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THE EFFECTS OF SUSPENSION TRAINING IN LOWER BODY MUSCLE STRENGTH AND BALANCE IN SEDENTARY

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Original research

ABSTRACT
The aim of this study was to determine the effects of TRX suspension applications on lower body muscle strength and balance skills in sedentary individuals. Materials and Methods: The study included 60 sedentary individuals aged 30-45 years. The participants were divided into 2 groups as Suspension Strength Group (SSG) and Traditional Strength Group (TSG). SSG performed 45 minutes of exercise for a total of 8 weeks, 2 days a week. The TSG group applied for an 8-week, 45-minute basic strength program for a total of 2 days a week. Anthropometric measurements, grip strength, push-up, squat, sit-up, plank and balance tests were taken before and after the 8-week exercise protocol. Results: In this study, which was conducted to determine the effects of TRX movements on strength and balance skills in sedentary individuals, significant differences were found in SSG as opposed to TSG as a result of the data in this study conducted to determine the effects of suspension exercises on muscle strength development in individuals. As a result of the exercise protocol lasting 8 weeks in total; improvement was found in all data of SSG and in certain parameters of TSG. According to the last measurements, there was a difference in push-up, squat, sit-up and plank performances. Conclusion: it was found that strength training on moving surfaces showed more improvement than traditional strength training. In addition, it is thought that suspension exercises may be a new alternative training model for strength development.

Keywords: Dynamic stability, fitness, mobilization, stabilization, trx.

INTRODUCTION

As we get older, the phenomena in daily life lead to a decrease in physical activity. The shortening of walking distances due to the opportunities provided by modern life and the technology ecosystem and the increased use of digital media affect the level of daily energy consumption (Peker et al., 2000). According to Bernstein, Morabia and Sloutskis, people who spend less than 10% of their energy for daily activities can be classified as "sedentary". Due to the negative effects of industrialisation and modern lifestyle, it is known that a sedentary lifestyle leads to serious health problems in middle and old ages and causes problems in the digestive and excretory systems with weakening of the abdominal muscles, obesity and impaired energy balance between energy intake and expenditure, health problems such as strength, flexibility, resistance and risk of injury (Bernstein et al. 1999; Booth et al. 2000; Carter and Heath 1990; Alan et al. 2000; Zorby 1999). One of the consequences of a sedentary lifestyle is a decrease in metabolic activity and blood glucose control in the body, which leads to an increased risk of type 2-diabetes (Mikus et al., 2012). In recent years, fitness experts have increasingly started to recommend core training in their research, and the effects of this training are seen as important and

necessary to maintain daily activities (Willardson 2007; Hamza 2013). These studies have revealed that when adequate trunk stabilisation is achieved on both fixed and moving surfaces, the upper and lower extremities begin to become stronger (Willardson 2007). With the inclusion of suspension exercises in more exercise programmes, resistance training practices using their own bodies have become more common (Rasha 2017).

It should be noted that suspension exercises are an advanced form of resistance exercises in sports that allow you to build muscle strength using your own weight without additional resistance and work the whole body in a short time. Suspension exercises are a variety of exercises consisting of functional movements that can be used to effectively perform stabilization and mobilization tests (Mohamed 2016).

Stability is an important element of the neuromuscular system to maximise movement efficiency and the ability to maintain joint motion control or postural balance while performing a specific movement provides stability (Crawford, M. J., 2007; Stefan et al., 2020). Through dynamic stability, mobilisation and stabilisation are defined simultaneously and dynamic stability ensures the safety of the joint movement chain. Stability and mobility result in neuromuscular integration that can respond appropriately to the range of motion of the joint. Core training is an example of the multi-joint principle. With core training it is possible to activate more muscle groups. Regular strength exercises increase muscle strength. Strength training helps to strengthen the muscles. Strength training plays an important role in the prevention of postural disorders and the elimination of dysfunctions in the spine.

It is also extremely important for the functionality of the kinetic chain. Kinetic chain is a definition used to explain human movements. Upper and lower extremity strengthening exercises can be planned as open kinetic chain or closed kinetic chain. In the open kinetic chain, the distal part of the moving limb (e.g. the foot) is free and not fixed to an object, as in leg extension and bench press movements. In a closed kinetic chain, the distal segment is fixed away from the body. Pull-ups, planks and push-ups are closed kinetic chain movements (Bates et al., 2023). How to optimise movement during training, a good muscle-joint-bone and nervous system connection means that the kinetic chain works in harmony. With core and suspension training, the kinetic chain structure works at an optimum level and supports the development of movement mechanics.

The aim of this study was to determine the effects of TRX-suspension applications on lower body muscle strength and balance skills in sedentary individuals.

METHODS

Pre-test, post-test control group experimental method was used in the study. The ethics committee certificate required for the data collection phase of the article was issued by Dokuz Eylül University Ethics Committee (2018/05-34).

Participants

The population of this study consisted of sedentary individuals who came to a private fitness centre in the province of Istanbul and sedentary male and female individuals who had not exercised for at least two years, had no history of injury or fracture, and were between the ages of 30-45 years constituted the sample of the study.

Inclusion Criteria

- To be between 30-45 years old,
- Not having practiced sports for at least two years
- No acute and/or chronic illness for the last 6 months

Exclusion Criteria

- History of fracture of any extremity,
- Having any disease that would prevent him/her from participating in the research

Individuals with a disability that prevents them from exercising were not included in this study.

Table 1 All participants percentage table.

Variables	n	Min.	Max.	mean	Std.
Men	30	1	30	15.5	8.80
Women	30	1	30	15.5	8.80

[a,b,c] Values within a row with different superscripts differ significantly at $P<0.05$.

Procedure

A total of 60 healthy and volunteer sedentary individuals aged 30-45 years participated in this study. Participants were randomly divided into 2 equal groups as Suspension Strength Group (SSG) and Traditional Strength Group (TSG). The suspension group applied a protocol consisting of 9 movements lasting 40-45 minutes in total 2 days a week for 8 weeks. On the other hand, the traditional strength training group performed a protocol consisting of 9 movements for a total of 40-45 minutes 2 days a week for 8 weeks. Anthropometric measurements, hand grip strength, push-up, squat, sit-up, plank and balance tests were measured before and after the 8-week training programmes.

The relevant literature was reviewed and 10 movements were determined for Suspension Strength Group (SSG) and Traditional Strength Group (TSG). The selected movements were adapted according to the research groups. No additional weight was added except for the bar weight used in the Traditional Strength Training group. As rest time, the load-rest relationship for suspension exercises recommended by Dudgeon (2015) was given as 1:2.

Height measurement
The height measurements of the participants were taken with Mesitaş (Mesilifi 13539) device. When they stood in an anatomical position, they were taken with reference to the top of the head and recorded in centimetres (Saygın 2003).

Body Weight
In order to determine the body fat ratios of the participants Inbody 270 Bioimpedance Body Composition Analyser was measured with a height-weight meter (South Korea). Participants participated in the test in bare feet and shorts-shirt.

Flexibility
Participants completed the flexibility test by placing the soles of their feet on the platform, reaching forward with their hands, moving the metal bar in front of them without moving their feet and knees and recorded in centimetres. The test was repeated 2 times and the best degree was recorded.

Hand Grip Test
The hand grip strength of the participants was taken with a Takei brand hand dynamometer (Japan). During the measurement, the device is gripped tightly without moving the body and completes the movement. Three repetitions were performed for each hand and the best degree was recorded in kilograms (Tamer et al., 1997).

Push-up Test
The push-up movement was completed by counting the number of regular movements performed for one minute and recorded as the number of repetitions (Biçer et al., 2004).

Squat Test
The participants performed the squat movement statically as long as they could endure for the maximum time and it was recorded in terms of duration.

Sit-up Test
Sit-up movements performed in a regular manner by bending for 1 minute were counted and recorded as repetitions (Biçer et al., 2004).

Plank Test
The maximum time they could stand on the elbows in a fixed manner with the body tense was recorded in seconds. The test of the participant whose body posture was warned 3 times was terminated (Afyon and Boyacı 2016).

Flamingo Balance Test
50 cm. in length, 4 cm. in height and 3 cm. on a large wooden balance beam was asked to stand with the dominant foot. For 1 minute, he/she tries to maintain his/her balance by bending the other foot at the knee and pulling it towards the hip and holding it with the same hand. Time stops when the balance is disturbed (if he/she lets go of his/her leg while holding it, falls from the board to the ground, touches the ground with any part of his/her body, etc.) (Hazar & Taşmektepligil, 2008).

Data-Analyses

Statistical analysis of the study was performed using SPSS-software (v21.0, SPSS Inc, Chicago, IL). The demographic characteristics of the participants (e.g. gender, age, height, BMI, years of sport experience) were evaluated using descriptive statistics. Whether the data were normally distributed was determined using the Kolmogorov-Smirnov test and homogeneity was tested using Levene's test. It was found that the data were normally distributed and homogenous. Pre- and post-test group comparisons were made using paired samples t test, and one-way ANOVA test was used for inter-group comparisons. Scheffe, one of the post hoc tests, was used to determine which $p<$differences existed between the groups.

RESULTS

Table 2, shows that the mean age of the group formed for TSG-training was 40.67±3.19 years, the mean height was 170.5±8.8 and the mean body weight was

Table 2 Traditional strength group descriptive table.

Variables	n	Min.	Max.	mean	Std.
Age (year)	30	35	45	40.67	3.198
Height (cm)	30	150.00	183.00	170.49	8.807
Body Weight (kg)	30	50.0	124.40	80.13	14.566

[a,b,c] Values within a row with different superscripts differ significantly at $P<0.05$.

80.13±14.56 (Table 1). Table 3, shows that the mean age of the group formed for the SKG-training was 39.10±3.36 years, the mean height was 167.23±7.53 and the mean body weight was 79.48±12.465 (table 2). Measurements of the TSG and SSG individuals participating in the study. The

absence of a significant difference indicates that the research groups were homogeneously distributed.

Table 3 Suspension strength group descriptive table.

Variables	n	Min.	Max.	mean	Std.
Age (year)	30	35	45	39.10	3.356
Height (cm)	30	150.00	185.00	167.23	7.532
Body Weight (kg)	30	53.40	93.80	79.48	12.465

[a,b,c] Values within a row with different superscripts differ significantly at P<0.05.

Table 4 shows that there was no statistically significant difference between the pre-test BMI, body fat percentage, right-left hand grip strength, push-ups, sit-ups, squats, planks, flexibility and balance measurements of the TSG and SSG individuals participating in the study. The absence of a significant difference indicates that the research groups were homogeneously distributed.

Table 4 Comparison of TSG pre-test and SSG pre-test.

Variables	n	TSG Pre-test	SSG Pre-test	t	p
BMI (kg/height^2)	30	27.40±4.64	26.90±4.41	.478	.636
Body Fat Percentage (%)	30	23.40±7.25	24.80±6.98	-.750	.459
Right Hand Grip (kg)	30	37.10±10.30	35.49±9.81	.830	.413
Left Hand Grip (kg)	30	36.31±10.44	34.05±8.70	1.198	.241
Push-up (rp)	30	14.47±7.12	16.67±7.05	-1.206	.238
Squat (sc)	30	54.27±22.67	60.34±27.55	-.763	.451
Crunch (rp)	30	21.00±4.01	22.90±6.29	-1.505	.143
Plank (sc)	30	54.73±19.47	63.40±35.10	-1.932	.163
Flexibility (cm)	30	25.10±9.38	25.30±9.53	-.103	.919
Balance (ec)	30	5.13±1.90	5.07±1.74	.372	.712

BMI: body mass index, %: percentile, kg: kilogram, rp: repeat, sc: second, cm: centimetre, ec: error count, TSG: Traditional strength group, SSG: Suspension strength group.

Table 5., no statistically significant difference was found between BMI, body fat percentage, right-left hand grip strength and push-up performance measurements taken at the end of 8 weeks of TSG. However, a significant difference was found between squat, sit-up, plank, flexibility and balance performances ($p<0.05$).

Table 5 Comparison of pre-test and post-test of TSG.

Variables	n	TSG Pre-test	TSG Pre-test	t	p
BMI (kg/height^2)	30	27.40±4.64	27.42±4.64	-.070	.945
Body Fat Percentage (%)	30	23.40±7.25	23.28±7.05	1.160	.256
Right Hand Grip (kg)	30	37.10±10.30	42.78±12.70	-1.069	.294
Left Hand Grip (kg)	30	36.31±10.44	36.38±10.48	-1.777	.086
Push-up (rp)	30	14.47±7.12	17.97±5.70	-1.857	.073
Squat (sc)	30	54.27±22.67	61.60±22.39	-5.593	.000*
Crunch (rp)	30	21.00±4.01	24.23±6.05	-5.859	.000*
Plank (sc)	30	54.73±19.47	58.53±23.76	-2.947	.006*
Flexibility (cm)	30	25.10±9.38	27.33±9.11	-11.404	.000*
Balance (ec)	30	5.13±1.90	3.33±1.44	7.449	.000*

BMI: body mass index, %: percentile, kg: kilogram, rp: repeat, sc: second, cm: centimetre, ec: error count, TSG: Traditional strength group, SSG: Suspension strength group.

Table 6., statistically significant differences were reported in BMI, body fat percentage, right-left hand grip, push-up, squat, sit-up, plank, flexibility and balance performances of the 8-week SSG group ($p<0.05$*).

Table 6 Comparison of pre-test and post-test of SSG.

Variables	n	SSG Pre-test	SSG Pre-test	t	p
BMI (kg/height^2)	30	26.90±4.41	26.24±4.44	10.315	.000*
Body Fat Percentage (%)	30	24.80±6.98	23.92±6.65	2.606	.014*
Right Hand Grip (kg)	30	35.49±9.81	36.27±9.72	-12.475	.000*
Left Hand Grip (kg)	30	34.05±8.70	34.80±8.80	-9.772	.000*
Push-up (rp)	30	16.67±7.05	22.77±7.90	-12.515	.000*
Squat (sc)	30	60.34±27.55	73.67±36.77	-10.059	.000*
Crunch (rp)	30	22.90±6.29	30.93±8.10	-10.283	.000*
Plank (sc)	30	63.40±35.10	84.73±39.80	-7.962	.000*
Flexibility (cm)	30	25.30±9.53	26.83±9.23	-7.439	.000*
Balance (ec)	30	5.07±1.74	3.80±1.84	-7.813	.000*

BMI: body mass index, %: percentile, kg: kilogram, rp: repeat, sc: second, cm: centimetre, ec: error count, TSG: Traditional strength group, SSG: Suspension strength group.

Table 7 shows that there was no statistically significant difference between the BMI, body fat percentage, right-left hand grip, flexibility and balance performances of the groups who applied 8 weeks of TSG and SSG. However, a significant difference was found in push-up, squat, sit-up and plank performances. The group that created this difference was the suspension strength group. In other words, push-up, squat, sit-up and plank performances of the suspension strength group were found to be more significantly different from the performance measurement results of the traditional strength group.

Table 7 Comparison of pre-test and post-test of TSG.

Variables	n	TSG Pre-test	TSG Pre-test	t	p
BMI (kg/height^2)	30	26.90±4.41	26.24±4.44	10.315	.000*
Body Fat Percentage (%)	30	24.80±6.98	23.92±6.65	2.606	.014*
Right Hand Grip (kg)	30	35.49±9.81	36.27±9.72	-12.475	.000*
Left Hand Grip (kg)	30	34.05±8.70	34.80±8.80	-9.772	.000*
Push-up (rp)	30	16.67±7.05	22.77±7.90	-12.515	.000*
Squat (sc)	30	60.34±27.55	73.67±36.77	-10.059	.000*
Crunch (rp)	30	22.90±6.29	30.93±8.10	-10.283	.000*
Plank (sc)	30	63.40±35.10	84.73±39.80	-7.962	.000*
Flexibility (cm)	30	25.30±9.53	26.83±9.23	-7.439	.000*
Balance (ec)	30	5.07±1.74	3.80±1.84	-7.813	.000*

BMI: body mass index, %: percentile, kg: kilogram, rp: repeat, sc: second, cm: centimetre, ec: error count, TSG: Traditional strength group, SSG: Suspension strength group.

DISCUSSION

The main objective of this study was to determine the effect of the use of suspension training on the increase in muscle mass and development of muscular strength in sedentary people. The main objective of this study

was to find a significant difference in push-up, sit-up, squat and plank performance in people training with TRX-equipment on moving surfaces. 8 weeks of regular suspension training showed statistically significant differences in body mass index, body fat percentage, right-left grip strength, push-up, squat, sit-up, plank, flexibility and strength scores. In the study applied in swimmers, strength measurements were taken from the legs of the participants before the test and it was checked whether there was a difference between the measurements after the test. Şenol (2017) compared the leg strength values before and after the test in the TRX group with the values in the body weight group and swimming group and found that the strength values in the TRX group showed a significant improvement (Şenol & Gülmez, 2017). In a study conducted in this context, it was found that the use of SDG tests in the squat test in sedentary individuals and their performance on fixed surfaces showed improvement in the development of lower extremity strength. Snarr (2013) examined muscle activation using electromyography (EMG) during conventional push-ups and TRX push-ups (push-ups with TRX-machines) in 21 participants and found that muscle activity during push-ups with TRX was significantly higher than conventional push-ups (Snarr and Esco 2013). In addition, McGill et al. investigated the differences between traditional push-ups and push-ups performed at angles with altered range of motion using suspension equipment in 14 male participants with an average age of 21.1 years. It was found that push-ups performed using TRX increased muscle activation on unstable surfaces and thus significantly increased muscle strength compared to traditional push-ups (McGill SM et al., 2013). It has been shown that the increases in upper extremity muscle strength and push-up repetitions in studies using suspension equipment are higher than those performed on unstable surfaces. In a study by Kibele and Behm (2009), 7-week resistance training on an unstable surface was compared with traditional resistance training and no significant difference was reported in balance tests (Kibele and Behm 2009). Similarly, Jeffrey J. et al. (Janot et al., 2013) found no significant change in balance based on data from a study of women aged 19 to 64 years (Janot et al., 2013). Therefore, it is said that the improvement in balance performance may be more likely to occur in studies applied to non-solid surfaces, but more research is needed in the literature. In this study, resistance training was used in both groups and although balance scores improved after training in both groups, no significant difference was found between DDG and SDG. Consistent with the literature, it is thought that the lack of a significant difference between the two groups in terms of balance after this study is due to the development of the muscles in the trunk region after the current training. Tomljanović M. et al. In a study conducted in 2011 on a group of 23 volunteers with an average age between 22 and 25 years, it was reported that no significant difference was observed when comparing the results of anthropometric measurements and pre-post tests performed in groups using traditional strength and functional training. Training equipment, for 5 weeks and 3 days per week (Tomljanović et al., 2011). This is because the training plan can be implemented in only 5 weeks. Mate-Munoz et al. (2014) examined basic strength training applied on moving surfaces and corresponding basic strength training. In a study of 36 healthy male participants, two experimental groups and a control group of 12 participants were formed. In the experimental group, eight movements consisting of TRX and Bosu devices were performed three times a week for seven weeks. In the control group; eight movements consisting of dumbbells and barbells were performed for the same period. Jumping, squatting, reaching press movements were applied as pre and post tests. Measurements showed that balance ball and TRX-training, similar to dumbbell and barbell training, contributed to strength and power development in sedentary people (Mate-Muñoz JL., et al., 2014). Based on the results of both training interventions, it is expected that improvements in strength and power will be observed even in untrained individuals. The most important question is which training intervention is more favourable for improvement. Measurements of muscle strength gains obtained as a result of TRX-training support the increase in SDG-indicators for upper and lower extremities in this study. The results of this study showed that the development of upper and lower extremity strength performance (push-ups, sit-ups, squats, right and left grip, and planks) was significantly higher in the performance of individuals exercising on unstable surfaces than in individuals performing basic resistance training. This is due to the fact that the group performing resistance training on unstable surfaces developed their strength through active training of various muscle groups during strength exercises on moving surfaces and with their own body weight. (2010) applied traditional and TRX strength exercises to measure muscle activity during squat exercises performed at different angles to the abdominal muscles. For specific abdominal exercises, training was performed using various suspension devices and it was shown that squat exercises with TRX further increased muscle activation and thus positively affected core muscle strength (Sannicandro et al., 2015). Similarly, Cosio-Lima et al. (2003) examined muscle activation using EMG in a 5-week study to determine the effects of swissball and floor exercise on static balance time in 30 female participants aged 19-23 years. The effect of swissball and floor exercises on static balance time and a

significant increase in the strength of the abdominal muscles and extensor muscles of the spine was observed in participants who participated in a functional training programme compared to group training on the floor. In a study using suspension exercises, it was observed that the effect of core muscle activation on plank strength increased (Behm and Anderson 2006). On the contrary, Sannicandro I. et al. (Sannicandro et al., 2015) found a decrease in muscle performance in a study investigating lower limb muscle strength using a suspension device and suggested that this result may be due to the presence of professional athletes during the season (Sannicandro et al., 2015). When the relevant literature was examined, it was assumed that the limited number of studies on strength training on unstable surfaces in sedentary individuals may lead to differences in the results. Therefore, we can say that core training activates more than one muscle group at the same time. Ghervan (2012) investigated the physical development of athletes using TRX exercises in a study on professional handball players (Ghervan 2012). According to the results of the study, improvement in physical parameters and a significant difference in abdominal strength were observed. The improvement of physical performance by suspension and traditional strength training is consistent with the results in the literature (Afyon and Boyacı 2016; Ghervan 2012; Boyacı and Tutar 2018). Based on the results of this study, it can be said that suspension exercise contributes to the development of core muscles called core. Because squat, push-up, squat and plank will be parameters that develop with basic training. In the studies Boyacı and Afyon (2017) found an increase in physical performance. In addition, similar findings were obtained in the study of Boyacı and Tutar (2018). Therefore, the results of the study showed that an improvement was observed in the selected parameters in both groups. When upper extremity strength studies in the literature are examined, increases in back, shoulder, chest and arm strength are observed (Mate-Munoz et al., 2011; Tomljanović et al., 2011; Snarr and Esco 2013; Herrington and Davis 2005; Yaşar et al., 2024). In a study by Mate-Munoz et al. it was found that the increase in grip strength in the upper extremity was due to working with overhead equipment and increased muscle activation on unstable surfaces. In a study reviewing the suspension literature, Rasha (2017) found a significant difference in flexibility test in a study with TRX devices on high school students (Rasha 2017). In addition, in a study conducted by Mohammed (2016) to prevent shoulder injuries in swimmers, it was found that the flexibility of the spine and upper limbs increased (Mohamed 2016). Increasing joint mobility and spine flexibility during strength training with suspension exercises and triaxial work leads to greater flexibility. They found that strength training on moving surfaces (push-ups, squats, sit-ups and planks) provided more improvement than traditional strength training. This difference may be due to the fact that the SKG movement is based on the articulated principle and swimming in different planes. Strength training on moving surfaces is thought to affect the development of physical performance through increased stimulation of the nervous system, activation of various muscle groups and increased stimulation of receptors. In addition to traditional strength training, we recommend strength training on moving surfaces, especially in a seated position and using suspension equipment. Hanging equipment for seated exercise is also recommended because it is easy to access, can be used anywhere and is attractively priced.

Conclusion

It was found that strength exercises (push-ups, squats, sit-ups and planks) performed on unstable surfaces showed more improvement than traditional strength training. This difference may be thought to be due to the fact that the movements of SSG-are performed in a suspended state, in different planes and in accordance with the multi-joint principle. Strength exercises performed on non-fixed surfaces are thought to affect the development of physical performance due to increased nervous system stimuli, activation of different muscle groups and more stimulation of receptors.

In addition to traditional strength training, strength exercises on non-fixed surfaces, especially in sedentary individuals, can be recommended with suspension equipment. In addition, suspension equipment can be recommended because it is accessible, can be used everywhere and is more attractive in terms of cost.

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Conflict of Interest

The authors do not have any conflicts of interest to disclose. All co-authors have reviewed and concurred with the manuscript's content, and no financial interests need to be reported.