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Original Article

Impact of pregnancy on back pain and body posture in women

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Abstract. [Purpose] The purpose of this single-center investigation was to study the impact of pregnancy on back pain and body posture. [Subjects] The subjects were 26 pregnant females. [Methods] Data were generated with a spine scanner (Diers® formetric 4D), trunk strength measurement (Diers® myoline), a numeric pain scale (0 to 10), and a biomechanical model. Parameters were compared during each trimester. [Results] The alteration in pain level at rest and lumbar lordosis angle in the females revealed a statistical trend during pregnancy. Spearman's test showed positive correlations between body weight and trunk inclination during the second trimester, and between body weight and the kyphosis angle in the third trimester. The trunk inclination and the kyphosis angle revealed a negative correlation in the third trimester. Based on our analysis, the highest moments and muscle strength must be expended in the third trimester. The actual muscle strength is greatest in the second trimester. [Conclusion] Pain at rest must be given greater attention in pregnant females, and their increasing lumbar kyphosis must be counteracted. Exercising the deep segmental muscles may serve as a preventive measure.

Key words: Pregnancy, Pain, Body posture

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INTRODUCTION

Many females experience back pain during pregnancy. The causes are manifold: their weight increase on the one hand, and the specific physiology of the spine on the other. During pregnancy, a woman's body weight increases by 15 to 25 percent; this signifies a greater burden on the tendons, ligaments, and joints[1)]. Furthermore, relaxin and estrogen loosen the ligaments and thus create an additional predisposition for injury[2, 3)]. The enlarged uterus and the increase in breast volume shift the body's center of gravity to the front. The pelvis is tilted simultaneously, and lumbar lordosis increases[1)].

In the course of evolution, the female body has reacted to the special circumstances of pregnancy by adapting the structures of the spine. Thus, the lumbar spine is more hyperlordotic in females than it is in males. Furthermore, three of the lower lumbar vertebrae are interlocked in females (as opposed to two in males), and therefore are stronger than those in males. The distance between the vertebrae is also greater in females. Thus, shear forces between the vertebrae are reduced, and they are able to move further backward to balance the weight increase in the frontal aspect without damaging the spine[4)].

The aim of the present study was to determine the time of onset of back pain during pregnancy, and the accompanying changes in posture with respect to the kyphosis angle, the lordosis angle, and trunk inclination. Data concerning posture analysis were processed with the aid of a biomechanical model developed by the authors, in order to draw conclusions about bending moments and forces at the spine. Simultaneously, we determind the actual trunk strength required in the individual trimesters of pregnancy. The following questions were addressed: Does a significant association exist between the infant's

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weight, the mother's weight increase during pregnancy, and a specific alteration of the spine? How does the alteration of the spine influence back pain in pregnant females? Can the forces determined in this setting provide an explanation?

SUBJECTS AND METHODS

Twenty-six pregnant females with an average age of 30.7 ± 4.9 years, recruited from the Greater Rostock area of Germany, participated in this study for its entire duration. Their height ranged from 1.58 meters to 1.88 meters. Their mean body weight in the second trimester was 67.8 ± 8.0 kg, and it increase to 76.6 ± 7.7 kg in the third trimester. Their mean weight postpartum was 66.5 ± 6.1 kg (Table 1).

The study was designed as a single-center investigation of a treatment group. Pregnant females were recruited from the University Clinic of Obstetrics and Gynecology at Klinikum Südstadt Rostock. The period of investigation was September 2011 to October 2013. The females were observed during their pregnancy and underwent clinical tests as detailed below. Immediately after the investigation period, the females were divided into the following trimesters: first trimester (1–12 weeks), second trimester (13–28 weeks), third trimester (29–40 weeks), and the postpartum period (after delivery). The first trimester is mentioned here for the sake of completeness, but it was not taken into account for making any qualitative statements (see the limitations of the study). The inclusion criteria for the clinical investigation were as follows: age above 18 years, medically confirmed pregnancy, and the ability to read and write German. The exclusion criteria were as follows: pre-existing anatomical deformities of the spine, pre-existing spinal retardation, previous surgery in the spine, and relevant neurological deficits.

After a detailed explanation of the purpose of the study, which was the documentation of posture and determination of quality of life, each participant consented in writing to the processing of her anonymized data. The clinical investigation was approved by the ethics committee of the State Chamber of Physicians of Rostock (registration number A 2011 101).

The females' subjective perception of pain during movement and pain at rest were scored on a numeric rating scale (NRS), which consists of 11 ratings from 0 (no pain) to 10 (worst pain imaginable)[5)]. The proband selects a number from this scale.

Video raster stereography (VRS) is a computer-aided screening procedure used to generate a profile of the body surface without radiation[6)]. A grid of parallel lines is projected onto the dorsal surface and is deformed by the surface contours of the body. Based on certain fixed points, the symmetry line of the spinous processes, vertebra prominens, left and right dimples, and sacrum), the device generates a system of coordinates corresponding to the shape of the body (Fig. 1). Using triangulation, mathematical parameters are employed to calculate frontal and sagittal planes and surface rotation automatically. We were interested in the kyphosis angle (KA), the lordosis angle (LA), and trunk inclination (TI). Video raster stereography is a sensitive gauge to monitor changes in, as well as analyze, defective posture[7)].

The biomechanics of the spine have been a subject of research for several years. Some models have provided valuable information about the effective forces and the stabilization of forces. One of these models was created by Bergmark[8)], and it is the basis of the present investigation (Fig. 2). The following symbols and units were used in the study: a (mm), distance from the most anterior disk midpoint to the gravity line; c (mm), distance from the global muscle to the gravity line**;** F (N), power**;** h (mm), lever arm**;** M (Nm), moment**;** x (mm), x-coordinate; and Φ (°), angle.

The following indices were used in the study: G, weight force; max LWK, maximum deflection of the lumbar spine to the ventral aspect; MP, muscle power; N, individual component; and n, running index of the individual planes. Additionally, the following parameters were considered important: trunk length, vertebral body heights, vertebral body mass, intervertebral disks, X-coordinate, weight force, gravitational line, muscle force, and the lever arm: Trunk length was determined based on the perpendicular line connecting the seventh cervical vertebra (C7) and the middle of the lumbar groove (DM) and taken as the y-coordinate. It was measured with VRS. Vertebral body heights were derived from a study by Berry et al[9)]. Vertebral body mass was the percentage distribution of the vertebral body mass from C7 to the first sacral vertebra (S1) is based on the data reported by Duval-Beaupere[10)]. The suggested percentage distributions are reflected in the calculation of actual body masses. Intervertebral disks are especially significant because their actual heights are subject to the circadian rhythm. It has been postulated that a human being is 10 to 20 mm taller in the morning than he/she is in the evening. The reason for this is changes in gravitational force on the spine. Roberts et al. reported a height difference of 8 to 26 mm in young females[11)]. Assuming that the height of the intervertebral disks increases from the cranial to the sacral aspect, we presumed a height difference of 11 to 16 mm. We performed a quasi-linear adjustment of heights for the model. To take the differences in trunk length of the females' into account, a compression ratio expressed in percentage was introduced. In the absence of a compression ratio, we used the original values mentioned by Berry and our presumed values. Compression is calculated by the following formula[9)]: reference height = original height × (1 − compression ratio). The model's trunk length can be adapted to the actual trunk length (VRS) with the aid of the compression ratio. According to Berry, the height of the vertebral body of L5 is 27 mm[9)]. For a pregnant woman with a trunk length of 508 mm, its height is 22.2 mm. This signifies a compression ratio of 17.8 percent. X-coordinate was determined from the lateral VRS images (Fig. 1c). Weight force, that is the weight force acting on each section of a segment, was the product of the mass of the section and the standard acceleration of gravity (9.81 m/s^2). The gravitational line is, on average, located about 1 cm anterior to the midpoint of the lumbar vertebra in the most ventral aspect, which, according to Asmussen, is the L4 lumbar vertebra[12)]. Muscle force (musculus erector spinae) was calculated under the assumption of a global center of gravity for the trunk[8)]. The following equation is important for the

Table 1. Characteristics of the study sample (n = 26)

	$\bar{x}$ ± SD	Min–max
Age (years)	30.7 ± 4.9	23.0–43.0
BMI (kg/m^2), 2nd trimester (n=14)	24.0 ± 3.7	20.0–32.4
BMI (kg/m^2), 3rd trimester (n=19)	26.4 ± 3.6	21.1–34.0
BMI (kg/m^2), postpartum (n=8)	22.7 ± 2.0	20.0–25.7
Parity (n)	0.5 ± 1.0	0–5
Maternal weight gain (kg; n=17)	17.1 ± 4.0	12–25
Infant’s weight at birth (g; n=18)	3,546.4 ± 537.1	1,930–4,490
	n	%
Parity		
Nulliparous	16	61.5
Primiparous	9	34.6
Multiparous	1	3.8
Family structure		
Nuclear	8	30.8
Large	12	46.2
Education		
≤ 12 years	8	30.8
12 years<	12	46.2
Work situation		
Worker	16	61.5
Nonworker	4	15.4
Perception of economic situation		
Inadequate	4	15.4
Adequate	16	61.5
Smoking		
Nonsmoker	16	61.5
Quit smoking in pregnancy	3	11.5
Smoker	1	3.8
Previous low back pain and history of pelvic pain during pregnancy		
Yes	11	42.3
No	9	34.6
Description of low back and pelvic pain		
Burning	6	23.1
Sharp	4	15.4
Blunt	9	34.6
No pain	1	3.8
Timing of most severe low back and pelvic pain		
Morning	2	7.7
Noon	2	7.7
End of the day	10	38.5
Night	2	7.7
All day	3	11.5
No pain	1	3.8

calculation: $M_G = F_G \times h$. The resulting moment must be equal to the moment derived from the muscle strength and the lever arm c (Fig. 2). The corresponding muscle force can be calculated from the above. Furthermore, the following also apply: $M_G = M_{MP}$ and $F_{MP} = M_G / c$.

The lever arm was the horizontal projection of the distance between the center of gravity of the viewed segment and the vertebral body midpoint of the respective segment. The lever arm consisted of several components. The first of these is distance “a” (Fig. 2). The second was the sagittal shift of the midpoint of the vertebral body in the most ventral aspect. The

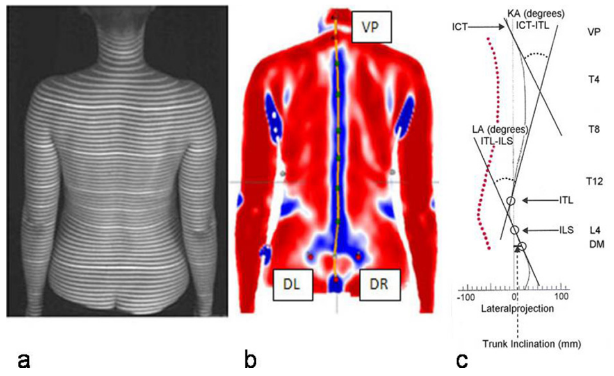

Fig. 1. a) Grid of parallel lines on the dorsal surface. b) Three-dimensional view of the dorsal surface with convex (red) and concave (blue) surface areas, vertebra prominens (VP), dimple left (DL), and dimple right (DR). c) Spine parameters in the lateral view, kyphosis angle (KA), lordosis angle (LA), trunk inclination (TI), cervicothoracic (ICT) inflection point, thoracolumbar (ITL) inflection point, lumbosacral inflection point, dimple middle (DM)

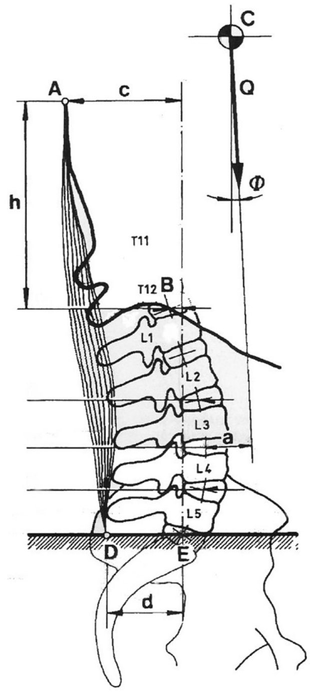

Fig. 2 Geometrical parameters to describe posture and the position of the gravity line. A: Sagittal view of the insertion of the erector spinae muscle, B: T12-L1 disk midpoint, C: The combined center of gravity of upper body weight and the weight that constitutes the outer load (Q), D: Sagittal view of the origin of the global muscle, E: L5-S1 disk midpoint, a: Distance from the most anterior disk midpoint to the gravity line. The coordinates of the erector spinae muscle on the rib cage are expressed by c and h. c = 59 + 21 mm and h = 100 mm. The coordinates of the origin D are expressed as d = 60mm, Φ = trunk inclination (Bergmark)

third was calculated from the x-shift due to trunk inclination (angle change Φ). This was selected in a manner such that the measured point (C7) concurs with the point on the model. The fourth component was the respective averaged x-value of the corresponding segment. The lever arm was calculated by the following formula: $h_n = a + x_{(max.LWK)} + x_{(\Delta\Phi)} - x_n$. The actual trunk strengths of pregnant females in flexion, extension, lateral flexion, and trunk rotation were determined with a Diers® myoline device. The system employs the DMS technique, by which isometrically introduced muscle strengths are registered with a strain gauge. Simultaneously, the software incorporated in the device determines the moments (Nm) and displays them in graphic form. We were primarily interested in absolute maximum strength values.

Data were stored and analyzed using IBM SPSS Statistics, version 19.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were computed for continuous and categorical variables. Statistics included means and standard deviations of continuous variables, frequencies, and relative frequencies of categorical factors.

Friedman's test was used for multiple dependent samples. All p-values resulted from two-sided statistical tests. The level of significance was set to $p < 0.05$. In case values of $p < 0.05$ were achieved in the Friedman test, we additionally performed Wilcoxon tests for pairs of dependent samples. This replaces the pairwise t-test, as the present study population was a small one and the random sample was in part normally distributed and in part not normally distributed. Furthermore, Spearman's correlations were determined between pairs of variables using the rank correlation coefficient.

RESULTS

Back pain in pregnant females was documented separately during movement and at rest. During movement, it was statistically nonsignificant throughout the entire period of pregnancy (Friedman test, $p = 0.717$). In contrast, a change or a trend was noted in pain levels at rest during pregnancy (Friedman test, $p = 0.076$).

Table 2. Force values

	$\overline{x} \pm$ SD	Min–max
Flexion$^{\Delta}$ (N)		
2nd trimester (n=8)	69.2 ± 33.8	24.0–131.0
3rd trimester (n=3)	66.0 ± 30.3	47.0–101.0
Postpartum (n=8)	84.9 ± 45.0	26.0–150.0
Extension$^{\Delta}$ (N)		
2nd trimester (n=8)	93.0 ± 62.3	42.0–242.0
3rd trimester (n=3)	77.7 ± 34.5	38.0–101.0
Postpartum (n=7)	76.4 ± 42.0	33.0–159.0
Trunk rotation on the left side$^{\Delta}$ (N)		
2nd trimester (n=8)	57.6 ± 21.5	31.5–88.0
3rd trimester (n=6)	27.2 ± 6.8	19.0–36.0
Postpartum (n=7)	51.3 ± 15.0	41.0–84.0
Trunk rotation on the right side$^{\Delta}$ (N)		
2nd trimester (n=8)	66.8 ± 34.9	38.0–130.0
3rd trimester (n=6)	37.2 ± 23.2	17.0–81.0
Postpartum (n=7)	47.3 ± 15.4	32.0–79.0
Lateral flexion on the left side$^{\Delta}$ (N)		
2nd trimester (n=7)	122.5 ± 40.2	76.0–190.0
3rd trimester (n=7)	97.3 ± 72.0	17.0–226.0
Postpartum (n=7)	102.3 ± 43.3	52.0–167.0
Lateral flexion on the right side$^{\Delta}$ (N)		
2nd trimester (n=8)	125.1 ± 54.1	59.0–199.0
3rd trimester (n=7)	84.9 ± 47.9	47.0–182.0
Postpartum (n=7)	100.6 ± 37.5	76.0–162.0
Torque segmental* (Nm)		
2nd trimester (n=10)	15.1 ± 2.3	9.6–17.7
3rd trimester (n=17)	16.1 ± 2.1	12.2–19.4
Postpartum (n=7)	13.9 ± 1.4	12.7–16.2
Torque global* (Nm)		
2nd trimester (n=10)	10.4 ± 1.8	7.7–13.0
3rd trimester (n=17)	11.0 ± 3.9	5.5–19.2
Postpartum (n=7)	8.0 ± 2.3	5.2–10.5
Muscle strength, erector spinae muscle* (N)		
2nd trimester (n=10)	130.3 ± 22.6	96.5–163.0
3rd trimester (n=17)	137.2 ± 48.7	69.3–240.2
Postpartum (n=7)	99.5 ± 28.7	65.4–131.0

$^{\Delta}$Diers® myoline device; *Calculations based on the biomechanical model

Owing to the specific physiology of the spine during pregnancy, posture parameters cannot be standardized for this period of time. Comparative studies, to our knowledge, do not exist. In the present investigation, the females had a kyphosis angle of 51.5° ± 5.5° in the second trimester, and the angle became even more marked in the subsequent course of pregnancy. In the third trimester, the kyphosis angle was 53.5° ± 5.8°. Postpartum it remained at almost this level. No significant difference in the kyphosis angle was noted at the three time points of measurement (Friedman test, $p = 0.105$). The same was true of trunk inclination (Friedman test, $p = 0.779$). In contrast, changes in the lordosis angle throughout the observation period showed a statistical trend (Friedman test, $p = 0.057$). Spearman's test revealed a positive correlation between trunk inclination and weight in the second trimester ($\rho = 0.534$, $p = 0.049$), and a negative correlation between trunk inclination and the kyphosis angle in the third trimester ($\rho = -0.520$, $p = 0.023$). Both correlation coefficients were statistically significant. Weight and the kyphosis angle were also significantly correlated in the third trimester ($\rho = 0.479$, $p = 0.038$).

The calculations obtained from the biomechanical model clearly show that the global moment increased a little from the second to the third trimester (10.4 Nm ± 1.8 Nm vs. 11.0 ± 3.9 Nm), but dropped markedly postpartum (Table 2). Therefore, the strength of the musculus erector spinae, which marks the limit of the global moment, increased from the second to the third trimester (130.3 ± 22.6 N vs. 137.2 ± 48.7 N), and also dropped markedly postpartum (Table 2).

Comparison of the theoretically determined global and segmental moment showed that the segmental moment was a little higher than the global moment. During pregnancy, the segmental moment increased initially from the second to the third trimester and then decreased postpartum (Table 2).

The measurements obtained with the Diers® myoline device showed that there was an increase in strength in flexion, especially after parturition (third trimester 66.0 N ± 30.3 N vs. PP 84.9 N ± 45.0 N). The strength level determined in the second trimester started to fall when the females approached the third trimester (Table 2).

In extension, the pregnant females achieved the greatest strength in the second trimester, which they were unable to achieve in the third trimester and postpartum (second trimester 93.0 N ± 62.3 N, third trimester 77.7 N ± 34.5 N, PP 76.4 N ± 42.0 N).

The strength values in rotation (left/right) revealed that the increase in strength started to fall as pregnancy progressed towards the second trimester and fell markedly as pregnancy progressed towards the third trimester. The strength level then increased postpartum (Table 2). Similar observations were made in lateral flexion (left/right). Overall, the strength level achieved in the second trimester was not achieved postpartum in any of the measured directions; the sole exception was flexion.

DISCUSSION

According to Martins et al., back pain occurs in approximately 80% of pregnant females and is mainly located in the lumbar and sacroiliac region[13]. The causes of back pain are manifold and not fully clarified. The following factors are known to influence it: number of births, preexisting back pain prior to pregnancy, body mass index, weight increase, and muscular dysfunction[14–16]. Parity was no major concern in the present investigation as, 61.5% of the females were nulliparous while a mere 3.8% were multiparous. The estimates concerning back pain during movement and at rest were interesting, as they permit potential conclusions about muscular dysfunction. In the present clinical study, back pain at rest increased markedly from the second to the third trimester, whereas pain during movement remained unchanged. One explanation for this phenomenon could be that, due to hormonal changes, the proprioceptors of tendons, muscles, and ligaments do not respond adequately. Solomonow et al. reported that stimulation of mechanoreceptors in the supraspinal ligament, the zygapophyseal joints, and the intervertebral disks evokes a reflex response in the musculus multifidus[17]. According to Richardson and Hides, contraction of spinal muscles close to joints stiffens their passive structures and thus indirectly improves the ability to perceive movement[18]. Such mechanisms are frequently discussed in chronic back pain and should be taken into account in pregnant females as well[19–21].

Another factor discussed in connection with back pain among pregnant females is age. According to Bühling, age is a major risk factor for low back pain[22]. The females in the present investigation were on average 30.7 ± 4.9 years old, and thus a little older than the average age of 29.2 years for primiparous females as reported by the Federal Statistical Office of Germany. In addition to age, Sjodahl et al. mentioned that the endurance of the trunk muscles influences pain[23].

What measures help to relieve back pain during pregnancy? In an investigation comprising 105 pregnant females aged on average 30.7 ± 4.0 years, Haakstad et al. concluded that a 60-minute fitness program performed twice a week achieves a nonsignificant reduction of back pain and pelvic girdle pain[24]. In a review article, Mazzarino et al. mentioned that the impact of Pilates exercises on the health of pregnant females has not been fully clarified[25]. A review article published by Close et al. indicates that alternative therapies have a rather minor effect on pelvic and back pain in pregnant females[26]. The investigations performed Kolu et al. and Pennick et al., among others, contradict the abovementioned studies[27, 28]. The authors report that physical activity during pregnancy influences the quality of life in women and that acupuncture reduces back pain more markedly than conventional precautionary measures. In a cross-sectional investigation comprising 1279 pregnant females, Nascimento et al. concluded that an active lifestyle is extremely important[29]. However, the ideal type of physical activity is not clear. Walking and water gymnastics are the most common forms of activity, since they have practically no contraindications[29]. In water gymnastics, the hydrostatic pressure of water promotes venous return of blood, which in turn exerts a positive impact on cardiovascular parameters. The simultaneously enhanced renal perfusion causes greater diuresis and natriuresis, which reduces pregnancy-related edema[2]. With regard to the activation of deep segmental muscles and the concomitant reduction of pain, the loss of gravity appears to be rather disadvantageous because these muscles require constant input from the proprioceptors. Therefore, we assume that such activation is best achieved by performing weight-bearing exercises with one's own body weight on an unstable surface (Pezzi ball, sling training). The existing body of data on this subject is still meager; further research is needed on these issues.

The use of raster stereography in pregnant females has been poorly investigated so far. Reference values determined by Schröder et al. for healthy males and females aged 19 to 40 years have been used to study the variance of posture parameters[30]. A kyphosis angle of 48 ± 9° was determined for both genders. The lordosis angle in males (36 ± 7°) was less pronounced than that in females (43 ± 8°). In the present study, pregnant females had a very marked kyphosis angle. The kyphosis angle in pregnant females may differ by more than 3.5° from that of nonpregnant females. The same was true of the lordosis angle. It was most marked in the second trimester (51.1° ± 9.1°) and started to reduce postpartum (48.4° ± 7.9°) (Table 3).

Table 3. Results

	2nd trimester (n = 14)	3rd trimester (n = 19)	Postpartum (n = 8)
Pain			
At rest‡	1.4 ± 2.0	2.6 ± 2.4	1.6 ± 1.8
During movement‡	2.4 ± 2.4	2.7 ± 2.3	2.9 ± 2.9
Posture			
Kyphosis angle#	51.5 ± 5.5	53.5 ± 5.8	54.1 ± 4.6
Lordosis angle#	51.1 ± 9.1	49.4 ± 6.8	48.4 ± 7.9
Trunk inclination*	8.8 ± 16.2	11.8 ± 18.1	15.1 ± 19.9

Data shown as means ± SD. ‡On the NRS from 0 to 10. #In degrees. *In mm.
Friedman's test for multiple dependent samples

Yoo et al. performed raster stereographic measurements in 19 pregnant and 15 nonpregnant females[31)]. In the second and third trimester, they observed increases of 0.83° and 1.02° in the angles of curvature of the thoracic and lumbar spine, respectively. Compared with the control group, a significant increase of 2.71° was noted in the lumbar spine. However, the authors assume that back pain, which is mainly observed in the first and second trimester, cannot be explained by a change in the curvature of the spine. Our calculations obtained from biomechanical models indicate the same result. Assuming that the body has a global center of gravity, the moment remains at a similar level from the second to the third trimester (Table 2). Therefore, the force exerted by the global system of the musculus erector spinae to stabilize the entire system hardly differs in the second and third trimesters. Viewing the segments separately, the distance between the center of gravity and the center of the vertebral body differs at every level. Viewed globally, the mean of the individual segments is not equivalent to the lever arm. Therefore, the total moments are somewhat higher. It is possible that in the individual segments, the deep muscle layers have to expend more energy to maintain a balance between the active moment and the local muscles. As regards the spinal curvature, Okanishi et al. reported that pregnant females tend to develop lumbar kyphosis, which is associated with specific symptoms[32)]. We observed the same result, especially in the period of transition from the second to the third trimester.

To our knowledge, the active moment on the spine of pregnant females has not been investigated so far in a biomechanical model. This aspect also needs further investigation.

Trunk strength in all directions of motion was higher in the second trimester than it was in the third trimester. The reasons for this only be surmised. It is possible that greater production of growth hormones in combination with weight increase, both of which occur in pregnant females, cause the adaptation of muscles[33)]. However, the muscles are able to unfold their strength effectively only when they are directed optimally, and this does not occur until the end of pregnancy. The muscles of the abdominal wall tend to become increasingly dehiscent during pregnancy.

The main limitation of the study is the small sample size, which hindered the use of complex statistical procedures as well as the pronouncement of generalized statements.

Most of all, a sufficient number of pregnant females in the first trimester could not be recruited for the study. A large number of flyers was sent to the offices of gynecologists and midwives in the Greater Rostock area. The reasons for the limited number of females in the first trimester are not clear. It could have been due to poor interest in scientific investigations, anxiety, or "inadequate" financial remuneration, or because the doctors and midwives lacked information about the clinical trial. Thus, the recruitment was largely confined to pregnant females in the second and third trimester. The biomechanical model was also a limitation of the study, specifically the actual distribution, stratification, and insertion of muscles in the individual segments. Furthermore, the height of vertebral bodies and intervertebral disks and distance "a" were taken from the published literature. MRI investigations were available in just a small number of cases. Our conclusions are as follows: Greater attention must be given to improving physical capacity in pregnant females[27, 34, 35)]. Back pain at rest can be alleviated by moderate strength and stabilization exercises[1, 36–38)]. The marked weight increase in the third trimester is closely related to the kyphosis angle in pregnant females. A change in balance strategy should be considered in pregnancy[39)].

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The authors declare that they have no competing interests.

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