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Comparison of the Effects of Sling Exercise and Total Body Resistance Exercise on Physical Functional Performance and Postural Balance : A preliminary study

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Abstract

Purpose : The purpose of this study was to investigate the effect of exercise using a suspension device (sling and total body resistance exercise; TRX) on physical functional performance and postural balance.

Methods : An experimental study comparing 2 different suspension exercise was conducted on 16 healthy college students. 16 subjects were assigned to two groups. They were classified into 8 sling group and 8 TRX group. Miniplus was used to evaluate physical functional performance. In this study, isokinetic resistance mode was used to compare and analyze seven movement patterns. Biorescue was used to evaluate postural balance. The intervention exercises in this study are as follows. Standing lean forward (SLF) using a sling and TRX was performed 3 times a week for 3 weeks. The SLF was held for 10 seconds and then rested for 15 seconds, repeated a total of 10 times for 3 sets.

Results : In the TRX group, significant increases were observed in physical functional performance ($p<.05$). Among the differences between groups, significant differences were confirmed on the front of the right arm, the back of the left arm, and the back of the right arm. In the sling group, significant increases were observed in left, right, front, and overall dynamic balance ($p<.05$). A significant increase in posterior dynamic balance was confirmed in the TRX group ($p<.05$). There was no significant difference between groups.

Conclusion : Based on the results of this study, TRX was effective in improving physical functional performance, while the sling was effective in enhancing postural balance. However, confirming the effectiveness of slings and TRX in the relationship between physical functional performance and postural balance proved inadequate. Therefore, additional research should be conducted to verify the effects of suspension.

Key Words : physical functional performance, postural balance, sling, suspension exercises, total body resistance exercise

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Ⅰ. Introduction

According to the national lifestyle sports survey, with the increasing level of individual awareness and interest in health in modern society, many people have become interested in exercising for self satisfaction, improving physical ability, preventing injury, and maintaining a healthy body, the same as in the previous year. Exercising has increased by 9 %~11 % compared with the previous year (Korean statistical information service, 2022). Many people encounter exercise through social network service or other media, learn exercise methods, and perform regular moderate intensity exercises of less than 70 % of the maximum oxygen consumption for the purpose of improving health (Kandola et al., 2019).

In the field of sports and rehabilitation exercise, exercises in unstable environments are mainly used as a common resistance exercise method not only to improve physical health but also to develop proprioception (Byrne et al., 2014). Instability can be acquired through equipment or techniques and can also be created using a Bosu ball or a Swiss ball. Specifically, the importance of suspension exercises aimed at whole body vibration, progressive resistance exercise, and task-oriented training has been emphasized (Byrne et al., 2014; Jeong et al., 2022).

Suspension exercises consist of using a rope and a webbing system to exercise against one’s own body weight. It uses swinging ropes and auxiliary tools to eliminate gravity, allowing for unstable environments, whole body vibration, progressive resistance exercises, and task oriented exercises. Training is provided without the risk of injury (Ihn & Paek, 2021). Closed chain exercises can be easily performed, and the exercise method is simple and easy to use (Kim et al., 2003). The types of suspension exercises include the FKPro system, Redcode, aeroSling, ELITE, the hook isometrics/suspension trainer, the Ztraniner suspension fitness system, and the total body resistance exercise (TRX) suspension trainer (Byrne et al., 2014).

What the two types of suspension movements have in common is that they are movements on a stable support surface. However, instability is formed due to unstable strings, and in that state, when the body’s center of gravity moves away from the support surface, rotational force due to gravity is generated, which must be resisted. Leg strength is also used, even when the arms are exercised. This improves whole body strength, muscle endurance, and joint mobility through progressive resistance and increases balance ability by enhancing proprioception (Hong & Yoon, 2022; Oh et al., 2003). The difference is that sling exercises require the installation of equipment. It is performed using ropes coming down from two axes, and many auxiliary tools are used so that the handle can be changed depending on the type of exercise. Conversely, TRX can be performed as long as there is space to tie the rope. It does not require auxiliary tools, so the handle cannot be changed. A rope comes down from one axis and splits on both sides (Luo et al., 2020).

Suspension exercises are high intensity training that can effectively enhance body coordination and stability. Specifically, it can improve stability not only in the core but also in various joints throughout the body by enhancing lower body function (Assar et al., 2020; Jung & Choi, 2019). Sling exercise has been studied in various contexts and has shown positive effects on different aspects of physical health. In basketball players, sling exercise improved core endurance and strength, as well as the speed of lay-ups over obstructions (Liu et al., 2022). In office workers with spinal diseases, sling exercise was found to have a significant effect on balance and foot pressure (Yoon & Park, 2023). NEURAC sling exercise method as a therapy that aims to improve trunk muscle activation and stability. The use of specific sling exercises (NEURAC) significantly improved functional movement screen test results in male volleyball players (Linek et al., 2016).

Bryan et al. (2014) reported that core muscle activity increased through TRX exercise. As a result of TRX exercise performed on elderly people, the increase in balance could be explained by the increase in core muscle activity and the ability to maintain balance (Pierle et al., 2022). TRX exercise using body weight was found to provide appropriate resistance to strengthen the core and limb muscles of patients with knee arthritis by stimulating the lumbar pelvic hip joint muscles (Assar et al., 2020).

Training on suspension equipment is effective in improving functional and muscular factors (Pierle et al., 2022). Suspension exercises are a novel and modern form of exercise that can simultaneously train all physical fitness components, such as flexibility, cardiovascular fitness, power, muscular strength, and endurance (Dudgeon et al., 2015). Suspension exercises promote stability and strengthen the core muscles, enabling proper force transfer from the arms to the legs, ultimately impacting stability and balance (Zemková & Zapletalová, 2022). Due to these effects, suspension exercises are recommended as one of the functional core stability exercises (Pierle et al., 2022).

The forward leaning position is mainly used when assessing the limits of functional stability using a sling and TRX, which are suspension exercises that clearly reveal commonalities in functional effects and differences in structural equipment (Opala-Berdzik et al., 2021). There has been a lack of research comparing physical functional performance and postural balance during suspension exercises using slings and TRX. Therefore, this study was conducted on healthy college students in their 20s to investigate physical functional performance and postural balance after performing standing leaning forward (SLF) using a sling and TRX three times a week for three weeks.

Ⅱ. Methods

1. Participants

This study was conducted on 20 healthy college students. We randomly assigned 10 subjects to the sling exercise group and 10 subjects to the TRX exercise group. A person not associated with this study randomly assigned the subjects to two groups based on their general information. However, two subjects from the sling exercise group and two subjects from the TRX exercise group dropped out, leaving the former with 8 subjects (6 men, 2 women) and the latter with 8 subjects (6 men, 2 women), for a total of 16 subjects. This study complied with the research ethics of the Declaration of Helsinki.

The criteria for selecting research subjects were as follows: 1) those without musculoskeletal and nervous system damage, 2) those with no posture control problems, 3) those with no strength training experience within the last six months, and 4) those who understood the purpose and methods of this study and voluntarily agreed to it. The general characteristics of the subjects are shown in Table 1.

Table 1. General characteristics of participants

Variables	Age (years)	Height (㎝)	Weight (㎏)
Sling group (n= 8)	23.63±3.74	173.38±4.24	69.00±9.58
TRX group (n= 8)	23.50±3.85	171.88±6.69	79.37±15.13

2. Equipment

1) Miniplus

To measure physical functional performance, we used a Miniplus machine (Miniplus, Ronfic, Korea), which is a musculoskeletal muscle function test device with a frame measuring 102.45 ㎝ wide, 76.05 ㎝ long, and 233.4 ㎝ high, with an auxiliary handle (Fig 1). Miniplus is a research device that helps predict joint range of motion and muscle strength levels in a standing position and evaluates strength and muscle function for movement within the maximum range of motion (Hyun et al., 2022). The muscle and nerve control of the torso and weight bearing legs must be efficient so that the movement and balance axes are maintained on the body's support surface while performing the test (Earl & Hertel, 2001).

The equipment has a measurement mode and an exercise mode. In exercise mode, resistance can be adjusted from 1 ㎏ to 100 ㎏ and can be set to isotonic, isokinetic, vibration, amplitude, and elasticity modes. In the measurement mode, isokinetic resistance was used to compare and analyze seven movement patterns. In this study, the measurement index was the physical functional performance assessed in a specific measurement mode, quantified in ㎏f (㎏ force), and utilized as the outcome variable.

Fig 1. Miniplus

2) Biorescue

To measure the postural balance of the subjects in this study, a balance ability measurement system called Biorescue (RMIngénierie, Marseille, France) was used (Fig 2). Biorescue can measure about 130 different types of static and dynamic balance. It connects a computer to a force platform consisting of 1,600 pressure sensors that measure the vertical pressure sway of both feet. It detects and observes the movement path line of the center of pressure, and the movement of the foot indicates a change in the center of pressure. The area (㎝), length (㎝), average speed (㎝/s), and limit of stability (LOS) can be calculated by measuring the movement path of the body's mass (㎟) during a specific movement while standing barefoot on a platform. In this study, the displacement of the human body's mass was used as the measurement variable.

Fig 2. Biorescue

3) Procedure

The exercise method used in this study was SLF performed using a sling and TRX three times a week for three weeks to assess physical functional performance and postural balance. The progress of the exercise was as follows (Fig 3).

1) Before starting the exercise, the subject performed it barefoot to prevent slipping.
2) Each subject was positioned in the center of the sling (Redcode AS, Staubo, Norway) and TRX (TRX PRO4 System, TRX, China) (Fig 4) strings.
3) The subject was prepared by standing upright, with both arms neatly placed next to the body, and adjusting the length of the rope so that the subject could hold the rope without his/her arms.
4) After holding the handles of both ropes, the shoulders were bent to the point where the shoulder bend was 90 °. The position was held for 10 s. When

returning to the original position, sufficient body weight was applied with a closed kinetic chain. A 15 s rest was allowed. This process was repeated 10 times and was performed for 1 set and a total of 3 sets. Rest between sets was allowed for 2 min and 30 s while sitting on a chair in a comfortable position (Hong & Yoon, 2022). Before this exercise, sufficient education was provided to the subjects about posture using a foam roller to prevent posture disturbance or compensation.

Fig 3. Exercise method

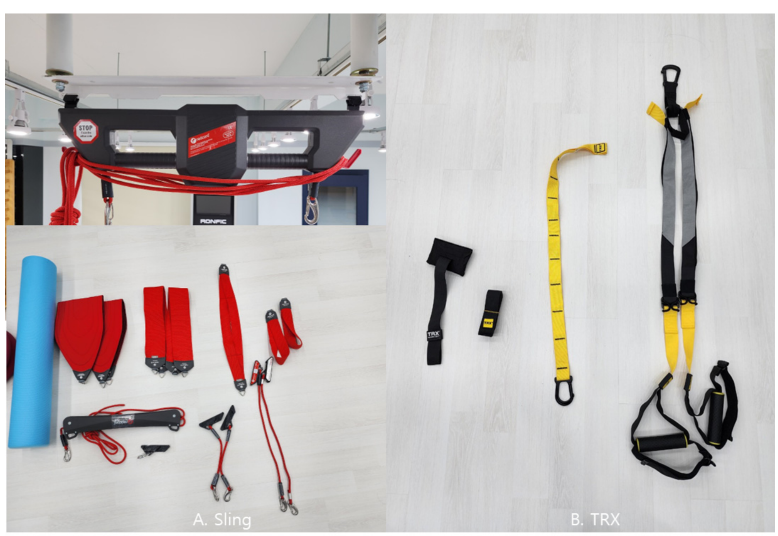

Fig 4. Suspension accessory

Miniplus measurement operation was as follows (Fig 5). (1) Unilateral push contralateral: as a right and left balance test of the anterior muscle oblique system, the pushing motion of the arm opposite the extended leg was measured five times for each of the right and left arms. Muscle contraction and force transmission were confirmed in the direction of the agonist muscles: the pectoralis major, the ipsilateral external oblique muscle, the internal oblique muscle, the abdominal fascia, and the contralateral leg adductor.

(2) Unilateral pull ipsilateral: as a right and left balance test of the anterior muscle tilt system, the pulling motion of the arm opposite the extended leg was measured five times for each of the right and left arms. When measuring, it was possible to check the transmission of force from the latissimus dorsi muscle to the lower outer ribs and behind the lateral oblique muscle, from the superior anterior iliac spine along the sternocleidomastoid muscle to the head of the tibia on the inside of the knee.

(3) Trunk rotation: as a right and left balance test for torso rotation, the muscle contraction and power transmission of the arms, torso, and legs were assessed by holding a cable with both hands and performing a rotating motion five times each on the right and left.

(4) Bilateral push with dominant leg: this was measured five times by testing the pushing force of the front of both arms. Contraction and force transmission of the superficial anterior and deep muscle lines (from the fingers to the pectoralis major muscle) were confirmed. At this point, the movement was performed with the dominant leg stepping forward.

(5) Bilateral pull with dominant leg: this was measured five times through a test of pulling force behind both arms. Muscle contraction was confirmed in the direction of backward and lateral movement of the arm and shoulder. At this point, the movement was performed with the dominant leg stepping forward.

(6) Squat: to check the muscle contraction and force transmission in the front of the body, a bar was attached to the cable, the cable was raised behind the neck, and the measurement was performed five times by rising from a squat position.

(7) Deadlift: this is a muscle test on the back of the body. A bar was attached to a cable. The legs were placed slightly narrower than shoulder width, and the torso was erect. The movement of rising from a sitting position while holding the bar was performed five times. At this point, squats and deadlifts were performed by adding a weight of 30 % of the subject’s body weight, and the remaining functional tests were performed by adding a weight of 10 % of the subject’s body weight. The speed limit was 100 ㎝/s for men and 140 ㎝/s for women when testing right and left torso rotations. The remaining tests were conducted at 60 ㎝/s for men and 90 ㎝/s for women. Measurements were conducted five times per movement, and the average value of the third to the fifth results, excluding the first and second results in which the subject adapted to the resistance of the measuring tool, was adopted as the final result (Hyun

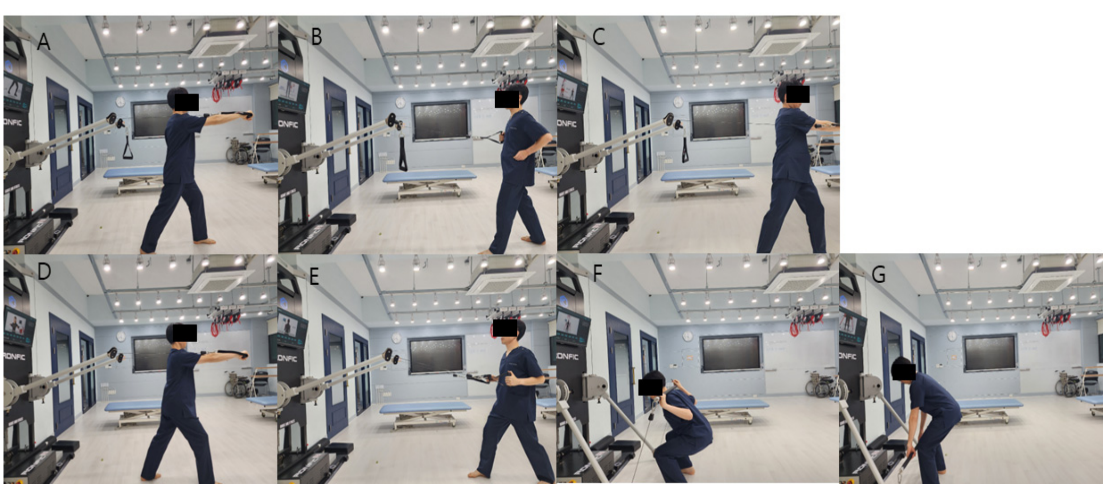

Fig 5. Measurement method

A) unilateral push, B) unilateral pull, C) trunk rotation, D) bilateral push, E) bilateral pull, F) squat, G) deadlift et al., 2022).

All measurements were made in accordance with the manual built into Miniplus, with a rest period of 8 s each time. The same measurements were taken before and after the exercise intervention. Sufficient explanations and practice were provided before the experiment.

To measure postural balance, the subjects were asked to stand barefoot on a platform without support, with both arms next to the torso and their feet spread hip width apart. The subject's feet were then externally rotated 15 degrees, and the subject was left standing comfortably. The subject followed the eight arrow directions (forward, back, left, right, and four diagonal directions) that appeared on the monitor screen located 1 m in front of the subject using an ankle strategy to move to a point where the subject could move within 8 s, maintain it, and return to the original position.

The subject was instructed to move in the direction of the arrow without any target action, such as the feet, hips, or torso. Prior to this measurement, each subject was allowed to practice once, and all measurements were taken identically before and after the exercise intervention. After measuring once, a 30 s break was provided, and after measuring three times, the average value was adopted as the result.

3. Statistical analyses

The data used in this study were processed using SPSS 22.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were used to confirm the general characteristics of the study subjects, and the mean and standard deviation were used for all variables. To confirm a normal distribution, the normality test was used using the Shapiro-Wilk test ($p>.05$). A paired samples t test was used to compare changes within the groups before and after exercise. An independent samples t test was used to compare changes between groups before and after exercise. The statistical significance level was set to .05.

Ⅲ. Results

1. Physical functional performance

In the TRX group, significant increases were observed in physical functional performance in the front of the right arm, the back of the left arm, the back of the right arm, the right trunk rotation, and the front leg muscle function ($p<.05$). In the differences between groups, significant differences were found in the front of the right arm, the back of the left arm, and the back of the right arm ($p<.05$) (Table 2).

2. Postural balance

In the sling group, significant increases were observed in left, right, front, and total postural balance ($p<.05$). A significant increase in posterior postural balance was found in the TRX group ($p<.05$). There was no significant difference between the groups ($p>.05$) (Table 3).

Table 2. Comparison between groups for physical functional performance (unit: kgf)

		Sling group (n= 8)	TRX group (n= 8)	t	*p*
Upper ventral Lt.	Pre	9.60±3.09	8.84±2.09		
	Post	10.85±6.98	9.76±3.69		
	Post-Pre	1.25±5.38	.93±2.63	.15	.880
	t	-.66	-.99		
	p	.532	.354		

Table 2. Comparison between groups for physical functional performance (Continue) (unit: kgf)

		Sling group (n= 8)	TRX group (n= 8)	t	*p*
Upper ventral Rt.	Pre	9.13±2.76	8.34±1,57		
	Post	8.73±2.74	9.96±2.46		
	Post-Pre	-40±1.92	1.63±1.61	-2.29	.038
	t	.59	-2.86		
	p	.574	.024		
Upper dorsal Lt.	Pre	10.55±4.40	9.48±2.27		
	Post	9.66±3.01	12.03±3.79		
	Post-Pre	-.89±3.05	2.55±2.92	-2.30	.037
	t	.82	-2.47		
	p	.437	.043		
Upper dorsal Rt.	Pre	10.83±4.57	9.29±2.36		
	Post	9.71±3.03	11.41±4.11		
	Post-Pre	-1.11±2.84	2.13±2.39	-2.47	.027
	t	1.11	-2.51		
	p	.305	.040		
Trunk rotation Lt.	Pre	10.16±3.92	9.66±3.73		
	Post	9.68±3.722	10.18±2.96		
	Post-Pre	-.49±1.36	.51±1.42	-1.44	.172
	t	1.02	-1.02		
	p	.344	.341		
Trunk rotation Rt.	Pre	9.11±2.79	8.76±2.36		
	Post	9.69±3.99	9.55±2.35		
	Post-Pre	.58±2.11	.79±.74	-.27	.792
	t	-.77	-3.00		
	p	.466	.020		
Upper dorsal	Pre	25.88±11.08	21.21±5.69		
	Post	24.43±11.66	24.35±5.56		
	Post-Pre	-1.44±11.14	3.14±5.16	-1.05	.310
	t	.365	-1.72		
	p	.726	.129		
Upper ventral	Pre	24.63±9.95	24.29±8.22		
	Post	20.78±7.78	24.14±6.20		
	Post-Pre	-3.85±7.50	-.15±3.53	-1.26	.227
	t	1.45	.120		
	p	.190	.908		
Lower ventral	Pre	68.35±30.16	66.34±26.43		
	Post	73.49±32.41	79.95±29.55		
	Post-Pre	5.14±8.42	13.61±13.76	-1.49	.160
	t	-1.73	-2.80		
	p	.128	.027		
Lower dorsal	Pre	68.85±34.98	56.65±21.61		
	Post	72.58±33.18	75.68±34.11		
	Post-Pre	3.73±18.75	19.03±24.30	-1.41	.180
	t	-.56	-2.22		
	p	.592	.062		

Lt; left, Rt; right

Table 3. Comparison between groups for postural balance (unit: ㎟)

		Sling group (n= 8)	TRX group (n= 8)	t	*p*
Left balance	Pre	5146.54±2115.48	6094.58±1341.79		
	Post	6362.79±3461.11	7274.13±2410.96		
	Post-Pre	1216.25±1419.70	1179.51±1673.11	.05	.963
	t	-2.42	-1.99		
	p	.046	.086		
Right balanc	Pre	5030.25±2488.86	5778.08±1280.97		
	Post	5939.54±2901.94	7050.17±1870.05		
	Post-Pre	909.29±905.87	1272.08±1600.43	-.56	.586
	t	-2.84	-2.25		
	p	.025	.059		
Forward balance	Pre	6003.00±2783.70	7122.71±1854.61		
	Post	7460.75±3630.70	8429.96±2661.54		
	Post-Pre	1457.75±1191.89	1307.25±2600.38	.15	.884
	t	-3.46	-1.42		
	p	.011	.198		
Backward balance	Pre	4174.17±1952.02	4749.79±1414.06		
	Post	5094.75±3412.04	6025.25±2107.73		
	Post-Pre	920.58±1774.50	1275.46±1038.54	-.49	.633
	t	-1.47	-3.47		
	p	.186	.010		
Total balance	Pre	10177.00±4576.57	11872.58±2553.64		
	Post	12488.88±6598.41	14384.67±4371.63		
	Post-Pre	2311.88±2307.49	2512±3266.99	-.14	.889
	t	-2.83	-2.18		
	p	.025	.066		

Ⅳ. Discussion

This study was conducted to determine the effects of SLF exercise on the physical functional performance and postural balance of college students in their 20s by assigning eight students each to the sling and TRX suspension devices.

In comparing physical functional performance, it was found that TRX was more effective in improving physical functional performance compared to the sling ($p<.05$). Physical strength can be improved using functional movements and dynamic postures to increase strength, balance, flexibility, and joint stability (Mohamed, 2016). Janot et al. (2013) confirmed that TRX exercise increased muscle function in adolescents and adults compared with traditional resistance exercise. Arazi et al. (2018) found that an increase in muscle strength through TRX was the result of neural adaptation that governs motor units rather than an increase in whole body muscle mass. These exercises can further activate muscle motor units and lead to functional strengthening (Dudgeon et al., 2015).

Sling exercises also enhance trunk control and postural alignment, improving movements such as functional movements, resulting in better gross motor movements (Song et al., 2021). In addition, it is a high intensity exercise for increasing functional independence more than other rehabilitation treatments, and participation in active exercise not only improves function and quality of life but also helps in static posture alignment (Lee et al., 2022; Luo et al., 2020).

However, the reason why the TRX results were more significant than those of the sling in terms of physical functional performance is related to the stability of the axis that forms the suspension. TRX has a configuration that runs from one row to two rows; thus, it has more stability force than a sling connected to two rows. This result is more actively requested (Luo et al., 2020). It is difficult to generalize the effects of sling and TRX on physical functional performance based on the results of this study due to the small number of subjects.

In comparing postural balance, effects were observed in several postural balance variables in the sling group rather than the TRX group ($p<.05$). Kirkesola (2009) introduced the sling, a suspension exercises, as a kinesiological method that promotes normal movement patterns and revealed that it stimulated the neuromuscular system at a high level in patients with muscle skeletal problems, leading to functional recovery. The sling promotes local and systemic stability in the torso muscles of chronic back pain patients and is considered effective in controlling the clinical symptoms caused by back pain (Gwon et al., 2020; Wang et al., 2019). This is due to muscle contraction against the perturbations occurring in the unstable string, especially an increase in the Ia muscle fiber activation rate and α motor neuron excitability (Srisaphonphusitti et al., 2022). It is also due to an increase in the muscle activity of the lumbar stabilizing muscles and is considered the result of the reacquisition of the motor control system, with an increased magnitude and speed of activation rate (Wang et al., 2019).

Moreover, the sling is useful in activating and stabilizing muscles in the lumbar pelvic region (Chen et al., 2019). Weight bearing closed chain exercises in suspension exercises can be performed more functionally due to the coordinated contraction of antagonist and synergistic muscles around the joints (Williams et al., 2021). Furthermore, the sling stimulates proprioception (Korakakis et al., 2021) and increases neuromuscular control (Wadsworth & Lark, 2020), thereby not only controlling pain but also increasing trunk stability in healthy adults (Chen et al., 2019) and reducing symptoms of chronic back pain (Li et al., 2022).

TRX training has been found to have positive effects on balance performance in various sports, including football, basketball and futsal (Sadettin, 2023). TRX plank exercise performed by young subjects showed a significant increase in abdominal, torso, and thigh muscle activity (Byrne et al., 2014). TRX requires maintaining balance using the arms and legs and provides various exercise planes for muscles and joints, as well as resistance exercise using force generated by body weight or gravity (Arazi et al., 2018). As a result, the significant increase in the sling group and the numerical increase in the TRX group resulted in increased neuromuscular control, strengthening of core muscles, improvement of joint stability, and cerebral motor and motor function compared with exercise on a stable support surface. This may be due to the stimulation of proprioception of balance and the ability to maintain balance (Chung & Shimer, 2021; Song et al., 2021).

There are several reasons why there is no difference between groups in postural balance and why there is a large difference between the mean and standard deviation in backward balance. First, the TRX group exhibited significant variability in postural balance results, suggesting that individual differences in balance ability were not adequately considered during the subject grouping process. Second, the small sample size limited the generalizability of the study results. Third, the exercise duration appeared to be relatively short. Therefore, further research should be conducted to correct and supplement the limitations of this study.

Ⅴ. Conclusion

This study was conducted to determine the effects of SLF exercise using a sling and TRX, a suspension device, on the physical functional performance and postural balance of college students in their 20s. TRX was effective in improving physical functional performance, while the sling was effective in enhancing postural balance. However, confirming the effectiveness of slings and TRX in the relationship between physical functional performance and postural balance proved inadequate. Therefore, additional research should be conducted to verify the effects of suspension.

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