Pilates Can Affect Sagittal Spinal Alignment: An Observational Study

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Abstract

Purpose: "Pilates" is known to be a gentle technique of strength training with an emphasis on the deep trunk muscle layers. Positive influences on spinal form parameters are assumed.

Methods: Spinal form parameters of 24 female volunteers (10 Pilates / 14 controls) were measured before and after a definite Pilates program (12 units, 60 minutes each, once a week) by means of video raster stereography (Formetric®-system), and analyzed using 2-way ANOVA.

Results: We found significant ($p<0.05$) spine shape changes in the form of spinal erection (decreasing thoracic angle, increasing spinal length) after Pilates-based training exercises.

Conclusions: We consider the controlled spinal shape adaptations – apparent in an erection of spinal alignment in the sagittal plane – to be valid and specifically exercise-induced, supporting a basic idea of the Pilates training concept.

Keywords: Pilates; Spinal alignment; Thoracic kyphosis; Raster stereography

Introduction

Spinal alignment was identified as one risk factor for the incidence of low back pain and may be affected negatively, due to occupational recommendations – like sitting time, or office work load [1]. Exercises – as therapy or prevention – may be suitable as a self-responsible behavioral aspect to counteract associated de-conditioning syndromes in terms of psychological and physiological dimensions, although no special kind of exercise could be identified as preferable [2,3]. This study was focussing on Pilates training and its role for spinal alignment in a non-patient sample.

Pilates is a strengthening training method characterized by special motor control and movement patterns as well as by definite breathing techniques. Co-contraction patterns of deep trunk muscle layers – involving the transversus abdominis as well as the internal and the external oblique abdominals are of special interest for Pilates's movement pattern instructions. Every Pilates exercise starts with a minor hollowing manoeuvre – marked by drawing in the belly button – which leads to an activation of the transversus abdominis. The resulting core tension has to be held during all the following phases of the exercise movements [4].

An isolated activation of the transversus abdominis can be supported by a submaximal contraction of the pelvic floor muscles [5]. Additionally, the deep paraspinal muscles – e.g. the multifidii – can be co-activated by the transversus abdominis muscle strain affecting the tension of the thoracic-lumbar fascia [6].

Due to the specific Pilates breathing instructions, the diaphragm muscle is involved in a co-contraction pattern of deep trunk muscle layers and pelvic floor muscles. Co-contractions of the diaphragm, the pelvic floor, the deep paraspinal back muscles and the deep ventrally located trunk muscle layers constitute an intra-abdominal pressure [7] with a bubble-effect, which is called 'Power House' by Pilates instructors.

Pilates training was invented by Josef Hubertus Pilates, who named it 'Contrology', due to the movement principles characterizing the concept of body and mind: control, focusing, precision, movement flow and conscious breathing rhythm. When ignoring the idea of a connection or the unity of body and mind, the Pilates co-contraction idea is very similar to the concept of Segmental Stabilization Training [8], or Sling Exercise Therapy [9].

Apart from its popularity all over the world, there are some – partly randomized controlled – scientific findings providing evidence of the effectiveness of the Pilates strengthening concept:

Rogers and Gibson [10] and Segal et al. [11] found positive effects for strength endurance and flexibility as well as reduced values for waist, breast and arm circumferences after eight weeks of traditional Pilates training.

In low back patients Gladwell et al. [12] found reduced pain scores associated with a better self-estimated state of health or physical flexibility values.

So far, training-associated alterations of postural parameters or spinal alignment in the sagittal plane were observed only as individual, subjective notes [11] or did not reach a significant level in biomechanical measures after 10 weeks of a Pilates training process [13].

This study was aiming at observing controlled adaptations of spinal alignment parameters following a standardized 12-week Pilates training programme.

Methods

Design

Measures were taken before and after an exercise intervention in a pre-post design for an active treatment group and a waiting control group leading to a two-factorial data model.

Subjects

To make sure that probable intervention effects were actually resulting from the specific Pilates training mode, only experienced participants were allowed to be included into the exercise group (PILATES). 10 females (age 53.1 ± 9.9 y, height 1.70 ± 0.05 m, mass 70.1 ± 16.5 kg, BMI 24.3 ± 5.5 kg/m²) – all of them having been practicing Pilates for more than 2 years and thus being able to perform the correct co-contraction patterns of the 'Power House' – could be recruited as volunteers for a pre-post analysis in a 12-week observation period. 14 athletically active females (age 32.1 ± 8.9 y, height 1.69 ±

0.08 m, mass 67.0 ± 12.1 kg, BMI 23.6 ± 4.1 kg/m²) with no Pilate's background served as controls (CON) in a waiting group not changing their individual lifestyle over the time period of data acquisition. The controls were significantly younger ($p<.05$), while other anthropometric parameters did not differ statistically.

Spine shape analysis

Spinal alignment was assed using a back shape reconstruction system (Formetric®, Diers, Schlangenbad, Germany) based on raster stereography algorithms. Anatomic landmarks like the vertebra prominens (VP), the sacrum point (SP), and the left (DL) and right (DR) lumbar dimples – according to the spinae iliaca posterior superior (SIPS) – could be detected automatically (error < 2 mm). The position of all points on the individuals' back surface (approx. 7,500 pts.) could be referred to a Cartesian coordinate system (y-axis: VP-SP; x-axis: DL-DR) (Figure 1). Surface points could be detected with a high resolution (10 pts/cm²) and a small reconstruction error (<0.2 mm) [14].
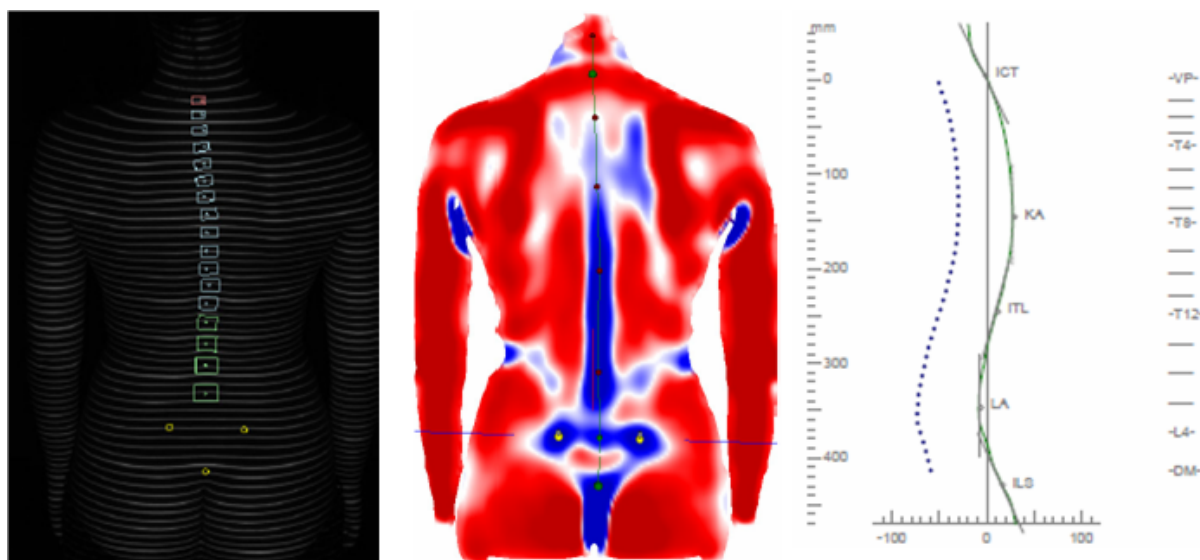

Figure 1: Raster stereography with projector lines on back surface including animated thoracic (T1-12 blue boxes with midpoint) and lumbar (L1-4 green boxes with midpoint) vertebrae plus vertebra prominens (C7 red box with midpoint), lumbar dimples and sacrum point (left side), the back shape reconstruction with convex (red areas) and concave (blue areas) curvatures plus animated landmarks (VP green dot, other processus spinonus red dots, lumbar dimples yellow dots, and sacrum point green dot) (middle), and sagittal back shape profile (calculated middle of vertebrae blue dotted line, back surface green drawn line, inflectional points from cervical to thoracic ICT, and to lumbar ITL and sacral spine ILS, as well as thoracic KA and lumbar LA apices) (right side)

Surface reconstruction leads to raster stereographic parameters describing the sagittal spinal alignment (spine length measured as distance from VP to midpoint between dimples [mm], trunk inclination [mm], thoracic kyphosis angle [°], lumbar lordosis angle [°], and pelvis tilt [°]) served as outcome variables in this investigation (Table 1).

Raster stereography was validated earlier by means of radiological criterions [15-17]. Reliability of data assessment in free bipedal standing was proved earlier, too [18,19].

Training mode

As the participants were assumed to be experienced in the specific movement patterns of the Pilates trunk muscle co-contractions, some 'new' exercises had to be integrated to provide additional neuromuscular or postural exercise-associated adaptations.

The treatment group went through a time period of 12 weeks, following a standardised training programme for 60 minutes once a week. The programme consisted of a warm-up (5 min) with an emphasis on the awareness of the correct Power-House co-contraction pattern, then 15 exercises being varied over the 12-week time period plus 4 special back extension exercises being practised continuously,

and, finally, a cool-down (5-10 min) with stretching exercises, especially for the back.

parameter	abbrev.	explanation
trunk inclination [mm]	Tr-Inc	position of Vertebra prominens related to midpoint between dimples in the sagittal plane
thoracic kyphosis angle (ICT-ITL) [°]	KA	kyphosis angle with tangent point (osculation) at the geometric point of inflection at the transition from the cervical-thoracic to the thoracic-lumbar spine
pelvis tilt [°]	PT	angle between plumb line and sagittal pelvis inclination measured over the dimples
lumbar lordosis angle (ITL-ILS) [°]	LA	lordosis angle with tangent point (osculation) at the geometric point of inflection at the transition from the thoracic-lumbar spine to lumbar-sacral spine
spine length [mm]	VP-DM	Distance from 7th cervical vertebral body (processus spinosus) to midpoint between dimples
abbreviations: ICT = inflectional point (osculation) at cervical-thoracic transition, ITL = inflectional point (osculation) at thoracic-lumbar transition, ILS = inflectional point (osculation) at lumbar-sacral transition		

Table 1: Spine shape parameters in the sagittal plane (Formetric®-System)

All exercises were performed slowly, and in a single-set training mode (8-15 reps) leading to a time-under-tension of about 45 to 60 seconds per exercise set with slow transitions to the following exercise tasks. Training intensity could be estimated as being approximately 50% to 60% of a hypothesized 1-Repetition-Maximum (muscular fatigue exerted by body weight and its torque as the load component combined with the time-under-tension and the number of repetitions as the corresponding training volume parameters).

Statistics

Data were described as mean (± standard deviation), and normal distribution was proved (Kolmogorof-Smirnof-test). A Student's t-Test was calculated to prove ad-hoc group differences, and a two-way ANOVA with repeated measurements was conducted to reveal significantly different developments of the two samples (interaction effect: between groups x within groups) (Statistica V9, Stat Soft, Tulsa, OK, USA). Significance was accepted for p-values ≤ .05. Cohen's d was calculated for dependent variables showing significant interaction effects, by comparing the post test means between groups.

Results

Sagittal plane spine shape parameters of the exercise group (PILATES) and the controls (CON) did not differ significantly before the beginning of the intervention period, and there were no significant interaction effects, neither for the lumbar lordosis angle (LA) nor the pelvis tilt (PT), nor the global trunk inclination (Tr-Inc) (p>.05). But in terms of significant interaction effects (group x time) we found differing changes following the end of the training period for the thoracic kyphosis angle (KA) and the spine length (VP-DM), meaning a spinal erection (Table 2).

The kyphosis angle changed significantly (F=5.004, p=.036) to a more erected spine shape for the PILATES group (47.2° ± 11.1° to 45.1° ± 11.7°) compared to the controls, while theirs changed into a rounder thoracic shape (47.7° ± 6.2° to 49.9° ± 7.6°). Posttest differences were indicating a moderate effect size (d=0.49).

Additionally, we found a significantly increased spine length measured from VP to DM in the vertical axis (F=6.018, p=.023) for the PILATES group (460.4 ± 14.5 to 470.9 ± 20.9) compared to the controls. Theirs did not change at all (452.2 ± 30.7 to 452.7 ± 31.0). Effect size for this posttest group difference was actually high (d=0.69) (Figure 2).

		pre		post		interaction effect	
		mean	SD	mean	SD	F(1, 22)	p
VP-DM [mm]	PILATES	460,4	± 14,5	470,9	± 20,9	6,018	0,023*
	CON	452,2	± 30,7	452,7	± 31,0		
Tr-Inc [mm]	PILATES	26,4	± 16,6	28,4	± 19,2	0,272	0,607
	CON	13,1	± 20,2	13,3	± 21,1		
LA [dgr]	PILATES	41,7	± 10,7	40,4	± 9,7	1,370	0,254
	CON	45,5	± 5,9	45,3	± 7,0		
PT [dgr]	PILATES	22,5	± 4,7	21,0	± 5,5	0,021	0,885
	CON	21,1	± 5,3	19,7	± 7,0		
KA [dgr]	PILATES	47,2	± 11,1	45,1	± 11,7	5,004	0,036*
	CON	47,7	± 6,2	49,9	± 7,6		
Legend: * means significant ANOVA interaction effect (between groups x within groups) at the .05 level							

Table 2: Sagittal plane spine shape parameters (pre-post) of exercise group (PILATES) and control group (CON)

Discussion

The primary outcome of this investigation was an exercise-induced effect of the spinal curvature in the sagittal plane. We found significant changes of spinal shape parameters indicating a spinal erection for the Pilates group compared to the controls.

First of all, spine length – measured from vertebra prominens to the midpoint between dimples (VP-DM) – increased with a strong effect size (d=0.69) as an indicator of a global spine shape adaptation in the sagittal plane. Probably due to specific exercises for the thoracic trunk, spinal erection was obviously located mostly towards at the thoracic portion of the spinal alignment as the kyphosis angle changed with a moderate effect size (d=0.49), while parameters describing the lumbo-pelvic transition did not change significantly (Table 2). A minor shift of about 1° lumbar lordosis erection in the Pilates exercise group might be representing the interdependency of spinal shape parameters: changes in the thoracic kyphosis angle should lead to compensating changes in the lumbar lordosis curvature, too [20]. The minor lumbar

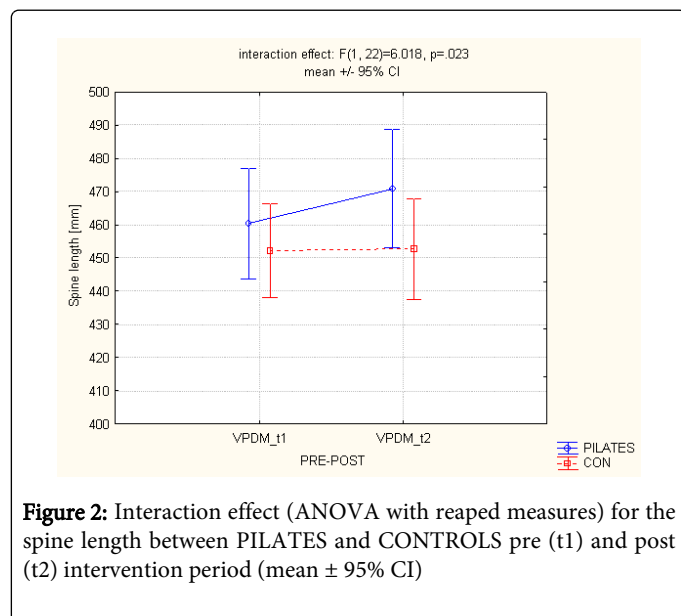erection observed in the Pilates group was also accompanied by a small change of the pelvis tilt of about 1°.

Figure 2: Interaction effect (ANOVA with reaped measures) for the spine length between PILATES and CONTROLS pre (t1) and post (t2) intervention period (mean ± 95% CI)

But both pelvis tilt and lumbar lordosis angle changes did not reach a significant level. Looking at the controls, the thoracic angle shift into a rounder spinal form should be discussed as a kind of time effect, we observed earlier in studies with repeated measures: participants got familiarized with the data assessment situation, where it was necessary to stand barely naked in the examination lab. Although, all measures were performed as repeated assessments aiming at a familiarization, volunteers tended to be more relaxed at a latter measurement, when they were used to be examined by means of raster stereography in the past – meaning that the sagittal sway showed a tendency for a rounder curvature in lumbar or thoracic portions of the spine. With respect to our experiences and the inclusion criterion – Pilates experienced participants – we consider the significant thoracic erection in the exercise group to be due to the specific exercises aiming at a focussed neuromuscular strengthening effect on the upper back (Figure 2).

The 'Power House' co-contraction patterns typical of Pilates training involve the transverse and internal oblique abdominals as well as the diaphragm and the pelvic floor muscles [4,5,7]. This might cause spine shape adaptations rather at the lumbar level than at the thoracic vertebral segments. But aiming at investigating the specific neuromuscular strengthening effects on the spinal alignment subsequent to Pilates training, it was necessary that all volunteers included into the exercise group were familiar with the Pilates 'Power House' co-contraction patterns.

On the one hand, familiarization helped to avoid interfering influences of motor learning processes or neuro-motor technical insufficiency. On the other hand, well experienced participants could be expected to having had their specific neuromuscular adaptations much earlier in their Pilates training history [21]. Focussing on the upper back muscles by inserting so far unknown exercises opened the door to detecting training-induced neuromuscular adaptations, while insuring correct Pilate's movement patterns at the same time. Maybe this conflict was the reason why Kuo and collaborators [13] could reveal only a tendency for a spinal erection after Pilates-based

exercises in healthy older adults, being not significant in their study [13].

Looking for comparable investigations, we could not find any study using the spine length as a video raster stereography-based parameter for the monitoring of exercise effects or any other interventions focussing on the spinal alignment. There have, however, been some studies aiming at investigating neuromuscular adaptations and also reflecting the spinal alignment that found significant effects looking at the thoracic angle [22,23]. Thoracic alignment adaptations in low back pain patients – accompanied by positive functional and clinical changes – were observed after different strengthening training modes, too [22]. For younger adolescents suffering of a hyper-kyphosis syndrome, e.g. Scheuermann's Disease, Weiß and cooperators [23] found an intended but non-controlled thoracic erection effect of about 4° by means of raster stereography in an observational study after an intense and high volume exercise programme.

At first glance our results – a thoracic erection of about 2° – appear to be minor, but they were achieved by following an exercise programme characterised by lower intensities and a lower volume mode than mentioned above. Additionally, the volunteers observed in our study did not show a hyper-kyphosis syndrome or pain associated malalignment, which might be dedicated to probably being modified much easier than 'normal' sagittal shape variations.

Small thoracic angle variations of about 2° to 3° could also be observed in functional single case examinations in repeated measures and reliability analyses by means of video raster stereography [18,24]. Those changes – not following an exercise period – were depending on varying stance positions in free bipedal standing. This error source should be kept in mind, while judging systematic changes to be depending on exercise effects. But our results were reflecting systematic changes of about 2° for the exercise group in one direction – decreasing values meaning a spinal erection – contrary to the controls, where we found increasing thoracic angles, meaning a rounder kyphosis of about 2°. These differing tendencies were considered not be accidental. As standing variations should lead to stochastically varying values into both directions, a tendency to a relaxed posture in follow-up spine shape assessments showing rounder kyphosis or lordosis angles could be observed in earlier investigations not published so far. This could explain the rounder kyphosis of the controls that was not observed in the exercise group. Contrarily, we found a flatter kyphosis that should be explained by the specific thoracic exercises performed by the Pilates group.

At least, an age-depending bias should be discussed. The Pilates exercise sample and the controls differed significantly in age. The controls were about 20 years younger, and this could implicate age-depending differences in spinal shape parameters, too [25]. A rounder thoracic kyphosis and – under definite conditions – a flatter lumbar lordosis could be due to degeneration and the time course of aging [26,27]. But apart from age, there were no significant or relevant differences between the younger controls, being 32 ± 9 years of age, and the Pilates sample, being 53 ± 10 years old, neither in their anthropometric data nor in their sagittal plane spinal curvatures. As the controls were serving as a waiting group only, differences in spine shape alterations could not be explained by the differing age, because a possibly higher plasticity of younger women performing an alternative exercise program – providing an easier spinal form adaptation – was not carried out. Therefore, we consider the difference in age not to be affecting the exercise interaction effect in this investigation of Pilates-

induced alterations of spinal alignment compared to a waiting control group.

Conclusion

Pilates training with its special co-contraction pattern and its almost low-impact intensities can affect spinal alignment, as was hypothesised in its original idea. The thoracic erection is considered to be a result of the specific Pilates mode, due to the fact that participants were well experienced and instructed. Postural adaptations should be considered separately from hypothesised positive health effects. Further research concerning this aspect will be needed.

Informed Consent

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). Informed consent was obtained from all participants for being included in the study.

Acknowledgement

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