A randomised controlled study investigating pulmonary function and respiratory muscle strength in older adults after training with Pilates

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Abstract

Almost all aspects of the respiratory system deteriorate with advancing age, decreasing the elderly's ability to perform strenuous exercise. However, it is speculated that the elderly can still engage in light to moderate exercise due to the respiratory system having a large reserve capacity. Pilates is a comprehensive training method for body conditioning that may arrest or reverse the age-related deteriorations in the respiratory system. The study used 50 inactive, apparently healthy females aged 60 years and older and were randomly assigned to a non-exercising control group (CG) (n = 25; mean age: 65.32 ± 5.01) or a Pilates training intervention group (IG) (n = 25; mean age: 66.12 ± 4.77) group. CG subjects were requested not to participate in any structured exercise throughout the eight-week period, while the IG subjects participated in an eight-week progressive mat Pilates training programme, three times weekly. Eight weeks of Pilates training significantly (p0.05) improved MEF 25% (from 3.59% ± 1.26 to 4.16% ± 1.25; p = 0.008) and PEF (from 4.06 f..sec'[1] ± 1.32 to 4.55 f..sec-[1] ± 1.46; p = 0.049). In terms of respiratory muscle strength, eight weeks of Pilates stgnificantly improved the strength of the transverse abdominus muscles (from 82.67 em ± 11.79 to 80.08 em ± 10.54; p = 0.012), quadrates Iumborum (100.10 mmHg ± 21.84 to 118.50 mmHg ± 21.01; p = 0.001) and lower rectus abdominus (26.40° ± 13.73 to 34.00° ± 10.89; p = 0.004) muscles. In conclusion, the present study highlights the limited success of Pilates in improving pulmonary function and respiratory muscle strength in the elderly. A common endorsement for all elderly individuals encouraging the use of Pilates is thus difficult to achieve and guidelines for Pilates training still need to be established as there is great diversity in the functional level and co-morbidities in the elderly.

Keywords: Aged, callisthenics, exercise tolerance, health-related quality of life, lung function, pulmonary rehabilitation.

Introduction

Almost all aspects of the respiratory system are affected with age and it is well known that vital capacity, maximum ventilation rates and gas exchange decrease with age (Davies & Moore, 2003; Jardin, 2008; Seeley, Stephens & Tate, 2006). These changes are related to the weakening of respiratory muscles and a decrease in the compliance of the thoracic cage, caused by the stiffening of cartilage and ribs. Lung compliance further decreases since parts of the alveolar wall are lost which reduces lung recoil. Residual volume has also been found to increase with age as the alveolar ducts and many of the larger bronchioles increase in diameter. These changes then increase the 'dead space' which decreases the amount of air available for gas exchange (alveolar ventilation). In addition, the gas exchange across the respiratory membrane is reduced since parts of the alveolar walls are lost which in turn decreases the surface area available for gas exchange and the remaining walls thicken which in turn decrease the diffusion of gases (Davies & Moore, 2003; Jardin, 2008; Richardson, Randall & Speck, 1998; Seeley, Stephens & Tate, 2006; Weibel, 1984). Furthermore, with advancing age, there is an age-associated increase in mucus accumulation within the respiratory passageways since the mucus-cilia 'escalator' is less able to transport the mucus as it becomes more subsistent in its nature. Additionally, the number of cilia and their rate of movement decreases. This results in elderly being more susceptible to respiratory infections and bronchitis (Davies & Moore, 2003; Jardin, 2008; Richardson *et al.*, 1998; Seeley, Stephens & Tate, 2006; Weibel, 1984).

Vital capacity decreases with age due to a minimised ability to fill the lungs (decreased inspiratory reserve volume) and a minimised ability to empty the lungs (decreased expiratory reserve volume) resulting in decreases in minute ventilation rates which, in turn, decreases the elderly's ability to perform strenuous exercise (Davies & Moore, 2003; Jardin, 2008; Richardson *et al.*, 1998; Seeley, Stephens & Tate, 2006; Weibel, 1984). However, it is speculated that the elderly can still engage in light to moderate exercise due to the respiratory system having a large reserve capacity.

Pilates is a method comprehensive to body conditioning that is directed toward the development of both the body and the mind of an individual (Muscolino & Cipriani, 2004) and focuses on the "power-house" or "the core" (abdominals, gluteus and paraspinal muscles) (Owsley, 2005), thus possibly resulting in improvements in respiratory function. This is so since Pilates involves progressive multiplantar excursion of the trunk and limb and each exercise starts with the stabilisation of the core muscles (Sorosky, Stilp & Akuthota, 2008). Further, the Pilates method incorporates six key principles including centering, concentration, control, precision, breath and flow (Muscolino & Cipriani, 2004) which all may assist in the improvement in respiratory function. Most Pilates exercises are non-weight bearing and focus is on performing each exercise controlled with the correct breathing (Sorosky, Stilp & Akuthota, 2008).While there is growing scientific evidence to rebuke its use as a treatment regimen for musculoskeletal diagnoses, Pilates is used increasingly for therapeutic benefits (Sorosky, Stilp & Akuthota, 2008). However, it is unknown whether Pilates is effective at improving respiratory function in the elderly. Thus, the aim of the present study was to investigate the effects of a Pilates programme on pulmonary function and respiratory muscle strength in the elderly.

Methodology

Subjects

The sample comprised 50 inactive, apparently healthy females aged 60 years and older. Subjects with relative and absolute contraindications to exercise or exercise testing were excluded from participation in the study. Subjects were randomly assigned to a non-exercising control group (CG) (n = 25; mean age: 65.32 ± 5.01) or a Pilates training intervention group (IG) (n = 25; mean age: 66.12 ± 4.77) group. The present study was approved by the Institutional Review Board of the Tshwane University of Technology, Pretoria, South Africa and was endorsed by the International Physical Activity Projects (IPAP). Permission to conduct the study at the caring facilities was obtained from the relevant care facilities and all subjects signed a written informed consent. Both groups took part in identical pre- and post-tests. Baseline subject demographic data are shown in Table 1.

Table 1:Baseline subject demographic data

Variable	Non-exercising control group (CG) (n =25)	Pilates training intervention group (IG) (n = 25)
Age (years)	65.32 ± 5.01	66.12 ± 4.77
Body Mass (kg)	75.19 ± 14.78	71.71 ± 14.92
BMI (kg.m^{-2})	29.32 ± 5.44	28.32 ± 6.77

Values are means ± standard deviation; kg: kilogramme(s); BMI: body mass index; kg.m^{-2}: kilogrammes per square meter

Pulmonary fimction evaluation

Forced vital capacity (FVC) (litres (t)), forced expiratory volume in one second (FEV1) (f), forced expiratory volume in one second/forced vital capacity ratio (FEV1/FVC) (%), peak expiratory flow (PEF) (f), inspiratory vital capacity (IVC) (f) and maximal voluntary ventilation (MVV) (t.sec^{-1}) were measured following standard recommendations (Miller *et a/.*, 2005) before and after the eight-week experimental period and at least 48 hours after the last training session (Koppers *et al.,* 2006) using a Cosmed® FX System spirometer (Pavona di Albano, Rome) which was calibrated as per Cosmed® FX System requirements prior to each test. Each test was performed at least three times, with each test not differing by more than 5% or 100 millilitres. In the final analysis, the largest value obtained from the three executions was used (George, Light, Matthay & Matthay, 1995).

Respiratory muscle strength evaluation

The strength of the respiratory muscles was manually tested, on the right side where applicable, according to the guidelines of Kendall, McCreary and Provance (1993) using either a Leighton Flexometer® (Spokane, WA, 99223, Spokane County) for the erector spinae, upper rectus abdominis and lower rectus abdominis muscles, a non-distendable tape (Holtain Ltd., Crosswell, Crymych, Pembs., SA41 3UF, UK) for the transverse abdominis muscle, or an aneroid sphygmomanometer (Alpk2 Sphygmomanometer, Japan) for the quadrates lumborurn, scalenes and sternocleidomastoid, serratus anterior, pectoralis major (clavicular portion), pectoralis major (sternocostal portion), pectoralis minor, upper trapezius and lattisimus dorsi muscles, held by the evaluator at the test position. The difference achieved by the subject from a baseline setting of 20 mmHg was recorded (in mmHg) as the specific respiratory muscle's strength.

Pilates training programme

The Pilates training programme was structured in accordance with the guidelines of Worth (2004). All sessions were conducted by a qualified Pilates instructor. The periodised, eight-week mat Pilates training programme consisted of three non-consecutive training sessions a week each lasting 60 minutes in duration. All subjects in the PIL group were initially familiarised with the exercise programme and then provided with simple step-by-step written instructions, an explanation of the basics of mat Pilates and the neutral position of the spine and the correct breathing techniques to be used during Pilates by a qualified practitioner. All sessions began with breathing, followed by a flowing system from standing, to sitting, to lying down exercises and ended with the rest position (Worth, 2004). The subjects in the NON group were instructed to maintain their normal daily activities throughout the eight-week period and not to perform any structured physical activities.

Statistical analysis

Statistical analysis consisted of basic statistics to determine pre- and post-test means and standard deviations. Hetro- and homogeneity was assessed at pre-test using Levene's test for equality of variances. A paired samples t-test was used to determine if a significant change took place in the measurements from pre- to post-test. A probability value of p 0.05 was considered as significant. Data were analysed using the Statistical Package of Social Sciences (SPSS) Version 17 (Chicago, IL).

Results

Pulmonary function

At pre-test, both the IG and CG were homogeneous in terms ofFVC (p =0.069), FEV1 (p =0.355), MEF 25% (p =0.835), MEF 50% (p =0.875), MEF 75% (p = 0.662), FEVdFVC% (p = 0.493), PEF (p = 0.879), PIF (p = 0.193) and FEF 25-75% (p = 0.962). Eight weeks of Pilates training significantly (p 0.05) improved MEF 25% (from 3.59% ± 1.26 to 4.16% ± 1.25; p = 0.008) and PEF (from 4.06 t.sec-^{1} ± 1.32 to 4.55 t.sec-^{1} ± 1.46; p = 0.049) (Table 2). However, no significant improvements were found in the IG in FVC (from 2.45t ± 0.47 to 2.4lt ± 0.49; p = 0.484), FEVt(from 1.93t± 0.39 to 1.92t ± 0.37; p = 0.937), MEF 50% (from 2.49% ± 0.81 to 2.59% ± 0.75; p = 0.312), MEF 75% (from 0.96% ± 0.38 to 0.90% ± 0.29; p =0.347), FEV1/FVC% (from 80.07% ± 5.72 to 81.72% ± 4.80; p = 0.157), PIF (from 3.22 t.sec-^{1} ± 1.33 to 3.08 tsep-^{1} ± 1.40; p = 0.543) and FEF 25-75% (from 1.93 t.sec-^{1} ± 0.59 to 1.98 t.sec-^{1} ± 0.55; p = 0.495).

Table 2: Pulmonary function changes following eight-weeks ofPilates training

Variable	Non-exercising control group (CG) (n = 25)		Pilatcs training intervention group (IG) (n = 25)	
	Pre-test	Post-test	Pre-test	Post-test
Forced Vital Capacity (FVC) (()	2.73:1: 0.59	2.54 :1: 0.45•	2.45 :1: 0.47	2.41:1: 0.49
Forced Expiratory Volume in I second (FEVa) (()	2.04 :1:0.47	1.97:1:0.41	1.93 :1: 0.39	1.92 ± 0.37
Maximum Expiratory Flow at 25% FVC (MEF 25%) (%)	3.67 ± 1.39	3.78 ± 1.42	3.59 ± 1.26	4.16 ± 1.25*
Maximum Expiratory Flow at SO% FVC (MEF 500/o) (%)	2.45 ± 0.93	2.46 ± 0.82	2.49 ± 0.81	2.59 :1:0.75
Maximum Expiratory Flow at 75% FVC (MEF 75%) (%)	1.00 ± 0.32	0.964 ± 0.21	0.96:1: 0.38	0.90:1: 0.29
Forced expiratory volume in one second/forced vital capacity ratio (FEVa!FVC %)	78.65 ± 8.53	80.18 ± 8.05	80.07 ± 5.72	81.72:1: 4.80
Peak Expiratory Flow (PEF) (Lsec-^{1}	4.00 ± 1.46	4.09 ± 1.51	4.06:1: 1.32	4.55 ± 1.46*
Peak Inspiratory Flow (PIF) (t.sec-^{1})	2.76 ± 1.10	2.67 ± 1.01	3.22 ± 1.33	3.08:1: 1.40
Forced Mid-Expiratory Flow (FEF 25-75%) (C.sec-^{1})	1.94 ± 0.59	1.98:1: 0.58	1.93:1: 0.59	1.98 :1: 0.55

Values are means± standard deviation; *: Statistically significant difference between pre- and post-test (p 0.05); t: litre;%: percentage; f.sec•: litre(s) per second; sec: secon

No significant changes were found in the CG for FEV_1 (from 2.04t ± 0.47to 1.97t ± 0.41; p = 0.240), MEF 25% (from 3.67% ± 1.39 to 3.78% ± 1.42; p = 0.619), MEF 50% (2.45% ± 0.93 to 2.46% ± 0.82; p = 0.939), MEF 75% (from 1.00% ± 0.32 to 0.964% ± 0.215; p = 0.347), FEV JIFVC% (from 78.65% ± 8.53 to 80.18% ± 8.05; p = 0.223), PEF (from 4.00tsec·^{1} ± 1.46 to 4.09 t.sec·^{1} ± 1.51; p = 0.692), PIF (from 2.76 t.sec·^{1} ± 1.10 to 2.67 t.sec·^{1} ± 1.01; p = 0.693), FEF 25-75% (from 1.94 t.sec·^{1} ± 0.59 to 1.98 t.sec·^{1} ± 0.58; p = 0.615) (Table 2). In tum, the CG were found to have significantly (p 0.05) and deleteriously decreased their FVC (from 2.73t ± 0.59 to 2.54t ± 0.45; p = 0.005).

Respiratory muscle strength

Prior to commencement of the present study, the IG and CG were homogeneous in terms of the strength of their pectoralis major sternocostal muscle (p = 0.313), pectoralis major clavicular portion (p = 0.432), pectoralis minor (p = 0.676), serratus anterior (p = 0.891), upper trapezius (p = 0.419), transverse abdominus (p = 0.658), latissimus dorsi (p = 0.066), upper rectus abdominus (p = 0.139) and lower rectus abdominus (p = 0.412). However, the IG and CG were heterogeneous at pre-test, in terms of the strength of their erector spinae (p = 0.001), scalenes and sternocleidomastoid (p = 0.028) and quadrates lumborum (p = 0.029).

Following the eight-week Pilates training, significant (p 0.05) improvements in strength were found in the transverse abdominus (from 82.67 em ± 11.79 to 80.08 em± 10.54; p = 0.012), quadrates lumborum (from 100.10 mmHg ± 21.84 to 118.50 mmHg ± 21.01; p = 0.001) and lower rectus abdominus (from 26.40° ± 13.73 to 34.00° ± 10.89; p = 0.004) (Table 3).

Table 3: Respiratory muscle strength changes following eight-weeks ofPilates training

Variable	Control Group (CG) (n = 25)		Intervention Group (IG) (n 25)	
	Pre-test	Post-test	Pre-test	Post-test
Erector Spinae Strength (")	64.72 ± 26.23	66.80 ± 28.70	88.84 ± 22.06	87.06 ± 24.23
Pectoralis Major Sternocostal Muscle Strength (mmHg)	70.96 ± 25.01	61.48± 19.81*	65.00 ± 15.11	66.20 ± 13.60
Pectoralis Major Clavicular Portion Strength (mmHg)	60.90 ± 19.03	45.88 ± 15.15*	57.16:1: 13.91	56.52:1:: 15.79
Pectoralis Minor Strength (mmHg)	86.26 ± 28.22	74.34 ± 17.79	83.54 ± 15.78	87.32 ± 15.65
Scalenes and Sternocleidomastoid Strength (mmHg)	62.82:1:: 16.18	69.44± 15.14*	73.32 ± 16.52	76.48:1:: 15.10
Serratus Anterior Strength (mmHg)	57.52 ± 18.61	51.24 ± 15.32	58.16± 13.98	59.32:!: 13.97
Upper Trapezius Strength (mmHg)	87.12± 14.70	93.50± 16.68	91.94 ± 25.64	96.76 ± 18.82
Transverse Abdominis Strength (em)	84.10± 10.89	81.46 ± 9.97*	82.67 ± 11.79	80.08 ± 10.54•
latissimus Dorsi Strength (mmHg)	55.44 ± 25.92	57.08±23.79	66.60:1:: 14.38	65.20:1: 16.24
Quadratus Lumborum Strength (mmHg)	85.40 ± 24.34	109.36:1:: 19.26*	100.10 ± 21.84	118.50:1: 21.01*
Upper Rectus Abdominis Strength (G)	28.56 ± 18.91	37.96 ± 25.58*	37.40± 22.50	41.60 ± 16.18
LowerRectusAbdominisStrength (")	22.60 ± 18.37	21.40± 14.68	26.40± 13.73	34.00± 10.89*

Values are means :1: standard deviation; *: Statistically significant difference between pre- and post-test (p :5 0.05); °: degrees; mmHg: millimetres mercury; em: centimetres

However, no significant change was found in the strength of the IG in terms of the strength of the erector spinae (from 88.84° ± 22.06 to 87.06° ± 24.23; $p = 0.741$), pectoralis major sternocostal muscle (from 65.00 mmHg ± 15.11 to 66.20 mmHg ± 13.60; $p = 0.695$), pectoralis major clavicular portion (from 57.16 mmHg ± 13.91 to 56.52 mmHg ± 15.79; $p = 0.854$), pectoralis minor (from 83.54 mmHg ± 15.78 to 87.32 mrnHg ± 15.65; $p = 0.304$), scalenes and sternocleidomastoid (from 73.32 mmHg ± 16.52 to 76.48 mrnHg ± 15.10; $p = 0.337$), serratus anterior (from 58.16 mmHg ± 13.98 to 59.32 mmHg ± 13.97; $p = 0.736$), upper trapezius (from 91.94 mmHg ± 25.64 to 96.76 mmHg ± 18.82; $p = 0.444$), latissimus dorsi (from 66.60 mmHg ± 14.38 to 65.20 mmHg ± 16.24; $p = 0.660$) and rectus abdominus (from 37.40° ± 22.50 to 41.60° ± 16.18; $p = 0.385$).

In the CG, no significant ($p \leq 0.05$) change was found in the strength of the erector spinae (from 64.72° ± 26.23 to 66.80° ± 28.70; $p = 0.618$), pectoralis minor (from 86.26 mmHg ± 28.22to 74.34 mmHg ± 17.79; $p = 0.086$), serratus anterior (from 57.52 mmHg ± 18.61 to 51.24 rnmHg ± 15.32; $p = 0.060$), upper trapezius (from 87.12 mmHg ± 14.70 to 93.50 mmHg ± 16.68; $p = 0.195$), latissimus dorsi (from 55.44 mmHg ± 25.92 to 57.08 mmHg ± 23.79; $p = 0.670$) and lower rectus abdominus (from 22.60° ± 18.37 to 21.40° ± 14.68; $p = 0.689$) (Table 3). However, the CG did experience a significant and deleterious decrease in the strength of their pectoralis major sternocostal (from 70.96 mmHg ± 25.01 to 61.48 mmHg ± 19.81; $p = 0.023$) and pectoralis major clavicular portion muscles (from 60.90 mmHg ± 19.03 to 45.88 mmHg ± 15.15; $p = 0.000$). In contrast, the CG did, however, significantly increase the strength of their scalenes and sternocleidomastoid (from 62.82 mmHg ± 16.18to 69.44 mrnHg ± 15.14; $p = 0.034$), transverse abdominus (from 84.10 em± 10.89 to 81.46 em ± 9.97; $p = 0.005$), quadrates lurnborum (from 85.40 mmHg ± 24.34 to 109.36 mmHg ± 19.26; $p = 0.001$) and upper rectus abdominus (from 28.56° ± 18.91 to 37.96° ± 25.58; $p = 0.031$).

Discussion

In order to determine the effectiveness of Pilates in improving respiratory function in the elderly, the present study investigated the effects of eight weeks of Pilates on pulmonary function and respiratory muscle strength. Findings of the present study demonstrated that eight weeks of Pilates training improved the pulmonary function variables of MEF 25% and PEF and the strength of the transverse abdominus, quadrates lumborum, and lower rectus abdominus muscles. Comparing this data with previous studies is challenging due to the lack of research in this area, the effect of Pilates on pulmonary function and respiratory muscle strength cannot be confirmed nor refuted.

Although a loss of elasticity of the lung tissue, stiffening of the chest wall and increased work of breathing are common in the elderly, the present eight-week Pilates programme was ineffective at altering all or the majority of the pulmonary function variables evaluated. This may be as a result of the lungs of the elderly still holding a remarkable reserve and still being able to maintain an adequate diffusion capacity to permit maximum exertion (Wilmore, Costil & Kenney, 2008), especially during the pulmonary function evaluations. The fact that Pilates in our cohort increased PEF is not surprising since this pulmonary function parameter is effort dependent, as opposed to FEV_1, which is effort independent (Ferguson *eta!.,* 2000).

Given that most of the elderly have respiratory and peripheral muscle weakness, dyspnea and functional exercise capacity may improve as a result of Pilates training since this mode of exercise training focuses on control, precision, breath and flow (Muscolino & Cipriani, 2004). Respiratory muscle training has been shown to positively influence the sensations of dyspnea, exercise tolerance and quality of life (Covey *et al.*, 2001), although the exact mechanisms remain unclear (Pertoviv *et a!.,* 2012). Exercise training may result in significant increases in the size of type 2 muscle fibers (Ramirez-Sarmiento *et al.,* 2002) and enhance the velocity of inspiratory muscle shortening (Villafranca *et al.,* 1998). However, the present study failed to demonstrate an improvement in strength in nine of the 12 measured respiratory muscles and may not shorten inspiratory time, allow more time for exhalation and relaxation and reduce dynamic hyperinflation thus facilitating lung emptying. Further, since there was a lack of improved respiratory muscle strength, this mode of exercise training may not result in decreases in breathlessness (Pertoviv *et al.,* 2012) for the elderly.

Conclusions

Methods to improve the quality of life for the elderly have become more important as the aging population continues to grow (Hagerman, 2000). In addition to conventional exercise regimes, there are also non-conventional exercise methods, such as Pilates, that could be considered for use in the elderly. However, while there is growing scientific evidence to caution Pilates use as a treatment regimen for musculoskeletal diagnoses, Pilates is increasingly being used for therapeutic benefits (Sorosky, Stilp & Akuthota, 2008). However, it is not definitively known whether Pilates is effective at improving respiratory function in the elderly. The present study demonstrated limited success ofPilates in improving pulmonary function and respiratory muscle strength in the elderly indicating that a common recommendation for all elderly individuals is difficult to achieve and the need for guidelines to be established. Despite this, some form of exercise is still generally recommended for the elderly.

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