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GUIDELINES AND POSITION STATEMENTS

Tissue biomechanical behavior should be considered in the risk assessment of perineal trauma at childbirth

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Abstract

Perineal trauma at childbirth is associated with strong negative impacts on a woman's health but remains unpredictable. Pregnancy induces several changes in biomechanical behavior in humans as in animals, namely, an increase in ligamentous laxity and an increase in vaginal distensibility. Pelvic floor muscles in rats are reported to exhibit specific behaviors during pregnancy. Increases in both stiffness and the number of sarcomeres in series are observed and might process that protect against perineal trauma at childbirth. Some data in humans have shown that the risk of perineal trauma is highly linked to the intrinsic characteristics of the tissue, suggesting the potential benefit of incorporating intrinsic biomechanical characteristics in the risk prediction for perineal trauma. Shear wave elastography might be a useful noninvasive tool to investigate the elastic properties of these tissues in pregnant women in vivo, with the goal of implementing these properties as a predictive strategy.

Keywords Obstetric anal sphincter injury · Shear wave elastography · Childbirth · Ligamentous laxity · Perineal trauma · Individualized strategy

Introduction

Perineal trauma is a frequent complication of vaginal delivery, and in the most severe cases, the trauma is complicated by obstetric anal sphincter injury (OASI). Perineal trauma can have major repercussions on a woman's physical health and quality of life, including sexual dysfunction, urinary and/or fecal incontinence, and pelvic organ prolapse [1]. The literature on this topic is abundant and reports several risk factors, including surgical delivery, nulliparity, and fetal macrosomia. Nevertheless, even when these risk factors are considered, perineal trauma at childbirth remains unsatisfactorily predicted, indicating that additional risk factors must be identified [1]. Some recent data suggest that the elastic properties of tissues can be a relevant factor that can be used to improve the risk prediction strategy [2, 3]. The objective of this opinion paper is to provide a synthesis of the published data about the changes in the biomechanical behavior of the tissue and the associated physiology during pregnancy. Recent data show the feasibility of assessing, in vivo and with noninvasive techniques, the elastic properties of a woman's pelvic floor. The expected prospects for perineal trauma prediction and prevention are discussed.

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Changes in a woman's joint laxity during pregnancy

In a previous prospective study, we reported an increase in the peripheral ligamentous laxity of women from the first to the third trimester using both a general scoring system (the Beighton score) and a specific assessment on the second metacarpophalangeal joint [4]. Similar increases in ligamentous laxity were reported for other joints by several authors [5, 6]. Another example, reported by different teams, is the change in the spinal curvature, which is probably allowed by the changes in ligamentous laxity, to maintain the women's center of gravity at the center of her support polygon [7]. Therefore, it seems that there is a decrease in the stiffness of the tissues during pregnancy that leads to some changes in joint biomechanics to provide physiological accommodation of pregnancy weight gain and the gravid uterus. These biomechanical changes might be considered to indicate the physiological adaptation of a woman to pregnancy-related constraints.

The biological mechanisms involved in these biomechanical changes are hardly known. One recurrent hypothesis involves the role of relaxin. This hormone is produced by the ovaries, the mammary tissue and the placenta and has a role in conjunctive tissue remodeling [5]. There are data reporting an association between higher maternal serum levels of relaxin and higher joint mobility and ligamentous laxity [8, 9]. Nevertheless, this point remains debated since such this association has not been reported in other studies [5, 6]. Another hypothesis is the effect of sexual hormones, especially estradiol, whose expression is important during pregnancy. Nevertheless, the impact of these hormones is unclear since different studies have reported contradictory results (an increase or a decrease in stiffness) for muscle and tendons [10, 11], and one study did not report any association between sex hormones and joint laxity during pregnancy [6]. Regardless of the potential role of relaxin or estradiol, the main hypothesis is a change in collagen modeling with a decrease in the ratio of type 1/type 3 collagen. Collagen is the main component of the muscular extracellular matrix that determines muscle biomechanical properties and its ability to sustain a load [12]. This point remains hypothetical since we cannot report data for ex vivo histological analysis of tissues in pregnant women. Finally, these hypotheses are mainly related to joint mobility and ligamentous laxity but not directly related to muscles or, particularly, pelvic floor muscles. Indeed, it is notable that most of the in vivo measurements of tissue mechanics in pregnant women were performed at the joint level and that no information exists for at the muscle level [13]. A recent study report that the stiffness of the patellar tendon does not decrease during pregnancy which suggest the possibility that the biomechanical behavior might be different from one tissue to another [14]. Such biomechanical changes that may exist in pelvic floor muscles may also be a form of physiological preparation of the woman's pelvic floor for childbirth to accommodate the major distension of perineal muscles during vaginal delivery. While no data exist about muscle mechanical changes during pregnancy in humans, animal experimentation has provided ex vivo evidence of biomechanical changes that are related to the effect of pregnancy.

Animal experimental data about pregnancy-associated changes in the biomechanical behavior of the pelvic floor

To analyze pelvic floor muscles, the most often considered animal model is the rat, as the organization of the pelvic floor muscles in rats is similar to that in humans [12]. There are data reporting an increase in muscular fiber length for the pelvic floor muscles of rats during pregnancy. The increase in muscle fiber length is explained by an increase in the number of sarcomeres in series. A concomitant increase in passive muscle stiffness has been found [15], which can be explained by a drastic increase in the total collagen content in pelvic floor muscles [12, 15]. This increase in stiffness can be seen as a physiological mechanism that strengthens the muscular structure during pregnancy and induces an important increase in muscle fiber length. Considering that tissue with lower stiffness has higher plasticity or rupture thresholds, representing the limit at which irreversible damage can occur in a structure [16], the increase in muscle stiffness can be considered to be a protective process against perineal trauma, especially muscle rupture. Of interest, these changes in fiber length and muscle stiffness occur only in pelvic floor muscles (the coccygeus, iliocaudalis and pubocaudalis muscles), while no significant changes occur in peripheral muscle (i.e., the anterior tibialis muscle). The authors conclude that these changes are probably due more to the local increase in mechanical loading applied to pelvic floor muscles than to a hormonal systemic effect [12].

There are animal experimental data about the impact of perineal distension during childbirth on these pelvic floor muscles. Authors from the same team as previous studies simulated the strain exerted by vaginal delivery by inducing vaginal distension, which replicates fetal crowning, in pregnant and nonpregnant rats [17]. They reported an increase in sarcomere length that was dramatically higher in nonpregnant rats. This result indicated that pregnancy-induced adaptations were efficient in limiting the sarcomere hyperelongation that may induce muscle damage. The largest differences between pregnant and nonpregnant rats were reported for the pubocaudalis and coccygeus muscles, especially for the entheseal region of the pubocaudalis muscle, which became translucent. This observation was reliable in terms of human clinical considerations since this region is the one in which levator avulsion due to childbirth occurs [17]. These observations were also consistent with computer modeling studies that identified the dorsal–caudal portion and its bilateral attachments to the pubis as the most stretched portions of the levator ani during vaginal delivery simulation [18].

These muscular adaptations contrast those observed with animal data on the elastic properties of the vaginal wall. Several authors have reported a decrease in stiffness of the vaginal wall during pregnancy [19–21], which is consistent with previously described observations in humans. These authors concluded that this decrease in stiffness might be a physiological process that accommodates vaginal distension during childbirth [19–21].

Since this decrease in stiffness is observed for the pelvic floor and peripheral tissues, it might be related to hormonal systemic changes. In contrast, pelvic floor muscles may have a specific behavior during pregnancy that is induced more by the mechanical loading applied to pelvic floor muscles than by hormonal mechanisms. The length and stiffness of pelvic floor muscles are increased during pregnancy, and this can be considered a protective process that avoids muscular rupture during childbirth. Pelvic floor damage may occur when the strain is too important and/or when the biomechanical changes induced by pregnancy are not sufficient to accommodate the strain induced by delivery.

Association between biomechanical characteristics and obstetrical pelvic floor trauma

To date, data on the impact of the intrinsic biomechanical properties of a woman and the risk of obstetrical pelvic floor trauma are limited. Meriwether et al. investigated whether there is an association between the perineal body stretch during delivery and the risk of OASI [22]. These authors reported a 65% increase in perineal body length from the antepartum to the expulsive phase, which is consistent with the previously reported data [22]. In this study, the importance of the perineal body stretch was not associated with OASI occurrence or any pelvic floor disorders [22].

Our research team recently published a prospective study of 300 women with an assessment of ligamentous laxity between 36 weeks of pregnancy and the onset of labor [2]. Ligamentous laxity was assessed at the second metacarpophalangeal joint (MCP laxity) by measuring the passive extension of the nondominant index finger for a 0.26-N m fixed torque using a specific extensometer. Women with higher ligamentous laxity were those with a higher risk of OASI. An MCP laxity greater than 64° was associated with OASI, with 75% sensitivity, 56% specificity and an area under the curve of 0.65 [2]. Therefore, the intrinsic biomechanical properties seem to be related to perineal trauma. We hypothesized that women with the greatest ligamentous laxity may be those with the weakest pelvic floor muscles and, by extension, those with the highest risk of OASI [2]. However, considering that the mechanisms involved in the increase in ligament laxity and the increase in pelvic floor muscle stiffness are different (see previous section), we currently have no direct evidence to validate this hypothesis. Therefore, it is now crucial to assess the biomechanical behavior of pelvic floor muscles in vivo in pregnant women to determine whether such measurements can help to predict OASI. The next section is dedicated to the available methods that can be used for this purpose.

How to assess the pelvic floor biomechanical behavior in a woman in vivo

Kruger et al. used an elastometer to assess the elastic properties of the levator ani muscle in pregnant and nonpregnant women [23, 24]. Their device is similar to a vaginal speculum associated with force sensors. This elastometer seems to provide the force/displacement curve with good reproducibility. Using this method, the authors reported that the stiffness of the levator ani muscle is higher in the postpartum assessment than in the prenatal assessment. While this innovative approach provides relevant information about pelvic floor behavior, it suffers from two main drawbacks. First, the device measures the displacement of the speculum, which is inserted within the vagina. Thus, it evaluates the elastic properties of both the levator ani and the vaginal wall. Considering that the changes in the stiffness of the levator ani and vaginal wall are opposite during pregnancy [12, 15, 17, 19, 20], this can lead to results that may be difficult to interpret. Second, this remains an intrusive vaginal examination that may be hard to accept for pregnant women [3, 23, 24].

Recent technologies of functional ultrasound imaging have been proposed for in vivo and noninvasive investigations of the elastic properties of several peripheral muscles [25]. Chen et al. reported the use of static elastography to assess the elastic properties of the perineal body in nonpregnant women [26]. This was the first study that used elastography for the pelvic floor. Because the static elastography technique provides a qualitative evaluation, it requires the interposition of a custom standoff pad to estimate the elastic properties of the perineal body in comparison to this reference. The authors reported that the mean compression modulus of the perineal body region was 28.9 kPa. The main strength of this technique is that it allows an in vivo assessment with a noninvasive approach. The main limitation is that the measurement is not directly focused to the pelvic floor, and we do not know which anatomical structure is measured (muscles, vaginal wall, etc.) [3, 26]. In addition, this technique provides a measurement along the transverse direction of the muscles that does not correspond to the "physiological" stiffness measured along the shortening direction, as performed in animal studies. Other research teams suggest similar procedures to provide qualitative assessments of a woman's pelvic floor elastic properties, especially for levator ani muscles [27–29].

We recently reported the use of shear wave elastography for direct and in vivo measurements of the elastic properties of levator ani muscles in nonpregnant women [3]. The levator ani muscle is identified with classical B-mode ultrasound using a transperineal approach with a linear probe. Once the muscle is identified, the shear wave elastography acquisition is performed to evaluate a shear modulus along the muscle shortening direction. This shear modulus is linked to Young's modulus for muscles [30]. In a feasibility study, we reported that from rest to the Valsalva maneuver, the shear modulus of the levator ani muscle increases by a factor of 2 (16–35 kPa for the shear modulus) [3]. This technique provides a direct and noninvasive elasticity measure of the levator ani muscle. However, this technique has not yet been used for pregnant women, and there are no data about the reproducibility of pelvic floor muscle measurements [3].

Therefore, techniques have been proposed for in vivo investigations of the elastic properties of a woman's pelvic floor. To directly and specifically investigate the properties of the pelvic floor muscles, shear wave elastography seems to be a more appropriate technology, but data on the feasibility of the technique in pregnant women and the reproducibility of the data are needed.

Prediction of perineal trauma

There are different predictive algorithms proposed for perineal trauma at childbirth and, more specifically, for OASI occurrence. Jelovskek et al. reported a model for fecal incontinence, and McPherson et al. reported a model for OASI; these models showed poor reliability, with areas under the curve of 0.68 and 0.64, respectively. This seems to be associated with too high a risk for an incorrect conclusion about the high or low risk of developing the outcome measured [31, 32]. Meister et al. reported a more satisfactory predictive model of OASI (area under the curve of 0.83); however, its use has not been reported in other studies, and its predictive value has not been validated in another sample, which is a main limitation for its clinical use [33].

All these predictive models are focused on the mode of delivery without any considerations of the woman's tissue biomechanical characteristics, which might explain the limitations of these predictive tools. There is strong evidence in animals and humans for large and specific changes in a woman's pelvic floor biomechanical behavior during pregnancy, and this is probably a protective process against perineal trauma. Therefore, we hypothesize that taking this biomechanical behavior into account in our risk prediction of perineal trauma at childbirth will probably improve the efficiency of the predictive models, leading to individualized risk assessments. In this perspective, we believe that shear wave elastography would be a very useful tool. All women will undergo several ultrasounds during their pregnancy monitoring, and it is easy to consider performing a short assessment of the viscoelastic properties of pelvic floor muscles during one of these ultrasound assessments, especially in the third trimester. By including these biomechanical properties in the risk prediction of perineal trauma at childbirth we may optimize the efficiency of the existing algorithms with a better identification of high-risk woman. Such an individualized risk assessments can lead to personalized information for a pregnant woman about her risk of perineal trauma, allowing personalized advice for the mode of delivery and/or implementation of preventive strategies (e.g., episiotomy, restriction of surgical delivery). More specifically, the place of protective interventions such as episiotomy would be individually discussed. Indeed, there are strong data reporting that there is no benefit of a routine use of episiotomy to prevent from perineal trauma or anal/urinary incontinence [34–36]. A recent biomechanical study using a computational modeling approach report that a mediolateral episiotomy decreases the stress on pelvic floor muscles and the force required to deliver successfully [37]. Nevertheless, due to the morbidity of the intervention (infection, bleeding, pain) and the absence of benefits in the overall population, the answer is to find out how high-risk women which could have a benefit of mediolateral episiotomy could be correctly identified [34–36].

Tissue biomechanical behavior consideration, assessed non-invasively using shear wave elastography during the last obstetrical ultrasound visit, would allow to identify women with an intrinsic high-risk of perineal trauma allowing a selective use of episiotomy. These women could benefit a personalized information on mediolateral episiotomy in their specific cases, how the intervention is performed, and what are the required cares after the delivery. Such an antenatal information will probably lead to better acceptability of the intervention and offer the possibility to collect a real free and informed consent compare to an emergency information during the delivery.

Conclusion

Pregnancy is associated with significant changes in pelvic floor biomechanical behavior that can be considered a protective process from perineal trauma during childbirth. Recent functional ultrasound imaging technologies, such as shear wave elastography, allow an in vivo assessment of the elastic properties of a woman's pelvic floor muscle elastic properties and may be useful for identifying women with an intrinsic high risk of perineal trauma. We contend that intrinsic tissue biomechanical behavior should be considered in the risk assessment of perineal trauma at childbirth to improve the individualized risk assessment with the goal of providing personalized counseling to women in prenatal courses or during labor and developing preventive strategies.

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