International Journal of Medical, Medicine and Health Sciences
ISSN: 2517-9969
Vol:9, No:7, 2015

Assessment of the Impact of Regular Pilates Exercises on Static Balance in Healthy Adult Women: Preliminary Report

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***Abstract*—**Background: Maintaining the correct body balance is essential in the prevention of falls in the elderly, which is especially important for women because of postmenopausal osteoporosis and the serious consequences of falls. One of the exercise methods which is very popular among adults, and which may affect body balance in the positive way is the Pilates method. The aim of the study was to evaluate the effect of regular Pilates exercises on the ability to maintain body balance in static conditions in adult healthy women. Material and methods: The study group consisted of 20 healthy women attending Pilates twice a week for at least 1 year. The control group consisted of 20 healthy women physically inactive. Women in the age range from 35 to 50 years old without pain in musculoskeletal system or other pain were only qualified to the groups. Body balance was assessed using MatScan VersaTek platform with Sway Analysis Module based on Matscan Clinical 6.7 software (Tekscan Inc., U.S.A). The balance was evaluated under the following conditions: standing on both feet with eyes open, standing on both feet with eyes closed, one-leg standing (separately on the right and left foot) with eyes open. Each test lasted 30 seconds. The following parameters were calculated: estimated size of the ellipse of 95% confidence, the distance covered by the Center of Gravity (COG), the size of the maximum shift in the sagittal and frontal planes and load distribution between the left and right foot, as well as between rear- and forefoot. Results: It was found that there is significant difference between the groups in favor of the study group in the size of the confidence ellipse and maximum shifts of COG in the sagittal plane during standing on both feet, both with the eyes open and closed ($p < 0.05$). While standing on one leg both on the right and left leg, with eyes opened there was a significant difference in favor of the study group, in terms of the size of confidence ellipse, the size of the maximum shifts in the sagittal and in the frontal plane ($p < 0.05$). There were no differences between the distribution of load between the right and left foot (standing with both feet), nor between fore- and rear foot (in standing with both feet or one-leg). Conclusions: 1. Static balance in women exercising regularly by Pilates method is better than in inactive women, which may in the future prevent falls and their consequences. 2. The observed differences in maintaining balance in frontal plane in one-leg standing may indicate a positive impact of Pilates exercises on the ability to maintain global balance in terms of reduced support surface. 3. Pilates method can be used as a form preventive therapy for all people who are expected to have problems with body balance in the future, for example in chronic neurological disorders or vestibular problems. 4. The results have shown that, further prospective randomized research on a larger and more representative group is needed.

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***Keywords*—**Balance exercises, body balance, Pilates, pressure distribution, women.

I. Introduction

BODY balance as an inherent component of human motor ability is defined as the sense of the body's position in space or the body's ability to maintain a certain position. It is also a characteristic enabling the body to regain this state during or after certain activities. Research findings and clinical observations indicate that being physically active and fit as well as increasing muscle strength facilitate the improvement of posture control, maintaining balance and generating normal muscle tonus, while the deterioration of balance ability may be caused by the sequelae of physical inactivity and ageing: sarcopaenia, increased muscle response time, decreased range of joint movement, loss of strength and proprioceptive disturbances [1], [2].

The main sign of postural instability is balance impairment, the most frequent and severe consequence of which is falls. Numerous scientists focus on this issue predominantly with regard to the elderly, especially women, as this social group is most prone to suffer falls and their dangerous consequences. Considering the ever increasing average life expectancy, motor activity is of considerable importance in preventing falls and lowering health care costs. The fear of falling itself may result in limited physical activity, impairment of physical functions, depression and social isolation [3]-[5].

Pilates is a system of physical exercises developed in the early 20th century by German-born Joseph Pilates. In his book "Return to Life through Contrology", he presents his method as the art of controlled movements, which, when executed correctly, should look and feel like training. According to Pilates, regular exercises improve flexibility, build strength, and develop control and stamina of the whole human body. His system allows for adjusting the difficulty level from beginner to advanced, as well as with regard to specific goals and restrictions. In Pilates method we can find various levels of exercises. There are basic exercises on a mat using only gravity and the weight of the body. More difficult are exercises with use of special Pilates equipment and accessories as well as balls, rollers, pulleys, elastic bands (Fig. 1). Exercises are always adapted to the condition of the patient, taking into account the difficulties attributes and skills of each person. Progression of exercise is achieved by manipulating the influence of gravity, the surface of the base support, or the length of the lever.

Pilates is based on six main principles: concentration, control, centre, flow, precision and breathing. From a clinical point of view, Pilates exercises are comprised of synergistic movement patterns involving isometric, eccentric, and concentric muscle contractions. These movement patterns are easily transferred into functional activities. The Pilates method emphasises lumbopelvic stability, movement precision, segmental mobility of the spine), coordination and body balance. In the case of muscle disorders inside the trunk (m. transversus abdomini, m. multifidus, muscles of the pelvic floor, diaphragma) stabilization are provided by a large muscle groups located externally (trapezius muscles of the back, the superficial layer of the back extensor muscle). This leads to chronic tension and fatigue of these structures, which leads the occurrence of pain and postural instability. Centralization and strengthening of the core is one of the basic principles of Pilates. Understanding this principle and its mastery ensures smooth movement, maintain correct posture and improve postural stability and balance [6], [7].

In recent times is a growing interest in the Pilates method utilizing its potential in postoperative rehabilitation. As a result, there has been a development of safe and customizable exercises for patients undergoing orthopedic surgery such as hip arthroplasty and knee. Recent findings suggest that Pilates exercises may also diminish such risk factors as impairment of balance and postural stability associated with falls [8]-[11].

Fig. 1 Exercises in Pilates method - examples

II. Objective

The aim of the study was to evaluate the effect of regular Pilates exercises on the ability to maintain body balance under static conditions in adult healthy women. The aim of the study was also to compare results of experimental group undertaking exercises twice a week with group of inactive women.

III. Material and Methods

The study involved a group of 40 women aged 38 to 49 years, divided into two groups. The experimental group consisted of 20 women undertaking Pilates exercises regularly twice a week for at least one year. Their average age was 42.25 years (range 38-48 years) and their average BMI was 22.6±1.1 kg/m^2. The control group comprised 20 physically inactive women at an average age of 43.15 years and BMI of 24.4±1.4 kg/m^2. Table I is showing anthropometric data of experimental and control group. The inclusion criteria were: signing the consent form to participate in the study, age range of 35 to 50 years, no lower-limb endoprostheses and no current pain. The two groups did not differ from each other with regard to anthropometric data.

TABLE I
Anthropometric Data of the Experimental and Control Groups

	Experimental Group	Control Group
Height [cm]	166,95± 6,95	165,5± 6,5
Weight [kg]	62,95 ± 4,95	66,7± 4,7
BMI	22,6± 1,1	24,4± 1,4

Before beginning of the experiment, all participants were informed of its purpose and the course and the anonymity and voluntary participation in it. Tests were made of standard research methodology. We started from the anamnesis and instructions for the participants.

A MatScanVersaTek posturographic platform (Tekscan Inc., U.S.A) was used to objectively assess the work of the postural control system (Fig. 2).

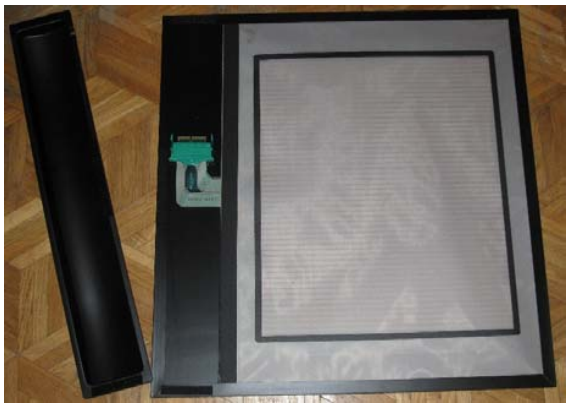

Fig. 2 A MatScanVersaTek posturographic platform

A posturographic study involved measuring the shift of COG projection on a dynamometric platform and evaluating the following parameters: the area of the confidence ellipse, the distance covered by the COG, the size of the maximum shift in the sagittal and frontal planes and load distribution between the left and right foot as well as between rear- and forefoot during one-leg standing, separately for either foot. The following four tests were performed, each lasting 30 seconds: standing on both feet with eyes open, standing on both feet with eyes closed and one-leg standing (separately on the right and left foot) with eyes open. The participants were

instructed to adopt a maximally relaxed position for each measurement. All tests were performed once.

Statistical analysis was conducted with the Microsoft Excel 2013 package, Statistica PL ver. 10.0. and Gretl ver. 1.9.11cvs. Wilcoxon's signed-rank test was used for within-group comparisons, while the Mann-Whitney U test was used for inter-group comparisons. The level of statistical significance in all tests was set at a threshold p-value of < 0.05.

TABLE II
COMPARISON OF DATA OBTAINED IN INDIVIDUAL TESTS FOR THE EXPERIMENTAL AND CONTROL GROUPS – MEANS ± STANDARD DEVIATIONS

Test	Parameter	Experimental group	Control group	*p-value*
Standing on both feet with eyes open	Confidence ellipse area [cm^2]	0.58±0.35	1.14±0.37	*0.001*
	COG distance [cm]	50.4±8.9	37.4±9.1	*0.001*
	Shift in the sagittal plane [cm]	1.39±0.52	2.17±0.90	*0.006*
	Shift in the frontal plane [cm]	0.87±0.20	0.96±0.26	0.355 (NS)
	Left/right foot load distribution [%]	48.9/51.1	49.7/50.3	0.478 (NS)
Standing on both feet with eyes closed	Confidence ellipse area [cm^2]	0.67±0.37	1.03±0.29	*0.001*
	COG distance [cm]	44.3±11.1	38.8±11.1	0.081 (NS)
	Shift in the sagittal plane [cm]	1.68±0.73	2.16±0.62	*0.028*
	Shift in the frontal plane [cm]	0.82±0.18	0.92±0.25	0.242 (NS)
	Left/right foot load distribution [%]	49.4/50.6	49.7/50.3	0.512 (NS)
Standing on left foot with eyes open	Confidence ellipse area [cm^2]	2.14±0.74	3.69±1.40	*0.001*
	COG distance [cm]	75.4±12.8	81.2±18.2	0.253 (NS)
	Shift in the sagittal plane [cm]	2.52±0.63	3.07±0.68	*0.013*
	Shift in the frontal plane [cm]	2.20±0.33	2.48±0.52	*0.035*
	Rear-/forefoot load distribution [%]	52.0/48.0	51.6/48.4	0.678 (NS)
Standing on right foot with eyes open	Confidence ellipse area [cm^2]	1.70±0.65	3.48±1.42	*0.001*
	COG distance [cm]	68.0±13.4	81.1±19.3	*0.040*
	Shift in the sagittal plane [cm]	2.25±0.60	3.24±0.74	*0.001*
	Shift in the frontal plane [cm]	1.89±0.34	2.26±0.65	*0.030*
	Rear-/forefoot load distribution [%]	52.4/47.6	51.6/48.4	0.678 (NS)

NS = non-significant

IV. RESULTS

The distance covered by the COG projection (p=0.010) emerged as statistically significant in the experimental group in the comparison of data from tests involving standing on both feet with eyes open and closed. A comparison of one-leg standing test results for the right and left foot revealed significant differences in the confidence ellipse area (p=0.030), distance (p=0.008) and shift in the frontal plane (p=0.011). In the control groups, comparisons of test results for standing on both feet with eyes open and closed as well as standing on the right and left foot yielded no statistically significant differences.

Data obtained during standing with eyes open differed significantly between the groups with regard to the confidence ellipse area, COG distance and the shift in the sagittal plane (p<0.05). In the test performed while standing with eyes closed, statistically significant differences between the groups were noted only in respect of the confidence ellipse area and shift in the sagittal plane (p<0.05). All those differences indicated superior body balance in the experimental group. The detailed results are presented in Table II.

Data obtained from one-leg standing tests in the control and experimental groups revealed statistically significant differences in favour of the experimental group with regard to the following parameters: the confidence ellipse area (in both limbs), COG distance while standing on the right foot and maximal shift in the sagittal and frontal planes for either limb (p<0.05). No statistically significant differences between the groups were found in load distribution between the rear- and forefoot. The detailed data are displayed in Table II.

V. DISCUSSION

The most distinctive differences between the experimental and control groups in our study were found in one-leg standing tests. All study parameters indicate poorer postural stability in the women who did not practise Pilates. It is also worth noting that COG distance in standing on both feet with eyes open was notably greater in the experimental group, while the same test with eyes closed yielded no statistically significant differences between the groups. This can be explained by relating the distance covered by the COG to the area of the confidence ellipse, which in tests with eyes open was approximately two times larger in the controls than in the experimental group. It may indicate shorter reaction time to loss of balance in women exercising by Pilates method. One-leg standing test produced different results, with higher values for the distance covered by the COG recorded in the control group. In this case, the relation of COG distance to the area of confidence ellipse is worth examining as well, as the latter was also significantly larger in the control group. This may be indicative of poorer postural stability in women from the control group. The finding of the biggest differences during one-leg standing tests is attributable to the fact that the participants in both groups were healthy and at the age when

disturbances of balance resulting from involution processes are not noticeable, which would also explain why the tests involving standing on both feet did not reveal noteworthy deviations from reference values.

Numerous studies have found that the Pilates method is conducive to increasing muscle strength, stamina and muscle flexibility and that it provides constant proprioceptive stimulation during exercise. Hall showed improved body balance in subjects in the age range of 65-81 years who practised two kinds of exercises, including the Pilates method, in comparison to a completely physically inactive group [12]. Johnson and Kaesler also found that Pilates exercises improved dynamic and static postural stability assessed using various tests [9], [10]. Rodrigues demonstrated similar results [13]. It can be inferred on their basis that exercising by Pilates method may improve functional autonomy and static balance in the elderly. Pilates-based exercises also positively influence motor learning of functional activities [14], [15].

Kaesler et al. assessed shifts in both anatomical planes before and after practising Pilates but did not find significant changes of the study parameters, with the exception of frontal plane in a test involving standing on an unstable surface with eyes closed [10]. It should be noted, however, that one training session might not produce desired effects, which can be achieved only by practising regularly over a longer time. Newell proved in his study that an 8-week Pilates exercise programme is enough to note an improvement in the parameters of gait and postural stability, including those associated with the risk of falls [11]. His findings are further confirmed in the present study, where the inclusion criterion was attending Pilates twice a week for at least 1 year.

VI. Conclusions

1. Static balance in women exercising regularly by Pilates method is better than in inactive women, which may in the future prevent falls and their consequences.
2. The observed differences in maintaining balance in the frontal plane in one-leg standing may indicate a positive impact of Pilates exercises on the ability to maintain global balance in terms of reduced support surface.
3. The Pilates method can be used as a preventive measure for all people who are expected to have problems with body balance in the future, for example in the course of chronic neurological disorders or vestibular problems.
4. Our results show that further prospective randomized studies on larger and more representative groups are advised.

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