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The Effect of Eight-Week Total Body Resistance Exercise on Liver Functional Parameters in Patients with Non-Alcoholic Fatty Liver Disease

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Abstract

Background: Non-alcoholic fatty liver disease (NAFLD) is a growing health problem and a serious risk factor for other diseases such as diabetes and heart disease.
Objectives: The aim of this study was to investigate the effects of eight-week total body resistance exercises (TRX) on liver functional parameters in patients with NAFLD.
Methods: In this semi-experimental study, 22 men with NAFLD were randomly divided into TRX training (n = 11) and control (n = 11) groups. The TRX group participated in a TRX training program for eight weeks (three sessions per week, 60 minutes per session). The body composition, anthropometric indices, liver fat content, and serum levels of alanine aminotransferase (ALT), aspartate aminotransferase (AST), and alkaline phosphatase (ALP) were measured by the enzymatic method before and after the training period.
Results: After TRX training, the liver fat content in the TRX group was significantly lower than in the control group (P = 0.001). Furthermore, the serum levels of ALT, AST and ALP significantly decreased in the TRX group, compared to the controls (P < 0.05). In addition, TRX training significantly reduced body weight, body mass index (BMI), fat percentage, and waist-to-hip ratio (P < 0.05), while no significant changes were observed in the control group (P > 0.05).
Conclusions: TRX training could be effective in improving liver fat content and reducing the serum levels of liver enzymes in men with NAFLD and can play a role in the management of this condition.

Keywords: TRX, Liver Enzymes, Liver Fat, Non-Alcoholic Fatty Liver Disease

1. Background

Along with the increasing prevalence of obesity and other non-communicable diseases in the world such as heart diseases, diabetes (type 2), and metabolic syndrome, the prevalence of nonalcoholic fatty liver disease (NAFLD) is on a growing trend (1, 2). The prevalence of the disease is approximately 25% - 35% in Western countries and 19% - 32% in Asian societies (3). NAFLD comprises a wide spectrum of liver damages, ranging from simple steatosis to cirrhosis and hepatocellular carcinoma (4). On the other hand, NAFLD causes high health costs because of its close relationship with other diseases and lack of specific and successful treatments.

NAFLD is recognized by the elevated levels of liver enzymes like alanine amino transferase (ALT), aspartate amino transferase (AST), and alkaline phosphatase and increased fat in liver cells (5).

Although the pathogenesis of NAFLD and determinants of its severity have not been fully elucidated, evidence suggests that sedentary lifestyle, obesity, and insulin resistance are among the most important NAFLD risk factors (6). So far, few pharmacological treatments have been proposed for NAFLD, including drugs increasing insulin sensitivity, drugs reducing fat content, and antioxidant drugs for fatty liver; nevertheless, because of their high costs and side effects, their persistent use is not recommended (7). Currently, lifestyle changes, including dietary modifications and physical activity, are the most important treatment suggestions for patients with NAFLD (6, 8). In this regard, exercise training is an important component of NAFLD treatment, as approved by the American Gastroenterological Association (9).

Evidence suggests that exercise training, especially when associated with weight loss, can improve liver function and insulin resistance (10). Total body resistance exercises (TRX) is an effective training method, which has been highlighted in recent years. TRX involves suspension training allowing individuals to utilize body weight resistance while performing exercises involving multiple movement planes, muscle groups and joints. Generally, TRX training is performed by a cache or a rope, and the body weight is used for resistance (11-13). In this training method, angels and mobility are challenging issues (14). Most studies around TRX are focused on physical fitness factors and the effect of these exercises on various physiological factors in different individuals is not clearly identified.

In a study, Smith et al. reported that eight-week TRX training in healthy adults with the average age of about 40 years improve the metabolic heart disease indicators such as body fat, waist circumference, and blood pressure (15).

2. Objectives

According to our investigations, there is a lack of robust evidence regarding the effect of TRX on liver functional parameters in patients with NAFLD. Therefore, it is still unclear whether these exercises have any effects on the liver fat content and enzyme levels of ALT, AST, and ALP in men with NAFLD. Considering the increasing prevalence of NAFLD, the widespread acceptance of TRX training, and limited information as to the effects of this type of exercise on the characteristics of NAFLD, we aimed at investigating the effects of eight weeks of TRX training on the liver fat content and liver enzymes of men with NAFLD.

3. Methods

3.1. Patients and Methods

In this semi-experimental study with a pretest-posttest control group design, the statistical population consisted of male NAFLD patients from Qazvin, Iran. The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki as reflected in a priori approval by the institution's human research committee. All the research stages were approved by the Ethics and Research Committee of Allame Gazvini University. The subjects was recruited by advertising in medical and administrative centers. The study samples included 22 men with NAFLD (31 - 49 years). The main inclusion criterion was the diagnosis of steatosis grade 1 or higher (> 5% triglyceride), which was confirmed via ultrasonography with an acceptable diagnostic accuracy. On the other hand, the exclusion criteria were as follows: genetic, metabolic, and endocrine diseases, alcohol consumption, cardiovascular and respiratory diseases, use of lipid-lowering drugs or dietary supplements, and lack of regular exercise in the past six months. Overall, the subjects were not suffering from other diseases except for NAFLD.

The sample size was determined based on previous studies through the single proportion formula at 95% confidence level and margin of error of 5% (16).

$$n = \frac{z^2_{\left(1-\frac{\alpha}{2}\right)} p\left(1-p\right)}{d^2} \quad (1)$$

A total of 20 eligible candidates were selected through purposive sampling. Before the study, a full description was presented to the subjects about the study implementation and protocols. Next, a consent form, a health questionnaire, and a 24-hour dietary recall were completed by the participants. All the principles of ethical human research were considered in this study. The subjects were aware of all aspects of the research and could withdraw from the project at any time. The subjects were advised not to change their normal diet (in some cases, we tried to control their diet using a 24-hour dietary recall), although it was not possible to completely control their diet during the study. The participants were randomly divided into two homogeneous groups of TRX (n = 11) and control (n = 11) based on the pretest results.

3.2. TRX Training Protocol

Before starting the research period, the training group were familiarized with the movements during two sessions. Then, the repetition maximum number was tested. This test was performed every two weeks in order to investigate the progress rate of the subjects and to implement the overload principle. To apply the overload principle, the repetition number of movements was begun from 70 percent of repetition maximum number in the first week and then it reached to 100 percent of repetition maximum number in the eighth week. The TRX protocol included 60 minutes of exercise, that is, 10 minutes of warm-up, 40 minutes of TRX training, and 10 minutes of cool down, three times a week for eight weeks (Table 1).

The TRX training program is designed and chosen in a way that most of the upper and lower extremities are involved. These exercises include TRX plank on elbows, TRX T deltoid fly, TRX chest press, TRX high row, TRX triceps press, TRX biceps curl, TRX squat, and TRX hip press (17, 18). In order to uniformize the movements, the speed of performing movements in all the subjects was standardized as shots per second by a metronome, and the movements were performed in a way that the joints had full range of motion. It should be noted that the control group did not engage in any other sports activities or exercises during the study.

Table 1. Details of the Total Body Resistance Exercise (TRX) Training Protocol Used in This Study

Variables	Week of Training							
	1	2	3	4	5	6	7	8
Exercise number	8	8	8	8	8	8	8	8
Set number	3	3	3	3	3	3	3	3
Rest between exercises (s)	90	90	90	90	90	90	90	90
Rest between sets (s)	60	60	60	60	60	60	60	60
Intensity (repetition maximum number, %)	70	70	80	80	90	90	100	100

3.3. Anthropometric Indices and Body Composition

One week before the study, the participants visited the Sports Sciences Laboratory of Imam Khomeini International University in Qazvin to be familiarized with the study tools and methods. Some anthropometric and body composition indices were measured before the training period and 48 hours after the final TRX training session. The participants' height was also measured using a Seca scale (Germany) with 0.01 accuracy. Moreover, the waist and hip circumferences were measured using a tape measure, and then, the waist-to-hip ratio was calculated. Weight and body fat percentage were also calculated based on bioelectrical impedance analysis, using a body composition analyzer (ZEUS 9.9, Korea) according to the manufacturer's guidelines.

3.4. Hepatic Fat Content and Liver Enzymes

The hepatic fat content and serum levels of liver enzymes were measured before the training period and 48 hours after the final TRX training session. Liver fat content was examined using an ultrasound system (Medison SonoAce X8, Korea). Ultrasonography was performed by an expert at the Advanced Medical Imaging Center after at least five hours of fasting. Hepatic steatosis was graded from one to three: grade I (mild), a slight increase in echogenicity; grade II (moderate), a moderate increase in echogenicity; and grade III (severe), a significant increase in echogenicity (19).

To determine the serum levels of liver enzymes, including ALT, AST, and ALP, blood samples were collected from the antecubital vein after 8 - 12 hours of fasting. The collected blood sample was poured into a test tube containing an anticoagulant. Then, the blood sample was centrifuged, and the separated serum was stored at -70°C until further analysis. The levels of ALT and AST enzymes were evaluated using quantitative detection kits (Pars Azmoon, Iran), based on the kinetic VV method in an Advia 1200 system (USA) according to the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) standards. Also, the level of ALP enzyme was determined using a quantitative diagnostic kit (Bionic) based on the photometric method according to the German Society for Biochemistry standards in an Advia 1200 system (USA).

3.5. Statistical Analysis

After data collection, the normal distribution of the data was evaluated by Shapiro-Wilk test. For descriptive statistics, mean and standard deviation were calculated. Paired *t*-test was used to examine intra-group differences, while Independent *t*-test was performed for inter-group differences. The significance level was set at 0.05, and all the statistical analyses were performed in SPSS software version 18.0 (SPSS, Inc. Chicago, Illinois, USA).

4. Results

Shapiro-Wilk test was first used to examine the normal distribution of the data in different groups. The results indicated that the collected data had a normal distribution, and the curve of the sample was assumed to be normal ($P > 0.05$). The anthropometric characteristics and body composition of the participants before and after TRX training are presented in Table 2. The findings showed that eight weeks of TRX training caused a significant reduction in the body weight, body mass index (BMI), fat percentage, and waist-to-hip ratio of middle-aged men with NAFLD, while no significant changes were observed in the control group (Table 2).

Also, the results showed that the liver fat content, which was evaluated via ultrasonography, significantly decreased in the TRX group after eight weeks of training, whereas no significant change was observed in the control group (Figure 1). In this way, the degree of liver steatosis in the training group decreased by about 40%. Moreover, there was a significant difference between the TRX and control groups with respect to the posttest liver fat content ($P = 0.001$) and range of liver enzyme changes ($P = 0.002$).

Regarding the level of liver enzymes, the results showed that all the three enzymes, namely, AST, ALT, and

Table 2. Characteristics of Subjects Before and After Eight Weeks of Total Body Resistance Exercise (TRX) Training in the Two Groups[a]

Variables	Control (N = 11)				TRX (N = 11)			
	Pretest	Posttest	Δ	P Value[b]	Pretest	Posttest	Δ	P Value[b]
Age, y	39.30 ± 4.64	-	-	-	42.3 ± 4.76	-	-	-
Height, cm	173.40 ± 4.81	-	-	-	172.2 ± 4.23	-	-	-
Weight, kg	82.10 ± 7.44	82.50 ± 7.47	0.4 ± 0.84	0.16	78.8 ± 11.55	74.51 ± 11.2	-4.29 ± 0.72*	< 0.001
BMI, kg/m²	27.39 ± 3.40	27.52 ± 3.41	0.13 ± 0.28	0.18	26.54 ± 3.55	25.09 ± 3.37	-1.45 ± 0.27*	0.02
Body fat, %	23.68 ± 2.32	23.74 ± 2.31	0.06 ± 0.18	0.34	23.95 ± 4.38	22.21 ± 3.63	-1.74 ± 0.51*	0.001
WHR, ratio	0.91 ± 0.01	0.91 ± 0.01	0.003 ± 0.006	0.39	0.93 ± 0.04	0.90±0.03	-0.03±0.01*	0.01

Abbreviations: BMI, body mass index; WHR, waist-to-hip ratio.
[a]Values are expressed as mean ± SD.
[b]P < 0.01, significant difference between control and TRX Training.

ALP, significantly reduced in the TRX group after eight weeks of training, while no significant changes were observed in the control group (Table 3). The serum levels of ALT, AST, and ALP enzymes in the TRX group reduced by about 7%, 10%, and 4%, respectively. Also, there was a significant difference between the TRX and control groups in the posttest serum levels of AST, ALT, and ALP and the range of enzyme changes (Table 3).

5. Discussion

Considering the importance of physical activity in the treatment of patients with NAFLD, it is essential to identify the most effective exercises for these patients. The present study was conducted to investigate the effect of eight weeks of TRX training on the liver fat content and liver enzymes of middle-aged men with NAFLD. The results indicated that eight weeks of TRX training significantly reduced the liver fat content (decreased liver steatosis grade) in middle-aged men with NAFLD, and the degree of liver steatosis in the training group decreased by about 40%. The reduction of liver fat content was associated with a significant decline in the serum levels of ALT, AST, and ALP following eight weeks of TRX training. The serum levels of ALT, AST, and ALP enzymes in the TRX group reduced by about 7%, 10%, and 4%, respectively.

TRX is a resistance training method and body's weight is used as resistance (13). The evidence indicates that TRX training, similar to traditional resistance exercises, in addition to improvement of muscle strength lead to the improvement of body composition index, endurance, coordination, flexibility, and cardiovascular fitness (20). Pastucha at el. in a review article suggested that TRX exercises, in addition to enhancing muscle strength and joint stiffness, also improve lung capacity (21). Thus, it seems that TRX is counted as a cardiovascular exercise besides its resistance nature. Most of the previous studies that used aerobic or resistance exercises indicated that these exercises have a positive impact on the reduction of liver's fat content and liver enzymes.

Houghton et al. showed that such exercises for 12 weeks lead to the reduction of liver fat and liver enzymes such as ALT and AST in patients suffering from NAFLD (22). Furthermore, Takahashi et al. suggested that the resistance exercises for 12 weeks lead to significant reduction in the degree of liver steatosis and liver enzymes such as ALT and AST in patients suffering from NAFLD (23). Haus et al. reported that even shorter workouts can improve liver fat content in patients with NAFLD, which can reduce the risk of NAFLD progress (24). According to our investigations, there is not strong evidence as to the effect of TRX on the liver functional parameters in patients with NAFLD. Therefore, it is still unclear whether these exercises have any effects on the liver fat content and levels of ALT, AST, and ALP in men with NAFLD. The present study is one of the first studies to investigate the effects of eight-week total TRX on the liver functional parameters in patients with NAFLD. Although the exact mechanism of improvement of liver's fat content and liver enzymes after exercise, specially resistance exercises, have not been clearly identified yet, it seems that TRX exercises improve the liver factors in patients with NAFLD through some mechanisms related to endurance exercises in addition to some mechanisms related to resistance exercises. Resistance exercises lead to up-regulated GLUT4 protein expression, glycogen synthase, and total glycogen synthase activity in skeletal muscles. Therefore, the glucose metabolism of the whole body increases (25, 26). Furthermore, Oh et al. reported that resistance exercises lead to the upregulation of the intracellular key molecules such as AMPKs and caveolins in type II muscle fibers (27). Therefore, it is probable that TRX improve the degree of fatty liver and reduce the liver enzymes through changes in muscle characteristics.

Table 3. Liver Enzyme Changes Before and After Eight Weeks of Total Body Resistance Training Exercise (TRX) Training in the Two Groups[a]

Variables	Control (N = 11)			TRX (N = 11)		
	Pretest	Posttest	Δ	Pretest	Posttest	Δ
ALT (U/L)	31.30 ± 5.90	31.70 ± 6.78	0.40 ± 1.26	36.50 ± 7.53	33.90 ± 8.76[b, c]	-2.6 ± 1.02[c]
AST (U/L)	23.80 ± 3.01	24.20 ± 2.89	0.40 ± 0.84	25.8 ± 4.32	23.1 ± 5.21[b, c]	-2.7 ± 1.11[c]
ALP (U/L)	157.55 ± 53.41	157.77 ± 69.60	0.22 ± 2.27	161.43 ± 37.47	154.67 ± 41.83[b, c]	-6.76 ± 4.08[c]

Abbreviations: ALP, alkaline phosphatase; ALT, alanine amino transferase; AST, aspartate amino transferase.
[a]Values are expressed as mean ± SD.
[b]P < 0.01, significant difference between pre and post.
[c]P < 0.05, significant difference between control and TRX Training.

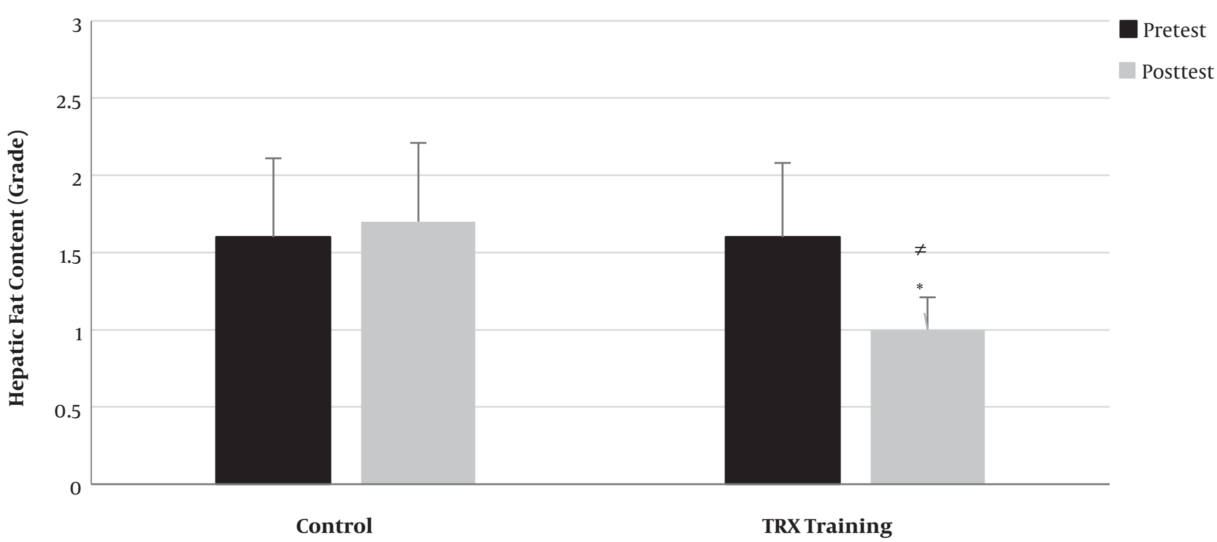

Figure 1. Hepatic fat content in the control and (total body resistance exercise) TRX groups before and after eight weeks TRX training. *P < 0.05, significant difference between pre and post; ≠P < 0.01, significant difference between control and TRX training.

According to the results of the presented study, TRX lead to 40% reduction in the liver's fat content. This fat reduction occurred besides weight and fat mass reduction in the TRX training group. Along with the presented study, some previous studies indicated that resistance exercises lead to reduction in liver fat content even without weight and fat mass reduction in patients with NAFLD (7, 28). Combination exercises such as TRX can reduce hepatic steatosis and insulin resistance independent of increase in muscle mass (29). Skeletal muscle contraction during TRX can act as an endocrine organ and produce and release myokinases such as irisin that affect the metabolism of other tissues and organs.

According to some evidence, irisin moderates lipid metabolism in liver cells (30). However, Polyzos et al. reported that the serum levels of irisin in patients with NAFLD are lower than in healthy individuals (31). In the same vein, Kim et al. investigated the effect of resistance and aerobic exercises on the serum levels of irisin and suggested that the serum level of irisin significantly increased in the resistance exercise group (32). A muscle-liver crosstalk may be the probable reason for the reduction of liver's fat content and serum levels of ALT, AST and ALP enzymes in TRX training group.

The present study has certain limitations which need to be addressed. First, considering the main inclusion criteria of our study, the sample size was limited; therefore, further research with a larger sample size is needed to increase the external validity of our findings. Second, in our study, ultrasonography was used rather than liver biopsy, which is the gold standard for measuring fatty liver (33) based on the guidelines of the American Association for the Study of Liver Disease (AASLD). Although the diagnostic accuracy of ultrasound is about 93% when liver steatosis is greater than 33%, its sensitivity reduces if liver steatosis is below 30% (34, 35). It should be noted that liver biopsy is an invasive and costly technique, and most patients are reluctant to undergo biopsy due to the possible side effects.

Third, although the subjects were advised not to change their normal diet (in some cases, we tried to control their diet using a 24-hour dietary recall), it was not possible to fully control their diet during the study; therefore, consumption of some foods, such as coffee, tea, soy, and vitamin A and E supplements, might have affected our results.

5.1. Conclusions

According to our results, TRX training can be effective in improving liver fat content and reducing the serum levels of ALT, AST, and ALP in men with NAFLD; therefore, TRX training can be used as a therapeutic approach for these patients. The positive effects of this particular type of exercise program can be interesting for physicians, patients and designers of training programs. However, further research is necessary to confirm our findings.

Supplementary Material

Supplementary material(s) is available here [To read supplementary materials, please refer to the journal website and open PDF/HTML].

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Footnotes

Authors' Contribution: Study concept and design and critical revision of the manuscript for important intellectual content: Abbas Sadeghi; analysis and interpretation of the data and statistical analysis: Hassan Pourrazi; drafting of the manuscript: Hamid-Reza Yazdi.

Conflict of Interests: It is not declared by the authors.

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References

1. Younossi ZM, Koenig AB, Abdelatif D, Fazel Y, Henry L, Wymer M. Global epidemiology of nonalcoholic fatty liver disease-Meta-analytic assessment of prevalence, incidence, and outcomes. *Hepatology*. 2016;**64**(1):73–84. doi: 10.1002/hep.28431. [PubMed: 26707365].
2. Hajighasem A, Farzanegi P, Mazaheri Z. Effects of combined therapy with resveratrol, continuous and interval exercises on apoptosis, oxidative stress, and inflammatory biomarkers in the liver of old rats with non-alcoholic fatty liver disease. *Arch Physiol Biochem*. 2019;**125**(2):142–9. doi: 10.1080/13813455.2018.1441872. [PubMed: 29463133].
3. Damor K, Mittal K, Bhalla AS, Sood R, Pandey RM, Guleria R, et al. Effect of progressive resistance exercise training on hepatic fat in Asian Indians with non-alcoholic fatty liver disease. *Br J Med Med Res*. 2014;**4**(1):114–24. doi: 10.9734/bjmmr/2014/4845.
4. Arshad T, Golabi P, Paik J, Mishra A, Younossi ZM. Prevalence of nonalcoholic fatty liver disease in the female population. *Hepatol Commun*. 2019;**3**(1):74–83. doi: 10.1002/hep4.1285. [PubMed: 30619996]. [PubMed Central: PMC6312650].
5. St George A, Bauman A, Johnston A, Farrell G, Chey T, George J. Independent effects of physical activity in patients with non-alcoholic fatty liver disease. *Hepatology*. 2009;**50**(1):68–76. doi: 10.1002/hep.22940. [PubMed: 19444870].
6. Kistler KD, Brunt EM, Clark JM, Diehl AM, Sallis JF, Schwimmer JB, et al. Physical activity recommendations, exercise intensity, and histological severity of nonalcoholic fatty liver disease. *Am J Gastroenterol*. 2011;**106**(3):460–8. quiz 469. doi: 10.1038/ajg.2010.488. [PubMed: 21206486]. [PubMed Central: PMC3070294].
7. Hallsworth K, Fattakhova G, Hollingsworth KG, Thoma C, Moore S, Taylor R, et al. Resistance exercise reduces liver fat and its mediators in non-alcoholic fatty liver disease independent of weight loss. *Gut*. 2011;**60**(9):1278–83. doi: 10.1136/gut.2011.242073. [PubMed: 21708823]. [PubMed Central: PMC3152868].
8. Ahmed IA, Mikail MA, Mustafa MR. Lifestyle interventions for non-alcoholic fatty liver disease. *Sau J Biol Sci*. 2019. doi: 10.5772/intechopen.86146.
9. American Gastroenterological Association. American Gastroenterological Association medical position statement: Nonalcoholic fatty liver disease. *Gastroenterology*. 2002;**123**(5):1702–4. doi: 10.1053/gast.2002.36569. [PubMed: 12404244].
10. Hagner-Derengowska M, Kałużny K, Budzyński J. Effects of nordic walking and pilates training programs on aminotransferase activity in overweight and obese elderly women. *J Educ Health Sport*. 2015;**5**(12).
11. Behm DG, Drinkwater EJ, Willardson JM, Cowley PM. The use of instability to train the core musculature. *Appl Physiol Nutr Metab*. 2010;**35**(1):91–108. doi: 10.1139/H09-127. [PubMed: 20130672].
12. McGill SM, Cannon J, Andersen JT. Analysis of pushing exercises: Muscle activity and spine load while contrasting techniques on stable surfaces with a labile suspension strap training system. *J Strength Cond Res*. 2014;**28**(1):105–16. doi: 10.1519/JSC.0b013e3182a99459. [PubMed: 24088865].
13. Kosmata A. *Functional exercise training with the TRX suspension trainer in a dysfunctional, elderly population [dissertation]*. Appalachian State University; 2014.
14. Yu KH, Suk MH, Kang SW, Shin YA. Effects of combined resistance exercise with TRX on physical fitness and competition times in Fin swimmers. *Int J Sport Stud*. 2015;**5**:508–15.
15. Smith LE, Snow J, Fargo JS, Buchanan CA, Dalleck LC. The acute and chronic health benefits of TRX Suspension Training® in healthy adults. *Int J Res Exerc Physiol*. 2016;**11**(2):1–15.
16. Arifin WN. Introduction to sample size calculation. *Educ Med J*. 2013;**5**(2):89–96. doi: 10.5959/eimj.v5i2.130.
17. Boonsit S, Peepathum P, Mitranun W. The acute effects of the different total body resistance exercise (TRX) postures on flow-mediated dilatation in elderly subjects. *J Exerc Physiol Online*. 2017;**20**(4).
18. Gaedtke A, Morat T. TRX suspension training: A new functional training approach for older adults - development, training control and feasibility. *Int J Exerc Sci*. 2015;**8**(3):224–33. [PubMed: 27182415]. [PubMed Central: PMC4833470].

19. Saki F, Karamizadeh Z, Honar N, Moravej H, Ashkani-Esfahani S, Namvar Shooshtarian MH. Association of plasma retinol binding protein-4 (RBP4) and sonographic grading of fatty liver in obese Iranian children. *Hepat Mon*. 2012;**12**(12). e7103. doi: 10.5812/hepatmon.7103. [PubMed: 23423766]. [PubMed Central: PMC3575548].
20. Dudgeon WD, Herron JM, Aartun JA, Thomas DD, Kelley EP, Scheett TP. Physiologic and metabolic effects of a suspension training workout. *Int J Sports Sci*. 2015;**5**(2):65–72.
21. Pastucha D, Filipcikova R, Bezdickova M, Blazkova Z, Oborna I, Brezinova J, et al. Clinical anatomy aspects of functional 3D training – case study. *Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub*. 2012;**156**(1):63–9. doi: 10.5507/bp.2012.016. [PubMed: 22580863].
22. Houghton D, Thoma C, Hallsworth K, Cassidy S, Hardy T, Burt AD, et al. Exercise reduces liver lipids and visceral adiposity in patients with nonalcoholic steatohepatitis in a randomized controlled trial. *Clin Gastroenterol Hepatol*. 2017;**15**(1):96–102 e3. doi: 10.1016/j.cgh.2016.07.031. [PubMed: 27521509]. [PubMed Central: PMC5196006].
23. Takahashi A, Abe K, Usami K, Imaizumi H, Hayashi M, Okai K, et al. Simple resistance exercise helps patients with non-alcoholic fatty liver disease. *Int J Sports Med*. 2015;**36**(10):848–52. doi: 10.1055/s-0035-1549853. [PubMed: 26090879].
24. Haus JM, Solomon TP, Kelly KR, Fealy CE, Kullman EL, Scelsi AR, et al. Improved hepatic lipid composition following short-term exercise in nonalcoholic fatty liver disease. *J Clin Endocrinol Metab*. 2013;**98**(7):e1181–8. doi: 10.1210/jc.2013-1229. [PubMed: 23616151]. [PubMed Central: PMC3701282].
25. Ferrara CM, Goldberg AP, Ortmeyer HK, Ryan AS. Effects of aerobic and resistive exercise training on glucose disposal and skeletal muscle metabolism in older men. *J Gerontol A Biol Sci Med Sci*. 2006;**61**(5):480–7. doi: 10.1093/gerona/61.5.480. [PubMed: 16720745].
26. Holten MK, Zacho M, Gaster M, Juel C, Wojtaszewski JF, Dela F. Strength training increases insulin-mediated glucose uptake, GLUT4 content, and insulin signaling in skeletal muscle in patients with type 2 diabetes. *Diabetes*. 2004;**53**(2):294–305. doi: 10.2337/diabetes.53.2.294. [PubMed: 14747278].
27. Oh YS, Kim HJ, Ryu SJ, Cho KA, Park YS, Park H, et al. Exercise type and muscle fiber specific induction of caveolin-1 expression for insulin sensitivity of skeletal muscle. *Exp Mol Med*. 2007;**39**(3):395–401. doi: 10.1038/emm.2007.44. [PubMed: 17603294].
28. Bacchi E, Negri C, Targher G, Faccioli N, Lanza M, Zoppini G, et al. Both resistance training and aerobic training reduce hepatic fat content in type 2 diabetic subjects with nonalcoholic fatty liver disease (the RAED2 Randomized Trial). *Hepatology*. 2013;**58**(4):1287–95. doi: 10.1002/hep.26393. [PubMed: 23504926].
29. Kawaguchi T, Shiba N, Maeda T, Matsugaki T, Takano Y, Itou M, et al. Hybrid training of voluntary and electrical muscle contractions reduces steatosis, insulin resistance, and IL-6 levels in patients with NAFLD: A pilot study. *J Gastroenterol*. 2011;**46**(6):746–57. doi: 10.1007/s00535-011-0378-x. [PubMed: 21340530].
30. Hashida R, Kawaguchi T, Bekki M, Omoto M, Matsuse H, Nago T, et al. Aerobic vs. resistance exercise in non-alcoholic fatty liver disease: A systematic review. *J Hepatol*. 2017;**66**(1):142–52. doi: 10.1016/j.jhep.2016.08.023. [PubMed: 27639843].
31. Polyzos SA, Kountouras J, Anastasilakis AD, Geladari EV, Mantzoros CS. Irisin in patients with nonalcoholic fatty liver disease. *Metabolism*. 2014;**63**(2):207–17. doi: 10.1016/j.metabol.2013.09.013. [PubMed: 24140091].
32. Kim HJ, Lee HJ, So B, Son JS, Yoon D, Song W. Effect of aerobic training and resistance training on circulating irisin level and their association with change of body composition in overweight/obese adults: A pilot study. *Physiol Res*. 2016;**65**(2):271–9. [PubMed: 26447516].
33. Singh S, Allen AM, Wang Z, Prokop LJ, Murad MH, Loomba R. Fibrosis progression in nonalcoholic fatty liver vs nonalcoholic steatohepatitis: A systematic review and meta-analysis of paired-biopsy studies. *Clin Gastroenterol Hepatol*. 2015;**13**(4):643–54 e1-9. quiz e39-40. doi: 10.1016/j.cgh.2014.04.014. [PubMed: 24768810]. [PubMed Central: PMC4208976].
34. Saadeh S, Younossi ZM, Remer EM, Gramlich T, Ong JP, Hurley M, et al. The utility of radiological imaging in nonalcoholic fatty liver disease. *Gastroenterology*. 2002;**123**(3):745–50. doi: 10.1053/gast.2002.35354. [PubMed: 12198701].
35. Dasarathy S, Dasarathy J, Khiyami A, Joseph R, Lopez R, McCullough AJ. Validity of real time ultrasound in the diagnosis of hepatic steatosis: A prospective study. *J Hepatol*. 2009;**51**(6):1061–7. doi: 10.1016/j.jhep.2009.09.001. [PubMed: 19846234]. [PubMed Central: PMC6136148].