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Effect of the 'Pilates stance' and Pilates-based matwork training on measurements of height, waist circumference, and interscapular distance

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ABSTRACT

Background: Standardised guidelines for stance are used to improve interobserver reliability in anthropometric measurements in clinical practice. A key feature of the stance in Pilates is the 'drawing in and up' of the abdomen. The aim of this study was to study the impact of the Pilates stance on height, waist circumference and interscapular distance, compared to that recommended in clinical practice.
Methods: 48 healthy females (median age 60 years) were assessed before and after 10-week Pilates-based matwork training. One Pilates expert and one novice took independent measurements of weight, height, waist circumference and interscapular distance (ISD).
Results: Pilates stance, compared to Normal, increased height by up to 2.7 cm and decreased waist up to 5.2 cm (each $P < 0.001$, repeated measures ANOVA). ISD decreased up to 14 mm ($P < 0.001$) and this decrease was greater after training ($P < 0.001$). After controlling for age and length of time learning Pilates, greater baseline ISD predicted a greater change in ISD after the intervention. Effect of Pilates stance was greater when the expert took the measurements (each $P \leq 0.001$).
Conclusions: Activation of trunk muscles in the Pilates stance increases height and decreases waist circumference, compared to the stance recommended in UK healthcare settings. A decrease in ISD was observed, which was greater after a Pilates-based matwork programme. There are significant inter-observer differences, therefore current clinical guidelines for stance are recommended for repeated anthropometry. The value of the Pilates stance in improving posture and the role of ISD as a marker, should be further studied in various contexts, including clinical settings.

1. Introduction

Posture has an impact on height and waist measurements. Attempt is made, therefore, to minimise variation in these parameters between observers and over time by providing standardised instructions in clinical settings (e.g., Scottish Government 2009). However, in practice, there is often noncompliance with such protocols (Greenwood et al., 2011). Posture is an important focus within Pilates teaching, however, to our knowledge, the difference in anthropometric measurements between the stance promoted within Pilates and that used in clinical settings has not been evaluated.

Joseph Pilates (1883–1967) placed a strong emphasis on posture in his writings (e.g., *Return to Life Through Contrology*, 1945). In an early interview (Ray 1934), Pilates suggested that people should attend to their posture at every opportunity: by observing themselves walking by shop windows, for example, he recommended they continually correct their stance by 'pulling in the abdomen and holding it as long as you can'. He explained that, in this way, 'standing up tall becomes a habit' and this would strengthen the muscles. When standing still, Pilates instructed that 'the weight to be on both feet equally, heels to be together, toes apart, neither allowing the knees to sag nor pressing them backward … but always pulling the abdomen in' (Ray 1934, p. 31). These instructions are commonly used in Comprehensive teaching in both Contemporary and Classical Schools and referred to in Pilates textbooks as the 'Pilates stance' (Siler 2000, pp. 19–23; Ungaro 2002, pp. 11–21; Muscolino and Cipriani 2004; Gadar 2013, p. 3; Isacowitz and Clippinger 2019, pp. 21–23). This is illustrated in Fig. 1B.

Today, the practice of Pilates ranges from Comprehensive teaching involving the use of apparatus designed by Joseph Pilates, to Pilates-based matwork. Based on views and practice across the sector

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internationally, it has been recommended that a framework based on the types of apparatus and exercises, and the order which the exercises are executed, is used when referring to what is being taught and therefore how it is described in clinical practice and research (Lewitt et al., 2019). This spectrum of Pilates exercises is designed to activate muscles of the trunk. When performed correctly, with the abdomen pulled in, ultrasound imaging shows activation of transversus abdominis and obliquus internus, which are important in promoting trunk stability (Endleman and Critchley 2008). The swan exercises activate the back muscles (Kim and Lee 2021), opening the chest and drawing the scapulae closer together. The double leg stretch (Panhan et al., 2019) and knee stretch (Lee 2021) series activate the abdominal muscles. Both back and abdominal muscles are activated in the going up front and mountain climb (Panhan et al., 2021). Positive longer-term effects of Pilates exercises have been reported on isometric trunk extension and flexion strength (Kliziene et al., 2017), and abdominal muscular strength and endurance (Sekendiz et al., 2007).

The aim of this study was to compare height, waist circumference and interscapular distance measurements in the stance recommended for clinical practice, compared to the Pilates stance, and to determine the impact of a 10-week Pilates-based matwork course on these parameters.

2. Methods

2.1. Participants

Participants were recruited from an established Classical Pilates studio and were adults expressing interest in a 10-week Pilates-based matwork course. The research was advertised via the studio electronic newsletter and posters in the studio. All were deemed likely to be able to complete the levels of activity required for the course: they had completed a Physical Activity Readiness Questionnaire (PAR-Q, based on Warburton et al., 2011) and none disclosed cardiovascular, respiratory, or musculoskeletal conditions. 53 participants were recruited (5 classes of up to 12 participants) and 49 completed a 10-week course. Those included in the training programme were ≥18 years of age with of absence of self-reported cardiovascular, respiratory and musculoskeletal conditions. At the end of the training, the one male participant and those not completing the 10-week Pilates-based matwork training were excluded.

Complete data was available and analysed from 48 females. The age of these participants ranged from 23 to 77 years (median 60; 95% confidence intervals (CI) 54–64) and they had been students of Pilates for up to 4 years (median 0.5, 95%CI 0.5–1.0). Fifteen participants had no previous experience of Pilates.

2.2. Intervention

The study was a repeated-measures intervention study. The intervention involved weekly Pilates-based matwork classes with a maximum of 12 participants for 10-weeks. The exercises were classified, according to the framework developed by Lewitt et al. (2019), as Pilates-based matwork: the exercises were close to the original Pilates exercises, following the original order and no large apparatus was used.

The classes were taught by Comprehensive (Classical) Pilates Teachers using exercises on the mat following the order of exercises, starting with lying and finishing with standing exercises, as detailed by Joseph Pilates (1945). There were also variations and additions by Romana Krysanoswska, a student from Pilates' original studio (Gallagher and Kryzanowska, 1999) and her students, Alyca Ungaro (2002) and Christina Maria Gadar (2013). In the first lesson, seven foundational mat exercises ("The Hundred", "The Roll Up", "The One Leg Circle", "Rolling Back", "The One Leg Stretch", "The Double Leg Stretch" and "The Spine Stretch") were introduced, along with accessory ending exercises and, over subsequent weeks, a further 24 exercises layered progressively to build up to an intermediate level repertoire. In accordance with Pilates' instructions to tailor the exercises according to the needs of the student, exercises were adapted as necessary. Experienced students executed more exercises earlier in the training course. Details of the exercises and adaptations are shown in Supplementary Table I.

The project was approved by the School of Science ethics committee, University of the West of Scotland.

2.3. Anthropometry

Measurements were carried out in week 1 and week 10 by two of the authors. One was a Comprehensive (Classical) Pilates teacher with nine years' experience (Observer B). The other had no Pilates experience. Participants wore light clothing and removed their shoes and were assessed by both researchers, who were blinded to each other's measurements and, at week 10, to the measurements taken at week 1.

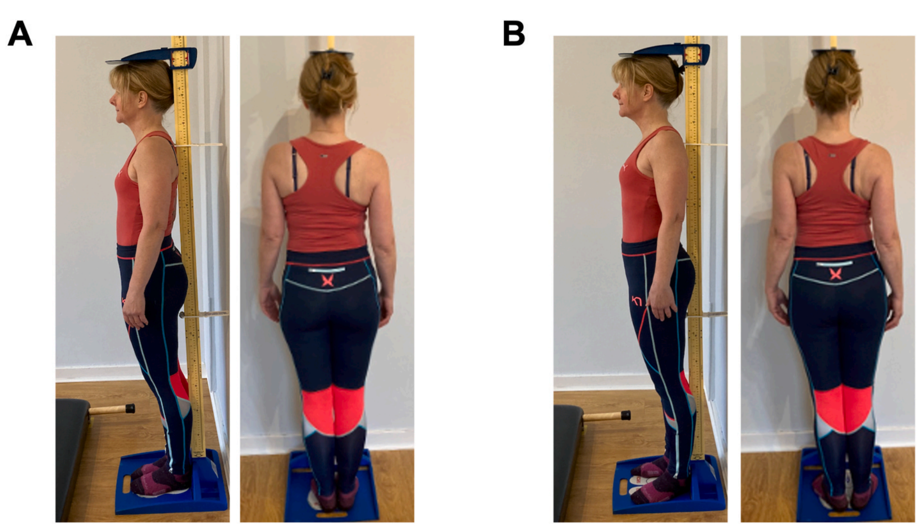

Fig. 1. Pilates stance
Instructions for the normal stance (A) were taken from the Scottish Government guidelines, as described in the Methods. For the Pilates stance (B), the individual was instructed to stand with heels together, feet slightly turned out, legs straight with upper thighs together and abdominals drawn in and up, lengthening the spine. In both stances the Frankfort plane was horizontal. Photos are reproduced with permission of person, who is a right-handed individual who spends several hours a day at the computer and has no clinical scoliosis.

Weight was measured to the nearest 0.1 kg by each observer in duplicate using Seca scales (Cardiokinetics, Salford, UK). The other anthropometric measures were measured in singleton, first in the 'normal' and then in the 'Pilates' stance. Participants were instructed in 'normal' stance using the procedure published by the Scottish Government (2009, Appendix B, Section 1.4): participants were asked to stand on a portable stadiometer (Leicester Height Measure, Seca, Cardiokinetics, Salford, UK) with their feet flat on the centre of the base plate with heels against the rod and their back as straight as possible. Their head was moved so that the Frankfort plane, through the ear canal and across the lower bone of the eye socket, was in a horizontal position. This is illustrated in Fig. 1A.

The instructions for the Pilates stance were provided by Observer B and align with practice in the Pilates sector, as described in the Introduction. Participants were asked to stand in the centre of the base plate of the stadiometer with their heels together, feet turned slightly outwards in a V shape and their legs straight but not locked. They were then asked to draw or scoop the abdominal muscles in and up and to pull the upper inner thighs together posteriorly. They were instructed to lengthen the spine, aiming for the sacrum to touch the stadiometer rod and to focus on a point straight ahead, while the head was moved so that the Frankfort plane was horizontal. They were asked to continue to breathe normally. If the shoulder girdle was observed to elevate, instructions were given to draw the shoulder blades down. The Pilates stance is illustrated in Fig. 1B. Note that the asymmetry observed in this right-handed individual in the 'normal stance' (Fig. 1A) is less apparent in the Pilates stance.

Height (Ht) was measured in each stance to the nearest mm. While in each stance, waist circumference (Wa), at the midpoint between the lowest rib and the iliac crest, and interscapular distance (ISD), between the inferior angles of the scapulae, was measured in singleton to the nearest mm using a flexible tape measure (Gulick Flexi-tape, Baty International, West Sussex, UK). None of the participants had visible evidence of scapular dyskinesis. Body mass index (BMI) was calculated using the formula weight/Ht^2 (kg/m^2), and the waist-to-height ratio (WaHtR) using the formula Wa/Ht (cm/cm).

2.4. Statistical analyses

Height, weight, waist and interscapular distance measurements were normally distributed and values are shown as the mean and 95% CI. There were no missing values. The reliability of each anthropometric measurement was determined by calculating intraclass correlation coefficients (ICC) and their 95% CI in SPSS® Statistics (Version 26, IBM Corporation), using a two-way mixed model for absolute agreement. Values greater than 0.80 were considered of high reliability, while those greater than 0.90 were considered very high.

Analysis of variance (ANOVA) was performed using Prism 9 (GraphPad Software, LLC). In addition to comparing the measurements taken in in each stance (NHS and Pilates) and by each observer (Observer A and Observer B), a comparison was made before and after the training course (1 week and 10 weeks). Therefore, repeated-measures, two-way ANOVA was performed for each measurement. In this analysis, the total variability was tabulated into variability among participants, variability by stance, observer and time-point, as well as the interactions between factors and the residual error. Where significant effects were observed in this analysis the Sidak test was used to correct for multiple comparisons *post hoc*.

The absolute change in height (ΔHt), waist (ΔWa) and ISD (ΔISD) from the Normal to the Pilates stances was determined for each individual, at each time point. The difference between each measurement at week 1 compared to week 10 was also calculated (Δt). Correlations between these differences were determined in Prism 9 using Pearson *r*. Hierarchical multiple regression analyses were performed with SPSS® Statistics with age and length of time learning Pilates entered at Step 1.

Since multiple variables were analysed, statistical significance was set at $P < 0.01$. Uncorrected P values are shown in the tables, and P values between 0.05 and 0.01 are reported as trends in the text.

3. Results

Anthropometric measurements obtained by each observer are shown in Table 1, along with the ICC values that indicate high reliability between observers for each measure. Weight measurements did not change significantly between week 1 and week 10 ($t = 1.597$, df = 47, $p = 0.117$).

There were significant differences in Ht, Wa and ISD measurements between the Normal and Pilates stance: results of two-way repeated measures ANOVA for each source of variation (time, observer, and stance), and their interactions, are shown in Table 2. Height was significantly higher in the Pilates stance, compared with the Normal stance, and there was a significant interaction effect between observer and stance. The differences between the height measurements in each stance are shown in Fig. 2A. A greater difference in Ht was apparent for Observer B, compared to Observer A, and consequently there was a tendency to a greater difference in BMI in the Pilates stance for Observer B (Fig. 2B). Waist and WaHtR measurements were lower in the Pilates stance, compared to Normal, and there were statistically significant interaction effects between observer and time, as well as observer and stance. As illustrated in Fig. 3, the differences between the stances in Wa and WaHtR were greater for Observer B, compared to Observer A.

ISD was significantly less in the Pilates stance, compared to Normal, and there were significant interaction effects between observer and stance, and time and stance (Table 2). As shown in Fig. 4, the effect of Pilates stance on ISD was more pronounced at week 10, compared to week 1 and the difference in ISD between stances was greater for Observer B, compared to observer A at week 10.

3.1. Relationships between anthropometric measurements

Measurements of Ht and Wa between the Normal and Pilates stance, by each observer and at each time point, were strongly correlated (Pearson's $r \geq 0.995$ and ≥ 0.991, for Ht and Wa respectively, all $P \leq 0.0001$, data not shown). Measurements between weeks 1 and 10 for each observer in each stance were also strongly correlated (Pearson's $r \geq 0.993$ and $r \geq 0.967$, for Ht and Wa, respectively, all $P \leq 0.0001$, data not shown), as were measurements between observers at each time point in each stance (Pearson's $r \geq 0.994$ and $r \geq 0.963$, for Ht and Wa, respectively, all $P \leq 0.0001$, data not shown). Table 3 shows the correlations between ΔHt and ΔWa, and participant age and length of time learning Pilates. There were significant correlations between observers for ΔHt and ΔWa at week 10, and for ΔWa at week 1. A significant inverse correlation between age and length of time learning Pilates and ΔHt for measurements taken by observer B was seen at week 1 i.e., there was a smaller difference in ISD between the Pilates and Normal stance for older participants and for those who had been learning Pilates for longer. There was a trend to a positive correlation between age and length of time learning Pilates (Pearson $r = 0.341$, $P = 0.018$).

The correlations amongst ISD and ΔISD measurements for Observer A and Observer B are shown in Table 4. For both observers, there was no correlation between ΔISD at week 1 and week 10, or with ISD measurements. However, the difference in ISD in Pilates stance at 10 weeks compared to week 1 (Δt), for both observers, was inversely correlated with ISD measurements at week 1 i.e., after a 10-week Pilates-based matwork course, the ISD achieved in the Pilates stance was smaller in those with higher ISD measurements at baseline. For ISD, there was a significant correlation between Δt in the Normal Δt in the Pilates stance (Observer A, $r = 0.719$, $P < 0.0001$; Observer B, $r = 0.691$, $P < 0.0001$). Similar correlations were observed when Δt for ISD was expressed a percentage of ISD at week 1 (data not shown). There were no correlations between length of time learning Pilates and ISD or ΔISD at week 1 or week 10, for either Observer (data not shown). (See Table 5)

Table 1
Effect of Pilates stance on anthropometry (mean and 95% confidence intervals).

	Baseline (week 1)			Post intervention (week 10)		ICC*
	Observer A	Observer B	ICC*	Observer A	Observer B	
Weight,kg	67.1 (63.6–70.6)	67.1 (63.6–70.6)	1.00 (1.00–1.00)	66.9 (63.4–70.4)	66.9 (63.4–70.4)	1.00 (1.00–1.00)
Height,cm						
Normal	161.5 (159.9–163.1)	161.3 (159.7–162.9)	0.997 (0.993–0.998)	161.8 (160.2–163.5)	161.6 (160.0–163.3)	0.997 (0.994–0.998)
Pilates	162.2 (160.6–163.8)	162.2 (160.6–163.8)	0.997 (0.995–0.998)	162.5 (160.8–164.1)	162.5 (160.8–164.2)	0.999 (0.998–0.999)
BMI,kg/m^2						
Normal	25.7 (24.5–26.9)	25.8 (24.5–27.0)	0.999 (0.999–1.00)	25.5 (24.3–26.7)	25.6 (24.3–26.8)	0.999 (0.999–1.00)
Pilates	25.5 (24.3–26.7)	25.5 (24.3–26.7)	0.999 (0.999–1.00)	25.3 (24.1–26.5)	25.3 (24.1–26.5)	1.00 (1.00–1.00)
Waist,cm						
Normal	83.1 (80.0–86.2)	83.0 (80.2–85.9)	0.980 (0.965–0.989)	81.5 (78.5–84.4)	80.3 (77.5–83.0)	0.986 (0.924–0.995)
Pilates	81.5 (78.5–84.4)	82.8 (79.8–85.7)	0.981 (0.956–0.990)	79.1 (76.4–81.8)	80.0 (77.4–82.7)	0.991 (0.972–0.996)
WaHtR,cm/cm						
Normal	0.515 (0.496–0.534)	0.515 (0.497–0.533)	0.981 (0.966–0.989)	0.502 (0.485–0.519)	0.512 (0.494–0.531)	0.985 (0.900–0.995)
Pilates	0.503 (0.484–0.521)	0.495 (0.477–0.509)	0.981 (0.957–0.991)	0.487 (0.471–0.504)	0.493 (0.477–0.509)	0.991 (0.972–0.996)
ISD,mm						
Normal	16.5 (60.1–17.0)	16.5 (16.0–17.0)	0.959 (0.928–0.977)	16.4 (16.1–16.8)	16.7 (16.2–17.2)	0.813 (0.669–0.895)
Pilates	16.2 (15.8–16.7)	15.9 (15.9–16.3)	0.926 (0.845–0.962)	15.5 (15.1–15.8)	15.1 (14.7–15.4)	0.858 (0.683–0.929)

Abbreviations: BMI = body mass index, WC = waist circumference, WHtR = waist-to-height ratio, ISD = interscapular distance, ICC = intraclass correlation coefficient (95% CI).
*each $P < 0.001$.

Table 2
Effect of Pilates stance, Pilates-based mat work training, and observer measurement on anthropometry (two-way repeated measures ANOVA, significant values in bold italics).

Source of variation	Height		BMI		Waist		WaHtR		ISD	
	F[a]	*P*	F	*P*	F	*P*	F	*P*	F	*P*
Time	0.071	0.790	0.056	0.814	0.354	0.553	0.453	0.502	1.811	0.182
Observer	5.341	0.023	***4.478***	***0.037***	1.804	0.1824	2.717	0.103	3.283	0.073
Stance	***329.1***	***<0.001***	***313.8***	***<0.001***	***407.4***	***<0.001***	***520.2***	***<0.001***	***180.7***	***<0.001***
Time x Observer	0.128	0.721	0.029	0.864	***19.29***	***<0.001***	***19.63***	***<0.001***	0.376	0.541
Time x Stance	0.228	0.634	0.329	0.567	0.869	0.354	0.600	0.441	***45.18***	***<0.001***
Observer x Stance	***12.96***	***0.001***	***13.41***	***<0.001***	***30.98***	***<0.001***	***38.23***	***<0.001***	***30.95***	***<0.001***
Time x Observer x Stance	0.000	0.987	0.022	0.882	3.259	0.074	2.640	0.108	5.517	0.021

Abbreviations: BMI = body mass index, WHtR = waist-to-height ratio, ISD = interscapular distance.
[a] F-value from two-way repeated measures ANOVA = (variation between sample means; df, 1)/(variation within samples; df, 94).

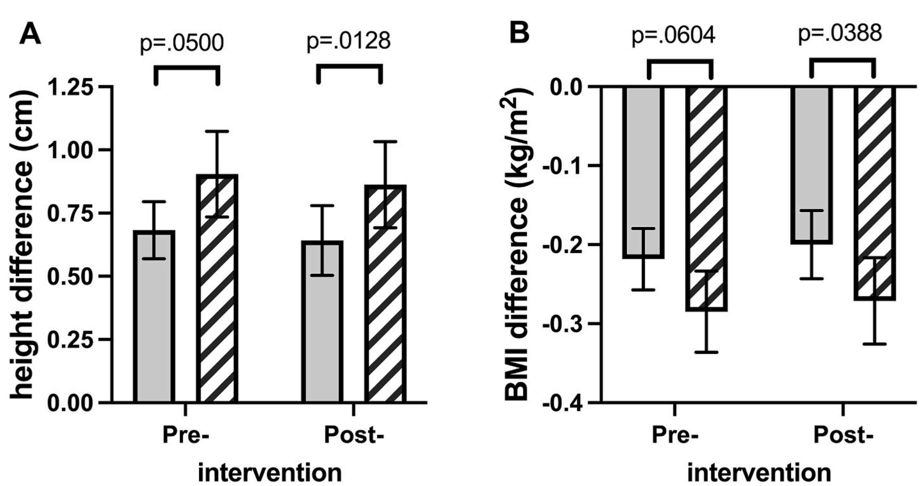

Fig. 2. Pilates stance is associated with greater height, and lower BMI measurements, compared with Normal stance
Effect of Pilates stance as described in the *Methods*, compared to normal stance on measurements of height (Panel A) and BMI (Panel B) by Observer A (grey bars) and Observer B (Pilates expert, hatched bars). There was a statistically significant effect of Pilates stance (see Table 2), with no difference at the end of 10-week Pilates-based matwork course. The interobserver differences, in the difference between stances for height and BMI, were significant (respectively, $F(1, 47) = 11.30$, $P = 0.0015$; $F = 12.45$, P 0.0009; repeated measures ANOVA). *P* values from *post hoc* comparisons (Šidák's multiple comparisons test) are shown on the graphs.

3.2. Predictors of change in interscapular distance

Hierarchical multiple regression analysis was undertaken to test predictions of the change in ISD. In the analysis for each Observers, neither age nor length of time learning Pilates were independent predictors of Δt in the Pilates stance (Model 1). For measurements made by Observer A, introduction of ISD in the Normal stance at week 1 (Model 2) explained 25% of the total variance in Pilates Δt for ISD ($P < 0.001$)

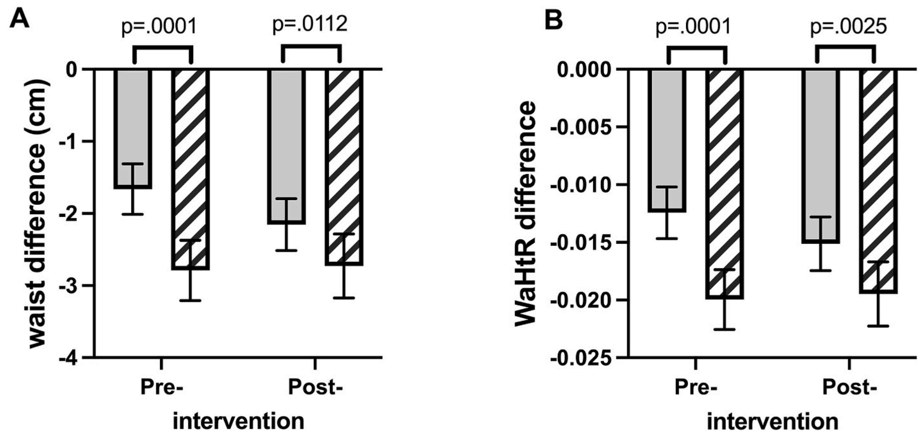

Fig. 3. Pilates stance is associated with lower waist measurements and waist-to-height ratios (WaHtR), compared with Normal stance
Effect of Pilates stance, as described in the *Methods*, compared to normal stance on measurements of Wa (Panel A) and WaHtR (cm/cm, Panel B) by Observer A (grey bars) and Observer B (Pilates expert, hatched bars). There was a statistically significant effect of Pilates stance (see Table 2), with interactions between time and observer. The interobserver differences, in the difference between stances in waist and WaHtR, were significant (respectively, $F (1, 94) = 14.18$, $P = 0.0003$; $F = 17.37$, $P < 0.0001$; repeated measures ANOVA). *P* values from *post hoc* comparisons (Šidák's multiple comparisons test) are shown.

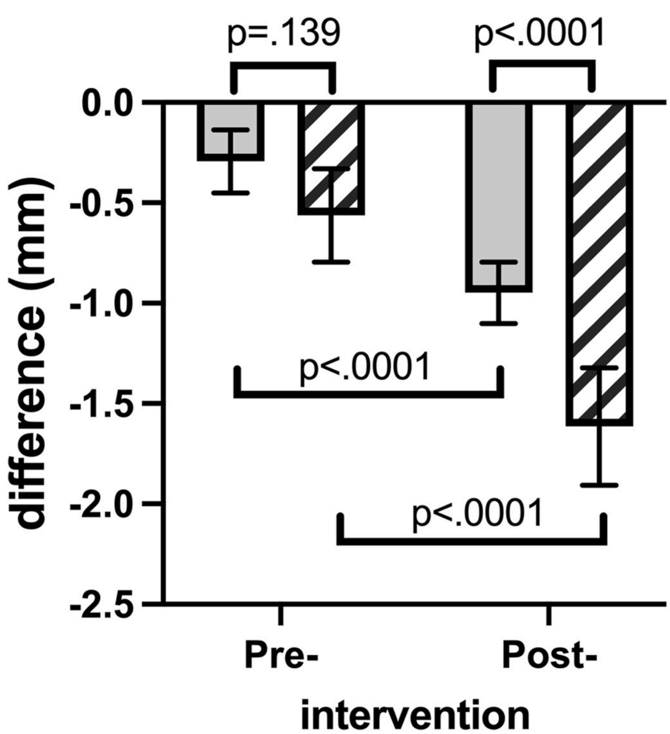

Fig. 4. Pilates stance and Pilates-based matwork training are associated with reduced interscapular distance
Effect of Pilates stance, as described in the *Methods*, compared to normal stance on measurement of interscapular distance (ISD, mm) by Observer A (grey bars) and Observer B (Pilates expert, hatched bars). There was a statistically significant effect of Pilates stance (see Table 2), with interactions between time and observer. The interobserver difference, in the difference between stances in ISD, was significant ($F (1, 94) = 17.37$, $P < 0.0001$; repeated measures ANOVA), and there was a significant effect of time ($F = 68.21$, $P = <0.0001$). *P* values from *post hoc* comparisons (Šidák's multiple comparisons test) are shown.

and there was no significant change when ISD in Pilates stance at week 1 was introduced (Model 3).

For measurements made by Observer B, introduction of ISD in Normal stance at week 1 (Model 2) explained 24% of the total variance in Pilates Δt for ISD ($P < 0.001$) and, after adding the ISD in Pilates stance at week 1, the total variance in the whole model was 42% ($P < 0.001$). In the final model, only ISD in Pilates stance at week 1 was statistically significant ($P < 0.001$), with higher ISD at baseline predicting greater Δt in the Pilates stance.

4. Discussion

In this article, we have demonstrated that the Pilates stance is associated with an increase in height and decrease in waist circumference and interscapular distance measurements, compared to the stance currently used to measure height in UK health care settings (referred to as Normal stance in this article). Two observers, one of whom was experienced in teaching Comprehensive (Classical) Pilates took anthropometric measurements before, and at 10 weeks after training, from 48 women with a median age of 60 years. At baseline, measurements of height, waist circumference and ISD in the Normal stance did not differ significantly between observers. However, there was a difference between observers in the effect of the Pilates stance on each of these measurements. The increase in height, and decrease in waist circumference and ISD, were greater for the experienced Pilates observer.

The way in which stance instructions are given has been observed to affect postural state and balance in healthy older adults (Cohen et al., 2020) with external cueing resulting in a more upright postural alignment compared to a relaxed stance. The smaller decrease in waist circumference for the Pilates novice compared to the Pilates expert was not as pronounced at week 10 of a Pilates-based matwork course compared to baseline. This may have represented learning by the novice, i.e., the stance instructions may have been more effectively delivered as their understanding of Pilates developed. Alternatively, there may have been a change in the way participants responded to instructions after a 10-week Pilates-based matwork course. This has an implication for evaluation of the impact of training. A change in waist measurement after an intervention could also be interpreted as a change in adiposity or muscle tone. After a 10-week intervention of the type presented here, one observer would report no change in waist or weight and therefore no change in adiposity whereas another, finding a smaller waist circumference, might conclude that muscle mass and tone had increased, and/or adiposity had decreased. Furthermore, an intervention that is expected to impact on posture, and therefore height, would further contribute to the variance.

Pilates-based exercises are effective in improving balance in older adults (Casonatto and Yamacita, 2020), trunk extension strength in older women (Carrasco-Poyatos et al., 2019) and upper-body muscular endurance in active middle-aged men and women (Kloubec 2010).

Table 3
Relationships between differences in height and waist measurements in the Normal to Pilates stance, before and 10 weeks after Pilates-based mat work training. Values are the Pearson *r* (*P* value) with significant values in bold italics.

	Observer	Week	Height difference (ΔHt)[a]				Waist difference (ΔWa)[b]			
			A		B		A		B	
			1	10	1	10	1	10	1	10
Age			−0.235 (0.108)	−0.327 (0.023)	***−0.404 (0.004)***	−0.213 (0.146)	0.175 (0.233)	0.005 (0.973)	−0.205 (0.162)	−0.345 (0.016)
Length of time learning Pilates			−0.089 (0.548)	−0.331 (0.022)	***−0.486 (0.000)***	−0.261 (0.073)	0.168 (0.253)	0.139 (0.974)	−0.005 (0.637)	−0.161 (0.274)
ΔHt[a]	A	1		0.325 (0.024)	0.076 (0.606)	0.263 (0.071)	−0.143 (0.331)	−0.017 (0.910)	−0.016f (0.915)	−0.130 (0.380)
		10			0.332 (0.021)	***0.532 (<0.001)***	−0.124 (0.401)	−0.157 (0.285)	−0.018 (0.903)	−0.059 (0.692)
	B	1				***0.419 (0.003)***	−0.074 (0.615)	0.006 (0.968)	0.056 (0.707)	0.329 (0.022)
		10					−0.021 (0.886)	−0.082 (0.581)	−0.057 (0.699)	0.097 (0.512)
ΔWa[b]	A	1						0.363 (0.011)	***0.408 (0.004)***	0.271 (0.034)
		10							0.200 (0.172)	***0.391 (0.006)***
		10								0.307 (0.015)

[a] Absolute difference in height measurement between the Pilates stance and the Normal stance.
[b] Absolute difference in waist circumference between the Pilates stance and the Normal stance.

Table 4
Relationships between interscapular distance measurements, before and 10 weeks after Pilates-based mat work training. Values are the Pearson ***r*** (*P* value) with significant correlations in bold italics.

week		Observer A				Observer B			
		10	10	10	Δt[b]	10	10	10	Δt[b]
		Normal stance	Pilates stance	ΔISD[a]		Normal stance	Pilates stance	ΔISD[a]	
1	Normal stance	***0.680 (<0.001)***	***0.647 (<0.001)***	−0.185 (0.208)	***−0.447 (0.001)***	***0.607 (<0.001)***	***0.583 (<0.001)***	0.295 (0.184)	***−0.456 (0.001)***
1	Pilates stance	***0.641 (<0.001)***	***0.616 (< 0.001)***	−0.161 (0.275)	***−0.380 (0.008)***	***0.633 (<0.001)***	***0.620 (<0.001)***	−0.164 (0.219)	***−0.617 (<0.001)***
1	ΔISD[a]	−0.182 (0.214)	−0.157 (0.286)	0.088 (0.554)	0.222 (0.130)	−0.129 (0.381)	−0.130 (0.488)	0.083 (0.575)	−0.164 (0.266)

[a] Absolute difference in ISD between the Pilates stance and Normal stance.
[b] Absolute difference between ISD in the Pilates stance at week 10 and the-Pilates stance at week 1.

Table 5
Model summary of hierarchical multiple regression analysis: predictors of change in interscapular distance (ISD) before (wk1) and 10 weeks (wk10) after Pilates-based mat work training.

	R	R^2	Adjusted R^2	SE of estimate	R^2 change	F change	df1	df2	F change *P*
Observer A									
Model 1	0.147[a]	0.022	−0.022	1.1513	0.022	0.496	2	45	0.612
Model 2	0.546[b]	0.298	0.251	0.9858	0.277	17.359	1	44	<0.001
Model 3	0.547[c]	0.299	0.234	0.9969	0.001	0.038	1	43	0.846
Observer B									
Model 1	0.327[a]	0.107	−0.067	1.2987	0.107	2.693	2	45	0.079
Model 2	0.535[b]	0.286	0.238	1.1739	0.180	11.072	1	44	0.002
Model 3	0.687[c]	0.473	0.424	1.0209	0.186	15.181	1	43	<0.001

[a] Predictors: (Constant), length of time learning Pilates, age.
[b] Predictors: (Constant), length of time learning Pilates, age, ISD wk 1 NHS stance.
[c] Predictors: (Constant), length of time learning Pilates, age, ISD wk 1 NHS stance, ISD wk10 Pilates stance.

Consistent with an impact on trunk extension, in our study, after a 10-week Pilates-based matwork course the Pilates stance was associated with a greater reduction in ISD, compared to the measurement in the Normal stance. In contrast to the measurements of waist and height, this change seemed to be independent of observer, suggesting that the participants were at least partly responsible. Whether this is related to a better understanding of the Pilates posture or muscle training, achieved during the training course, is not clear from our study. However, length of previous experience with Pilates did not correlate with the change in ISD in relation to stance or training, suggesting that this may be independent of muscle training. On the other hand, it has been observed that those with no Pilates experience are not able to reach the same levels of concomitant abdominal and low back muscle contractions during the 'drawing-in' manoeuvre compared to those with at least three months of twice weekly sessions of Pilates practice (Barbosa et al., 2018). It has also been shown that experienced Pilates practitioners activate their abdominal and low-back core muscles more effectively than non-experienced individuals (Lee 2021).

The focus on posture in the Pilates method underpins use of Pilates exercise as a clinical intervention to improve neck-shoulder pain (Emery et al., 2010) and low back pain (Owen et al., 2020; Hayden et al., 2021). It has been reported to improve lower and upper body strength and flexibility (Bertoli et al., 2022) and to improve postural alignment (Fretta et al., 2021) in breast cancer survivors on hormone therapy, and postural control in Parkinson's disease (Çoban et al., 2021). A systematic review of 10 randomised controlled trial concluded that it may reduce the Cobb angle and trunk range of motion in patients with scoliosis (Gou et al., 2021). Another systematic review, of rehabilitation interventions in multiple sclerosis, identified that approaches that specifically target the trunk, such as Pilates, are associated with improved trunk performance (Raats et al., 2021). While these reports label the exercise as Pilates-based, the exercises are often not described in detail, and therefore some may not meet the definition used in Pilates teaching practice (Lewitt et al., 2019). Before the Pilates stance could be considered as reliable and reproducible for measuring height, waist and ISD in wider clinical practice, there would need to be clear definition and guidelines.

4.1. Strengths and limitations of this study

Pilates-based matwork classes attract participants from across a wide range of ages and levels of physical fitness. While this diversity is reflected in our study population, it may be difficult to extrapolate the findings to particular groups. However, there were no significant independent effects of age or length of time learning Pilates on anthropometric differences between stances in females in this study. While the Pilates stance increased height and decreased waist and ISD measurements compared to Normal in females, the impact in males is yet to be determined and should be addressed in future research.

If an intervention is likely to change posture, then it may affect anthropometric measurements in a range of settings, including healthcare. A strength of the study was that the observers were blinded to each other's measurements and, after the intervention, to baseline measurements. However, there were only two observers in this study, and we could not control completely for individual biases. While significant observer effect in relation to stance for height, waist and ISD measurements was not surprising, since achieving the Pilates stance involves an interaction between observer and participant, further study, involving more observers is clearly needed. Studies using Pilates experts and novices to clarify the extent of interobserver differences, and the impact of Pilates teaching and role of learner understanding on the differences observed, would be worthwhile. We would recommend that such studies include measures of participant muscle strength, flexibility and balance and include measurements by Pilates experts drawn from across teaching practice Framework (Lewitt et al., 2019).

4.2. Clinical relevance

- current clinical guidelines for stance are recommended for repeated anthropometry in clinical practice
- the value of the Pilates stance in improving posture should be studied in clinical settings
- the value of interscapular distance as a marker of improved posture is worthy of further study

CRediT authorship contribution statement

Mairi Dent: Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Lesley McPherson:** Conceptualization, Data curation, Investigation, Methodology, Resources, Writing – review & editing. **Moira S. Lewitt:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

All authors declare that they have no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jbmt.2024.02.047.

References

Barbosa, A.C., Vieira, E.R., Silva, A.F., Coelho, A.C., Martins, F.M., Fonseca, D.S., Barbosa, M.A., Bordachar, D., 2018. Pilates experience vs. muscle activation during abdominal drawing-in maneuver. J. Bodyw. Mov. Ther. 22, 467–470. https://doi.org/10.1016/j.jbmt.2017.05.002.

Bertoli, J., Bezerra, E.S., Winters-Stone, K.M., Alberto Gobbo, L., Freitas, I.F.J., 2022. Mat Pilates improves lower and upper body strength and flexibility in breast cancer survivors undergoing hormone therapy: a randomized controlled trial (HAPiMat study). Disabil. Rehabil. https://doi.org/10.1080/09638288.2022.2032410.

Carrasco-Poyatos, M., Ramos-Campo, D.J., Rubio-Arias, J.A., 2019. Pilates versus resistance training on trunk strength and balance adaptations in older women: a randomized controlled trial. PeerJ 7. https://doi.org/10.7717/peerj.7948 e7948-e7948.

Casonatto, J., Yamacita, C.M., 2020. Pilates exercise and postural balance in older adults: a systematic review and meta-analysis of randomized controlled trials. Complement. Ther. Med. 48, 102232 https://doi.org/10.1016/j.ctim.2019.102232.

Çoban, F., Belgen Kaygısız, B., Selcuk, F., 2021. Effect of clinical Pilates training on balance and postural control in patients with Parkinson's disease: a randomized controlled trial. J.Comparat. Effeven. Res. 10 (18), 1373–1383. https://doi.org/10.2217/cer-2021-0091.

Cohen, R.G., Baer, J.L., Ravichandra, R., Kral, D., Mcgowan, C., Cacciatore, T.W., 2020. Lighten up! Postural instructions affect static and Dynamic balance in healthy older adults. Innovat. Aging 4 (2), igz056. https://doi.org/10.1093/geroni/igz056.

Emery, K., De Serres, S.J., Mcmillan, A., Côté, J.N., 2010. The effects of a Pilates training program on arm–trunk posture and movement. Clin. BioMech. 25, 124–130. https://doi.org/10.1016/j.clinbiomech.2009.10.003.

Endleman, I., Critchley, D.J., 2008. Transversus abdominis and obliquus internus activity during pilates exercises: measurement with ultrasound scanning. Arch. Phys. Med. Rehabil. 89, 2205–2212. https://doi.org/10.1016/j.apmr.2008.04.025.

Fretta, T.B., Boing, L., Baffa, A.D.P., Borgatto, A.F., Coutinho De Azevedo Guimarães, A., 2021. Mat pilates method improve postural alignment women undergoing hormone therapy adjunct to breast cancer treatment. Clinical trial. Compl. Ther. Clin. Pract. 44, 101424 https://doi.org/10.1016/j.ctcp.2021.101424.

Gadar, C.M., 2013. Pilates an Interactive Workbook: if Your're Going to Do it, Do it Right. Gadar Inc.

Gallagher, S.P., Kryzanowska, R., 1999. The Pilates Method of Body Conditioning. BainBridge Books, 1891696084.

Gou, Y., Lei, H., Zeng, Y., Tao, J., Kong, W., Wu, J., 2021. The effect of Pilates exercise training for scoliosis on improving spinal deformity and quality of life: meta-analysis of randomized controlled trials. Medicine (Baltim.) 100, e27254. https://doi.org/10.1097/MD.0000000000027254.

Greenwood, J.L.J., Narus, S.P., Leiser, J., Egger, M.J., 2011. Measuring body mass index according to protocol: how are height and weight obtained? J. Healthc. Qual. 33, 28–36. https://doi.org/10.1111/j.1945-1474.2010.00115.x.

Hayden, J.A., Ellis, J., Ogilvie, R., Stewart, S.A., Bagg, M.K., Stanojevic, S., Yamato, T.P., Saragiotto, B.T., 2021. Some types of exercise are more effective than others in people with chronic low back pain: a network meta-analysis. J. Physiother. 67, 252–262. https://doi.org/10.1016/j.jphys.2021.09.004.

Isacowitz, R., Clippinger, K.S., 2019. Pilates Anatomy. Human Kinetics.

Kim, Y.S., Lee, N., 2021. Effects of applied swan pilates motions on upper body muscle activities. J. Bodyw. Mov. Ther. 26, 290–293. https://doi.org/10.1016/j.jbmt.2020.12.031.

Kliziene, I., Sipaviciene, S., Vilkiene, J., Astrauskiene, A., Cibulskas, G., Klizas, S., Cizauskas, G., 2017. Effects of a 16-week Pilates exercises training program for isometric trunk extension and flexion strength. J. Bodyw. Mov. Ther. 21, 124–132. https://doi.org/10.1016/j.jbmt.2016.06.005.

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

Lee, K., 2021. The relationship of trunk muscle activation and core stability: a biomechanical analysis of Pilates-based stabilization exercise. Int. J. Environ. Res. Publ. Health 18, 12804. https://doi.org/10.3390/ijerph182312804.

Lewitt, M.S., Mcpherson, L., Stevenson, M., 2019. Development of a Pilates Teaching Framework from an international survey of teacher practice. J. Bodyw. Mov. Ther. 23, 943–949. https://doi.org/10.1016/j.jbmt.2019.02.005.

Muscolino, J.E., Cipriani, S., 2004. Pilates and the "powerhouse"—II. J. Bodyw. Mov. Ther. 8, 122–130. https://doi.org/10.1016/S1360-8592(03)00058-5.

Owen, P.J., Miller, C.T., Mundell, N.L., Verswijveren, S., Tagliaferri, S.D., Brisby, H., Bowe, S.J., Belavy, D.L., 2020. Which specific modes of exercise training are most effective for treating low back pain? Network meta-analysis. Br. J. Sports Med. 54, 1279–1287.

Panhan, A.C., Gonçalves, M., Eltz, G.D., Villalba, M.M., Cardozo, A.C., Bérzin, F., 2019. Electromyographic evaluation of trunk core muscles during Pilates exercise on different supporting bases. J. Bodyw. Mov. Ther. 23, 855–859. https://doi.org/10.1016/j.jbmt.2019.03.014.

Panhan, A.C., Gonçalves, M., Eltz, G.D., Villalba, M.M., Cardozo, A.C., Bérzin, F., 2021. Core muscle activation during Pilates exercises on the Wunda chair. J. Bodyw. Mov. Ther. 25, 165–169. https://doi.org/10.1016/j.jbmt.2020.10.025.

Pilates, J., 1945. Return to life through Contrology. Present. Dynam. Reprinted 1998.

Raats, J., Lamers, I., Merken, I., Boeckmans, J., Soler, B.M., Normann, B., Arntzen, E.C., Feys, P., 2021. The content and effects of trunk rehabilitation on trunk and upper limb performance in people with multiple sclerosis: a systematic review. Eur. J. Phys. Rehabil. Med. 58 (1), 26–32. https://doi.org/10.23736/S1973-9087.21.06689-2.

Ray, M.B., 1934. Cutting a Fine Figure. Readers Digest August 1934.

Scottish Government, 2009. The Scottish Health Survey 2008, : 9780755981076. Scottish Government.

Sekendiz, B., Altun, Ö., Korkusuz, F., Akın, S., 2007. Effects of Pilates exercise on trunk strength, endurance and flexibility in sedentary adult females. J. Bodyw. Mov. Ther. 11, 318–326. https://doi.org/10.1016/j.jbmt.2006.12.002.

Siler, B., 2000. The Pilates Body. Penguin Books, London, UK.

Ungaro, A., 2002. Pilates Body in Motion. Dorling Kindersley, London.

Warburton, D.E.R., Gledhill, N., Jamnik, V.K., Bredin, S.S.D., McKenzie, D.C., Stone, J., Charlesworth, S., Shephard, R.J., 2011. Evidence-based risk assessment and recommendations for physical activity clearance: consensus Document 2011. Appl. Physiol. Nutr. Metabol. 36, S266. https://doi.org/10.1139/h11-062.