

# Spinal posture and pelvic position during pregnancy: a prospective rasterstereographic pilot study

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Received: 22 August 2013/Revised: 18 August 2014/Accepted: 18 August 2014/Published online: 26 August 2014  
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## Abstract

**Purpose** Despite the high prevalence of low back pain during pregnancy there is still a lack in the understanding of its aetiology. Changes of the spinal posture due to the anatomical changes of the pregnant body seem to be in part responsible for the back pain. In this pilot study we assessed the potential to accurately measure the spinal posture and pelvic position during pregnancy without any harmful radiation using a spine and surface topography system.

**Methods** Thirteen pregnant women were examined during the second and third trimester of their pregnancy, and postpartum. Twenty female, non-pregnant volunteers comprised the control group. The spinal posture and pelvic position were measured with a radiation-free spine and surface topography system.

**Results** We found a significant increase in thoracic kyphosis during the course of pregnancy, but no increased lumbar lordosis. The lateral deviation of the spine also decreased significantly. However, we did not measure

significant changes of the pelvic position during or after pregnancy.

**Conclusions** The results of our study show that pregnancy has an effect on the spinal posture, and that spine and surface topography can be used to measure these changes three-dimensionally and without any harmful radiation. In future studies this technique could allow to further evaluate the relationship between posture and low back pain during pregnancy, helping to understand the aetiology of low back pain in pregnancy as well as to identify methods for its prevention and treatment.

**Keywords** Back pain · Pregnancy · Rasterstereography · Spine and surface topography · Posture

## Introduction

The prevalence of low back pain during pregnancy is described as being anywhere from 20 to 90 % [1]. Women with severe low back pain during their pregnancy are also at high risk for developing low back pain later in their lives [2]. Despite the significant effects of low back pain on pregnant women there is still a lack of understanding of its aetiology. A recent study found a significant relationship between changes of the spinal posture and low back pain in healthy people [3].

However, it is challenging to reliably measure postural and spinal changes during pregnancy, since most imaging studies cannot be used due to the radiation burden. A non-isotopic spine and surface topography measurement system could potentially fill this void; it uses the projection of visible light lines from a slide projector onto the back surface. The use of this technique during pregnancy would not only allow documentation of the three-dimensional

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back surface, but also of the underlying spine, using a spine model that was created by Turner-Smith [4]. In this pilot study we assessed the potential to accurately measure the spinal posture and pelvic position during pregnancy without any harmful radiation using a spine and surface topography system.

## Materials and methods

Thirteen pregnant women were examined twice during pregnancy (2nd trimester: 14–26 weeks and 3rd trimester: 27–40 weeks) and once after delivery (postpartum—12 weeks after delivery) with a spine and surface topography system. Twenty female, non-pregnant volunteers comprised the control group. The anthropometric data of both groups can be found in Table 1. Inclusion criteria were age between 18 and 45 years and gestational age of at least the 14th week. Women with a history of spine fracture or spinal abnormality were excluded from this study. The study was approved by the local human subjects research review board and all subjects were informed about the

study, gave their written consent and were given the option to discontinue participation at any time. All participants completed the German version of the Roland-Morris disability questionnaire and the Oswestry low back disability questionnaire (ODQ) at each visit. The current level of back pain was measured with a visual analogue pain scale (VAS). In addition, the weight and abdominal circumference of the women were documented at each visit.

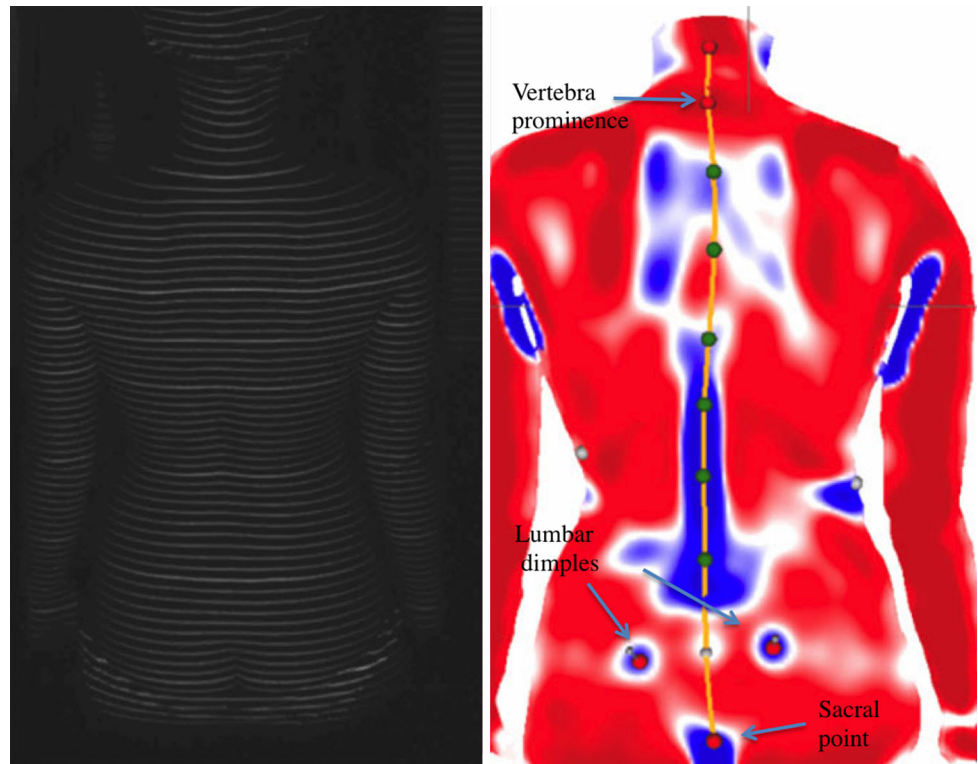
The spinal posture and pelvic position were measured with a radiation-free spine and surface topography system (Formetric, Diers International GmbH, Germany). Therefore, horizontal parallel light lines are projected onto the unclothed back surface by a slide projector (Fig. 1). A surface reconstruction of the back is performed by transforming the lines and their corresponding curvature into a three-dimensional scatter plot (Fig. 1). Transverse and sagittal profiles, the spinous process line and several spinal angles and indices can be calculated with this 3D model. It is also possible to use the two lumbar dimples to determine pelvic obliquity and torsion, because they are in close relation to the underlying posterior superior iliac spines [5].

**Table 1** The anthropometric data of the pregnant women and of the women of the control group are shown in this table

Parameter	Pregnant women (SD)	Range	<i>p</i> value	Control group (SD)	Range
Age (years)	32.29 (4.62)	17	–	27.42 (3.13)	16
Height (cm)	169.35 (6.87)	23	–	169.89 (7.27)	32
Initial weight (kg)	68.46 (11.90)	42	–	69.89 (10.51)	39
Weight gain (kg)					
2nd trimester	7.14 (64.10)	9	–	–	–
3rd trimester	13.64 (6.43)	9	<0.001	–	–
Postpartum	4.58 (3.29)	9	<0.001	–	–
Abd. Circumference (cm)					
2nd trimester	97.05 (8.45)	17	–	–	–
3rd trimester	107.86 (13.29)	92	0.01	–	–
Postpartum	95.00 (16.01)	9	0.002	–	–
Back pain VAS					
2nd trimester	2.19 (1.41)	4	–	–	–
3rd trimester	3.31 (2.22)	7	0.118	–	–
Postpartum	1.97 (1.95)	6	0.054	–	–
ODQ (%)					
2nd trimester	5.54 (4.89)	20	–	–	–
3rd trimester	16.41 (12.02)	40	<0.001	–	–
Postpartum	6.32 (7.52)	24	0.001	–	–
Roland Morris					
2nd trimester	1.38 (3.44)	16	–	–	–
3rd trimester	4.64 (4.68)	18	0.022	–	–
Postpartum	3.11 (4.59)	12	0.637	–	–

The clinical outcome was measured during each visit with the visual analogue pain scale (VAS), the Oswestry low back disability questionnaire (ODQ) and the Roland-Morris disability questionnaire

**Fig. 1** Horizontal parallel light lines are projected onto the unclothed surface of the back of the pregnant women by a slide projector, as seen on the left. Then a surface reconstruction of the back is performed by an automatic transformation of the horizontal lines and their corresponding curvature into a three-dimensional scatter plot. The spinous process of the 7th cervical vertebra (vertebra prominence), the two lumbar dimples, and the sacral point are automatically detected by the system and further used as reference points to calculate the parameter



For the purpose of this study it is necessary to define certain terms regarding the parameters that were measured. The pelvic obliquity is the amount of tilt in degrees or mm from the horizontal of a line between the two lumbar dimples DL (left dimple) to DR (right dimple). A positive value indicates that the right dimple is higher than the left and a negative value indicates that the left dimple is higher than the right. The pelvic torsion measured in degrees is the rotation of the surface normals of the two lumbar dimples (DL and DR). A positive pelvic torsion means that the right hipbone is oriented farther anterior than the left hipbone and a negative value signifies that the left hipbone is farther anterior than the right hipbone. The pelvic inclination is defined as the mean vertical torsion of the two surface values on the two lumbar dimples. The surface rotation is the value of the horizontal components of the surface normals on the line of symmetry (line connecting the spinous processes of the spine) measured in degrees ( $^{\circ}$ ). The lateral deviation is defined as the deviation of the spinal midline from the line between the vertebra prominens (VP) to midpoint between DL and DR (DM) in the frontal plane. Trunk inclination was calculated as the distance in the sagittal plane between VP and the lumbar dimples (DM). A positive value was interpreted as an increase in inclination in an anterior direction, whereas a negative value represents a more upright or even hyper-extended standing position. The lateral distance between the VP and the DM is called the trunk imbalance. A positive value signifies a

shift of the VP to the right and a negative value to the left. The kyphotic angle is the angle between the surface tangents on points VP and the calculated spinous process of the 12th thoracic vertebrae (T12) and the lordotic angle is the angle between the surface tangents on points T12 and DM.

#### Data analysis

All data were checked for Gaussian distribution by the Chi-square test and presented as means with standard deviations or 95 % confidence level. Paired *t* tests and unifactorial ANOVA were used to check for changes between the values. The level of significance was set at  $p < 0.05$ . Correlations between the spinal and pelvic parameters from the 2nd, 3rd trimester and postpartum measurements were correlated with the respective results of the VAS back pain, the ODQ, and the Roland Morris disability questionnaire using Pearson's correlation. Statistical analysis and graphic presentation were prepared using software SPSS 20.0<sup>®</sup> (SPSS Inc., Chicago, USA).

#### Results

During pregnancy women gained significantly weight ( $p < 0.001$ ) between the 2nd trimester and 3rd trimester (Table 1). They lost significantly weight ( $p < 0.001$ ), as

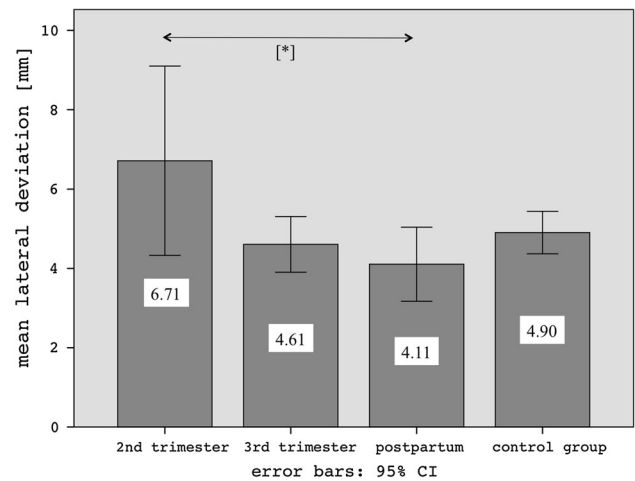
**Table 2** The results for the pelvic parameters: pelvic obliquity, pelvic torsion and pelvic inclination during the 2nd trimester, 3rd trimester and postpartum, as well as for the control group are shown here

Parameter	Results (SD)	Range	<i>p</i> value
<b>Pelvic torsion (°)</b>			
2nd trimester	2.10 (2.05)	7	–
3rd trimester	1.82 (1.20)	5	1.00
Postpartum	2.16 (1.42)	4	1.00
Control group	1.73 (1.26)	5	1.00
<b>Pelvic obliquity (°)</b>			
2nd trimester	3.43 (3.59)	15	–
3rd trimester	5.29 (4.62)	18	1.00
Postpartum	6.84 (5.24)	15	0.681
Control group	4.62 (4.27)	16	0.075
<b>Pelvic inclination (°)</b>			
2nd trimester	23.19 (5.69)	23	–
3rd trimester	21.79 (6.60)	26	1.00
Postpartum	19.53 (7.39)	27	1.00
Control group	21.57 (6.57)	29	1.00

expected, after the delivery (Table 1). We also measured a significant increase ( $p = 0.01$ ) in the abdominal circumference from a mean value of  $97.05 \pm 8.45$  cm (mean value  $\pm$  standard deviation) during the 2nd trimester to a mean abdominal circumference of  $107.86 \pm 13.29$  cm during the 3rd trimester. After the delivery the abdominal circumference decreased significantly ( $p = 0.002$ ) to a mean value of  $95.0 \pm 16.01$  cm.

Pregnant women had a mean Roland-Morris disability score of  $1.38 \pm 3.44$  during the 2nd trimester (Table 1). This score increased significantly ( $p = 0.022$ ) to a mean score of  $4.64 \pm 4.68$  during the 3rd trimester and decreased ( $p = 0.637$ ) after the delivery to a mean score of  $3.11 \pm 4.59$  (Table 1). The ODQ also increased significantly ( $p < 0.001$ ) during pregnancy from  $5.54 \pm 4.89$  during the 2nd trimester to  $16.41 \pm 12.02$  during the 3rd trimester (Table 1). Postpartum, the index dropped significantly ( $p = 0.001$ ) to a mean value of  $6.33 \pm 7.52$  (Table 1). The mean VAS score at survey time during the 2nd trimester was  $2.19 \pm 1.41$  (Table 1). During the 3rd trimester the pain level did not increase significantly ( $p = 0.118$ ). Postpartum the mean score decreased not significantly ( $p = 0.054$ ) to  $1.97 \pm 1.95$  (Table 1).

Table 2 shows a non-significant increase ( $p = 1.0$ ) in pelvic obliquity from  $3.43 \pm 3.59$  mm during the 2nd trimester to  $5.29 \pm 4.62$  mm during the 3rd trimester, and to  $6.84 \pm 5.24$  mm postpartum. At no time during and after pregnancy we found significant differences ( $p > 0.05$ ) between the pelvic obliquity of the women in the control group ( $4.62 \pm 4.27$  mm) and the pregnant women. We



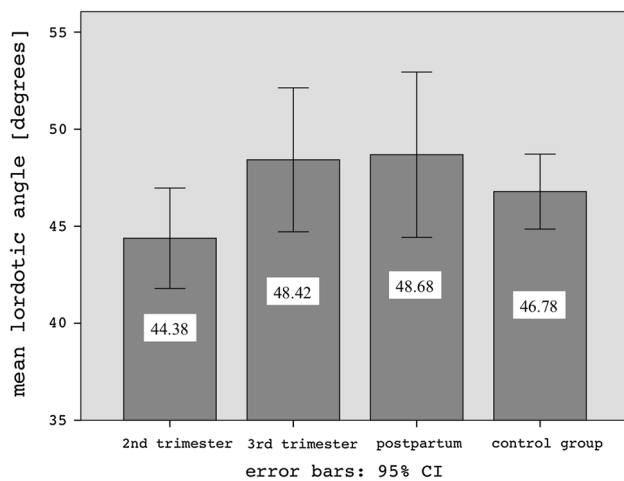
**Fig. 2** The lateral deviation is defined as the deviation of the spinal midline from the line between the spinous process of the 7th cervical vertebra to the midpoint between the two lumbar dimples in the frontal plane. Between the 2nd trimester measurements and the postpartum measurements we found a significant decrease in lateral deviation ( $p = 0.031$ )

**Table 3** The results for the spinal parameters: trunk imbalance, trunk inclination and surface rotation during the 2nd trimester, 3rd trimester and postpartum, as well as for the control group are shown in this table

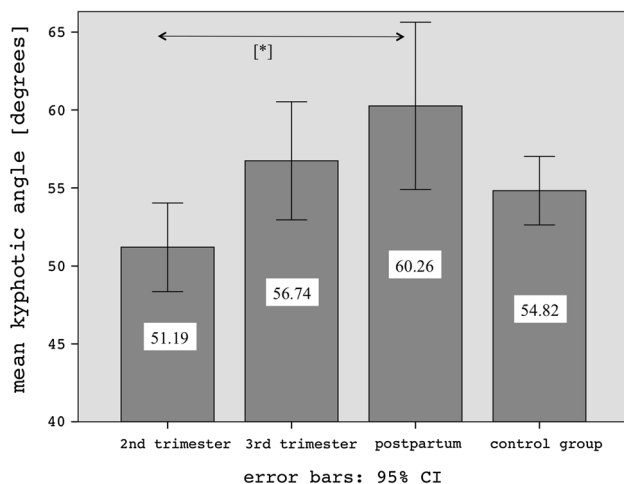
Parameter	Results (SD)	Range	<i>p</i> value
<b>Trunk imbalance (°)</b>			
2nd trimester	8.1 (7.01)	26	–
3rd trimester	7.29 (5.39)	20	1.00
Postpartum	7.95 (5.84)	21	1.00
Control group	7.71 (5.59)	25	1.00
<b>Trunk inclination (°)</b>			
2nd trimester	2.71 (2.31)	8	–
3rd trimester	2.13 (2.56)	10	1.00
Postpartum	2.37 (3.29)	9	1.00
Control group	2.63 (2.54)	12	1.00
<b>Surface rotation (°)</b>			
2nd trimester	4.24 (2.43)	10	–
3rd trimester	3.79 (1.42)	6	1.00
Postpartum	3.11 (0.99)	3	1.00
Control group	3.75 (1.45)	8	0.134

also did not measure any significant differences ( $p = 1.0$ ) for the pelvic torsion and pelvic inclination between the groups (Table 2).

As shown in Fig. 2 the lateral deviation of the spine did not decrease significantly ( $p = 0.05$ ) during pregnancy from  $6.71 \pm 5.25$  mm (2nd trimester) to  $4.61 \pm 2.14$  mm (3rd trimester). However, there was a significant decrease



**Fig. 3** The lordotic angle is defined as the angle between the surface tangents on points 12th thoracic vertebra and the midpoint between the lumbar dimples. In our study we measured a not significant increase ( $p = 0.709$ ) in lumbar lordosis during the pregnancy



**Fig. 4** The kyphotic angle is defined as the angle between the surface tangents on points 7th cervical vertebra and the calculated spinous process of the 12th thoracic vertebrae. The results of our study showed a significant increase of the kyphotic angle ( $p = 0.043$ ) during pregnancy

( $p = 0.031$ ) in the lateral deviation of the spine between the 2nd trimester values and the postpartum values ( $4.1 \pm 1.94$  mm) (Fig. 2). No significant differences ( $p > 0.05$ ) for this parameter were found between the control group and the pregnant women. For the surface rotation we did not measure any significant differences ( $p > 0.05$ ) during pregnancy and postpartum, as well as between the control group and the pregnant women (Table 3). The results for the parameters trunk imbalance and trunk inclination are shown in Table 3. For both parameters we did not measure any significant ( $p > 0.05$ ) between the groups and during and after pregnancy.

The sagittal spinal parameters of interest in this study are the lordotic and kyphotic angle. The lordotic angle in the pregnant women did not significantly increase ( $p = 0.709$ ) during pregnancy (Fig. 3). During the 2nd trimester the mean lordotic angle was  $44.38 \pm 5.69^\circ$  and during the 3rd trimester  $48.42 \pm 11.28^\circ$  (Fig. 3). Postpartum the mean lordotic angle did not change significantly ( $p = 0.917$ ) with a mean value of  $48.68 \pm 8.84^\circ$ . No significant differences ( $p > 0.05$ ) were found for the lordotic angle between the non-pregnant and pregnant women ( $46.78 \pm 9.43^\circ$ ). The kyphotic angle did increase significantly ( $p = 0.043$ ) between the 2nd trimester measurements and the postpartum measurements (Fig. 4). During the 2nd trimester we measured a mean kyphotic angle of  $51.19 \pm 6.23^\circ$  and postpartum of  $60.26 \pm 11.14^\circ$  (Fig. 4). No significant differences for this sagittal spine parameter were found between the control group and the pregnant women ( $p > 0.05$ ).

The correlation between changes of the spinal posture and pelvic position during pregnancy and the clinical outcome and pain levels were analysed using linear regression. As expected we found a significant correlation between the VAS and the Roland-Morris disability score ( $r$  0.395;  $p < 0.001$ ) and the ODQ ( $r$  0.576;  $p < 0.001$ ). Statistically significant negative correlations between the magnitude of the trunk inclination and either the VAS ( $r$   $-0.236$ ;  $p = 0.039$ ), the Roland-Morris disability score ( $r$   $-0.331$ ;  $p = 0.003$ ) or the ODQ ( $r$   $-0.493$ ;  $p < 0.001$ ) were found. We also found a significantly negative correlation between the magnitude of the lateral deviation of the spine and ODQ ( $r$   $-0.243$ ;  $p = 0.034$ ). However, no other statistically significant ( $p > 0.05$ ) correlations were found between the spinal and pelvic parameters.

## Discussion

The results of this first pilot study show that rasterstereography can be used to three-dimensionally measure the spinal posture and pelvic position and their respective changes during pregnancy without exposing the pregnant women to any harmful radiation. Rasterstereography was initially developed to reduce the number of X-rays needed in patients with scoliosis. During pregnancy the subcutaneous fatty tissue and the abdominal circumference increase, which may influence the accuracy of rasterstereography. However, multiple studies have shown a strong test–retest reliability as well as inter- and intrarater reliability of this technique [6, 7], even in subjects with high BMIs [8]. Studies by Hackenberg et al. [9] and Goh et al. [10] demonstrated a strong correlation between rasterstereographic measurements and radiographs for the frontal deviation of the spine. Crawford et al. [11] and Goh et al.

[10] also showed a high correlation between rasterstereographically and radiologically measured kyphotic and lordotic angles in their studies.

The aetiology of back pain during and post pregnancy is still not completely understood. It is believed that mechanical factors, such as an increase in abdominal and sagittal diameter during pregnancy, are in part responsible for the high incidence of low back pain by shifting the body center of gravity anteriorly, which then leads to an increase in load and stress on the lower back [3]. Increased hormone levels, e.g. of oestrogen or relaxin, and their destabilising effects on the musculoskeletal apparatus are also considered as risk factors for low back pain [12, 13].

The main finding of our study is a significant ( $p = 0.043$ ) increase in thoracic kyphosis from  $51.19^\circ \pm 6.23^\circ$  during the 2nd trimester to  $60.26^\circ \pm 11.14^\circ$  postpartum. We also found a tendency to increasing lumbar lordosis over the course of the pregnancy in our cohort of women from  $44.4^\circ \pm 5.69^\circ$  during the 2nd trimester to  $48.68^\circ \pm 8.84^\circ$  at the postpartum measurements. In 1998 Franklin and Conner-Kerr [14] showed in 12 women that the lumbar lordosis and the pelvic tilt increases with pregnancy. Further studies confirmed these findings, indicating that an increase in lumbar lordosis could be the result of the changing female anatomy [15–17]. In contrast to these studies, Östgaard et al. [18] found no significant changes of the lumbar lordosis during pregnancy. Whitcome et al. in 19 women and Borg-Stein et al. in their review even described a decrease in lumbar lordosis during pregnancy, which could in part be explained by the different measuring techniques used in these studies [17, 19]. It is interesting that there are only a few studies that have measured changes of the thoracic kyphosis during pregnancy. Dumas et al. [20] suggested that there are changes of the thoracic kyphosis early during pregnancy, even though they were not able to detect such changes using lateral photographs [20]. However, our results show a significant ( $p < 0.05$ ) increase in thoracic kyphosis. Another spinal parameter that changed significantly ( $p = 0.031$ ) during pregnancy in our study is the lateral deviation. This could indicate that women compensate for the increasing weight load during pregnancy with a more upright position of the spine, which is reflected by a decrease in lateral deviation. An explanation for the trend to a decrease in lateral deviation between the 3rd trimester and postpartum could be that it may take more than 3 months postpartum for the women's body and spinal posture to return to pre-pregnancy values. The increase in weight and abdominal circumference during pregnancy, may also lead to an increase in back muscle strength and muscle mass. Such an increase might be necessary to keep the women's body in an upright position during pregnancy. After the delivery women experience a sudden decrease in

abdominal circumference and body weight; however their musculoskeletal system, in particular their back and abdominal muscles, is still used to the increased weight during pregnancy so that this may result in a further slight decrease in the lateral deviation of the spine and thereby in a more upright position.

In future studies it would also be of interest to investigate the association between lumbar back pain and changes in the barycenter during pregnancy. The use of a force plate in addition to rasterstereography could then help to further dissect the association between trunk inclination, changes in the barycenter and weight gain during pregnancy.

Although Franklin and Conner-Kerr [14] found that changes of the pelvic position occur during pregnancy, we did not measure any significant changes of the pelvic position in our study, which is maybe caused by our relatively small sample size.

In our study we found a non-significant ( $p = 1.18$ ) increase in the pain level of the pregnant women on the VAS score, but we measured a significant increase in the ODQ and Roland Morris disability index with pregnancy. Recent studies have found a significant correlation between larger kyphosis or lordosis and an increased frequency of low back pain in healthy subjects [21–23]. In our study of 13 pregnant women we were not able to show a significant correlation between the clinical scores and changes of the kyphosis and lordosis angle.

In contrast to our findings, Keskin et al. [24] found in their study mean values for the VAS between 6 and 7 and for the Roland Morris Index between 12 and 15 during pregnancy. Sjødahl et al. [25] measured values between 15 and 16 for the ODQ in their study, which is comparable to our findings, with an increase from 5.54 during the 2nd trimester to 16.41 during the 3rd trimester. The results of our study seem to indicate that these pregnant women were not as much affected by back pain during pregnancy as the women in other studies.

A limitation of this present study is the relatively small sample size of 13 women that were measured during and after pregnancy. However, in the present literature it is difficult to find studies with higher numbers of pregnant women measured. The main goal of this pilot study was to evaluate the applicability of spine and surface topography in the measurement of posture changes in pregnant women, which was successfully demonstrated.

## Conclusion

We found a significant increase in thoracic kyphosis and decrease in lateral deviation. The results of our study show that pregnancy has an effect on the spinal posture of pregnant women, and that rasterstereography can be used

to measure these changes three-dimensionally without any harmful radiation. In future larger cross-sectional or longitudinal studies this technique could allow to further evaluate the relationship between posture and low back pain during pregnancy.

**Acknowledgments** We would like to thank all women for participating in this study. We also thank the team of the Department of Obstetrics and Gynaecology of the University Hospital Duesseldorf for their support. No funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

**Conflict of interest** None.

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