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RESEARCH ARTICLE

# EFFECTS OF SLACKLINE VS. PILATES ON ANTERIOR CORE MUSCLE STRENGTH

**Yonatan Galkin, Nadav Gilad and Eli Carmeli**

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ABSTRACT

***Background*** Using Slackline and Pilates exercise are arousing interest among athletes and enhance treatment compliance of different patients, and thus might serve as an effective tool to improve muscle strength.

***Aim*** to determine the effects of Slackline vs. Pilates on abdominal muscle strength.

**Methods** 11 volunteers were randomly allocated into the Slackline group (n=6; 26.5 ± 3.5 years) and the Pilates group (n=5; 26.5 ± 2.5). The outcome measures for both groups underwent the Y Balance Test, Plank Test, Trunk Flexion Test, and Straight Leg Lift before and after intervention. The intervention was 60 minutes, twice a week, for seven consecutive weeks.

***Results*** After training, the four outcome measurements were improved in both groups regardless the group ($p<0.05$). No difference was found between Slackline vs. Pilates.

***Conclusions*** This is the first study designed to test the effects of Slackline on core muscles and compare it with Pilates. We found that Slackline is as beneficial as Pilates in strengthening the anterior core muscles.



## INTRODUCTION

The function of core muscles is extremely important both for physical rehabilitation and sports activity (1, 2). The anterior core muscles (i.e., pelvic floor muscles, tranversus abdominis, internal oblique abdominal, external oblique abdominal and multifidus) are also necessary for daily activities such as coughing, sneezing, and lifting an object. Most daily activities as well as sports and other physical activities depend on stable core muscles. Weak core muscles can cause low back pain and bad posture (1-3). However, aside from occasional sit-ups and pushups, core exercises are often neglected .

Although core muscle strengthening is important for good health, some individuals fail to carry out core muscle exercises for various reasons, such as lack of interest, unawareness of the importance of such exercises, and difficulty maintaining repeated practice. Another factor related to the low level of compliance with core exercises is the feeling of ‘not belonging’ to group trainee circles (2, 4).

The Slackline exercise method, which has recently gained popularity, strengthens the lower leg muscles (5) and promotes postural control in children (6). Little is known regarding the effects of Slackline when the focus is on the core muscles. Slackline is a relatively new sport device made of polyester or nylon fibers strip, 2.5-5 cm wide and a length ranging from a few meters to several tens of meters. The strip is usually placed 30-50 cm above the ground. One side of the strap has a small loop that is fastened to a tree or any similar static object. On the other side of the strip there is a ratchet stretcher, which also is connected to a stable static object. The idea of the Slackline is to challenge the body and concentration by standing on it as long as possible, and by walking on the Slackline as far as possible Pilates is a well-known technique that has been gaining popularity among therapists and trainers. It focuses on core stability, flexibility, posture, muscle strength, and breathing, sometimes using a special Pilates bed (7)

The aim of this study was first to determine the effect of Slackline on increasing core muscle strength. Then we hypothesized that a Slackline exercise protocol would streng then core muscles more than used in Pilates (Figure 1).
We had 4 hypotheses :

- Training will improve the four measurements regardless the group.
- A combined effect of group (Slackline/ Pilates) and training will be found, so that training will improve the results of the four measures, but the improvement will be greater in the Slackline group of than in Pilates group.
- Training will improve overall success regardless the group.
- A combined effect of group (Slackline/ Pilates) and training will be found so that training can improve the

*✉ ***Corresponding author:*** **Yonatan Galkin**

overall success, but the improvement will be greater in Slackline group than in Pilates group.

Figure 1

## METHODS

This cross-sectional, descriptive study was carried out among female university students.

***Subjects***

Recruitment of subjects was done through by posting on bulletin boards in several locations and departments at the University of Haifa, through social networking (i.e., Facebook group, emails), advertising in Pilates groups around the Haifa region and by word-to-mouth.

In order to participate, subjects were required to meet the following criteria: healthy, young girls (age 20-30 years old), no background in any professional sports of any kind or membership in any sports club, did not engage in any physical activity such as yoga, Pilates, TRX, Tai chi, etc. in the last month, and did not engaged in any exercise or sport over 150 minutes per week.

Exclusion criteria included body mass index (BMI) measured by weight in kg/height (in cm)$^2$ under 18.5 and over 25.5, any neurological or orthopedic disorder or pain that would interfere with any physical effort or balance capability. Among 27 volunteers, only 13 subjects met the study criteria. Others were excluded due to history of back or leg pain (70%) and BMI <18.5 or > 25.5. Two subjects excluded due to low scores in the Y balance test (see below).

***Randomization and Blindness***

Upon being recruited, each of the subjects was given a number from 1 to 13. All subjects with an uneven number were assigned to the Slackline group and subjects with an even number were assigned to the Pilates group. Data were collected by one of the researchers who was blinded to the subject groups.

***Outcome measures***

Before starting the intervention (T1) and immediately after its conclusion (T2), all subjects underwent a series of four clinical tests to evaluate their sensory-motor abilities. One of the clinical tests, the Y balance test, also served as a cut-off assessment. Thus, those who did not score at least 0.8 (reaching distance in cm dividing by leg length) were excluded from the study. Two subjects did not score 0.8 or higher in the Y balance test, thus only 11 subjects participated in the study.

***Y Balance Test (YBT)***

The Y balance test (YBT) is designed to examine balance. The test requires good core muscle strength.

Test procedure: the subjects stand on one leg and tries to push an object with the other foot as far as possible in three directions, forward, backward and medial posterior lateral while maintaining stability. The pushing foot cannot touch the ground and must return to the starting point without losing balance. Subjects were asked to reach the minimum grade (reaching distance in cm dividing by each subject leg length) of 0.8 in 3 different directions. The test was found valid and reliable for testing dynamic stability (8-12).

***Plank Test (PT)***

This procedure is designed to test the strength of the core muscles. The PT starts with the subject's upper body supported off the ground by the elbows and forearms, and the legs straight with the weight taken by the toes. The hip is lifted off the floor creating a straight line from head to toe. As soon as the subject is in the correct position, the stopwatch is started. The test is over when the subject is unable to hold the back straight and the hip is lowered. The subject was asked keep the trunk aligned relative to the ground relying on toes and forearms only throughout the test. The above posture had to be maintained for 60 seconds, followed by 6 additional positions, each maintained for 15 seconds and then 30 seconds: one hand forward off the floor followed by one foot of the floor, then second hand off followed by the second leg of the floor and last alternate limbs off the floor.The test was found reliable (13) by numerous assessments including sEMG, particularly with respect to sports (14).

***Trunk Flexion Test (TFT)***

The trunk flexion test (TFT) is very commonly used and reliable test (15,16) for evaluating bending strength and torso endurance. This procedure examines anterior core muscle strength and endurance. The subject is asked to hold the upper body for as long as possible at an angle of 60° after removing the angular pad holding the back when hip joint position is maintained at 90° and knee joints also 90°. The position angles were measured using a goniometer.

***Straight Leg Lift (SLL)***

This procedure tests the anterior core muscles, to assess if subject fails to flatten the lumbar lordosis (lumbar spine curve). Procedure: the subject lies on his back when the examiner puts his hand beneath the subject's lumbar spine. The subject lifts the legs slowly straight up when asked to push against the examiner's hand as much as possible. When the examiner feels that he has no contact with the lumbar spine, subject must stop and the angle between the feet with the ground is measured and recorded using a goniometer. The SLL was found sensitive for assessing young and adult athletes and people with low back pain (17,18,19).

***Intervention***

Group I (Slackline) practiced twice a week for seven consecutive weeks , each session for 40-50 minutes. This was followed by regular training on the rope which basically included walking forward, backward, turning, sideways walking, and standing with hands either held close to the body or extended.

The participants tried to walk as much as possible on the Slackline, with a pause of a couple of minutes every few tries.
Group II (Pilates) exercised for seven consecutive weeks, twice a week for 45 minutes on mat exercises. To monitor compliance, all participants filled a weekly book log. The researchers also contacted the participants once a week and recorded their compliance.

***Ethical considerations***

The study was approved by the Institutional Review Board of the University of Haifa. The study protocol complied rigorously with data protection legislation, and was conducted according to the principles of the Helsinki Declaration, following standards of good clinical practice.

***Statistical analysis***

Since there were four measurements (YBT, SLL, TFT, PT) which measured a single nominal variable, a repeated measures multivariate analysis was performed to check the first two hypotheses. The alternative analysis was to 4 times mixed-ANOVA, but this is a methodology error that increases the alpha. The two other hypotheses a repeated univariate analysis measures were performed to test the other two hypotheses.
In order to calculate an index measurement which considers all four clinical tests and gives each subject a general outcome, the four tests were received a standardized score and 3 was added (linear transformation), in order to avoid negative numbers (so that the average of each measure is 3, with a standard deviation of ±1). Once that linear transformation was performed on all four measures, "overall success" was set as a new variable by averaging the four measurements.

The Shapiro–Wilk test was used to examine the normal distributions of the participants and the variables. Except for the SLL test, all participants and the three tests were normally distributed (Table 2**).**

## RESULTS

Demographic findings of the participants are noted in Table 1. All patients improved in all four measurements after intervention. However, it should be noted that all measurements except YBT had large standard deviations. It also shows that when interpreting the 4 measurements of success for each subject, namely relating to the variable "overall success", no general improvement was seen and the averages before and after the intervention were similar. Table 2 demonstrates descriptive statistics for the differences between pre- and post-intervention.

**Table 1** Demographic Findings of the participants

| Variable | Group 1 | Group 2 |
|---|---|---|
| | Mean±SD, (range) | Mean±SD, (range) |
| Age (years) | 26.17±2.23, (7) | 26.6±1.82, (5) |
| Weight (kg) | 61.17±4.4, (12) | 55.6±5.55, (14) |
| Height (cm) | 163.67±5.82, (14) | 161.4±9.26, (22) |
| BMI ($kg/cm^2$) | 22.85±1.41, (4.12) | 21.44±2.61, (5.84) |

SD- Standard Deviation; BMI –Body Mass Index

**Table 2** Descriptive statistics of the study variables

| Variable | Time | Group 1 | Group 2 |
|---|---|---|---|
| | | Mean±SD, (range) | Mean±SD, (range) |
| Y Balance Test | | 0.92±0.03, (0.07) | 0.92±0.09, (0.22) |
| Straight Leg Lift | | 17±1.26, (3) | 15.2±3.49, (9) |
| Trunk Flexion Test | T1 | 82.83±58.52, (145) | 96.4±48.23, (112) |
| Plank Test | | 76.17±44.72, (107) | 94±44.41, (100) |
| Overall Success | | 3.00 | 3.00 |
| Y Balance Test | | 0.97±0.08, (0.21) | 0.94±0.05, (0.14) |
| Straight Leg Lift | | 23.17±6.68, (19) | 16.2±1.92, (5) |
| Trunk Flexion Test | T2 | 105±54.91, (150) | 123.6±63.85, (171) |
| Plank Test | | 106.67±53.09, (141) | 96.2±32.23, (84) |
| Overall Success | | 3.00 | 3.00 |
| Y Balance Test | | 0.05±0.07, (0.21) | 0.02±0.04, (0.11) |
| Straight Leg Lift | | 6.17±6.24, (17) | 1±0.04, (0.11) |
| Trunk Flexion Test | Delta | 22.17±32, (79) | 27.2±3.08, (77) |
| Plank Test | | 30.5±21.49, (49) | 2.2±24.28, (63) |
| Overall Success | | 0.00 | 0.00 |

n=11, *$p<0.05$

Hypothesis 1 was evaluated after multivariate analysis repeated measures were performed. Scores were lower before the training than after the training [F (1,9) = 13.37, p <.01]. For interaction with the type of the tests, the 'sphericity assumption' was tested by Greenhouse-Geisser test and was found to be insignificant [F (1,14) = 3.93, *p* = 0.052]. It should be noted that the Huynh –Feldt test which is less stringent, showed an interaction, and that results of the Greenhouse-Geisser test was borderline significant. Therefore, simple effects were examined separately for each measure, to see if there were differences between the variables. In order to assess the existence of differences we carried out four continual tests by paired *t*-test. For YBT found that the subjects received higher scores after the training (M = 0.95, SD = 0.063) compared to before the training (M = 0.91, SD = 0.071) significantly [t (10) = 1.93, p (single- tailed) <. 05]. For SLL, we found that subjects after the training (M = 20.00, SD = 6.08) scored significantly higher [t (10) = 2.29, p <.05] than pre assessment (M = 16.18, SD = 2.56) and this score consistent with the hypothesis (see Figure 2).

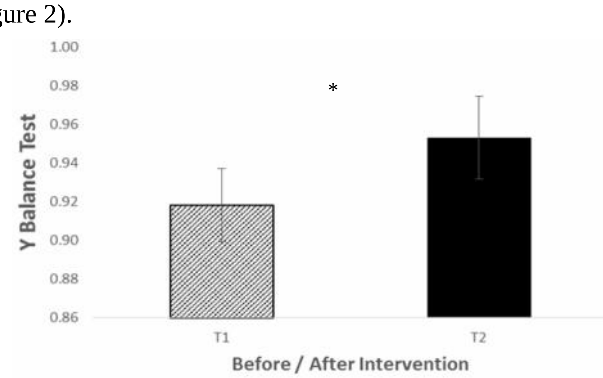


**Figure 2** YBT time measurement-dependent

p (single-tailed) <. 05

For the TFT, subjects post-training (M = 113.45, SD = 56.86) received high and significantly [t (10) = 2.76, p <.05] scores than pre training (M = 89.00, SD = 51.89), and this score consistent with the hypothesis (see Figure 3).

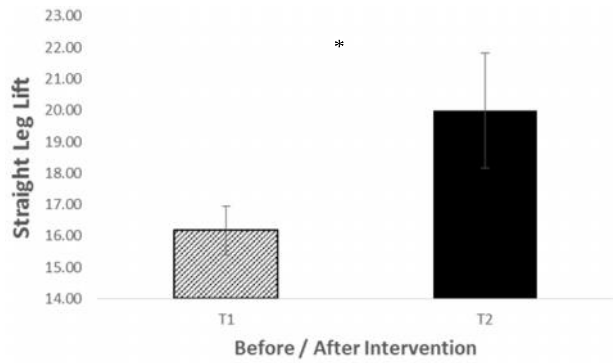


**Figure 3** SLL time measurement-dependent

*p<.05

For PT we found that the subjects post training (M = 101.91, SD = 43.07) received significantly [t (10) = 2.23, p <.05] high scores than pre training (M = 84.27, SD = 43.31), and this score is consistent with the hypothesis (see Figure 4).

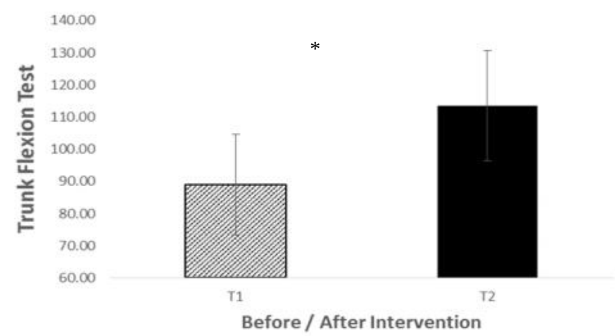


**Figure 4** TFT time measurement-dependent

*p<.05*

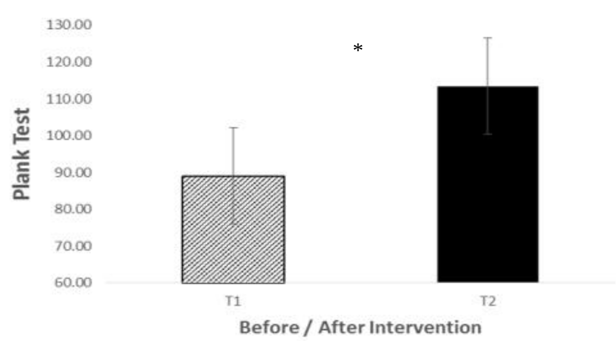


**Figure 5** PT time measurement-dependent

*p<.05

You can see that for the same size group, lower significance (one-tailed) indicates a smaller effect. Therefore, we can say that for YBT, the difference pre-training and post-training was low relative to other variables. However, the first hypothesis was entirely confirmed.

The second hypothesis was evaluated through performing repeated measures multivariate analysis. No difference was found between group type (Slackline / Pilates) and training [F (1,9) = 1.36, p = 0.28]. The hypothesis was not supported.

Hypothesis 3 and 4 were evaluated by repeated measures univariate analysis, and there was no difference between the groups before and after the training for overall success [F (1,9) = . 008, p = 0.93]. Thus, hypothesis 3 was not supported. No interaction was found between group type (Slackline/ Pilates) and training for overall success [F (1,9) = . 99, p = .35], thus the hypothesis 4 was not supported.

***Additional Findings***

To evaluate that all variables indeed measured the same nominal variable (which is physical fitness), Cronbach's alpha reliability test was performed. No sufficient value (0.7> alpha) was found even after dropping items that reduced the reliability. Therefore, it appears that the measures are not good for use as scattered, but have to be measured separately.

To examine the relationship between the overall success of the differences and the four research variables raw (YBT, SLL, TFT, PT), 10 Pearson linear correlation tests were performed. Strong, positive significant relationships were found among all variables except for TFT. We can conclude that this variable does not change along with other variables. The strongest relationship was found between overall success and the SLL. The second strongest relationship and first in power for only the raw data, was between PT and SLL (Table 3).
Put here Table 3

**Table 3** Table of Pearson correlation values

| Variable | YBT | SLL | TFT | PT | Overall Success |
|---|---|---|---|---|---|
| YBT | 1 | .79** | .07 | .66* | .87** |
| SLL | | 1 | .07 | .80** | .88*** |
| TFT | | | 1 | ..-10 | .24 |
| PT | | | | 1 | .80** |
| Overall Success | | | | | 1 |

n=100, **p<.05, **p<.01, ***p<.001*

## DISCUSSION

The study results show that Slackline and Pilates can both be equally useful as a therapy protocol for individuals who need to streng then their anterior abdominal core muscles. No deleterious effects related to both approaches were found. Although it was practical to undertake a research study comparing the two treatment approaches, the absence of any discernible difference makes it difficult to know how easily distinguishable the two approaches would be in clinical practice. As Gabel *et al*., (5) demonstrated, Slackline can be beneficial in providing both a prophylactic and a rehabilitation action. Slackline training can be further challenged both physically and cognitively by stretching the line longer (which increases its oscillations), fixing the line with less tension (which also increases posture stability), or stretching the line higher and longer (which also requires muscle endurance).

These adjustments demand the trainee to have higher muscle control. In particular, the core muscles and postural control are challenged by stimulating three inter-connected systems: vestibular, proprioceptive and cerebellum. In addition, changing the height of the Slackline challenged cognitive abilities such as concentration, attention, placing steps more accurately and precisely; feedback and feed forward mechanisms of the sensory muscle activity are also required.

Results from this study show that the Slackline approach resulted in improvement in all measures as the Pilates approach. It could be argued that these measures are not sufficiently sensitive to discern a change in the quality of performance or in the endurance or the strength of the specific core muscles. The implications are that Slackline exercises can also be transitioned with equal effectiveness into the rehabilitation and management of ankle and hip as well as core and whole body stabilization work (5). Nesser *et al*., suggested that core training is necessary for optimal sport performance and should not be dismissed (20).

Surprisingly, even Y Balance test outcomes were not better in the Slackline group then in the Pilates group. Since Slackline training focused specifically on walking on a narrow and unsteady line that forced subjects to maintain balance, we expected to see better scores than in Pilates for this test. Yet, we did not find a significant difference between the groups.

The tests that were used in this study are valid and reliable and have been previously used in other studies; therefore, it is unlikely that the failure to detect differences arose from poor measurement. All the subjects reported that the training was worthwhile, including those who did not improve in any parameters. The improvement in balance alone made a difference for these subjects when carrying out functional tasks. Akuthota *et al*., said that "core strength is an integral component of the complex phenomena that comprise balance". Balance requires a multidimensional interplay between central, peripheral, sensory, and motor systems.

Training in the domain of balance is important for functional activities (2). Gabel *et al*. found that the strengths that this study replicates the clinical situation and has direct application to daily practice (5). Overall, core endurance tests were the most reliable measurements. Therefore, when assessing core stability, it is critical to understand that the reliability of the related measurements may vary.

***Limitations***

The small sample size made it difficult to demonstrate significant clinical improvement; therefore, no definitive conclusions can be drawn about the relative effectiveness of the two approaches, except to note that differences, if they exist, are not significant. The study did not include an untreated control group and so conclusions about specific benefits arising from either treatment need to be drawn cautiously. However, the results are definitive that the two approaches improved muscle strength in all subjects. The lack of any major difference in outcome between the two approaches is not entirely surprising given the distinctive nature of the two approaches; both are mainly core muscle-oriented.

Lastly, the cross-sectional design is a limitation of this study. Determining the long term effect of Slackline vs. Pilates could contribute further information and justification to use one approach over the other for core muscle strengthening (21).

## CONCLUSIONS

This study found no major differences in outcomes between two Slackline and Pilates when used to improve strength and endurance of the abdominal core muscles in healthy young subjects, although subtle differences may have been missed in such a small study. The results suggest that individuals with weak core muscles may benefit from a relatively short period of enjoyable exercise activity such as Slackline or Pilates. We think that interest in the exercise will improve compliance.

***Abbreviations***

YBT – Y Balance Test
SLL – Straight Leg Lift
TFT – Trunk Flexion Test
PT – Plank Test

***Conflict of Interest Statement***

All authors certify that they have NO financial interest in the subject matter discussed in this study.

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