ACTA GYMNICA, 2022, Volume 52, Article e2022.008
https://doi.org/10.5507/ag.2022.008

ORIGINAL RESEARCH

Effect of Pilates training on respiration, joints mobility, and muscle strength in healthy middle-aged women with sedentary occupations

Olha Kolomiitseva[1], Anna Prikhodko[1]✉, Inna Bodrenkova[1], Ihor Hrynchenko[2], Ivan Vashchenko[3], and Roman Honchar[4]

[1]Department of Physical Education, Yaroslav Mudryi National Law University, Kharkiv, Ukraine; [2]Department of Olympic and Professional Sports, Sports Games and Tourism, H. S. Skovoroda Kharkiv National Pedagogical University, Kharkiv, Ukraine; [3]Department of Physical Education, T. H. Shevchenko National University "Chernihiv Collegium", Chernihiv, Ukraine; and [4]Research Center, National Academy of the National Guard of Ukraine, Kharkiv, Ukraine

Abstract

Background: Pilates training has proven to be an effective method of mental and physical conditioning in rehabilitation, and it has become increasingly popular within the general fitness community. **Objective:** This study aimed to determine the effect of Pilates training practice on the respiratory system, joint mobility, and muscle strength of healthy middle-aged women with sedentary occupation. **Methods:** Thirty-two healthy women (age 45.4 ± 2.3 years, range 40–49 years; body mass 73.5 ± 1.5 kg; body height 1.70 ± 0.03 m) were recruited and randomised into experimental (n = 18) and control (n = 14) groups. The experimental group participated in a 12-week series of 1-hour Pilates workouts (beginner level) three times per week. **Results:** After intervention, the experimental group revealed significant positive changes in the vital capacity test (p = .05), Stange test (p = .001), and Gencha test (p = .001). Respiratory rate and body mass index improved slightly. All joint mobility and muscle strength variables of the participants showed significant differences compared with the baseline data (p < .05). The most significant improvements were observed in variables of the shoulder girdle mobility during flexion (p = .003), abdominal strength (p = .041), and body strength endurance (p = .003 and .034). No significant changes were observed in the control group. **Conclusions:** The results confirmed that a 12-week series of 1-hour Pilates workouts three times per week is effective in improving parameters of the respiratory system, shoulder girdle, abdominal strength and endurance, and hip and shoulder joint mobility in healthy middle-aged women with a sedentary occupation.

Keywords: Pilates, body strength, flexibility, breathing, body composition, sedentary behaviour

Introduction

Physical activity is one of the real proven factors in maintaining and strengthening people's health (Bauman et al., 2012). However, in recent years, people living the so-called 'western lifestyle' are increasingly showing a propensity for a sedentary lifestyle and behaviour, which is recognised as a risk factor for mortality and morbidity (Gardner et al., 2016; Katzmarzyk, 2010). Extensive sedentary behaviour in the workplace is a major global health threat (Zhu et al., 2020). At the same time, a reduction in health-promoting behaviours due to preventive public health measures during the corona virus disease 2019 (COVID-19) pandemic, such as social distancing and closure of recreation centres, city parks, and playgrounds has also impacted the physical activity of people and increased the amount of sedentary behaviour, especially among women (Nienhuis & Lesser, 2020). In recent years, more studies that measure sedentary lifestyles to quantify and study their effects on human health have emerged (Katzmarzyk, 2010; Zhu et al., 2020), including affordable test and comfortable training programmes to overcome physical inactivity (Gardner et al., 2016; Kloubec, 2010).

In the modern fitness and healthcare industry, Pilates training exercise occupies a special place and its popularity continues to grow every year (de Souza Cavina et al., 2020; Kolomiitseva et al., 2019; Mikalački et al., 2017). Pilates (Contrology) is a mind-body exercise that focuses on strength, core stability, flexibility, muscle control, posture, and breathing (Bernardo, 2007; Di Lorenzo, 2011; Kloubec, 2011; Wells et al., 2012); it is a popular exercise approach for women (Kao et al., 2015; Kloubec, 2010; Mazzarino et al., 2015; Şavkin & Aslan, 2017). The desire to stop the ageing process and improve quality of life, correct body composition, and other reasons motivate women of different ages to practice Pilates exercise (Kao et al., 2015; Kloubec, 2010; Kolomiitseva et al., 2019; Mazzarino et al., 2015; Şavkin & Aslan, 2017; Tejada Medina et al., 2020).

In the past two decades, most research has focused primarily on the effectiveness of the Pilates method for correcting posture in people with low back pain (Cruz et al., 2016;

✉ **Corresponding author:** Anna Prikhodko, e-mail annaprikhodko05071963@gmail.com, ORCID® record https://orcid.org/0000-0002-0806-3132

Article history: Received March 25 2021, Accepted May 24 2022, Published August 24 2022

Kloubec, 2011; Levine et al., 2009; Wells et al., 2012). The Pilates training exercises have been proven to be effective in the rehabilitation of patients with musculoskeletal disorders. Researchers concluded that an important advantage of the Pilates system is that it primarily focuses on developing functional, safe, and convenient activities rather than performing an exercise for the sake of exercising (Kao et al., 2015). Pilates exercise also improves the cardiorespiratory system and normalises blood pressure (Mikalački et al., 2017; Souza et al., 2021; Tinoco-Fernández et al., 2016; Tomilina, 2016).

Research focusing on the effectiveness of Pilates exercise method in healthy participants is limited (Wells et al., 2012). There is moderate evidence that Pilates training can increase muscle strength and endurance in healthy individuals (Campos et al., 2016; Cruz-Ferreira et al., 2011; Kao et al., 2015; Rogers & Gibson, 2009), trunk flexibility (Kao et al., 2015; Rogers & Gibson, 2009), lower extremity endurance (Mazzarino et al., 2015), dynamic postural control, balance, joint movement around the low back-pelvic-hip complex (Bernardo, 2007; Johnson et al., 2007; Kloubec, 2010), and improve the quality of life of women (Mazzarino et al., 2015). Modern Pilates programmes include approximately 25–50 simple exercises with minimal impact on flexibility and muscle endurance, but with an emphasis on muscular exertion in the abdomen, lower back, hips, thighs, and buttocks (Bernardo, 2007; Kloubec, 2010, 2011). According to Merkel and Kozik (2016), the main criterion for choosing exercises that provide a specific result should be the rule 'state–dose–effect'.

Similarly, systematic reviews and meta-analyses (Bernardo, 2007; Campos et al., 2016; Cruz et al., 2016; Cruz-Ferreira et al., 2011; de Souza Cavina et al., 2020; Kloubec, 2011; Mazzarino et al., 2015; Tejada Medina et al., 2020) highlighted the need to carefully validate the effectiveness of Pilates exercise in improving flexibility, abdominal and lumbopelvic muscle stability, and muscle activity. First and foremost, this is explained by the lack of reliable research methodologies in each specific study. Therefore, there is an obvious need for new research with high methodological quality and standardisation of evaluation instruments (Kloubec, 2011). Empirical quantitative data, indicating a positive effect of Pilates exercises on weight parameters, body composition, and cardiorespiratory functions of sedentary women of different ages and occupations are not enough to make objective statements (Mascarin et al., 2015; Mazzarino et al., 2015; Rogers & Gibson, 2009; Şavkin & Aslan, 2017; Souza et al., 2021; Tinoco-Fernández et al., 2016). According to Kloubec (2011), these findings are only the results of pilot studies and require additional clarification and confirmation in a specific population.

In view of the above, this study aimed to determine the effect of Pilates training practice on the respiratory function, joints mobility, and muscle strength of healthy middle-aged women with sedentary occupation. We hypothesised that practitioners would improve each of these variables after a 12-week Pilates training programme (36 workouts).

Methods

Participants

Thirty-two healthy women (age 45.4 ± 2.3 years, range 40–49 years; body mass, 73.5 ± 1.5 kg; body height 1.70 ± 0.03 m) were recruited to participate in a randomised controlled study. Volunteers aspired to an active lifestyle, but had sedentary occupations. The contingent of participants consisted of university administrative staff (librarians, accountants, and department secretaries). Physical inactivity was partly a consequence of the peculiarities of their workplaces. In Ukraine, quarantine restrictions introduced between March 2020 and June 2020 due to the COVID-19 pandemic contributed to a decrease in the participants' physical activity. The participants volunteered to participate in testing at all stages of the study.

Eighteen participants were assigned to the experimental group (Exp), and eighteen to the control group (Con). Four participants were excluded from the control group because of incomplete data; therefore, its final sample size was reduced (n = 14). The participants were informed about the purpose, content, and potential risks of participating in the research, after which they provided written informed consent to participate. The procedures followed the ethical principles of the 1964 Helsinki Declaration (and its later amendments) for human experiments. The study was approved by the Research Ethical Committee of Yaroslav Mudryi National Law University.

Procedures

Dependent variables of our experiment were selected based on previous statements of the Pilates training results. Therefore, the participants' body mass and height were measured using Apex Digital Scales with Mechanical Height Rods (DETECTO, Webb City, MO, USA). Functional tests were chosen as markers for assessing the state of the participants' respiratory system: respiratory rate (RR) standing, vital capacity (VC), breath-hold on inhalation (Stange test), and exhaled breath test (Gencha test; Shyian & Papusha, 2019). A stopwatch and Spirobank II Advanced spirometer (BIOMED, Kyiv, Ukraine) were used for the measurements. When performing the Stange test, the participant took a deep breath and exhaled while in a sitting position, then inhaled (approximately 3/4 of the depth of a full inhalation) and held the breath while simultaneously pinching the nose with the fingers. Breath-holding time was recorded using a stopwatch (seconds). The Gencha test was performed in the prone position on a bench. The participant performed a normal (not deep) exhalation and held the breath. The breath-hold duration was recorded with a stopwatch, which was started at the end of exhalation and stopped at the moment of inhalation. This test was performed at least 5–7 min after the Stange test. The measurements were performed in accordance with the recommendations of the American Lung Association (2020).

The participants' physical abilities were measured using the standard Pilates tests (Isacowitz & Clippinger, 2019). Hip flexion mobility and hamstring elasticity were assessed using the sit-and-reach test (cm). A prone shoulder flexion test (cm) was used to assess the flexion mobility of the shoulder girdle (Figure 1). In the prone position, the arms were extended forward and upward, and the participants were required to raise their arms above the floor while keeping the body still. A side lift (repetitions) was used to assess shoulder girdle stability in the frontal plane (Figure 2). Lying on its side with support on the forearm, thigh, and the outer edge of the foot (feet together), the participants were required to raise the pelvis off the floor while simultaneously raising the upper leg and arm to the 'star' position. Roll-up with bent legs and straight legs (repetitions) served as markers for assessing abdominal strength (Figure 3). From the starting position, sitting, lower your arms forward to the prone position, articulate with the entire spine, and return smoothly to the starting position. Static endurance of the body muscles (seconds) was determined using the leg pull front (Figure 4). Frontal arm strength was determined (repetitions) using push-ups on a single knee (Figure 5). Starting position: support lying, hands under the shoulder joints, support of the legs on one knee, and the other leg lying on the foot of the bent leg. Testing of the participant was carried out before and after a 12-week period of the Pilates training programme. Measurements were performed under the same conditions on the same day.

Pilates intervention

The experimental group took part in a 12-week series of 1-hour Pilates workouts, three times per week. The Pilates workout lasted 60 minutes: 5-minute standardised dynamic warm-up, 50-minute Pilates exercises series, and 5-minute cool-down. The workouts were led by the same Pilates instructor. The training series consisted of 20–25 basic exercises (beginner level) with modifications according to the Polestar Pilates method. The exercises were tailored toward the health conditions of the experimental group during a specific workout. Special attention was paid to breathing: adjustments were made in which phase of the exercise to

Figure 1 Prone shoulder flexion

Figure 2 Side lift

Figure 3 Roll-up with bent legs

Figure 4 Leg pull front

Figure 5 Push-up on single-knee

inhale and in which to exhale. Towels and rubber bands were used to teach the students proper breathing. Typically, a Pilates exercise series had the following sequence: exercises in the supine position, then a gradual transition to the prone position, on the side, sitting, and quadruped. As a rule, the Pilates workout ended with standing exercises.

Spike balls and foam rollers were used to increase joint mobility. The use of a foam roller and spike balls is a common myofascial therapy used to increase range of motion. A foam roller was also used to relieve the axial stress according to the tensegrity model (Myers, 2020). In the supine position along with the foam roller (Starfish Stretch), it was suggested for the participants to spend 3–5 min on diaphragmatic breathing. After that, the Pilates practitioners moved on to the mat and performed the planned exercises. The foam roller has also been used for massage and to incorporate an unstable surface into the workout. According to Polestar Pilates, we used 'mental images' according to the Franklin's method (Franklin, 2012) to help Pilates practitioners better understand the meaning of the exercises and their performance. Additionally, the concept of 'Anatomical Trains' by Myers (2020) was used. To increase the hip joint mobility, the following exercises were used: shoulder bridge with various modifications, hip extension and abduction in the prone position, hip flexion and extension lying on the side, and hip abduction while lying on the side. Occasionally, we used spike balls and foam rollers when performing these exercises. To stimulate and increase the elasticity of the hamstrings, we used various leg movements while lying on the side and articulation of the feet in various leg positions. Shoulder girdle stabilisation in the frontal plane was achieved by varying the exercises lying on the side with support on the forearm. All the above exercise variations, in varying degrees, required participation in the work of the abdominal muscles. Additionally, to increase abdominal strength, basic exercises were used: one leg circle, cross to cross, one leg stretch, double leg stretch, and roll-up. Exercises with the support of the body on the hands were used to increase strength and endurance of the shoulder girdle.

The control group was asked to maintain their daily and habitual levels of physical activity and to avoid other types of exercise throughout the experiment.

Statistics

Descriptive statistics were reported at baseline, 12 weeks, and as a change from the baseline. Data processing was carried out using Microsoft Excel (Version 2016; Microsoft, Redmond, WA, USA) and SPSS Statistics for Windows (Version 17.0; SPSS, Chicago, IL, USA). Normal data distribution was verified using the Kolmogorov-Smirnov test.

Differences between baseline and post-intervention values were assessed using a paired Student's *t*-test. To assess the statistical significance of differences, the significance level was set at a p-value of $< .05$.

The difference between the baseline and post-intervention values in percent (Δ) was calculated using the formula % = (post-intervention – baseline)/baseline × 100.

Results

In the baseline study, the participants' body mass index (BMI) was recorded at the 'overweight' level. After the intervention, the BMI indicated a normalisation of this variable in the participants of the experimental group. The BMI indicators of the control group remained unchanged at all stages of the measurements. In general, at the end of the 12-week series of exercises, the anthropometric indicators of the Pilates practitioners did not differ significantly from those of the control group.

Respiratory test values obtained at baseline were below normal (Table 1). The RR at baseline of the study slightly exceeded the upper threshold of the norm. Post-intervention, the practitioners' RR improved after the Pilates practice, with a relative increase of 13.43%. During the study, we noted significant changes in the variables among the practitioners ($p < .05$), with an increase of 25.5% (VC), 25.5% (Stange test), and 38.3% (Gencha test). Post-intervention, the percentage of the predicted VC value in the experimental group was 94.54% (baseline, 75.28%). The indicators of the variables in the control group did not show any changes. Post-intervention, a comparison of the indicators in both groups showed significant differences in the VC, Gencha, and Stange tests ($p < .05$).

Table 1 Means, standard deviations, and *t*-test statistics for anthropometric and respiratory system variables

Variable	Norm	Baseline	Post-intervention (Δ)	*t*	*p*
Body mass (kg)	–				
Exp		73.1 ± 1.42	71.3 ± 1.50 (−2.47)	0.87	.38
Con		74.0 ± 1.50	74.1 ± 1.44 (+0.01)	0.04	> .99
Height (cm)	–				
Exp		170.6 ± 3.40	171.1 ± 3.10 (+0.3)	0.10	.92
Con		169.7 ± 1.70	169.6 ± 1.50 (−0.1)	0.04	> .99
Body mass index (kg/m²)	18.5–24.9				
Exp		25.00 ± 1.06	24.30 ± 0.91 (−4.0)	0.50	.45
Con		25.90 ± 0.78	25.60 ± 0.74 (0.0)	0.09	> .99
Respiratory rate (rep/min)	12–20				
Exp		21.60 ± 1.80	18.70 ± 1.06 (−13.43)	1.38	.19
Con		21.28 ± 1.77	21.50 ± 1.69 (+1.03)	0.09	.92
Vital capacity (L)	3–4				
Exp		2.62 ± 0.27	3.29 ± 0.16 (+25.57)	2.16	.05
Con		2.67 ± 0.20	2.65 ± 0.18 (−0.8)	0.03	> .99
Stange test (s)	40–50				
Exp		32.22 ± 1.51	40.44 ± 2.06 (+25.51)	3.30	.001
Con		32.64 ± 1.73	32.28 ± 1.63 (−0.02)	0.15	.92
Gencha test (s)	35–40				
Exp		19.88 ± 0.90	27.50 ± 1.24 (+38.32)	4.52	.001
Con		19.50 ± 1.01	19.57 ± 0.85 (+0.35)	0.05	> .99

Note. Δ%, percent change from baseline; Exp = experimental group; Con = control group; rep = repetition.

The results of measuring the physiological variables of the Pilates practitioners indicated a tendency to improve their physical abilities (Table 2). After the Pilates intervention, the indices were significantly different compared with the baseline data ($p < .05$). The most significant changes occurred in the indicators of shoulder girdle mobility in flexion, abdominal strength, and body strength endurance ($p < .01$). All variable values in the experimental group improved by more than 50% after the intervention. No significant changes were observed in the control group.

Discussion

After 35 years in women, the elasticity of the muscles and ligaments decreases, and the muscle corset weakens. This leads to muscle imbalance. The shortened, and therefore, inelastic muscles have a great load. It could cause injury. Muscle imbalance affects the entire musculoskeletal system: posture and work of internal organs change, back pain appears, etc. (Myers, 2020). Age-related changes in many modern women are aggravated by sedentary lifestyle and occupation. Consequently, they often experience pain in the lumbosacral spine and headaches (Kolomiitseva et al., 2019). Therefore, to improve the quality of life in middle-aged and elderly women, participation in special training programmes is recommended.

Our research has shown that 12-week Pilates training, three times per week, is an effective method for improving respiratory system performance, strength, and endurance of the muscles of the shoulder girdle and abdominal muscles, and hip and shoulder mobility in healthy and active middle-aged women with a sedentary occupation. Physical activity and exercise are among the most important and common components of body mass loss and management programmes (Vispute et al., 2011). de Souza Cavina et al. (2020) and Şavkin and Aslan (2017) stated that Pilates workouts have a positive effect on body composition in overweight and obese women. Rogers and Gibson (2009) noted significant changes in body composition in adult female novice practitioners after an 8-week traditional mat Pilates training programme. However, our Pilates practitioners did not show significant changes in body mass or BMI. We can assume that a period of systematic training longer than 12 weeks could lead to more significant changes in body mass in women. At the same time, the moderate intensity of training that is characteristic of the Pilates beginner level may not have provided the conditions under which the energy deficit required to change body composition and reduce the practitioner's body mass was created. We believe that both these assumptions require additional verification.

Table 2 Means, standard deviations, and *t*-test statistics for joint mobility and muscle strength

Variable	Baseline	Post-intervention	*t*	*p*
Sit and reach (cm)				
Exp	4.50 ± 1.29	8.33 ± 1.02	2.33	.034
Con	4.78 ± 0.80	4.71 ± 0.60	0.70	.49
Prone shoulder flexion (cm)				
Exp	1.23 ± 0.39	3.22 ± 0.43	3.43	.003
Con	1.10 ± 0.21	1.07 ± 0.18	0.11	.92
Side lift (reps)				
Exp	1.18 ± 0.40	4.83 ± 1.24	2.80	.012
Con	1.07 ± 0.26	1.00 ± 0.39	0.14	.92
Roll-up with bent legs (rep)				
Exp	3.22 ± 1.30	6.39 ± 0.61	2.20	.041
Con	3.00 ± 1.03	2.91 ± 0.91	0.06	> .99
Roll-up with straight legs (rep)				
Exp	1.19 ± 0.40	4.77 ± 1.00	3.30	.004
Con	1.16 ± 0.38	1.08 ± 0.28	0.17	.92
Leg pull front (s)				
Exp	11.44 ± 1.09	25.27 ± 3.54	3.60	.003
Con	11.50 ± 1.65	11.28 ± 1.26	0.10	.92
Push-up on single-knee (rep)				
Exp	2.11 ± 0.83	5.00 ± 0.90	2.30	.034
Con	2.00 ± 1.03	1.92 ± 0.91	0.06	> .99

Note. Exp = experimental group; Con = control group; rep = repetition.

Our research results suggest that the Pilates sessions were associated with a non-significant increase in the participants' height. This is not typical for this age group. A similar result was obtained by Kloubec (2010). At the same time, Segal et al. (2004) reported no change in height in their participants with subjective reports of improved posture. Kloubec (2010) explained this result by 'structural changes' and improved posture.

Changes occurred in the parameters of the practitioners' respiratory systems. We observed significant changes in the VC and breath-holding tests. It should be said that the research known to us about the effects of Pilates practice on respiratory function is very limited. The founder of this method, Josef Pilates, considered breathing to be the basis of all exercises (Pilates & Miller, 2021). Nevertheless, Souza et al. (2021), Suzuki et al. (1995), and Tinoco-Fernández et al. (2016) also found positive changes in cardiorespiratory parameters in women of different ages after regular Pilates exercise for up to 50 min. Niehues et al. (2015) explained this finding by the fact that 'Pilates works through the core, made up of the abdominal muscles and lumbar gluteus muscles, which are responsible for the stabilisation of the static and dynamic body that is associated with breath control'. Researchers have observed that different Pilates exercises increase the activation and recruitment of abdominal muscles (Niehues et al., 2015). These muscles are important in respiration, during both expiration and inspiration, through facilitation of diaphragmatic action. Thus, strengthening abdominal muscles can help improve respiratory function, leading to improvements in lung volume and capacity (Niehues et al., 2015). Thus, we support this view. Additionally, the previous results confirmed by us, in our opinion, are very important in the context of the ongoing COVID-19 pandemic.

The data obtained showed significant and positive changes in the elasticity of the hamstring and mobility of the hip joints in flexion in the experimental group compared with the control group. This result became possible due to the inclusion of such exercises in the Pilates training, as rolling on the foam roller and spike balls, flexion, extension, abduction of the hip, and articulation of the foot. Junker and Stöggl (2015), Kao et al. (2015), Kibar et al. (2016), Kloubec (2010), and Rogers and Gibson (2009) reported similar results when using Pilates exercises to increase hamstring elasticity in women of different age groups. Park et al. (2020) reported the beneficial effects of Pilates exercise on hamstring flexibility in male athletes. Overall, our study confirmed the effectiveness of the Pilates method in increasing the hamstring elasticity.

A feature of the posture of people who spend a long time in a sitting position in front of a computer is their shoulders brought forward (Zolina & Izmerov, 1983). As a result, shortening occurs, which means a decrease in the elasticity of the pectoral muscles. This does not allow one to raise straight arms without involving the thoracic spine in action. To improve the flexibility of the shoulder girdle inflection in the Pilates training programme, we used variations of the traditional swimming and leg pull front exercises and observed a positive effect.

The Pilates training led to a slight improvement in shoulder girdle stability in the frontal plane. Holding the side plank with the leg and arm abducted (side lift) requires significant effort from the shoulder muscles, trunk, and hips. Among the scientific publications available to us, we did not find studies using such exercises that allowed us to confirm or deny the indicators we obtained. We found that long-term support on the forearm caused pain in the neck and shoulders of women. We believe that in this case, we can discuss the insufficient ability of the shoulder girdle to maintain such a static position. We, like Isacowitz and Clippinger (2019), consider this a consequence of the lack of physical exertion on this part of the trunk and weakness of the abdominal muscles.

The shoulder and abdominal muscle strength and endurance improved from the baseline. For middle-aged women with sedentary occupations, these physical qualities are a prerequisite for a full life. Using push-up exercises with various modifications at a dosage of 6–8 reps per workout allowed us to improve the practitioners' strength and endurance of the upper body. In the leg pull front with various modifications, women performed between 5–20 s in one workout, which also contributed to the increase in strength and endurance of the upper body. Thus, we confirmed the results of the study by Campos et al. (2016) that Pilates exercises performed 2–3 times per week for 5–12 weeks, improved abdominal muscular endurance for both sexes, when compared with no exercise. The correct organisation of the shoulder girdle from the hand to the shoulder blade contributes to an improvement in the quality of exercise. Abdominal strength, endurance, and pelvic control are important for these exercises. Most Pilates exercises involve the abdominal muscles to some extent and require strength or endurance. The manifestation of both the strength and endurance of these muscles can be traced to the so-called 'advanced' high level of Pilates proficiency. Exercises aimed at developing strength endurance can be actively used at this level. In our workouts, we used the principle 'from simple to complex'. At the beginning of the Pilates training programme, we used simplified modifications of the roll-up exercise with bent legs, gradually moving to the full version. The changes in abdominal muscle strength were more likely than the changes in the flexibility and mobility of the shoulders and legs due to the inclusion of numerous abdominal exercises in the Pilates training programme. Previous studies have also shown an improvement in abdominal muscle strength as a result of Pilates training, but used a shorter training series (Johnson et al., 2007; Kloubec, 2010).

A limitation of our study was the lack of objective information about the participants' physical activity before the experiment, and the control group during the experiment. As the participants were employees of different universities, the collection of such objective data was technically difficult. In future studies, it should be taken into account that the results of applying the Pilates programme proposed by us and the control tests on a different age, gender, and professional sample may differ due to the different reactions of a body of representatives of these groups to physical activity. Pilates training early in the morning and late evening can and should be different due to the inclusion of exercises in the programme that helps waking up or relieve body fatigue.

Conclusions

The 12-week Pilates training practice was shown to be effective in improving respiratory function, shoulder girdle parameters, abdominal strength and endurance, and hip and shoulder joint mobility in healthy middle-aged women having a sedentary occupation.

Acknowledgments

The authors thank the women who volunteered to participate in the study.

Conflict of interest

The authors report no conflict of interest.

References

American Lung Association. (2020). *Lung procedures, tests & treatments. Spirometry*. https://www.lung.org/lung-health-diseases/lung-procedures-and-tests/spirometry

Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J. F., & Martin, B. W. (2012). Correlates of physical activity: Why are some people physically active and others not? *Lancet, 380*(9838), 258–271. https://doi.org/10.1016/S0140-6736(12)60735-1

Bernardo, L. M. (2007). The effectiveness of Pilates training in healthy adults: An appraisal of the research literature. *Journal of Bodywork and Movement Therapies, 11*(2), 106–110. https://doi.org/10.1016/j.jbmt.2006.08.006

Campos, R. R., Dias, J. M., Pereira, L. M., Obara, K., Barreto, M. S., Silva, M. F., Mazuquin, B. F., Christofaro, D. G., Fernandes, R. A., Iversen, M. D., & Cardoso, J. R. (2016). Effect of the Pilates method on physical conditioning of healthy subjects: A systematic review and meta-analysis. *Journal of Sports Medicine and Physical Fitness, 56*(7–8), 864–873. https://www.minervamedica.it/en/journals/sports-med-physical-fitness/article.php?cod=R40Y2016N07A0864

Cruz, J. C., Liberali, R., da Cruz, T. M. F., & Netto, M. I. A. (2016). The Pilates method in the rehabilitation of musculoskeletal disorders: A systematic review. *Fisioterapia Em Movimento, 29*(3), 609–622. https://doi.org/10.1590/1980-5918.029.003.ao19

Cruz-Ferreira, A., Fernandes, J., Laranjo, L., Bernardo, L. M., & Silva, A. (2011). A systematic review of the effects of Pilates method of exercise in healthy people. *Archives of Physical Medicine and Rehabilitation, 92*(12), 2071–2081. https://doi.org/10.1016/j.apmr.2011.06.018

de Souza Cavina, A. P., Pizzo Junior, E., Machado, A. F., Biral, T. M., Lemos, L. K., Rodrigues, C. R. D., Pastre, C. M., & Vanderlei, F. M. (2020). Effects of the mat

Pilates method on body composition: Systematic review with meta-analysis. *Journal of Physical Activity and Health, 17*(6), 673–681. https://doi.org/10.1123/jpah.2019-0171

Di Lorenzo, C. E. (2011). Pilates: What is it? Should it be used in rehabilitation? *Sports Health, 3*(4), 352–361. https://doi.org/10.1177/1941738111410285

Franklin, E. (2012). *Dynamic alignment through imagery* (2nd ed.). Human Kinetics.

Gardner, B., Smith, L., Lorencatto, F., Hamer, M., & Biddle, S. J. H. (2016). How to reduce sitting time? A review of behaviour change strategies used in sedentary behaviour reduction interventions among adults. *Health Psychology Review, 10*(1), 89–112. https://doi.org/10.1080/17437199.2015.1082146

Isacowitz, R., & Clippinger, K. (2019). *Pilates anatomy* (2nd ed.). Human Kinetics. https://www.human-kinetics.co.uk/9781492567707/pilates-anatomy

Johnson, E. G., Larsen, A., Ozawa, H., Wilson, C. A., & Kennedy, K. L. (2007). The effects of Pilates-based exercise on dynamic balance in healthy adults. *Journal of Bodywork and Movement Therapies, 11*(3), 238–242. https://doi.org/10.1016/j.jbmt.2006.08.008

Junker, D. H., & Stöggl, T. L. (2015). The foam roll as a tool to improve hamstring flexibility. *Journal of Strength and Conditioning Research, 29*(12), 3480–3485. https://doi.org/10.1519/JSC.0000000000001007

Kao, Y. H., Liou, T. H., Huang, Y. C., Tsai, Y. W., & Wang, K. M. (2015). Effects of a 12-week Pilates course on lower limb muscle strength and trunk flexibility in women living in the community. *Health Care for Women International, 36*(3), 303–319. https://doi.org/10.1080/07399332.2014.900062

Katzmarzyk, P. T. (2010). Physical activity, sedentary behavior, and health: Paradigm paralysis or paradigm shift? *Diabetes, 59*(11), 2717–2725. https://doi.org/10.2337/db10-0822

Kibar, S., Yardimci, F. Ö., Evcik, D., Ay, S., Alhan, A., Manço, M., & Ergin, E. S. (2016). Can a Pilates exercise program be effective on balance, flexibility and muscle endurance? A randomized controlled trial. *Journal of Sports Medicine and Physical Fitness, 56*(10), 1139–1146. https://www.minervamedica.it/en/journals/sports-med-physical-fitness/article.php?cod=R40Y2016N10A1139

Kloubec, J. A. (2010). Pilates for improvement of muscle endurance, flexibility, balance, and posture. *Journal of Strength and Conditioning Research, 24*(3), 661–667. https://doi.org/10.1519/JSC.0b013e3181c277a6

Kloubec, J. (2011). Pilates: How does it work and who needs it? *Muscles, Ligaments and Tendons Journal, 1*(2), 61–66. http://www.mltj.online/pilates-how-does-it-work-and-who-needs-it

Kolomiitseva, O., Anatskyi, R., & Prikhodko, A. (2019). Efficiency of classes on the Pilates system with women of the second mature age. *Research Journal of Pharmaceutical, Biological and Chemical Sciences, 10*(1), 1251–1257. https://www.rjpbcs.com/pdf/2019_10(1)/[161].pdf

Levine, B., Kaplanek, B., & Jaffe, W. L. (2009). Pilates training for use in rehabilitation after total hip and knee arthroplasty: A preliminary report. *Clinical Orthopaedics and Related Research, 467*(6), 1468–1475. https://doi.org/10.1007/s11999-009-0779-9

Mascarin, N. C., Rayes, A. B. R., Lira, C. A. B., Vancini, R. L., & Andrade, M. S. (2015). Effects of 8 weeks of Pilates training on isokinetic muscular performance of overweight/obese female adults. *Medicine & Science in Sports & Exercise, 47*(5S), 669. https://doi.org/10.1249/01.mss.0000478547.04551.45

Mazzarino, M., Kerr, D., Wajswelner, H., & Morris, M. E. (2015). Pilates method for women's health: Systematic review of randomized controlled trials. *Archives of Physical Medicine and Rehabilitation, 96*(12), 2231–2242. https://doi.org/10.1016/j.apmr.2015.04.005

Merkel, M., & Kozik, S. (2016). *Osteopathische Übungen mit dem Pilates-Roller [Osteopathic exercises with the Pilates-roll]*. Meyer & Meyer.

Mikalački, M., Čokorilo, N., & Ruiz-Montero, P. J. (2017). The effects of a Pilates-aerobic program on maximum exercise capacity of adult women. *Revista Brasileira de Medicina Do Esporte, 23*(3), 246–249. https://doi.org/10.1590/1517-869220172303156004

Myers, T. W. (2020). *Anatomy trains: Myofascial meridians for manual therapists & movement professionals* (4th ed.). Elsevier. https://www.elsevier.com/books/anatomy-trains/myers/978-0-7020-7813-2

Niehues, J. R., Gonzáles, I., Lemos, R. R., & Haas, P. (2015). Pilates method for lung function and functional capacity in obese adults. *Alternative Therapies in Health and Medicine, 21*(5), 73–80.

Nienhuis, C. P., & Lesser, I. A. (2020). The impact of COVID-19 on women's physical activity behavior and mental well-being. *International Journal of Environmental Research and Public Health, 17*(23), Article 9036. https://doi.org/10.3390/ijerph17239036

Park, J. H., Kim, H., Choi, D. H., Park, S., & Hwang, Y. Y. (2020). Effects of 8-week Pilates training program on hamstring/quadriceps ratio and trunk strength in adolescent baseball players: A pilot case study. *Journal of Exercise Rehabilitation, 16*(1), 88–95. https://doi.org/10.12965/jer.1938732.366

Pilates, J. H., & Miller, W. J. (2021). *Return to life through contrology*. Mockingbird Press.

Rogers, K., & Gibson, A. L. (2009). Eight-week traditional mat Pilates training-program effects on adult fitness characteristics. *Research Quarterly for Exercise and Sport, 80*(3), 569–574. https://doi.org/10.1080/02701367.2009.10599595

Şavkin, R., & Aslan, U. B. (2017). The effect of Pilates exercise on body composition in sedentary overweight and obese women. *Journal of Sports Medicine and Physical Fitness, 57*(11), 1464–1470. https://doi.org/10.23736/S0022-4707.16.06465-3

Segal, N. A., Hein, J., & Basford, J. R. (2004). The effects of Pilates training on flexibility and body composition: An observational study. *Archives of Physical Medicine and Rehabilitation, 85*(12), 1977–1981. https://doi.org/10.1016/j.apmr.2004.01.036

Shyian, B. M., & Papusha, V. G. (2019). *Metodika prepodavaniya sportivno-pedagogicheskikh distsiplin v vysshikh uchebnykh zavedeniyakh fizicheskogo vospitaniya i sporta [Methods of teaching sports and pedagogical disciplines in higher educational institutions of physical education and sports]*. OVS Press.

Souza, C., Krüger, R. L., Schmit, E. F. D., Wagner Neto, E. S., Reischak-Oliveira, Á., de Sá, C. K. C., & Loss, J. F. (2021). Cardiorespiratory adaptation to Pilates training. *Research Quarterly for Exercise and Sport, 92*(3), 453–459. https://doi.org/10.1080/02701367.2020.1749222

Suzuki, S., Sato, M., & Okubo, T. (1995). Expiratory muscle training and sensation of respiratory effort during exercise in normal subjects. *Thorax, 50*(4), 366–370. https://doi.org/10.1136/thx.50.4.366

Tejada Medina, V., Díaz Caro, C., González García, C., & Ruiz Montero, P. J. (2020). Programas de intervención física en mujeres mayores a través del método Pilates: Una revisión sistemática [Physical intervention programs in older women through the Pilates method: A systematic review]. *Retos, 39,* 1006–1016. https://doi.org/10.47197/retos.v0i39.78005

Tinoco-Fernández, M., Jiménez-Martín, M., Sánchez-Caravaca, M. A., Fernández-Pérez, A. M., Ramírez-Rodrigo, J., & Villaverde-Gutiérrez, C. (2016). The Pilates method and cardiorespiratory adaptation to training. *Research in Sports Medicine, 24*(3), 76–81. https://doi.org/10.1080/15438627.2016.1202829

Tomilina, Y. (2016). Vplyv pilatesu na dykhal'nu systemu zhinok pershoho zriloho viku [Effect of Pilates on the respiratory system of women of the first mature age]. *Youth Scientific Journal Lesya Ukrainka Eastern European National University, 21,* 76–81. https://sportsvisnyk.vnu.edu.ua/index.php/sportvisnyk/article/view/307

Vispute, S. S., Smith, J. D., LeCheminant, J. D., & Hurley, K. S. (2011). The effect of abdominal exercise on abdominal fat. *Journal of Strength and Conditioning Research, 25*(9), 2559–2564. https://doi.org/10.1519/JSC.0b013e3181fb4a46

Wells, C., Kolt, G. S., & Bialocerkowski, A. (2012). Defining Pilates exercise: A systematic review. *Complementary Therapies in Medicine, 20*(4), 253–262. https://doi.org/10.1016/j.ctim.2012.02.005

Zhu, X., Yoshikawa, A., Qiu, L., Lu, Z., Lee, C., & Ory, M. (2020). Healthy workplaces, active employees: A systematic literature review on impacts of workplace environments on employees' physical activity and sedentary behavior. *Building and Environment, 168,* Article 106455. https://doi.org/10.1016/j.buildenv.2019.106455

Zolina, Z. M., & Izmerov, N. F. (1983). *Rukovodstvo po fiziologii truda* [Manual of occupational physiology]. Meditsina.