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The effect of Pilates and TRX exercises on the pelvic tilt angle of females with excessive anterior pelvic tilt

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Abstract

Background: Excessive anterior pelvic tilt (APT) is a common condition that can lead to musculoskeletal problems in females. Pilates and TRX exercises have been suggested as potential interventions to address APT.

Aim: The present study aimed to investigate the effect of these exercises on the pelvic tilt angle (PTA) in females with excessive APT.

Materials and Methods: The current study utilized a pre-test post-test design and was conducted as a quasi-experimental study. Twenty females between the ages of 35 and 55 were purposefully selected to participate in the study. The pelvic tilt angle (PTA) was measured using an inclinometer. The study participants were randomly assigned to the two groups. Then 8-week TRX and Pilates exercises were carried out. The data was analyzed by paired-sample t-test and analysis of covariance (ANCOVA) at a significance level of $P<0.05$ using SPSS V. 16.

Results: The results showed a significant decrease in PTA in both Pilates ($t(9)= 16.74$, $P= 0.001$) and TRX ($t(9)= 9.73$, $P= 0.001$) exercises groups. But, there was no a significant difference between the two groups ($F(1, 17)=0.01$, $P= 0.922$, partial eta squared= 0.001).

Conclusion: The results of the study demonstrated a significant decrease in the pelvic tilt angle (PTA) of participants with excessive anterior pelvic tilt (APT) following 8 weeks of Pilates and TRX exercises. These findings highlight the importance of these exercise interventions in correcting postural deformities.

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1. Introduction

Excessive anterior pelvic tilt (APT) is a deformity of the pelvis in the sagittal plane in which the pelvic tilt angle (PTA) is larger than normal [1]. Muscle imbalance in the lumbopelvic region can contribute to the APT. In the excessive APT abnormality, hip flexors, such as iliopsoas and rectus femoris, and erector spinal muscles are facilitated, whereas gluteus maximus, hamstring, and abdominal muscles are inhibited [2]. Excessive APT may be accompanied by compensatory motions and postures including hyperlordosis, thoracic hyperkyphosis, forward head, rounded shoulders, cervical hyperextension, genu recurvatum, and ankle plantarflexion [3, 4]. Each of these postures and motions has consequences; for example, lumbar hyperlordosis may increase loads on the lumbosacral junction and lumbar zygapophyseal joints [5, 6]. A high prevalence of abnormal PTA has been reported among rice farmers [7], but there are no epidemiological studies on the prevalence of excessive APT among females.

Excessive APT is associated with several acute and chronic musculoskeletal injuries [3, 8, 9, 10, 11, 12, 13, 14]. For example, Hertel, Dorfman, and Braham (2004) in a retrospective study reported a correlation between a history of anterior cruciate ligament (ACL) injury and APT [10]. It is suggested that the excessive APT places the hamstrings and hip flexors in a shortened position (SP) and lengthened position (LP), respectively. As a result of being in LP, hamstrings might not be able to perform their role as an ACL agonist. Furthermore, the shortening of hip flexors may reinforce the quadriceps dominance phenomenon as a risk factor for ACL injury [10]. Lim, Roh and Lee (2013) found that the PTA is significantly increased in low back sufferers compared to the healthy population [12]. In a meta-analysis study, Laird et al. (2014) reported greater APT in people with low back pain compared to people without back pain, but the difference was not statistically significant [11]. Patel et al. (2020) showed that at high flexion position in people with femoroacetabular impingement syndrome, the APT led to the quicker happening of femoroacetabular impingent (FAI), whereas posterior pelvic tilt led to the delayed happening of FAI [13]. Moreover, a high level of both static and dynamic APTs is linked to hamstring injuries [8, 14]. It also has been postulated that APT is a risk factor for patellofemoral pain syndrome by increasing femoral internal rotation and dynamic knee valgus [3, 9].

Several studies have investigated the effects of different conservative modalities on dynamic and static pelvic tilt (PT) [15, 16, 17, 18, 19, 20, 21, 22]. Two studies evaluated the effects of core stabilization and extension traction on the PT of people with nonspecific and chronic low back pain [17, 19]. The purpose of these studies was to examine whether the core stabilization and extension traction would increase the PT or not. Barbosa et al. (2013) investigated the impact of high-velocity, low-amplitude (HVLA) manipulative thrust applied to the sacroiliac joint, and quadriceps eccentric and hamstring concentric contractions on APT [15]. Lee et al. (2014) evaluated the impact of the one-day application of posterior pelvic tilt taping on the APT in women with sacroiliac joint pain [20]. Two randomized control trials evaluated the effects of manipulation/ mobilization and strength training on the PT of asymptomatic healthy participants [18, 21]. Brekke et al. (2020) examined the impact of home-based exercises and activity modification

programs on the PTA in participants with acetabular retroversion and excessive APT [16]. Mendiguchia et al. (2020) investigated the impact of a multimodal intervention on the dynamic APT during gait [22].

Conflicting results have been reported in these studies, so that some studies showed significant changes in PTA [15, 17, 18, 19, 20, 22], whereas others reported no change or non-significant changes [16, 21]. It seems that there is a lack of evidence about the effects of the supervised exercise programs on the PTA. Therefore, the purpose of this study was to bridge the gap that has been emerged, both in research and practical environments.

It has been stated that exercises and other treatment methods for diminishing excessive APT are important and there is a lack of evidence to support the various conservative treatments that are appropriate to correct excessive APT [1]. Given the commonness of excessive APT, its numerous consequences on the musculoskeletal system, the importance of treatment methods to reduce APT, conflicting reports in the literature, and a lack of evidence about the effects of Pilates and TRX on the APT, this study aimed to investigate the effects of Pilates and TRX exercises on the APT.

The null hypothesis is as follows: there is no significant difference between pre-intervention and post-intervention mean measures of the PTA in the sagittal plane. The alternative hypothesis is as follows: there is a significant difference between pre-intervention and post-intervention mean measures of the PTA in the sagittal plane.

2. Materials and Methods

2.1. Participants

This was a comparative quasi-experimental study. A total of 20 healthy females aged 35-55 years were selected, using purposeful sampling. The participants from Babol city, Mazandaran province, were enrolled in this study. The participants were recruited from sports clubs. Considering α=0.05, the power of 80%, and an effect size of 0.9, the sample size was 10 by using G*Power software [23]. Healthy females with an APT angle of more than 13 degrees and an age range of 35 to 55 were included in this study. Participants with acute low back pain, chronic low back pain, lack of capacity to perform TRX and Pilates exercises, scoliosis, and neuromuscular disorders were excluded from the study. In addition, the participants were excluded if they were involved in other training programs and missed Pilates or TRX practice for two successive sessions or more [24]. Participants were allocated to two groups using simple randomization (tossing a fair coin independently for each participant).

All participants were informed about the purpose of the study, procedures, duration of participation, benefits, risks or discomforts, voluntary nature of the study, and confidentiality of data, and they signed the informed consent form before the start of the study [25].

2.2. Outcome measures

The PTA in the sagittal plane was examined using the pelvic inclinometer. The pelvic inclinometer comprises an inclinometer and two arms. The pelvic inclinometer has moderate validity for measuring anterior-posterior pelvic tilt angles [26]. Inter-rater and intra-rater reliability of pelvic inclinometer is reported to be excellent (ICC=0.93 and ICC=0.98, respectively) [26].

For the measurement of the angle, each participant stood with feet approximately shoulder-width apart. To manage postural sway, participants were asked to look at a fixed point ahead of them [27]. Participants assumed an erect posture and arms crossed

over their chest, then the examiner palpated the Anterior Superior Iliac Spine (ASIS) and Posterior Superior Iliac Spine (PSIS) [27, 28] (Figure 1). One arm of the pelvic inclinometer was placed on ASIS and the other one was placed on PSIS. In this study, the PT is defined as the angle between the horizontal line and a line that connects ASIS to PSIS [29]. Anterior pelvic tilts of more than 13 degrees are considered excessive. The PT was measured before and after 8 weeks of Pilates and TRX exercises.

Figure 1. Measurement of pelvic tilt angle using an inclinometer

2.3. Pilates training protocol

After 10 min of warm-up, at the beginning of the training session, participants in the Pilates intervention group performed four Pilates exercises, namely, spine stretch, thigh stretch, leg pull front, and chest lift for 40 min, using body weight as a load [30, 31]. These exercises were selected to modify force couples that can control the PT in the sagittal plane. At the end of each training session, a cool-down was done for 10 min. Pilates exercises were performed for 8 weeks under the supervision of the Pilates coach (Table 1). Mild to moderate intensity exercises for 40-60 min, 3 days/week were prescribed for participants in the Pilates intervention group based on the FITT principle. The intensity of the exercises was increased progressively by an increase in the number of repetitions, an increase in stretching time, and a decrease in rest time.

2.4. TRX training protocol

After 10 min of warm-up, participants in the TRX intervention group performed four TRX exercises, namely, pigeon stretch, reaching hip flexor stretch, hamstring curl, and TRX crunch for 40 min [32]. These exercises were selected to modify force couples that can control the PT in the sagittal plane. At the end of each training session, a cool-down was done for 10 min. TRX exercises were performed for 8 weeks under the supervision of a certified TRX specialist (Table 2). Mild to moderate intensity exercises for 40-60 min, 3 days/week were prescribed for participants in the TRX intervention group based on the FITT principle. The intensity of the exercises was increased progressively by an increase in the number of repetitions, an increase in stretching time, and a decrease in rest time.

2.5. Statistical analysis

The data were analyzed using SPSS (Version 16; IBM). The Shapiro-Wilk test was used to investigate the normality of data. The paired-sample t-test was used to compare the within-group differences. Levene's test for equality of variances was employed to assess the assumption of homogeneity of variances. To compare the effects of TRX and Pilates exercises, an analysis of covariance (ANCOVA) was performed by adding the pretest data as the covariate. A P-value < 0.05 was considered statistically significant.

3. Results

A total of 20 women aged 33-55 years participated in this study (Table 3). The

approximately normal distribution of data was confirmed using the Shapiro-Wilk test. A paired-samples t-test was used to assess the impact of Pilates exercises on APT. There was a statistically significant decrease in APT from pre-test (Mean= 15.75, SD= 1.65) to post-test (Mean= 13.50, SD= 1.49), t(9)= 16.74, *P*= 0.001. The mean decrease in APT angles was 2.25 with a 95% confidence interval ranging from 1.94 to 2.55. The eta squared statistic (0.96) indicated a large effect size (Table 4).

Another paired-samples t-test was conducted to evaluate the impact of the TRX on APT. There was a statistically significant decrease in APT from pre-test (Mean= 15.40, SD= 1.50) to post-test (Mean= 13.20, SD= 1.18), t(9)= 9.73, *P*= 0.001. The mean decrease in APT angles was 2.20 with a 95% confidence interval ranging from 1.68 to 2.71. The eta squared statistic (0.91) indicated a large effect size (Table 4).

The result of Levene's test indicated that there is no significance difference (F=2.52, *P*= 0.130). Also, the homogeneity of regression slopes was confirmed (F=1.418, *P*= 0.251). To put it another way, the analysis of data was followed by the fundamental hypothesis of ANCOVA. ANCOVA was to compare the impact of Pilates and TRX exercises designed to reduce excessive APT. Participants' pelvic tilt angles on the pre-test were used as the covariate in this analysis. After adjusting for pre-intervention PTAs, there was no significant difference between the two groups with respect to post-intervention PTAs F(1, 17)= 0.01, *P*= 0.922, partial eta squared= 0.001 (Table 5).

Table 1. Variables of Pilates exercises

Week	Days	Exercises	Sets	Repetitions (r) or Time (sec)	Rest (sec)
1	Saturday, Monday, Wednesday	Spine stretch Thigh stretch Leg pull front Chest lift	3	10 sec 10 sec 8 r 10 r	15 15 60 60
2	Saturday, Monday, Wednesday	Spine stretch Thigh stretch Leg pull front Chest lift	3	15 sec 15 sec 10 r 15 r	15 15 60 60
3	Saturday, Monday, Wednesday	Spine stretch Thigh stretch Leg pull front Chest lift	3	20 sec 20 sec 12 r 20 r	15 15 50 50
4	Saturday, Monday, Wednesday	Spine stretch Thigh stretch Leg pull front Chest lift	3	25 sec 25 sec 14 r 25 r	15 15 50 50
5	Saturday, Monday, Wednesday	Spine stretch Thigh stretch Leg pull front Chest lift	4	30 sec 30 sec 16 r 30 r	10 10 40 40
6	Saturday, Monday, Wednesday	Spine stretch Thigh stretch Leg pull front Chest lift	4	35 sec 35 sec 18 r 35 r	10 10 40 40
7	Saturday, Monday, Wednesday	Spine stretch Thigh stretch Leg pull front Chest lift	4	40 sec 40 sec 20 r 40 r	10 10 30 30
8	Saturday, Monday, Wednesday	Spine stretch Thigh stretch Leg pull front Chest lift	4	45 sec 45 sec 22 r 45 r	10 10 30 30

Table 2. Variables of TRX exercises

Week	Days	Exercises	Sets	Repetitions (r) or Time (sec)	Rest (sec)
1	Saturday, Monday, Wednesday	Pigeon stretch Reaching hip flexor stretch Hamstring curl TRX crunch	3	10 sec 10 sec 8 r 10 r	15 15 60 60
2	Saturday, Monday, Wednesday	Pigeon stretch Reaching hip flexor stretch Hamstring curl TRX crunch	3	15 sec 15 sec 10 r 15 r	15 15 60 60
3	Saturday, Monday, Wednesday	Pigeon stretch Reaching hip flexor stretch Hamstring curl TRX crunch	3	20 sec 20 sec 12 r 20 r	15 15 50 50
4	Saturday, Monday, Wednesday	Pigeon stretch Reaching hip flexor stretch Hamstring curl TRX crunch	3	25 sec 25 sec 14 r 25 r	15 15 50 50
5	Saturday, Monday, Wednesday	Pigeon stretch Reaching hip flexor stretch Hamstring curl TRX crunch	4	30 sec 30 sec 16 r 30 r	10 10 40 40
6	Saturday, Monday, Wednesday	Pigeon stretch Reaching hip flexor stretch Hamstring curl TRX crunch	4	35 sec 35 sec 18 r 35 r	10 10 40 40
7	Saturday, Monday, Wednesday	Pigeon stretch Reaching hip flexor stretch Hamstring curl TRX crunch	4	40 sec 40 sec 20 r 40 r	10 10 30 30
8	Saturday, Monday, Wednesday	Pigeon stretch Reaching hip flexor stretch Hamstring curl TRX crunch	4	45 sec 45 sec 22 r 45 r	10 10 30 30

Table 3. Basic demographics of the participants

Variable	Intervention groups (n=20) Mean±SD
Age (year)	40.80±5.36
Height (cm)	165±2.66
Weight (kg)	65.90±4.49

Table 4. The results of paired sample t-tests comparing pre-intervention and post-intervention APT angles

Intervention group	Variable	Mean±SD		t	*P*
		Pre-test	Post-test		
Pilates	APT angle	15.75±1.65	13.50±1.49	16.74	0.001
TRX	APT angle	15.40±1.50	13.20±1.18	9.73	0.001

Table 5. The results of ANCOVA comparing TRX and Pilates interventions

Source	Type III sum of squares	DF	Mean square	F	Sig.	Partial eta squared
Group	0.002	1	0.002	0.010	0.922	0.001
Error	4.294	17	0.253			
Total	3597.500	20				

4. Discussion

This study was designed to verify the effects of Pilates and TRX exercises on APT after 24 training sessions. The results of the study showed a significant decrease in APT in both Pilates and TRX intervention groups. Also, there was no significant difference between the two groups with respect to the effects of the two intervention methods on APT. These results are consistent with those of previous studies [18, 20, 22].

Mendiguchia et al. (2020) demonstrated a significant decrease in dynamic APT angle during walking after participation in a 6-week multimodal intervention [22]. They attributed the decrease in dynamic APT to active corrective exercises and manual therapy. In their active corrective exercises program, several exercises were embedded including hip flexors stretching, hip extensor strengthening, self-myofascial release with the foam roller, neuromuscular control training, and drills that emphasize posterior pelvic tilt.

The reduction in APT following soft tissue manipulation is reported by Cottingham, Porges and Richmond (1988) [18]. They evaluated the effect of the Rolfing method on the standing pelvic tilt angle of 32 young healthy men and proposed two mechanisms as possible causes of reduction in standing APT including connective tissue plasticity and modifications in the tone of rotator muscle groups that attach to the pelvic.

Lee et al. (2014) showed that APT in women with sacroiliac joint pain decreased immediately after and one day after posterior pelvic tilt taping application [20]. They applied kinesiology tape on the rectus abdominis muscle and lateral fibers of the external oblique muscle, to tilt the pelvic posteriorly in participants with anteriorly tilted innominate. Improvement in functions of the rectus abdominis and external oblique muscles was mentioned as a contributor to APT diminution.

To the best of our knowledge, this is first study showing changes in static pelvic tilt angle after two exercise programs (i.e., TRX and Pilates). The TRX and Pilates exercises were specifically selected to decrease APT in females with excessive APT. Hip extensor and abdominal muscles as a force couple have this capacity to tilt pelvic posteriorly by their contraction [2, 3, 5, 6]. In the present study, based on force couple theory in the pelvic region strengthening of these muscles, two exercises (i.e., hamstring curl and TRX crunch) in the TRX intervention program and two exercises (i.e., leg pull front and chest lift) in Pilates intervention program [30, 31, 32] were considered. On the other hand, by their contraction, hip flexor and back extensor muscles as a force couple can tilt pelvic anteriorly [2, 3, 5, 6]. Thus, in this study based on force couple theory in the pelvic region increasing the flexibility of these muscles was considered by including two exercises (i.e., pigeon stretch, reaching hip flexor stretch) in the TRX intervention program and two exercises (i.e., spine stretch, thigh stretch) in Pilates intervention program [30, 31, 32]. Change in strength and tone of hip extensor and abdominal muscles as powerful retroversor muscles and flexibility and tone of hip flexor and back extensor muscles as powerful anteversor muscles might be the mechanism by which reduction in excessive APT occurred [18, 22]. Change in connective tissue plasticity as a result of a stretching exercise in TRX and Pilates programs may account in part for the reduction in APT angle found in our study [18].

Our results show a significant reduction in APT, but two studies have found opposite results [16, 21]. In both of these studies, home-based exercises were prescribed contrary to our training, in that, all of the exercises were performed under the supervision of Pilates coach and TRX specialist. Levine, Walker and Tillman (1997) prescribed stretching exercises for the hamstring muscle group that might nullify the positive effects of posterior pelvic tilt and curl-up exercises on pelvic tilt angle in the sagittal plane. Moreover, in their study, the subjects did not use the written logs to record the exercise program, and only 50% of them performed the stretching exercises [21]. Brekke et al. (2020) investigated the effects of home-based exercises in patients afflicted with acetabular retroversion and excessive APT [16]. It seems that structural changes in the skeletal system, namely, acetabular retroversion may not be affected by corrective exercises.

This study has some limitations which have to be pointed out. First limitation is the small number of participants. Therefore, it is best to conduct studies with large sample size. The second limitation is the lack of a control group. Thirdly, the present study did not include a follow-up measurement to further assess the long-term efficiency of TRX and Pilates exercises on APT. Finally, the APT angle was measured in standing posture, so the results may not be generalized to the functional and dynamic postures.

5. Conclusions

The results of this study indicated that performing selected TRX and Pilate exercises for 8 weeks could reduce APT angle in females with excessive APT. Selected TRX and Pilates exercises can be used in the rehabilitation and prevention field by fitness and health professionals.

Highlights

- Selective Pilates exercises decrease excessive anterior pelvic tilt in the females.
- Selective TRX exercises reduce the pelvic tilt angle of females with excessive anterior pelvic tilt.
- There is no significant difference in the effect of TRX and Pilates exercises on tilt angle in the sagittal plane.

Plain Language Summary

An excessive pelvic tilt angle in the sagittal plane is associated with injuries in both contractile and non-contractile tissues, such as hamstring group muscles and ligaments in the knee. Also, greater anterior pelvic tilt can cause low back pain. The purpose of the present study was to investigate the effect of 8-week selective Pilates and TRX exercises on the pelvic tilt angle of females with excessive anterior pelvic tilt. Females with anterior pelvic tilt greater than 13 degrees participated in this study voluntarily. The participants in Pilates and TRX groups performed selective exercises for 8 weeks, 3 sessions per week, each session lasting 40-60 min. Selective exercises were selected to correct the muscle imbalance in the pelvic region. Before and immediately after the execution of the training protocol, the pelvic tilt angle was measured using a pelvic inclinometer. A significant decrease in pelvic tilt angle was seen in both intervention groups. Based on the results, there was no significant difference between intervention groups, indicating that both Pilates and TRX exercises are effective in reducing pelvic tilt angle in the sagittal plane. Thus, both TRX and Pilates selective exercises can be used in the rehabilitation and prevention field by fitness and health

professionals to target excessive anterior pelvic tilt.

Conflict of interest

The authors declared no conflicts of interest.

Authors' contributions

All authors contributed to the original idea, study design.

Ethical considerations

The author has completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc. The participants were informed about the purpose of the research and its implementation stages; they were also assured about the confidentiality of their information. Moreover, they were allowed to leave the study whenever they want, and if desired, the results of the research would be available to them.

Data availability

The dataset generated and analyzed during the current study is available from the corresponding author on reasonable request.

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