attention to the effects of resistance exercise on muscle injury indices considering the damages. Scheett et al. (2010) conducted a study to determine the physiological responses to TRX exercises. The findings showed that after 30-second intervals and 60-second rests, lactate values immediately increase after the activity increases to 8 minimal (Scheett, Aartun, Thomas, Herrin, & Dudgeon, 2010). Clarkson et al. (2006), in their study on 203 volunteers who performed 50 extrovert contractions of the elbow flexor maximal contraction, concluded that maximal extrovert contractions significantly increased the levels of aspartate aminotransferase and alanine aminotransferase enzymes (Clarkson, Kearns, Rouzier, Rubin, & Thompson, 2006). Atshak et al. (2012) also observed a significant increase in CK enzyme following a session of resistance exercise with 100% of a maximal repetition (Atashak & Baturak, 2012). Although resistance training improves the performance of soccer players, it cannot prevent the secretion of inflammatory and traumatic factors; hence these factors can cause acute sports injuries, which are especially important at a young age. This will be of the greatest concern where resistance training should be performed concurrently with the main soccer training, as it will increase the likelihood of injury and risk factors for injury. On the other hand, previous studies have reported muscle injury factors that cause delayed muscle soreness following resistance exercise, with intensities greater than 80% of a maximal repetition in athletes, thus, it is essential to use athletes with an appropriate intensity of exercise. Therefore, regarding the importance of using resistance training by soccer players and considering the use of TRX training, the question arises whether participating in TRX training may cause more muscle injury than traditional exercise training? Also, considering the contradictory results on the effect of resistance training on muscle injury and lack of sufficient research to compare the effect of TRX and traditional resistance training on muscle injury indices, the aim of this study was to compare the effect of TRX and traditional resistance training session and the injury indices were lactate dehydrogenase, creatine kinase, and aspartate aminotransferase in young soccer players.

Materials and Methods

Subjects

The study was a field and quasi-experimental study. The statistical population of the study consisted of 27 young men aged 18 to 21 years from Aran and Bidgol soccer club who had at least 3 years of regular training. Due to the experimental nature of the research and observing ethical issues, sampling was done voluntarily. From among the volunteer samples, subjects were selected by purposeful sampling according to the criteria of entrance to the study. The first correspondence was made with the CEO of the club, and among those who announced readiness, 36 players were selected in a way that they were as similar as possible in terms of anthropometric and physiological indices. Subjects then filled out the personal consent form and medical record and expressed their consent to participate in this research project in writing. They were then randomly divided into three equal groups of 12: TRX, traditional resistance (RT), and control groups.

Exercise training program

Subjects were summoned during a pre-test session to familiarize with training tools and resistive and traditional TRX exercise protocols, as well as to determine a maximum repetition (1RM). The maximum repetition rate for each subject was determined by the Brzeski equation. This equation is used for subsurface repeats (less than 10 repetitions). To use this test, the person repeated the displacement of a maximum weight to the point of exhaustion, and then, using the following equation, a maximum repetition was estimated for that motion (Seo et al., 2012).

[(Repeat × 0/0278) -1/0278] ÷ 1 kg shifted weight = one repetition maximum

The TRX training program was performed using TRX straps mounted at a height of 2.44 meters above the ground. A measure

Table 1: Anthropometric measurements of the study subjects.

Group / Variable	Control		RT		TRX	
	mean	Std. Deviation	mean	Std. Deviation	mean	Std. Deviation
Age (years)	19.2	1.8	18.8	1.4	20.1	1.1
Weight (kg)	67.5	7.62	69.4	8.15	67.7	7.33
Height (cm)	179.5	3.73	176.8	4.02	178.2	7.87
BMI(kg/m^2)	21.01	1.36	21.49	1.59	21.64	1.01

Table 2: Levels of CK, LD and AST in different groups of study (mean ± standard deviation)

Variable	Group	Pre-test	Post-test	* P within group	Mean change	**P between groups
Creatine kinase (dl/ng)	RT training	68.5±20.27	105.5±49.5	0.003	-37	0.739
	TRX training	70.8±16.9	112±34.9	0.001	-41.2	
	Control	68.25±17.2	70.1±18.3	0.12	-1.85	
Lactate dehydrogenase (dl/ng)	RT training	300.7±64.6	345.8±98.2	0.033	-45.1	0.087
	TRX training	271.8±107.8	272.5±81.9	0.767	-0.7	
	Control	286.3±92.1	284.9±61.7	0.685	1.4	
Aspartate aminotransferase (dl/ng)	RT training	30.9±2.97	28.8±2.8	0.270	2.1	0.859
	TRX training	24.97±2.12	26.3±1.92	0.367	-1.33	
	Control	26.7±1.12	27.7±1.74	0.296	-1	

* P value for dependent T-test result (significance level P< 0.05), **P value for ANOVA test results (significance level P<0.05).

of the perceived pressure of the exercise was used to obtain appropriate training intensity (Jakobsen, Sundstrup, Persson, Andersen, & Andersen, 2014). The goal was to achieve levels 7 to 10 of this scale in TRX exercises. The TRX training program consisted of multiple joint movements that were performed in 2 sets, with isometric repetition of 8 times. The duration of muscle tension in each movement was estimated to be 20 seconds and the total duration of exercise was 90 minutes with warming and cooling.

The traditional resistance training program consisted of single or multiple joint movements using sport equipment and free weights. In these exercises, weights were selected at 80% of a maximum repetition, with the goal of achieving 7 to 10 levels of the RPE scale. These movements were performed in 2 sets, with isometric repetition of 8 times. The rest time between each movement was 5 seconds and the rest time between each set was 20 seconds. The duration of muscle tension in each movement was estimated to be 20 seconds and the total duration of exercise was 90 minutes with warming and cooling. The movements of both groups to involve the body and parts of the body selected for this study included chest press, Langue, armpit, squat, YTM, single-leg lift, tri-arm extension, hamstring rotation, Planck and isometric torsion were lateral.

Biochemical analysis

For evaluation of biochemical variables, blood sampling was performed in two stages before exercise and immediately after exercise by radial vein. In the first step, subjects in each group were asked to do no exercise two days before the test and maintain their usual diet. Then, in sitting position and at rest, 10 cc of blood was taken from left radial vein of subjects in both groups before and after exercise. After blood sampling, serum was immediately separated by centrifugation at 4000 to 6000 rpm for 10 minutes and stored in the refrigerator for -70 ° C until the day of measurement. The samples were left in the freezer for 30 minutes at room temperature to be melted and brought to room temperature. They were then reversed 5 times until the concentration of gradient due to freezing and thawing was resolved and the concentration of the samples was uniform. CK, LDH and Aspartate aminotransferase were measured by ELISA and using ELISA Reader, Merck German production and Pars Test packaging.

Body composition

Individuals' weights were measured using a digital weighing machine with an accuracy of 0.1 kg without shoes and minimum clothing. Individuals' height was measured using a wall-height - meter with precision of 0.1 cm in stand-by-shoe-free condition beside wall while the shoulders were in normal condition and bo-dy weight was equally distributed on both legs and eyes were parallel to the horizontal surface. To measure BMI, samples' height and weight were first measured, and then, by dividing the weight by the square of the height, the body mass index of the subjects was obtained in kg / m^2.

Statistical analysis

In this research, descriptive statistics was used for analyzing mean, standard deviance, and percentage of changes; the Kolmogorov-Smirnov test was used to evaluate the normal distribution of the data and the Levin test was used to assess the homogeneity of the variances. According to the significance of the above tests, dependent t-test was used to examine group differences and one-way analysis of variance (ANOVA) using Tukey post hoc test to compare intergroup differences. Data were analyzed using SPSS19 and Excel 2010 software and the results were considered at significant level of 0.05 ($p \leq 0.05$).

Results

The characteristics of the research subjects are shown in table 1. According to the results of table 1, there was no significant difference between the age, height, weight and BMI between the study groups ($p>0.05$). Also, Kolmogorov-Smirnov test showed normal distribution of data between groups and Levin test of homogeneity of variance of the three studied groups.

According to the results of the analysis of variance with Tukey post hoc test, there was no significant difference in creatine kinase levels between the traditional and TRX resistance groups ($p>0.05$), while a significant difference was observed between the experimental and control groups. Also, the intra-group evaluation of the data showed a significant change in creatine kinase index from pre-test to post-test in traditional resistance training and TRX group. There was a 58% increase, which was significant in both traditional resistance training ($p=0.003$) and T-

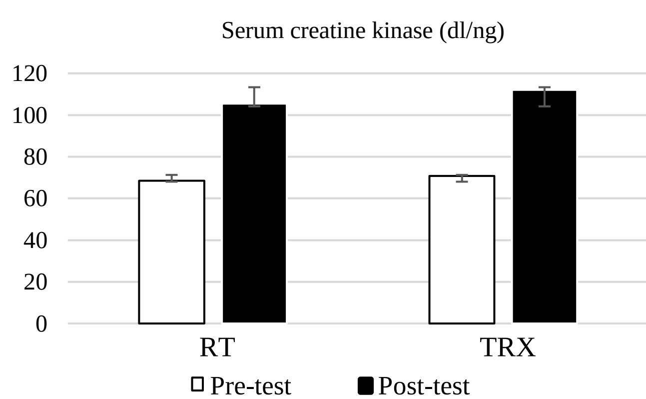

Figure 1. Comparison of the effect of RT and TRX on levels of CK. Data were show as mean±SD.

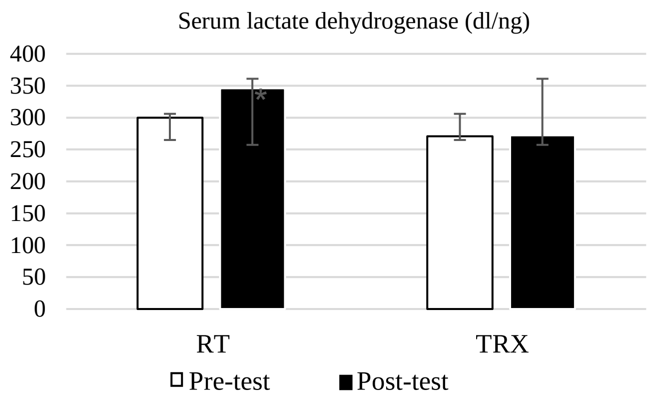

Figure 2. Comparison of the effect of RT and TRX on levels of LDH. Data were show as mean±SD.

-RX training (p=0.001) (Table 2 and Figure 1).

Also, the results of ANOVA with Tukey post hoc test showed no significant difference between the two experimental groups on the amounts of lactate dehydrogenase (p>0.05), but there was a significant difference between the experimental and control groups. And intra-group evaluation of dependent t-test showed that lactate dehydrogenase increased 14.99% in traditional resistance training group and 0.25% in TRX training group, which was significant only in traditional resistance training group (p=0.033) (Table 2 and Figure 2).

Results of inter-group comparisons of aspartate aminotransferase also showed no significant difference between the two experimental groups (p>0.05). Also, according to the intra-group evaluation, the values of aspartate aminotransferase in the traditional resistance training group decreased by 6.79% and in the TRX group increased by 5.32%; although this change was not significant (table 2 and figure 3).

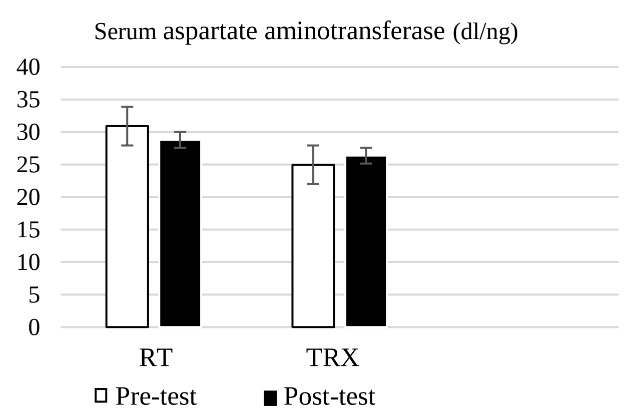

Figure 3. Comparison of the effect of RT and TRX on levels of AST. Data were show as mean±SD.

Discussion

Enzymes and Skeletal muscle serum proteins show muscle tissue efficiency condition, and increase in the amount of these enzymes can be sign of cell necrosis or tissue damage resulting from acute and serious injuries and performing exercising activities especially cardio exercises along with muscle injuries in different research. On the other hand, there is no study on different types of resistance activity. Therefore, the purpose of the present study was to compare the effect of TRX and traditional resistance training on the response of some muscle injury indices of soccer players. The results showed a significant increase in serum creatine kinase levels after cardio TRX and traditional exercise training. The results of this study were in line with the findings of Dolzal et al., as well as Pardanjani et al. (Dolezal, 1998; Pardanjani, Ebrahimi, & Changizi, 2015). Dolezal et al. (2000) examined a measure of resistance exercise on creatine kinase index as well as perceived muscle pain in 9 trained and 9 untrained men and observed creatine kinase accumulation as a result of resistance training. Pardanjani et al. (2015) also examined the effect of one session of resistance exercise on indices of muscle injury and delayed muscle fatigue in 20 male athlete students and increased serum levels of muscle injury and muscle soreness indices were reported as a result of resistance exercise with 75% of maximal repetition. However, our results were inconsistent with those of Callegari et al. (2017) who examined the response of creatine kinase to both resistance and endurance activities in trained men, and found no significant change in creatine kinase content as a result of resistance training (Callegari et al., 2017). The possible reasons for this contradiction can be related to individual differences in response to creatine kinase and individual responses of creatine kinase to the health level as well as the kind and time of physical activity. Overall, the researchers state that extreme resistance exercise due to applying more mechanical-metabolic stress on setae leads to rupture of the setae and fluid plates Z, rupture of the sarcolemma, organelles displacement of intracellular unstable plasma membrane and increased secretion of proteins after performing the resistance and intense actions. In fact, fatigue of muscle fibers which are subsequent of exhausting activities can lead to increased permeability of the cell membrane after exhaustive activity on intracellular free calcium ion and sodium-potassium pump dysfunction and activation of proteases and lipases cell membrane instability (Brancaccio, Lippi, & Maffulli, 2010). As such, there is a close relationship between the release of phospholipase and the pathogenesis from their creatine kianse coming from prophylactic enzymes within intracellular stimulated by calcium in the mammalian's disconnected muscle (Barquilha et al., 2011).

Other findings of the present study were the differences in serum CK values in the two training protocols. The results of this study are consistent with the findings of Azizbighi et al. (2015) who compared the effect of two types of resistance training protocols on antioxidant capacity and creatine kinase enzyme in 20 untrained men anddid not observed significant differences in creatine kinase levels between the two training protocols (Azizbeigi Boukani & Atashak, 2015). Although, our results were inconsistent with those of Soleimani et al. (2017) who examined changes in some of the muscle injury indices of 2 overweight active male students following aerobic and anaerobic power training and found that muscle injury in Aerobic power activity is less than anaerobic power activity (Soleimani, Shakerian, & Ruhollah, 2017). Intensity, compared to the type of exercise, appears to be a stronger factor in CK response to exercise. Since the aim of this study was to equalize the intensity of the two exercises, no difference in serum CK values is not out of the question. During and after exercise, many factors determine the level of elevated serum activity of each enzyme. Most enzyme-induced serum activity is found after long-term competitive athletic activities, such as running a marathon or triathlon. Also, weight-bearing exercises, including extravascular muscle contractions, such as running downhill, produce the largest increase in serum enzyme activity (Toft et al., 2002). Because the participants in the study were at an acceptable level of fitness and previously experienced muscle injury due to extravagant contractions in soccer practice, it is likely that for distinguishing between the TRX, traditional and resistance protocols, more intensity of these exercises is needed.

In this study, serum lactate dehydrogenase levels significantly increased only in the traditional resistance training group and the increase in serum LDH levels in the TRX group was not significant. This result is consistent with the findings of Pantoja et al. (2009) who evaluated indirect muscle injury in nine healthy men after performing three movements, bending and opening the muscles of the elbow with 10 repetition maximum, declared that creatine kinase enzyme and lactate dehydrogenase plasma showed a significant increase immediately after exercise (Pantoja, Alberton, Pilla, Vendrusculo, & Kruel, 2009). The most important mechanism justifying the increase in LDH after resistance training is that an extravascular exercise session results in a greater increase in LDH enzyme activity than an intravascular exercise session, and LDH between the third to the fifth day and sometimes even the seventh day after exercise, increases (Brancaccio et al., 2010). Alternatively, local damage to muscle tissue and fragmentation and destruction of sarcomeres due to sarcomere stretch during intense muscle activity can increase the concentration of these enzymes in the blood. Such damage can cause neutrophils to get to the site of injury and lead to respiratory bursts by the release of free radicals. This mechanism can continue for several days and cause further damage in the coming hours (Talaie et al., 2007).

On the other hand, this result is inconsistent with the findings of Shirvani et al. (2015) who investigated the effect of a karate competition course on inflammation and muscle tissue damage indices in karate soldiers and reported no significant increase in lactate dehydrogenase enzyme levels (Shirvani, Rahimi, & Rostamkhani, 2015). Also, Fatouros et al. (2010) investigating circular resistance exercises session for 30 minutes in 17 healthy young men reported little change in lactate dehydrogenase activity compared to pre-exercise (Fatouros et al., 2010). The cause of the differences in findings may be attributed to different subjects in the research as well as the involvement of various variables such as the length of time the subjects engaged in, nutrition, daily activity of the subjects, as well as the exercise program. The rate of increase depends on the intensity and duration of activity. As Brancasio et al. reported, after long-term endurance exercise such as marathons, LDH activity doubles and remains elevated for two weeks (Brancaccio et al., 2010).

No significant difference was observed in serum lactate dehydrogenase levels between TRX and traditional resistance groups. Failure to measure serum lactate dehydrogenase levels during the peak response period may be one of the reasons for not significant lactate dehydrogenase change between the two groups. Because lactate dehydrogenase has a slower response to exercise than creatine kinase, changes in this enzyme occur later than creatine kinase and usually within 24 to 48 hours after stress gradually increase (Talaie et al., 2007). Therefore, in order to obtain more accurate resultsabout the difference between the two training protocols, lactate dehydrogenase should be measured at two stages after exercise.

As a result of both TRX and traditional resistance exercise, serum aspartate aminotransferase levels did not show a significant change compared to the pre-test. In confirmation of this findings, Robinson and et al. (2000) also did not report the effect of short-term exercise on the amount of AST activity (Robinson, Sewell, Casey, Steenge, & Greenhaff, 2000). Possibly, various mechanisms influence on this activity and kind, duration and intense of exercise can be effective on the action of this enzyme. AST is another enzyme involved in liver metabolism and because liver is involved in more long term activities than others, long term and resistance activities whose creating energy is more aerobic are more effective on the amount of AST activities. Also, for continuing these activities, there is a need for creating energy from aerobic equipment especially provided by anaerobic and liver enzymes. ATS enzymes are not much involved in creating energy (Pettersson et al., 2008) and since it is lower than creatine kinase and lactate dehydrogenase in skeletal muscle cells, non-change in its serum levels can be attributed to its tissue content (Parikh & Ramanathan, 1977). Contrary to the results of the present study, the findings of some studies indicate an increase in the amount of AST enzyme in all exercises. In this regard, patt-

-erson et al. (2008) investigated the effect of one-hour workout resistance exercise on the clinical chemical parameters of 15 healthy men with physical fitness and observed an increase in lactate dehydrogenase and aspartate aminotransferase indices (Pettersson et al., 2008). Parikh et al. also reported a significant effect of 30-minute up-and-down the stair on AST levels (Parikh & Ramanathan, 1977). As it is shown, the more time and intensity of activities and exercise increased, the more involvement of liver enzymes, including AST, in creating ATP increased, so that, according to the theory of enzyme release, its releasing from inside to outside the cell by cytoplasmic membrane may increase AST permeation into bloodstream (Pettersson et al., 2008). Because resistance exercise has been considered in the present study, it might cause the difference in the results. This exercise may cause some adaptations in the cell which have stabilized membrane and finally reduced releasing AST to blood (Santos, Bassit, Caperuto, & Rosa, 2004).

Also, the results of the present study showed that serum levels of aspartate aminotransferase were not significantly different between TRX and traditional resistance groups. Some mechanisms that can cause no change in AST after resistance exercise are due to measurement and study of liver status as well as its low level in skeletal muscle causing its serum level muscle injury not to increase as much as CK and LDH. According to the results of this study, in order to differentiate between TRX and traditional resistance training protocols, we need more intensity. Moreover, the duration of physical activity in this study is short and may require longer time to see the influence of exercise on muscle injury indices. The present study was a quasi-experimental study in the soccer players' community; therefore, the control of all effective factors such as genetic factors was out of the researchers' control and these factors can influence the results.

Conclusion

Overall, the results of the present study showed that the performance of TRX and traditional resistance exercise led to an increase in creatine kinase and lactate dehydrogenase after exercise, while there was no significant difference between traditional and TRX resistance training after a training session and there was no evidence of muscle damage. Therefore, TRX or traditional exercise has no superiority over the other in terms of their effect on muscle injury index during exercise and the use of these two types of exercises by soccer players is similar in terms of the amount of impact on muscle injury indices.

What is already known on this subject?

One of the consequences of resistance training, especially in the early stages of exercise, is delayed congestion that indicates an increase in inflammatory markers. Most players in sports, including soccer, use resistance training to increase their performance that may increase the risk of injury factors by factor aggregation while playing soccer. In fact, vigorous activities such as resistance training cause rupture and disruption of the normal structure of muscle proteins due to high metabolic and mechanical stress and increase the extracellular calcium concentration.

What this study adds?

TRX training and traditional resistance training have no superiority in terms of less impact on muscle injury and less increase in muscle injury index during exercise, and the use of these two types of training by football players is similar in terms of impact on muscle injury indicators.

Acknowledgements

We would like to acknowledge and thank all the subjects in this study who assisted the researchers.

Funding

No funding.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in the current study involving human participants were in accordance with ethical standards of the institutional research committee and with the 1975 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the ethical committee of Qom University (No. 7258).

Informed consent All participants signed a written informed consent form that was approved by the ethical committee.

Author contributions

Conceptualization: M.A., G.M.; Methodology: Z.S., M.A.; Software: M.A.; Validation: Z.S., M.A.; Formal analysis: M.A.; Investigation: M.A.; Resources: Z.S.; Data curation: G.M.; Writing- original draft: M.A., G.M. Writing - review & editing: Z.S., M.A.; Visualization: M.A.; Supervision: M.A.; Project administration: M.A.; Funding acquisition: G.M.

References

Andring, J. M. (2006). The consistency of inflammatory responses and muscle damage to high-force eccentric exercise. Montana State University-Bozeman, College of Education, Health & Human, URL: https://scholarworks.montana.edu/xmlui/handle/1/839

Atashak, S., & Baturak, K. (2012). The effect of BCAA supplementation on serum C-reactive protein and creatine kinase after acute resistance exercise in soccer players. Annals of Biological Research, 3(3), 1569-1576. URL: https://www.researchgate.net/publication/304825164

Azizbeigi Boukani, K., & Atashak, S. (2015). The Effect of Rest Intervals between Sets of Resistance Exercise on Plasma Antioxidant Capacity Changes and Cell Injury Index. Journal of Sport Biosciences, 7(2), 225-239. doi: https://dx.doi.org/10.22059/jsb.2015.55227

Barquilha, G., Uchida, M. C., Santos, V. C., Moura, N. R., Lambertucci, R. H., Hatanaka, E., . . . Hirabara, S. M. (2011). Characterization of the effects of one maximal repetition test on muscle injury and inflammation markers. doi: https://dx.doi.org/10.9754/journal.wmc.2011.001717

Bompa, T., & Buzzichelli, C. (2015). Periodization training for sports, 3e: Human kinetics. URL: https://www.amazon.com/Periodization-Training-Sports-Tudor-Bompa/dp/1450469434

Brancaccio, P., Lippi, G., & Maffulli, N. (2010). Biochemical markers of muscular damage. Clinical chemistry and laboratory medicine, 48(6), 757-767. doi: https://doi.org/10.1515/CCLM.2010.179

Callegari, G. A., Novaes, J. S., Neto, G. R., Dias, I., Garrido, N. D., & Dani, C. (2017). Creatine kinase and lactate dehydrogenase responses after different resistance and aerobic exercise protocols. Journal of human kinetics, 58, 65. URL: https://dx.doi.org/10.1515%2Fhukin-2017-0071

Clarkson, P. M., Kearns, A. K., Rouzier, P., Rubin, R., & Thompson, P. D. (2006). Serum creatine kinase levels and renal function measures in exertional muscle damage. Medicine and science in sports and exercise, 38(4), 623. doi: https://doi.org/10.1249/01.mss.0000210192.49210.fc

Dolezal, B. A. (1998). Muscle damage and resting metabolic rate after acute resistance exercise with an eccentric overload: University of Kansas. doi: https://doi.org/10.1097/00005768-200007000-00003

Fatouros, I., Chatzinikolaou, A., Paltoglou, G., Petridou, A., Avloniti, A., Jamurtas, A., . . . Lazaropoulou, C. (2010). Acute resistance exercise results in catecholaminergic rather than hypothalamic–pituitary–adrenal axis stimulation during exercise in young men. Stress, 13(6), 461-468. doi: https://doi.org/10.3109/10253891003743432

Fong, S. S., Tam, Y., Macfarlane, D. J., Ng, S. S., Bae, Y.-H., Chan, E. W., & Guo, X. (2015). Core muscle activity during TRX suspension exercises with and without kinesiology taping in adults with chronic low back pain: implications for rehabilitation. Evidence-based complementary and alternative medicine, 2015. doi: https://doi.org/10.1155/2015/910168

Helgerud, J., Engen, L. C., Wisloff, U., & Hoff, J. (2001). Aerobic endurance training improves soccer performance. Medicine and science in sports and exercise, 33(11), 1925-1931. doi: https://doi.org/10.1097/00005768-200111000-00019

Helgerud, J., Høydal, K., Wang, E., Karlsen, T., Berg, P., Bjerkaas, M., . . . Bach, R. (2007). Aerobic high-intensity intervals improve V˙ O2max more than moderate training. Medicine & science in sports & exercise, 39(4), 665-671. doi: https://doi.org/10.1249/mss.0b013e3180304570

Hunkin, S. L., Fahrner, B., & Gastin, P. B. (2014). Creatine kinase and its relationship with match performance in elite Australian Rules football. Journal of science and medicine in sport, 17(3), 332-336. doi: https://doi.org/10.1016/j.jsams.2013.05.005

Jakobsen, M. D., Sundstrup, E., Persson, R., Andersen, C. H., & Andersen, L. L. (2014). Is Borg's perceived exertion scale a useful indicator of muscular and cardiovascular load in blue-collar workers with lifting tasks? A cross-sectional workplace study. European journal of applied physiology, 114(2), 425-434. doi: https://doi.org/10.1007/s00421-013-2782-9

Janot, J., Heltne, T., Welles, C., Riedl, J., Anderson, H., Howard, A., & Myhre, S. L. (2013). Effects of TRX versus traditional resistance training programs on measures of muscular performance in adults. Journal of Fitness Research, 2(2), 23-38. URL: https://research.usc.edu.au/esploro/outputs/journalArticle/Effects-of-trx-versus-traditional-resistance/99448883602621

Lowe, D. A., Warren, G. L., Hayes, D. A., Farmer, M. A., & Armstrong, R. (1994). Eccentric contraction-induced injury of mouse soleus muscle: effect of varying [Ca2+] o. Journal of Applied Physiology, 76(4), 1445-1453. doi: https://doi.org/10.1152/jappl.1994.76.4.1445

Marcora, S., & Bosio, A. (2007). Effect of exercise‐induced muscle damage on endurance running performance in humans. Scandinavian journal of medicine & science in sports, 17(6), 662-671. doi: https://doi.org/10.1111/j.1600-0838.2006.00627.x

Melrose, D., & Dawes, J. (2015). Resistance characteristics of the TRX TM suspension training system at different angles and distances from the hanging point. Journal of athletic enhancement, 4(1), 2-5. doi: http://dx.doi.org/10.4172/2324-9080.1000184

Nameni, F., Kashef, M., & Lari, A. (2004). The effect of warming on the relationship between CK and LDH in athletic women recovery. Olympic J, 4(28), 97-106.

Nieman, D. C., Henson, D. A., McAnulty, S. R., McAnulty, L., Swick, N. S., Utter, A. C., . . . Morrow, J. D. (2002). Influence of vitamin C supplementation on oxidative and immune changes after an ultramarathon. Journal of Applied Physiology, 92(5), 1970-1977. doi: https://doi.org/10.1152/japplphysiol.00961.2001

Nissen, S., Sharp, R., Ray, M., Rathmacher, J., Rice, D., Fuller Jr, J., . . . Abumrad, N. (1996). Effect of leucine metabolite β-hydroxy-β-methylbutyrate on muscle metabolism during resistance-exercise training. Journal of Applied Physiology, 81(5), 2095-2104. doi:

https://doi.org/10.1152/jappl.1996.81.5.2095

Pantoja, P. D., Alberton, C. L., Pilla, C., Vendrusculo, A. P., & Kruel, L. F. (2009). Effect of resistive exercise on muscle damage in water and on land. The Journal of Strength & Conditioning Research, 23(3), 1051-1054. doi: http://dx.doi.org/10.1519/JSC.0b013e3181a00c45

Pardanjani, A., Ebrahimi, M., & Changizi, M. (2015). Effect of one session of resistance activity on muscle injury and delayed muscular soreness in athlete male students. Res Sports Edu, 8, 37-52. http://dx.doi.org/10.29252/koomesh.22.2.351

Parikh, D., & Ramanathan, N. (1977). Exercise induced serum enzyme changes in untrained subjects. Indian journal of physiology and pharmacology, 21(3), 175-180. URL: https://pubmed.ncbi.nlm.nih.gov/612598/

Pettersson, J., Hindorf, U., Persson, P., Bengtsson, T., Malmqvist, U., Werkström, V., & Ekelund, M. (2008). Muscular exercise can cause highly pathological liver function tests in healthy men. British journal of clinical pharmacology, 65(2), 253-259. doi: https://doi.org/10.1111/j.1365-2125.2007.03001.x

Robinson, T. M., Sewell, D. A., Casey, A., Steenge, G., & Greenhaff, P. L. (2000). Dietary creatine supplementation does not affect some haematological indices, or indices of muscle damage and hepatic and renal function. British journal of sports medicine, 34(4), 284-288. doi: https://doi.org/10.1136/bjsm.34.4.284

Santos, R., Bassit, R., Caperuto, E., & Rosa, L. C. (2004). The effect of creatine supplementation upon inflammatory and muscle soreness markers after a 30km race. Life sciences, 75(16), 1917-1924. doi: https://doi.org/10.1016/j.lfs.2003.11.036

Scheett, T., Aartun, J., Thomas, D., Herrin, J., & Dudgeon, W. (2010). Physiological Markers as a Gauge of Intensity for Suspension Training Exercise: 2636: Board# 244 June 4 8: 00 AM-9: 30 AM. Medicine & science in sports & exercise, 42(5), 696. URL: https://ur.booksc.eu/book/66730348/3f2213#:~:text=10.1249/01.mss.0000385941.71566.aa

Seo, D.-i., Kim, E., Fahs, C. A., Rossow, L., Young, K., Ferguson, S. L., . . . Kim, D. (2012). Reliability of the one-repetition maximum test based on muscle group and gender. Journal of sports science & medicine. 11(2): 221–225. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3737872/

Shirvani, H., Rahimi, M., & Rostamkhani, F. (2015). Effect of a karate competition on indicators of inflammation and muscletissue injury in soldier's karate-ka. Journal of Military Medicine, 17(3), 137-143. doi: http://militarymedj.ir/article-1-1333-en.html

Soleimani, A., Shakerian, S., & Ruhollah, R. (2017). Changes in muscle damage enzymes inactive overweight male students after exhausted aerobic and anaerobic exercise. Journal of Birjand University of Medical Sciences, 24(3), 190-198. doi: http://journal.bums.ac.ir/article-1-2259-en.html

Talaie, H., Pajouhmand, A., Abdollahi, M., Panahandeh, R., Emami, H., Hajinasrolah, S., & Tghaddosinezhad, M. (2007). Rhabdomyolysis among acute human poisoning cases. Human & experimental toxicology, 26(7), 557-561. doi: https://doi.org/10.1177%2F0960327107078667

Toft, A. D., Jensen, L. B., Bruunsgaard, H., Ibfelt, T., Halkjær-Kristensen, J., Febbraio, M., & Pedersen, B. K. (2002). Cytokine response to eccentric exercise in young and elderly humans. American Journal of Physiology-Cell Physiology, 283(1), C289-C295. doi: https://doi.org/10.1152/ajpcell.00583.2001

Uchida, M. C., Nosaka, K., Ugrinowitsch, C., Yamashita, A., Martins Jr, E., Moriscot, A. S., & Aoki, M. S. (2009). Effect of bench press exercise intensity on muscle soreness and inflammatory mediators. Journal of sports sciences, 27(5), 499-507. doi: https://doi.org/10.1080/02640410802632144