ISSN 1413-3555
Rev Bras Fisioter, São Carlos, v. 15, n. 6, p. 445-51, Nov./Dec. 2011

Abdominal muscle electrical activity during labor expulsive stage: a cross-sectional study

Atividade elétrica muscular abdominal durante os esforços expulsivos do parto: um estudo transversal

Belisa D. R. Oliveira[1], Armèle Dornelas de Andrade[2], Andréa Lemos[2], Vitor C. Brito[3], Manuela L. Pedrosa[1], Thayse N. S. Silva[1]

Abstract

Background: During the second stage of labor, the progression of the fetal expulsion depends on many factors related to maternal and fetal parameters, including the voluntary abdominal pushing. **Objectives:** This study aimed to correlate the maternal and fetal parameters that may influence the voluntary maternal pushes during the second stage of labor by using surface electromyography. **Methods:** The electromyographic activity of the rectus abdominis and external oblique muscles were measured during the second stage of labor in 24 Brazilian pregnant women. The diastasis of the rectus abdominis, the body mass index and the uterine fundal height were analyzed as maternal parameters and the fetal weight, cephalic circumference, APGAR scores and arterial pH and CO_2 were analyzed as fetal parameters. The oxytocin usage and the expulsive phase duration were considered. **Results:** A negative correlation between the rectus abdominis diastasis and the rectus abdomini muscle electromyographic parameters was found (*r=-0.407 p=0.04*). No statistically significant correlations were found among the rectus abdominis and external oblique muscles electromyography and the other maternal or fetal parameters, as well as among expulsive phase duration and the oxytocin usage. **Conclusions:** This study suggests that the rectus abdominis diastasis may be an influential parameter in generating voluntary pushes during the second stage of labor, however it cannot be considered the only necessary parameter for a successful labor.

Keywords: physical therapy; natural childbirth; electromyography; second labor stage; rectus abdominis; external oblique.

Resumo

Contextualização: Durante o segundo estágio do parto, a progressão da expulsão fetal depende de vários fatores ligados a parâmetros maternos e fetais, dentre eles, o esforço abdominal voluntário. **Objetivos:** Correlacionar os parâmetros maternos e fetais que podem influenciar os esforços voluntários durante a fase do segundo estágio do parto por meio da eletromiografia de superfície. **Métodos:** As atividades eletromiográficas dos músculos retoabdominal e oblíquo externo foram medidas durante o segundo estágio do parto em 24 gestantes. A diástase do músculo retoabdominal, o índice de massa corpórea e a altura de fundo de útero foram analisados como parâmetros maternos, e o peso fetal, o perímetro cefálico, os índices de Apgar e o pH e pCO_2 arterial foram analisados como parâmetros fetais. O uso de ocitocina e o tempo do período expulsivo foram considerados. **Resultados:** Encontrou-se uma correlação negativa entre a diástase umbilical e os parâmetros eletromiográficos do músculo retoabdominal (p=0,04; r=-0,407). Não se encontrou correlação significativa entre a eletromiografia dos músculos retoabdominal e oblíquo externo e os demais parâmetros maternos e fetais, bem como entre o tempo do período expulsivo e o uso da ocitocina. **Conclusões:** O presente estudo sugere que a diástase umbilical pode ser um parâmetro influente na geração de esforços voluntários durante o período expulsivo do parto, porém não deve ser considerada de forma isolada para o sucesso do andamento do trabalho de parto.

Palavras-chave: fisioterapia; parto normal; eletromiografia; segundo estágio; retoabdominal; oblíquo externo.

Received: 01/28/2011 – **Revised:** 06/16/2011 – **Accepted:** 07/16/2011

[1] Physical Therapy Department, Faculdade Integrada do Recife (FIR), Recife, PE, Brazil
[2] Physical Therapy Department, Universidade Federal de Pernambuco (UFPE), Recife, PE, Brazil
[3] Department of Animal Morphology and Physiology, Universidade Federal Rural de Pernambuco (UFRPE), Recife, PE, Brazil
Correspondence to: Belisa Duarte Ribeiro de Oliveira, Rua Marquês do Paraná, 160 - 1202, Espinheiro, CEP 52021-050, Recife, PE, Brazil, e-mail: belisaduarte@yahoo.com.br

Introduction

The progression of the fetus through the birth canal depends on the uterine contractions as well as on the voluntary abdominal contraction. However, just one study evaluated the abdominal musculature action in the normal labor[1].

Pregnant women are encouraged to use the abdominal pushing along with uterine contractions, in order to reduce the duration of the expulsive stage of labor. This stage, generally defined as active pushing or directed pushing occurs by the abdominal muscles contraction together with the diaphragm during a strong air exhalation with the glottis closed[2]. Similar to the defecation, the abdominal musculature function and its integrality during the labor process are not completely understood[3].

Some authors[4] described the maternal anatomy (the maternal pelvis bone formation) as a factor that influences the process of normal labor. In the obstetric practice, however, this parameter does not predict the success of a normal delivery[5]. On the other hand, other authors suggest that the rupture of the amniotic sac increases the pressure on the uterus that may contribute to the reduction of the second stage duration[6-8]. Another factor that constitutes the maternal anatomy refers to the flexibility of the pelvic floor musculature. These muscles contractions help the rotation and the flexion of the fetus head in the passage through the birth canal[9].

Some authors[2,4,9] state that the fetus has an active role on labor and some of its characteristics like weight, cephalic circumference and the presentation inside mother's pelvis may alter the physiological course of the expulsive phase, such as the duration of the second stage. However, the maternal and fetal variables that may affect abdominal voluntary contraction during labor are not clear in the literature.

This study aims through the electromyography surface to verify which maternal and fetal parameters can influence the voluntary abdominal pushing during the second stage and how these contractions can influence some parameters of labor.

Table 1. Maternal Characteristics related to age, number of gestations, body mass index (BMI), gestational age (GA), uterus fundus height (UFH), supra-umbilical diastasis (SUD), umbilical diastasis (UD) and infra-umbilical diastasis (IUD).

	Mean±SD
Age (years)	24.4±5.01
Number of gestations	1.8±1.36
BMI (kg/m^2)	26.1±1.99
GA (weeks)	39.4±0.97
UFH (cm)	33.2±3.31
SUD (cm)	6.1±1.44
UD (cm)	5.6±1.61
IUD (cm)	4.0±1.56

Methods

Sample

Participants were recruited sequentially and by convenience and included a total of 24 pregnant women in the second stage of labor. This study was previously approved by the Ethics of Research with Human Subjects Committee of the Instituto de Medicina Integral Professor Fernando Figueira, Recife, PE, Brazil (number CAAE: 0162.0.099.000-07). Pregnant women that wanted to participate were informed about the study objectives and procedures and then they signed the consent form. The maternal, fetal and birth characteristics are listed on Table 1. Pregnant women between the 37th and 40th gestational week, confirmed by the date of the last menstruation or by an ultrasonography during the 1st trimester; with longitudinal fetal presentation during labor, aged from 18 to 35 years and Body Mass Index (BMI) adequate to their gestational age (i.e. from 18.5 to 29 Kg/m^2) were included. We excluded high-risk pregnant women as well as women with a BMI of 29 Kg/m^2 or more. We did not considered fetal data from children with fetal distress, such as the ones suffering from umbilical cord compressions or meconium, for example[10,11].

Maternal data

Rectus Abdominis Muscle Diastasis (RAMD)

The RAMD data was obtained when the patient was on the first stage of labor, by using a digital paquimeter (JOMARCA®) with 0.02 mm accuracy. The measurement was performed passively on three levels, starting from the umbilical scar and measured 4.5 cm above supra-umbilical diastasis (SUD), 4.5 cm below infra-umbilical diastasis (IUD) and on the umbilical scar level umbilical diastasis (UD), as suggested by Hsia and Jones[12]. During the measurements, the pregnant was positioned on supine position, with the hips flexed at 90°, the knees flexed at 120° and the feet rested on the plinth. Women were asked to flex the torso with the arms stretched out in a way that the spines of the scapula were lifted from the bed, until the moment that the examiner could find, by palpation the RAMD and mark it with a demographic pencil. After the pregnant woman returned to the resting position, the digital paquimeter was then placed perpendicularly to the torso in order to perform the measurement (Figure 1).

Electromyography measurement protocol

In the beginning of the second stage, when the pregnant had 10 cm cervical dilatation, the electromyographic signal for the abdominal muscle activity was obtained. The surface

electrodes were positioned on a rectus abdominis muscle bundle, 5 cm above and 3 cm to the sides of the umbilical scar, following Vera-Garcia, Grenier and McGill[13] reccomendations. In those cases that the diastasis was higher than 3 cm to the sides of the umbilical scar, the medial edge of the muscle was taken as reference position to place the electrode. To obtain the external oblique muscle activity data the electrode was placed on the 8th rib, in the direction of the muscular fibers[14] and a reference electrode at the wrist of each patient was used to eliminate external interference (30 mm x 45 mm x 1 mm) (Figure 2). In order to normalize the electromyography signal, the patient was asked to relax for 10 seconds and the electromyography data related to this period were stored in a computer software (DATAQ® for windows).

Later on, the electromyography signals were captured from the moment that the patient started the spontaneous expulsive efforts in second phase of labor. Those signals were captured for 15 minutes, being the strongest abdominal push signal captured during 5 seconds in each contraction used for the data analysis. The electrodes were removed from the patient's abdomen and discarded immediately after 15 minutes of signal capturing. Labor process data, like the expulsive period duration and the usage of oxytocin were considered.

In order to extract the electromyographic measurements an analog-to-digital converter module was used, using 4000 Hz frequency, 1000 times total internal gain, common mode rejection ratio of >120Db, a 20 Hz high-pass filter and a 500 Hz low-pass filter. Two cardiology-type surface electrodes made of silver (Ag) and silver chloride (AgCl) were used – each of them with 4.5 cm in length and the distance between their components was 2 cm. The software Aqdados® was used to analyze the signals and the Root Mean Square (RMS) of each contraction was used as a parameter to measure the activity level of electromyography signal.

Measurements from the Uterus fundus height (UFH), Gestational Age (GA) and Body Mass Index (BMI) were taken from medical records.

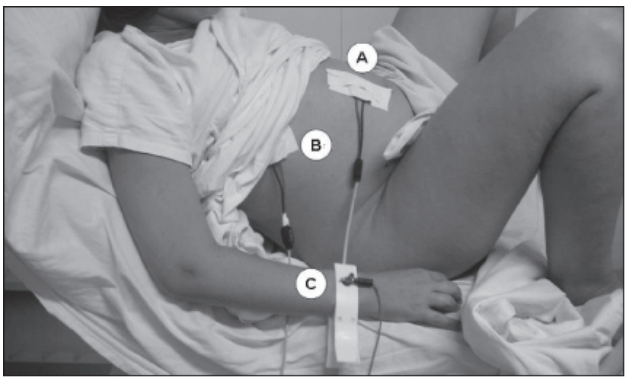
Neonatal data

Arterial gasometry

To collect the arterial blood from the umbilical vein, a 10 cm segment of the umbilical cord was clamped and isolated for further analysis. A previously heparinized 1ml seringe was used to collect a blood sample of 1 ml from the umbilical vein, being this sample immediately analyzed in a digital gasometer.

A) The pregnant flexing the torso with the arms stretched out in a way that the spines of the scapula went out of the bed; B) Starting from the umbilical scar and measuring 4.5 cm above (SUD), 4.5 cm below (IUD) and on the umbilical scar level (UD), it was used a digital paquimeter.

Figure 1. Rectus abdominis muscle diastasis measurement.



A) Rectus abdomini muscle - 5 cm above and 3 cm to the sides of the umbilical scar; B) External oblique muscle - On the 8th rib, in the direction of the muscular fibers; C) Reference electrode.

Figure 2. Electrodes position.

APGAR index, Cephalic circumference and newborn weight

The data referring to the APGAR from the first and the fifth minutes, cephalic circumference and birth weight were acquired from the hospital medical records.

Labor data

Labor parameters like expulsive period duration and oxytocin usage by the pregnant women were collected.

Statistical analysis

All the tests were applied with a significance level of 95% ($p<0.05$). To test the association of the dependent and independent variables we used the Spearman's correlation coefficient. In order to compare the duration of second stage of labor Mann-Whitney test was used. The SPSS 13.0 for Windows and the Excel 2003 software were used for all analysis.

Results

The mean age of the sample in this study was 24.4 (SD 5.01) years and the mean gestational age was 39.4 (SD 0.97) weeks (Table 1). The mean second stage of labor duration of the studied population was 41.7 (SD 32.26) minutes. Duration of the second stage of labor was similar in multiparae and nuliparae (43.69; SD=27.58 min for the nuliparae and 37.75 SD=42 min for the multiparae) (p=0.284).

No statistically significant correlation was found between the electromyographic parameters of the rectus abdominis (RA) and external oblique (EO) muscles and the most of maternal parameters – BMI (RA: p=0.063; r=0.094/ EO: p=0.757; r=-0.067); uterus fundus height (RA: p=0.787; r=-0.058/ EO: p=0.353; r=0.198), supra umbilical diastasis (RA: p=0.124; r=-0.323/ EO: p=0.074; r=0.371), umbilical diastasis (EO: p=0.612 ; r=0.109) and infra-umbilical diastasis (RA: p=0.082; r=-0.362/ EO: p=0.227; r=0.256), except for the negative correlation found between the electromyographic activity of the rectus abdominis muscle and the umbilical diastasis (p=0.04; r=-0.407) - Figure 3.

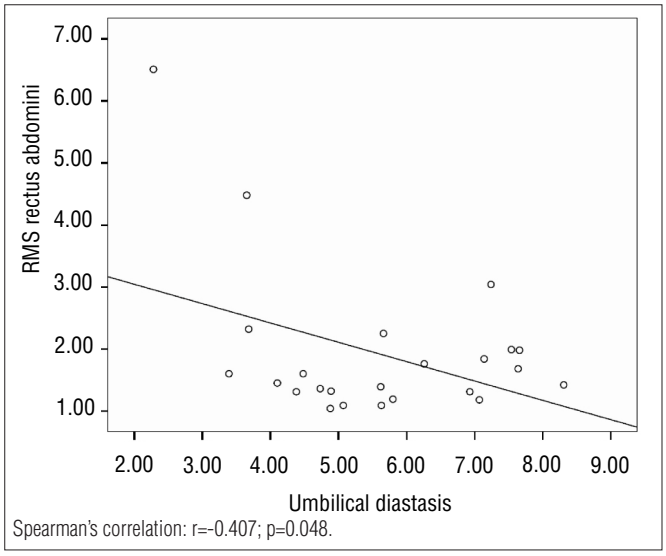


Figure 3. Correlation between the rectus abdomini electromyographic activity (RMS) and umbilical diastasis.

The other fetal parameters were also not correlated with the electromyographic data of both muscles - fetal weight (RA: p=0.059; r=-0.390/ EO: p=0.978; r=0.006); one-minute APGAR score (RA: p=0.808; r=-0.052/ EO: p=0.923; r=0.021); five-minute APGAR score (RA: p=0.165; r=0.263/ EO: p=0.549; r=-0.129); arterial pH (RA: p=0.869; r=-0.035/ EO: p=0.487; r=-0.149) and arterial pCO^2 (RA: p=0.675; r=-0.09/ EO: p=0.366; r=-0.193). No correlation was found between the duration of second stage and the electromyographic activity of both muscles (RA: p=0.989; r=-0.003/ EO: p=0.740; r=-0.072).

A significant correlation was also found between the supra-umbilical diastasis and the fetal cephalic circumference (p=0.036; r=0.431), although this parameter was not associated with electromyographic parameters of the rectus abdominis and external oblique muscles (RA: p=0.07, r=-0.37; EO: p=0.34; r=0.20). The use of oxytocine was not associated with electromyography of the studied musculature (RA: p=0.815; EO: p=0.640).

Discussion

The uniqueness of the importance of this study is that the umbilical diastasis may interfere in the maternal voluntary pushing, and, to date, its potential impact has not been well studied. This is the first study that has considered the relationship between the abdominal muscle electromyographic activity and the abdominal diastasis. The abdominal muscle is an important factor to the increase of the intra-abdominal pressure during the second stage of labor. In clinical practice, pregnant women are encouraged to use these muscles to help fetal expulsion[4].

Physiological functions in which the abdominal pressure increases (such as defecation or delivery), the action of these muscles is related to reflexes that occur due to the stretching of specific muscle receptors. Located in the pelvic floor, these receptors send afferent impulses through the pelvic nerve to the medulla when triggered, stimulating motor neurons that are responsible for the abdominal muscles contraction[3]. Although being triggered by a reflex, the maternal voluntary pushing

efforts during the second stage of labor are an important factor to predict the success of labor[15].

A pilot study about surface electromyography of the abdominal muscles demonstrated that the transmission of the intrauterine pressure through the birth canal, and the recruiting the abdominal musculature with the voluntary pushes during the second stage of labor are essential to the fetal mobility through the uterus[1]. It was observed an increase of 62% in the intrauterine pressure in pregnant women that had used voluntary efforts during the spontaneous uterine contractions when compared to those who did not performed those pushes. However, other factors that are beyond maternal desire and medical care may influence the effectiveness of pushing and be strongly related to the optimization of expulsive efforts[2].

Some factors may contribute to the pushing efficiency, like fetus weight, the absence of augmentations, BMI and the myometrium thickness. Studies have shown that the myometrium thickness was the factor that most contributed for the pushing efficiency. This thickness specifically around 6 mm eases the transfer of the abdominal wall pressure strength to the uterine wall, helping the fetal expulsion[2].

Although BMI has been suggested as an influencing factor in the labor process, little is known about the real influence on the efficiency of the pushing. BMI may be linked to this relationship, since the fat excess inside the abdominal wall makes the transference of force from the abdomen to the uterus difficult, which may be associated with high oxytocin index in obese mothers[16,17]. In our study, it was not possible to detect a correlation between BMI and pushing efficiency, because the sample had only pregnant women with normal BMI as an inclusion criterion.

Besides those previously given factors, there are authors[18,19] who believe that imbalance in the abdominal wall musculature (external and internal oblique, transverse abdominis and rectus abdominis) influence its functions, hampering the increase of the intra-abdominal pressure, as well as impairing the generation of effective pushing on the second stage of labor.

During the third trimester of gestation the fetus size along with a larger abdominal wall distension of the pregnant woman promote a biomechanical disadvantage to the abdominal muscles, giving it relatively lower contraction power when compared to non-pregnant woman. This may interfere in other abdominal wall functions, impairing its strength generation capacity[20]. In this phase of the gestation the rectus abdominis muscle line of action suffers a modification in its insertion angle, thus altering this line of action.

The uterus fundus height (UFH) may be used as a parameter to evaluate the abdominal wall distention, since it is a measurement that starts on the pubic symphysis ending up on the uterine fundus[21]. During pregnancy there is an increase of about 115% in the rectus abdominis musculature length at 38 weeks[18]. Based on this length tension relationship, it is known that an overload on the muscle fiber is able to interfere in the capacity of producing normal tension. According to our findings, however, there was no correlation between UFH and the electromyographic activity for the rectus abdominis muscle. Even being overloaded by a large distention the muscle is highly adaptable and sarcomeres are acquired according to the muscle length. Studies in animals show that sarcomeres are added to the muscle fibers when they are stretched for more than three weeks, thus increasing its strength. There are reports of an increase in the muscular length in humans when the muscles are progressively stretched[22]. One can therefore infer that the absence of correlations between the electromyography data and the UFH is due to prolonged and progressive stretching that the abdominal musculature undergoes during pregnancy under hormonal as well as due to mechanic influences.

The biomechanical changes in the abdominal muscles that occur during gestation, including the rectus abdominis muscle diastasis, probably cannot affect the muscle activity by themselves. Since the muscular adaptations are not isolated, it is possible that the entire muscle group torque generation capacity is already compromised. In our study a negative correlation between the UD and the electromyography activity of the rectus abdominis muscle was observed, which may indicate a compromise in the strength generation capacity of this muscle during excessive effort. The first investigation about the RAMD began in 1988[18] when a study investigated whether the RAMD influence the expulsive phase of labor. The anterior abdominal wall trauma increases the difficulty to increase the intra-abdominal pressure, which is necessary to the fetus expulsion, decreasing the expulsive efforts during the second stage of labor. With a large diastasis during expulsive period, the increase of intra abdominal pressure would cause the ejection of the uterus ahead, through the space between the rectus abdominis muscle bundles, instead of expelling the fetus through the birth canal, what clearly is a biomechanical disadvantage as it alters the longitudinal axis between the fetus and the pelvis, impairing the voluntary efforts' optimization[19].

An important question would be how to identify the cut-off values considered pathological for a rectus abdominis muscle diastasis. The literature[12,22] is not conclusive about the possible physiopathologic repercussions of this diastasis. In fact, there is no actual scientific evidence to point out the exact numerical value of a pathological diastasis and its biomechanical repercussions. The only parameters described in literature are the criteria established in a study[23], which defined a RAMD of 3 cm as pathological, but without any further biomechanical basis.

There was no correlation between the infra-umbilical diastasis and the electromyographic findings in this study. As for the morphologic and anatomic characteristics of the abdominal region, the rectus abdominis tendinous band, known as linea alba, is stronger below the umbilical scar. In this region the aponeurosis from the four abdominal wall muscles cross right in front of the rectus abdominis muscle. Both sides of this muscle resemble a "V" when close to their insertion in the pubis, along with the other muscles, strengthening this area and decreasing its distention[24].

Studies about the electromiographyc activity of abdominal muscles in pregnant, suggest that during pregnancy the maternal organism have compensatory mechanisms that impaired physiologic functions, even with important biomechanical alterations. This fact may be described in the results of our study, in which, even with lower electromyographic activity in pregnant women that had larger diastasis, we did not found important alterations when we correlated the electromyography and the other parameters related to the birth labor and to the newborn[22].

The duration of the second stage of labor, the APGAR scores, the arterial pH and the pCO_2 of neonates blood were not correlated to a minor effectiveness of the push, from where it was suggested having any loss in the physiological of the labor mechanism, lower pushing efficiency, thus having no damage in the physiological mechanism of labor. Some studies[25-28] that correlated fetal indices with the push efficiency found correlations between the voluntary push decrease and lower arterial PH and O_2 saturation in newborns. Those studies, however, were performed in mothers that were anesthetized during delivery, therefore being part of the exclusion criteria of this study, in which no motor block technique was used.

This study suggests that the umbilical diastasis may act as an influent parameter in the generation of voluntary pushes during the expulsive period of labor. Although this parameter should not be considered by itself in the study as a predictive factor of the voluntary abdominal effort in the expulsive period of labor, we suggest a link between this factor and other parameters described in literature (that were not evaluated in our study), like intra-uterine pressure and myometrium thickness. This association will make possible to develop, in future studies and with a largest sample, more detailed information about the expulsive period dynamics in order to help the obstetricians, nurses and physical therapists to optimize pregnant woman's expulsive efforts during labor.

Acknowledgments

The Brazilian agency *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq) and the Obstetrics Group of *Instituto de Medicina Integral Professor Fernando Figueira* (IMIP) for their assistant and support.

References

1. Demaria F, Porcher R, Sheik-Ismael S, Amarenco G, Benifla JL. [Recording expulsive forces during childbirth using intercostal muscle electromyogram: a pilot study]. Gynecol Obstet Fertil. 2005;33(5):299-303.
2. Buhimschi CS, Buhimschi IA, Malinow AM, Kopelman JN, Weiner EP. The effect of fundal pressure manoeuvre on intrauterine pressure in the second stage of labour. BJOG. 2002; 109(5):520-6.
3. Shafik A, El Sibai O, Shafik IA, Shafik AA. Electromyographic activity of the anterolateral abdominal wall muscles during rectal filling and evacuation. J Surg Res. 2007; 143(2):364-7.
4. Liao JB, Buhimschi CS, Norwitz ER. Normal labor: mechanism and duration. Obstet Gynecol Clin North Am. 2005;32(2):145-64, vii.
5. Buhimschi C, Boyle M, Garfield RE. Electrical activity of the human uterus during pregnancy as recorded from the abdominal surface. Obstet Gynecol. 1997;90(1):102-11.
6. Chen DC, Ku CH, Huang YC, Chen CH, Wu GJ. Urinary nitric oxide metabolite changes in spontaneous and induced onset active labor. Acta Obstet Gynecol Scand. 2004; 83(7):641-6.
7. Okawa T, Vedermikov YP, Saade GR, Garfield RE. Effect of nitric oxide on contractions of uterine and cervical tissues from pregnant rats. Gynecol Endocrinol. 2004;18(4):186-93.
8. Väissänen-Tommiska M, Nuutila M, Ylikorkala O. Cervical nitric oxide release in women postterm. Obstet Gynecol. 2004;103(4):657-62.
9. Ponkey SE, Cohen AP, Heffner LJ, Lieberman E. Persistent fetal occiput posterior position: obstetric outcomes. Obstet Gynecol. 2003;101(5 Pt 1):915-20.
10. Atalah ES, Castilho CL, Castro Santoro R, Aldea AP. Propuesta de un Nuevo estándar de evaluación nutricional en embarazadas. Rev Méd Chile. 1997;125(12):1429-36.
11. Ministério da Saúde. Pré-natal e puerpério.: Atenção qualificada e humanizada. Brasília: Ministério da Saúde; 2005.
12. Hsia M, Jones S. Natural resolution of rectus abdominis diastasis. Two single case studies. Aust J Physiother. 2000;46(4):301-7.
13. Vera-Garcia FJ, Grenier SG, McGill SM. Abdominal muscle response during curl-ups on both stable and labile surfaces. Phys Ther. 2000;80(6):564-9.
14. Ng JK, Kippers V, Richardson CA. Muscle fibre orientation of abdominal muscles and suggested surface EMG electrode positions. Electromyogr Clin Neurophysiol. 1998;38(1):51-8.
15. Cheng YW, Hopkins LM, Caughey AB. How long is too long: Does a prolonged second stage of labor in nulliparous women affect maternal and neonatal outcomes? Am J Obstet Gynecol. 2004;191(3):933-8.
16. Jensen H, Agger AO, Rasmussen KL. The influence of pregnancy body mass index on labor complications. Acta Obstet Gynecol Scand. 1999;78(9):799-802.
17. Buhimschi CS, Buhimschi IA, Malinow AM, Weiner CP. Intrauterine pressure during the second stage of labor in obese women. Obstet Gynecol. 2004;103(2):225-30.
18. Boissonnault JS, Blaschak MJ. Incidence of diastasis recti abdominis during the childbearing year. Phys Ther. 1988;68(7):1082-6.
19. Thornton SL, Thornton SJ. Management of gross divarication of the recti abdominis in pregnancy and labour. Physioterapy. 1993;79(7):457-8.

20. Fast A, Weiss L, Ducommun E, Medina E, Butler JG. Low back pain in pregnancy. Abdominal muscles, sit-up performance, and back pain. Spine (Phila Pa 1976). 1990;15(1):28-50.

21. Freire DMC, Paiva CSM, Coelho EAC, Cecatti JG. Curva da altura uterina por idade gestacional em gestantes de baixo risco. Rev Bras Ginecol Obstet. 2006;28(1):3-9.

22. Gilleard WL, Brown JM. Structure and function of the abdominal muscles in primigravid subjects during pregnancy and the immediate postbirth period. Phys Ther. 1996;76(7):750-62.

23. Noble E. Essential Exercises for the Childbearing year. Boston: Houghton Mifflin Co; 1982.

24. Thompson AM. Maternal behavior during spontaneous and directed pushing in the second stage of labour. J Adv Nurs. 1995;22(6):1027-34.

25. Spencer JA, Koutsoukis M, Lee A. Fetal heart rate and neonatal condition related to epidural analgesia in women reaching the second stage of labor. Eur J Obstet Gynecol Reprod Biol. 1991;41(3):173-8.

26. Aldrich CJ, D'Antona D, Spencer JA, Wyatt JS, Peebles DM, Delpy DT, et al. The effect of maternal pushing on fetal cerebral oxygenation and blood volume during the second stage of labour. Br J Obstet Gynaecol. 1995;102(6):448-53.

27. Myles TD, Santolaya J. Maternal and neonatal outcomes in patients with a prolonged second stage of labor. Obstet Gynecol. 2003;102(1):52-8.

28. Tracy S, Sullivan E, Wang YA, Black D, Tracy M. Birth outcomes associated with interventions in labour amongst low risk women: a population-based study. Women Birth. 2007;20(2):41-8.