Journal of Gynecology Obstetrics and Human Reproduction 48 (2019) 351–357

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com/en

Original Article

Evaluation of ligament laxity during pregnancy

Yosra Cherni[a,d,1], David Desseauve[a,b,1], Arnaud Decatoire[a], Nikolaus Veit-Rubinc[c], Mickaël Begon[d,e], Fabrice Pierre[b], Laetitia Fradet[a,*]

[a] Institut Pprime. Axe RoBioSS, CNRS UPR 3346 Université de Poitiers, Téléport 2, boulevard Marie et Pierre Curie BP 30179, 86962, Futuroscope, France
[b] Service de Gynécologie Obstétrique et Médecine de la Reproduction, CHU de Poitiers, 2 rue de la Milétrie, 86021, Poitiers Cedex, France
[c] Department of Obstetrics and Gynecology Medical University of Vienna, Austria
[d] Département de Kinésiologie, Université de Montréal, 1700 rue Jacques-Tétreault, H7N 0B6, Laval, Québec, Canada
[e] Centre de recherche du centre de réadaptation Marie-Enfant, CHU Sainte-Justine, 5200 Rue Bélanger, H1T 1C9, Montréal, Québec, Canada

ARTICLE INFO

Article history:
Received 19 February 2018
Received in revised form 28 January 2019
Accepted 19 February 2019
Available online 20 February 2019

Keywords:
Hypermobility
Quantification
Extensometer
Clinical tests

ABSTRACT

Objective: Pregnancy-related changes in ligament laxity have been shown to be associated with various disorders such as back pain or pelvic floor disorders. The purpose of this study was to assess laxity changes during pregnancy by confronting different methods in order to suggest a simple clinical tool helping to prevent the aforementioned problems.
Design: Seventeen pregnant women were evaluated at the first, second and third trimesters as cases and 16 non-pregnant women participated as controls. Ligamentous laxity was measured using an extensometer for the metacarpophalangeal joint of the index, a fingertip to floor test and a sit and reach test to assess hip and lumbar flexibility and the Beighton score. Statistical analysis included independent samples *t*-tests, analysis of variance and Pearson correlation coefficients.
Results: Laxity of the metacarpophalangeal joint increased by 11% from the first to the second trimester of pregnancy and stabilized until delivery. The Beighton score was significantly higher in the second trimester of pregnancy ($p < 0.05$). The flexibility of the hip and lumbar vertebra showed a significant increase of the distance measured between the foot soles and the middle fingers at third trimester ($p < 0.05$). A moderate correlation was observed between the results given by the extensometer and the Beighton score in both the cases and the control group at first trimester ($r = 0.60$, $p < 0.05$) but none was found for the two hip and lumbar flexibility tests.
Conclusion: Laxity reached its maximum at the second trimester. The combination of an objective measurement by the extensometer and a global evaluation of the laxity by the Beighton' score for example may be useful for a daily assessment of laxity. However, the chosen clinical tests don't seem appropriate to be used alone in pregnant women

1. Introduction

Pregnancy is a unique physiological condition that induces large morphologic changes (*e.g.* weight and posture) and also modifications of intrinsic parameters like ligamentous laxity [1]. The ligamentous laxity is at its maximum in early childhood after this, it decreases rapidly until adulthood [2]. However, in the female population, this gradual decline may be suspended and even reversed during pregnancy. In this regard, some authors explain that some hormones such as relaxine, progesterone or oestradiol which levels increase during pregnancy modify the ligament structure [3–5]. These hormonal changes result in physiological relaxation of the ligaments in the pelvic joints in order to enhance the passage of the baby through the birth canal [6]. This loosening would enable the pelvic joint to become more flexible but, as a counterpart, would also affect the pelvic joint and the spine responses to mechanical load. Some authors hypothesize indeed that these modifications of pelvic joint and spine responses favor pelvic dysfunctions and the occurrence of pain in this body region [7,8]. During pregnancy, hormonal changes affect not only ligaments in the pelvic joints but more generally collagen of connective tissues [9] and therefore ligaments and tendons in general (*e.g.*, hand [10], wrist [11]). The observations concerning pelvic and spine joints are then extendable to the human body joints in general such as increased laxity may be related to various

* Corresponding author at: Institut PPRIME, UPR3346 CNRS Université de Poitiers ENSMA, Axe "Robotique, Biomécanique Sport Santé", SP2MI, Téléport 2, Bd Pierre et Marie Curie, 86360 Chasseneuil du Poitou, Futuroscope, France.
E-mail address: Laetitia.Fradet@univ-poitiers.fr (L. Fradet).
[1] YC and DD participated equally to this work.

http://dx.doi.org/10.1016/j.jogoh.2019.02.009
2468-7847/

musculoskeletal disorders and increased pain in various joints of the body during pregnancy [12,13]. In the aforementioned studies investigating the relation between ligament laxity and disorders during pregnancy, the evolution of ligament laxity hasn't been assessed throughout pregnancy. Nevertheless, early detection of its increase would be of particular interest in order to develop prevention of various disorders appearing with pregnancy.

In the literature, there is then a wide variety of *in vivo* laxity assessment devices and methods. The first type of methods try to assess directly the lengthening of a ligament after applying a specific force using medical imaging [14] or knee ligament arthrometers [15,16]. This methods allow measurement of small laxity changes with an accuracy up to 0.1 mm [17] but is quite expensive for a clinical follow up and requires some technical expertise. Moreover, not many ligaments can be isolated.

The second category of devices proposes to evaluate indirectly the ligament laxity through the measurement of articular mobility [1,7,8,11] even though articular mobility results from the mechanical behavior of various ligaments, tendons and capsules [18]. Typically, these systems, such as the extensometer of Jobbins [19], measure the amplitude reached by a joint of the pregnant woman for a specific torque applied on this joint. Such devices are portable, easy to use, affordable, atraumatic and reliable [1]. The main drawback is that the proposed devices measure flexibility in upper limb joint. Now, upper joints are affected by pregnancy-related changes in laxity but less involved in pathology.

The third category of methods would be clinical tests that estimate joint flexibility. The Beighton score [20] is the most commonly used test to assess the overall ligamentous laxity. It is a nine-point score evaluating laxity in the upper and lower limbs and lumbar and hip flexibility with a score $\geq$4/9 required to conclude a generalized hyper joint mobility. The reliability and reproducibility of this score was suggested as good to excellent in screening for generalized joint laxity in females [21] and children [22] and has already been used in pregnant women [1,23]. Calguneri and colleagues observed no significant difference in Beighton scores between the third trimester and postpartum [1]. Van Dongen and colleagues used the Beighton scale to study the generalized laxity in pregnant South African women [23]. They showed that hypermobility in this women is low (only 4.9% of the 509 pregnant women), decreasing with age, but not increasing during pregnancy. However, the main limit of the Beighton score would be the computation of the score based on the sum of one and zeros corresponding to the ability to reach or not specific joint postures.

In the literature, other more targeted clinical tests have been suggested to evaluate the lower back flexibility such as the "fingertip to floor test" [24] or the "sit and reach test" [25]. These tests have been intensively used in epidemiologic studies [26] and sport sciences [27]. They are easy to administer and require minimal skills training [26]. To the best of our knowledge, they have never been used to assess joint laxity in pregnant women. Conversely to the Beighton score, the performance corresponds to a distance, which is continuous measure. As such, they could be more sensitive to small changes in joint laxity and then present a good alternative to assess joint laxity throughout pregnancy. The "fingertip to floor test" is a little bit easier to spread than the "sit and reach test". During the "fingertip to floor test", the distance is indeed measured between the fingertip and the floor. During the "sit and reach test", the distance is measured between the fingertip and a box. One has then to have an adequate box to be able to perform this test. However, a doubt remains about the ability for pregnant women to realize the "fingertip to floor test" at the end of pregnancy. The morphologic changes in terms of abdominal circumference, weight, and modification of the center of gravity position might indeed obstruct the ability to bend forwards as required by the "fingertip to floor test".

In this study, we conducted a longitudinal monitoring of ligament laxity at a wide range of joints in pregnant women by combining an objective measure, the extensometer, that has been proven to be efficient to detect small changes in ligament laxity [1,19], and simple clinical tests. The aims of this study were to determine how laxity during pregnancy evolves and to propose a simple clinical methodology that could be used in daily practice helping to prevent pathologies associated with increase in laxity. An objective quantification of laxity could allow us to carry out further studies for a better understanding of the origins of back pain and pelvic floor disorders during pregnancy.

2. Material and methods

2.1. Population

Eligible participants were women with age over 18 years and with a BMI inferior to 40. None of the participants presented current or previous inflammatory joint disease affecting the integrity of the musculoskeletal system; hypermobility syndrome like Ehlers Danlos or Marfan syndrome. The control group was included to have a baseline value of the laxity before pregnancy. The Ethics Committee of the Poitiers Hospital and the National Agency of Drug Safety reviewed and approved this study protocol and each participant signed a written informed consent.

The metacarpophalangeal joint laxity, hip and lumbar flexibility and generalized joint laxity were measured in pregnant women at the first, second and third trimesters while women of the control group were tested only once.

2.2. Metacarpophalangeal joint laxity assessment

An extensometer of the metacarpophalangeal joint of the index was purpose-made (Fig. 1) according to Jobbins and colleagues principle [19]. The extension force applied on this joint was measured by a force sensor while the metacarpophalangeal joint angle and force direction derived from reflective markers captured by an optoelectronical motion system (Vicon Motion System Ltd). Force and kinematic data were synchronized using the Nexus Motion Capture Software (version 1.8.5). Specifically, participants were asked to sit comfortably in front of the extensometer and be relaxed. They put their index of the non-dominant hand in the extensometer interstice. The proximal portion of the metacarpus was immobilized to only measure the movement of the metacarpophalangeal joint of the index. One reflective marker was placed on the base of the finger and a second marker on the tip of the support of the extensometer to measure the metacarpophalangeal joint angle. Then the experimenter turned the rack slowly and continuously until the participant experienced discomfort. Based on the force, its direction and the metacarpophalangeal joint angle, the joint moment was calculated. From the time histories of both joint angle and moment, the angle obtained when the metacarpophalangeal joint underwent a moment of 0.26 Nm was selected [1,19].

2.3. Hip and lumbar flexibility tests

The first measurement corresponded to the fingertip to floor test (F2F test). From a 20 cm high platform, women were instructed to reach the floor with their fingertips while keeping knees extended and feet together. The distance between the middle finger and the base of the platform was expressed in centimeters. A positive value corresponded to a position of the middle finger above the platform level and a negative value below (Fig. 2A).

The second measure was an adapted version of the "sit and reach test" that will be later referred to as the horizontal Sit and

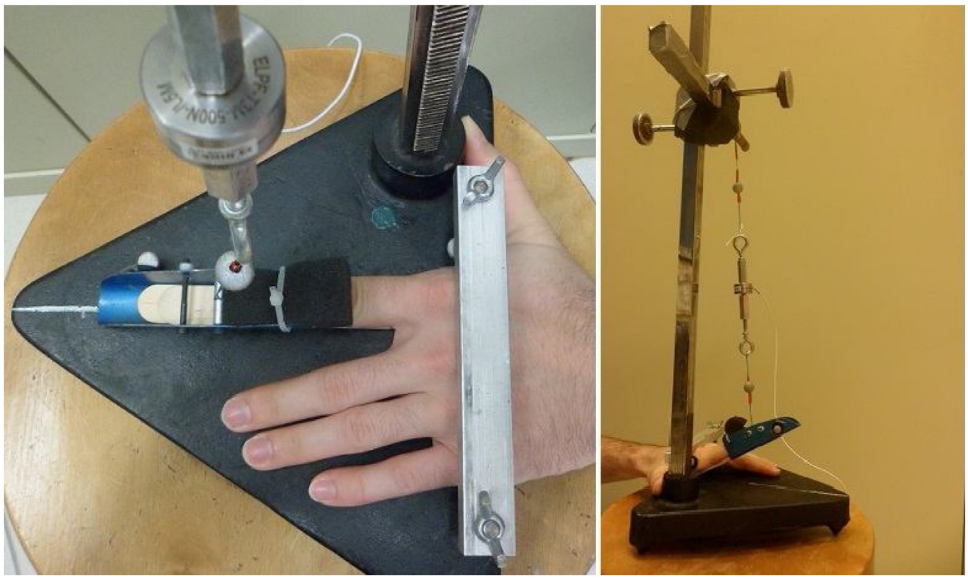


Fig. 1. Installation of the patient's hand inside of the extensometer which is equipped with reflective markers and a force sensor (ELPF-T3M-500N, Sensix, France) allowing to measure the angle in function of the applied torque to the metacarpophalangeal joint.

Reach test (hSR test). The acquisition was done on the delivery bed, where the woman was seated with legs straight. The participant maintained her arms horizontal and bent the trunk as much as possible. For this test, the distance between the middle finger and the vertical plane passing by the soles of the feet was measured (a negative value corresponding to a position of the middle finger that exceeds the passing by the soles of the feet vertical plane, see Fig. 2B). In both tests, performance was measured by the optoelectronical system using markers placed on the foot soles and the right middle finger tip.

2.4. Beighton score

For each participant generalized joint laxity was also assessed using the Beighton score [20] as depicted on Fig. 3. The laxity of nine joints was assessed using nine "all-or-nothing" tests (*i.e.* thumbs opposition, hyperextension of the 5th fingers, recurvatum of the elbows, hyperextension of the knees of the left and right sides, lumbar flexibility). The total score varies from 0 to 9 with high scores denoting more generalized joint laxity.

2.5. Statistical methods

For the statistical treatment, the normality of the distributions was confirmed by a Shapiro Wilk test. Differences for age, height, body mass and BMI between controls and pregnant women in the first trimester were examined using independent samples *t*-tests. During pregnancy, the trimester effect (three levels: first, second and third trimesters) was analyzed using a repeated measures analysis of variance (ANOVA). In case of significance, Tukey post hoc tests were performed to identify trimesters that were significantly different from each other. The effect size was calculated by dividing the difference between the means for the outcome variable by the pooled SD and was interpreted in

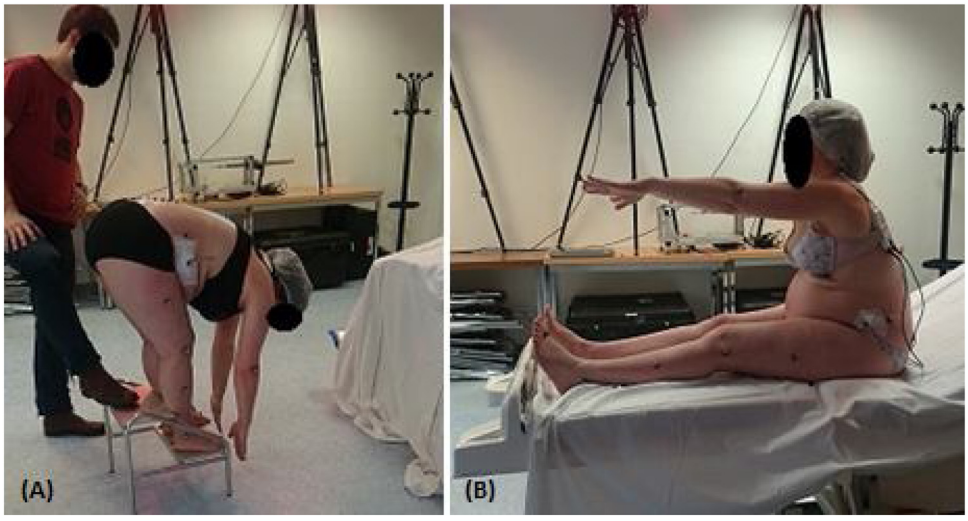
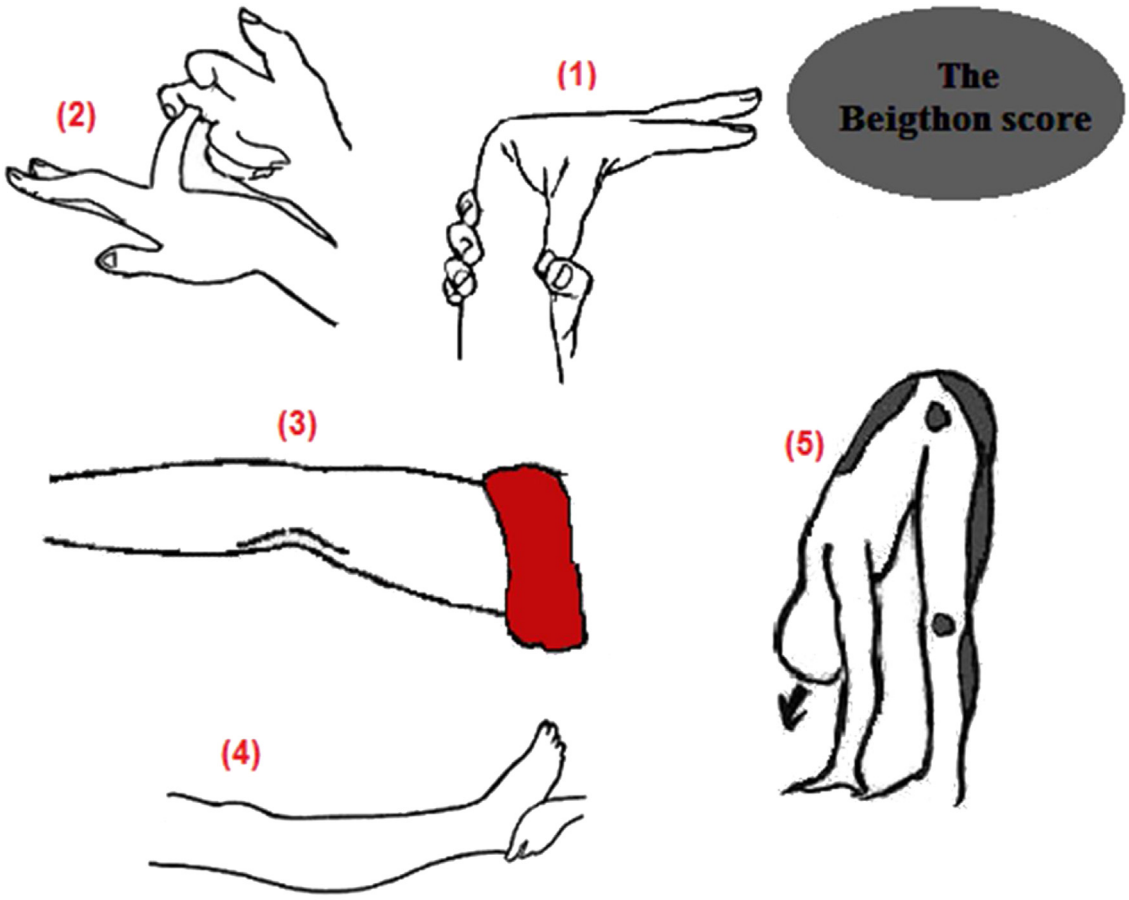


Fig. 2. **(A)** Classical version of Finger to floor test; **(B)** Sit and reach test (hSR test). For these two tests, reflective markers are placed at the tip of the 3rd finger of the right hand, the external malleolus, heels and the bases of the 2nd metatarsal. Distance measured between the marker placed at the tip of the finger and the horizontal plane passing by the soles of the feet. Negative value is obtained when below.



	Unable to perform (0 Points)	Able to perform (1 Points)
1. Passive apposition of thumb to forearm		
Right	0	1
Left	0	1
2. Passive hyperextension of fifth finger > 90 degrees		
Right	0	1
Left	0	1
3. Active hyperextension of elbow >10 degrees		
Right	0	1
Left	0	1
4. Active hyperextension of knee >10 degrees		
Right	0	1
Left	0	1
5. Forward flexion of trunk, legs straight, palms touching floor	0	1
Total Beighton Score (Sum of points for each maneuver)	0 to 9 points	

Fig. 3. The Beighton score. The figure was taken from the Hypermobility Syndromes Association.

accordance with Cohen's guidelines: 0.20 as small, 0.50 as moderate, and 0.80 as large. The correlations between the tests were studied using Pearson correlation coefficients. The significance level adopted was less than 0.05. All analyses were executed using the Statistica software (StatSoft, Tulsa, OK).

3. Results

Seventeen pregnant women (age: 36 ± 2 years, BMI_1: 24 ± 3 kg/m^2, BMI_2: 25 ± 3 kg/m^2, BMI_3:27 ± 3 kg/m^2 at the first, second and third trimesters respectively including 6 primiparous and 11 multiparous) and sixteen controls (age: 31 ± 6 years, BMI: 21.3 ± 1.6 kg/m^2) were recruited during a routine gynecological consultation at the University Hospital of Poitiers.

Regarding the anthropometric data, no significant differences between the control group and pregnant women in the first trimester were found for age ($p = 0.35$) and height ($p = 0.7$) as shown in Table 1. The body mass and BMI were significantly higher in pregnant women (all $p = 0.01$).

All women were able to perform all of the laxity tests. However, three have reported discomfort in performing the F2F test. Joint laxity measurements are summarized in Tables 2 and 3. No

Table 1
Participant anthropometric characteristics (mean ± standard deviation) and *p* values of the comparisons between the control group and pregnant women at the first trimester (PW1).

	Control (n = 16)	PW1 (n = 17)	*p* value
Age (years)	31.7 ± 6.3	35.8 ± 1.8	0.35
Height (m)	1.64 ± 0.06	1.65 ± 0.05	0.74
Body Mass (kg)	57.3 ± 5.3	64.2 ± 7.9	0.01*
BMI (kg/m^2)	21.3 ± 1.6	23.7 ± 2.9	0.01*

Table 2
Results (mean ± standard deviation) of all tests (extensometer, F2F test, hSR test, Beighton score) of the control group and pregnant women at the first trimester of pregnancy (PW1).

	Control	PW1	*p* value	Effect size
Extensometer (degree)	38.6 ± 7.4	40.8 ± 8.7	0.412	0.30
F2F test (cm) (n with distance ≤0)	1.8 ± 15.7 (n = 10)	7.2 ± 11.4 (n = 4)	0.050	0.40
hSR test (cm)	−2.2 ± 10.8	−4.5 ± 9.7	0.751	0.22
Beighton score (n with score ≥4/9)	1.8 ± 1.5 (n = 2)	3.5 ± 2.6[c] (n = 10)	0.022*	0.80[b]

NOTE: [c] statistically significant compared with the control group; $p < 0.05$. *, $p < 0.05$; a, moderate effect size; b, large effect size.

significant difference was found for all the laxity tests between the control group and pregnant women at the first trimester, except for the Beighton score ($p = 0.02$, Cohen's $d = 0.80$), which was significantly higher in pregnant women (Table 2).

During the pregnancy (Table 3), the extensometer results showed a trimester effect ($F(2, 32) = 4.88$, $p = 0.018$). Tukey post hoc tests highlighted that the laxity was significantly smaller at the first trimester compared to the second ($p = 0.024$, Cohen's $d = 0.5$) and the third ($p = 0.033$, Cohen's $d = 0.5$). No significant change between the 2nd and 3rd trimester was observed ($p = 0.917$, Cohen's $d = 0.0$).

As regards the results of the flexibility of the hip and lumbar, we observed a significant change during pregnancy for the fingertip to floor test ($F(2, 32) = 3.78$, $p = 0.034$) and the hSR test ($F(2, 32) = 7.69$, $p = 0.001$). The distance measured between the foot soles and the middle fingers tip was significantly greater at the third trimester of pregnancy compared to the first ($p < 0.05$) and the second trimester ($p < 0.05$) according to the results of post hoc tests. No difference between the first and the second trimesters was revealed for these two tests. The Beighton score demonstrated statistically significant changes of generalized laxity during the course of the pregnancy ($F(2, 32) = 4.75$, $p = 0.029$). Post hoc tests revealed a significant increase at the second trimester ($p = 0.024$, Cohen's $d = 0.6$) compared to the first trimester which decrease after at the third trimester ($p = 0.017$, Cohen's $d = 0.8$).

Pearson correlation coefficients showed a moderate correlation between the results given by extensometer and the Beighton scores in the control group and pregnant women at the first trimester ($r = 0.60$, $p < 0.05$). This correlation was low in pregnant women for the second and third trimester ($r = 0.40$, $p = 0.02$). There was no correlation between joint laxity measured by the two hip and lumbar flexibility tests and the extensometer ($p > 0.05$).

4. Discussion

Since laxity could be associated with development of different conditions such as back pain [7,8] or pelvic floor dysfunctions [28], it is important to find an assessment as simple as possible to enable its deployment in clinical settings for prevention and patients follow-up regarding the pre-cited conditions. To the best of our knowledge, this is the first study that confronts data from extensometer for longitudinal monitoring of metacarpophalangeal joint laxity among pregnant women with a series of complementary clinical measures of generalized laxity. Calguneri and colleagues used Jobbin's extensometer for pregnant women only between the third trimester of pregnancy (from 24th to 40th week) and after delivery [1].

Our results confirmed Calguneri's findings (1982) that metacarpophalangeal joint laxity evolved during pregnancy [1]. Our results showed that this peripheral laxity measured by the extensometer increased by 11% from the first to the second trimester of pregnancy to keep the same level thereafter which reveals an important evolution of metacarpophalangeal laxity. We believe that these findings are of great interest for the management of conditions associated with increased laxity in pregnant women.

Compared with those of Calguneri and colleagues, the values obtained in the present study are smaller (around 40° in our study and around 65° for Calguneri and colleagues' study (1982)). This difference might be explained by the definition of the torque applied. Indeed, we sought to apply an external torque of 0.26 N.m at the metacarpophalangeal joint. To compute this torque, we took into account the finger weight by measuring the joint torque when horizontal. In the original publication by Jobbins and colleagues, it isn't clear whether the finger weight was taken into account or not and what exactly represents the external torque applied at the metacarpophalangeal joint [1,19].

Generalized joint laxity assessed by the Beighton score increased at the second trimester and was moderately correlated with the results given by the extensometer. Therefore, we concluded that laxity evolution is particularly widespread during the two first trimesters of pregnancy by affecting different joints of the body. However, the Beighton score decreased in the third trimester. This result may be due to the inability of women to perform the forward flexion of the trunk in a standing position (only 3/17 participants were able to complete the 5th item) because of the abdominal volume which is higher in the third trimester and which could hamper the execution of this item. Overall, this test is simple to use and evaluates different type of joints. However, we believe that the use of this score to assess the evolution of laxity in pregnant women remains insufficient due to

Table 3
Results (mean ± standard deviation) of all tests (extensometer, F2F test, hSR test, Beighton score) of pregnant women for the three trimester of pregnancy (PW1, PW2 and PW3).

	PW1	PW2	PW3	*p* value	Effect size	Observed power
Extensometer (degree)	40.8 ± 8.7	45.5 ± 11.2[1]	45.1 ± 9.7[1]	0.018	0.40	0.7
F2F test (cm) (n with distance ≤0)	7.2 ± 11.4 (n = 4)	8.3 ± 13.8 (n = 5)	12.1 ± 11.5[1,2] (n = 3)	0.012	0.20	0.8
hSR test (cm)	−4.5 ± 9.7	−3.3 ± 9.2	4.5 ± 7.2[1,2]	0.001	0.50	1.0
Beighton score (n with score ≥4/9)	3.5 ± 2.6 (n = 10)	5.2 ± 2.8[1] (n = 12)	3.1 ± 2.4[2] (n = 6)	0.029	0.40	0.7

NOTE: [1, 2] statistically significant compared with the first and second trimester value respectively ($p < 0.05$).

its lack of sensitivity to changes and to the aforementioned problematic of the forward flexion of the trunk with large abdominal volume. The score is indeed based on the sum of ones and zeros corresponding to the ability to reach or not specific joint postures. It is therefore necessary to improve the test interpretation. For instance, the negativity should not allow excluding the diagnosis of hyper laxity.

The Finger to Floor test and the Sit and Reach test are simple clinical tests to evaluate the flexibility in the hip and lumbar joints. These joints are thought to be more exposed to local changes of pregnancy (uterine weight, increased abdominal volume, advancement and lowering of the center of mass [29], balance alterations and increase of the risk of falls [30]). For this reason, we expected that the results from these tests would reflect the changes in joint laxity during pregnancy. However, our results do not confirm this hypothesis. For the Finger to Floor test, the distance measured between the fingertip and the horizontal plane passing by the sole of the feet increased during pregnancy when it should have been the opposite to reflect an increased hip/lumbar joint laxity. None of the pregnant women refused or even mentioned any apprehension to perform the test at the end of pregnancy. However, they often mentioned that the volume and the weight of the abdomen seriously hampered there realization of this test. In our study, the horizontal Sit and Reach was intended to anticipate that some women would refuse to perform the Finger to Floor test. The results indicated a reduction of the distance between the finger and the vertical plane passing by the soles of the feet during the first part of pregnancy compared to control group even though not significant and an increase at the third trimester. The increase in abdominal volume here again and the anterior shift in the location of the center of mass during pregnancy could explain the alteration of the results of these tests[31]. In summary, evaluating the flexibility of the trunk by these two last tests or by the 5th item of the Beighton score do not seem suitable for pregnant women.

Regarding limitations, our study may be limited by the small sample size. Furthermore, the difference in age between the case group and the control group could have slightly influence on the results of laxity, while it has been cited that laxity changes inversely with age. However, according to the literature [32,33], this difference in age (only four years of average difference) is considered negligible to cause significant changes in laxity. Finally, the laxity measure was here based on the use of an optoelectronical capture system. A simplified version of the extensometer that doesn't require an optical motion capture system is been built.

In conclusion, metacarpophalangeal and generalized laxity increased considerably at the second trimester of pregnancy. According to Carvalho and colleagues low back pain is also more frequent in the second trimester of pregnancy [34] and pain in the hand and wrist is known to be the second most prevalent musculoskeletal symptom during pregnancy [10]. These concomitant findings indicate the need for prevention strategies that enable better quality of life for pregnant women. The combination of an objective measurement by the extensometer and a global evaluation of the laxity by the Beighton' score may be useful for a daily assessment of laxity in order to establish a specific laxity profile based on which we can choose a special monitoring for pregnant women.

These results will be reinvested by two adjacent studies: a first study analyzing the eventual relationship between ligament laxity and pelvic floor disorders in pregnant women and a second one interested in the prevalence of lumbar lordosis in pregnant women.

Conflict of interest statement

The authors have no conflict of interest.

References

[1] Calguneri M, Bird HA, Wright V. Changes in joint laxity occurring during pregnancy. Ann Rheum Dis 1982;41(April):126–8.
[2] Clinch J, Deere K, Sayers A, Palmer S, Riddoch C, Tobias JH, et al. Epidemiology of generalized joint laxity (hypermobility) in fourteen-year-old children from the UK: a population-based evaluation. Arthritis Rheum 2011;63(September (1)):2819–27.
[3] MacLennan AH, Nicolson R, Green RC, Bath M. Serum relaxin and pelvic pain of pregnancy. Lancet Lond Engl. 1986;2(August (2)):243–5.
[4] Charlton WP, Coslett-Charlton LM, Ciccotti MG. Correlation of estradiol in pregnancy and anterior cruciate ligament laxity. Clin Orthop 2001;(June):165–70.
[5] Reese ME, Casey E. Hormonal influence on the neuromusculoskeletal system in pregnancy. In: Fitzgerald CM, Segal NA, editors. Musculoskeletal health in pregnancy and postpartum: an evidence-based Guide for clinicians. Cham: Springer International Publishing; 2015. p. 19–39, doi:http://dx.doi.org/10.1007/978-3-319-14319-4_2 Available from:.
[6] Hakim AJ, Cherkas LF, Grahame R, Spector TD, MacGregor AJ. The genetic epidemiology of joint hypermobility: a population study of female twins. Arthritis Rheum 2004;50(August):2640–4.
[7] Lindgren A, Kristiansson P. Finger joint laxity, number of previous pregnancies and pregnancy induced back pain in a cohort study. BMC Pregnancy Childbirth 2014;14:61.
[8] Ostgaard HC, Andersson GB, Schultz AB, Miller JA. Influence of some biomechanical factors on low-back pain in pregnancy. Spine 1993;18(January):61–5.
[9] Miller BF, Hansen M, Olesen JL, Schwarz P, Babraj JA, Smith K, et al. Tendon collagen synthesis at rest and after exercise in women. J Appl Physiol Bethesda Md 1985 2007;102(February):541–6.
[10] Nygaard IE, Saltzman CL, Whitehouse MB, Hankin FM. Hand problems in pregnancy. Am Fam Physician 1989;39(June):123–6.
[11] Marnach ML, Ramin KD, Ramsey PS, Song S-W, Stensland JJ, An K-N. Characterization of the relationship between joint laxity and maternal hormones in pregnancy. Obstet Gynecol 2003;101(February):331–5.
[12] Bermas BL. Musculoskeletal changes and pain during pregnancy. [cited 2016 November 21]. Available from:. 2016. http://cursoenarm.net/UPTODATE/contents/mobipreview.htm?34/52/35648.
[13] Castellanos J, Smith SR. Poster 279 radial neuropathy exacerbated by ligamentous laxity in pregnancy and by chemotherapy: a case report. PM&R 2016;1(September (8)):S251.
[14] Abramson D, Roberts S, Wilson PD. Relaxation of the pelvic joints in pregnancy. Surg Gynecol Obstet 1934;58:595–613.
[15] Schauberger CW, Rooney BL, Goldsmith L, Shenton D, Silva PD, Schaper A. Peripheral joint laxity increases in pregnancy but does not correlate with serum relaxin levels. Am J Obstet Gynecol 1996;174(February):667–71.
[16] Dumas GA, Reid JG. Laxity of knee cruciate ligaments during pregnancy. J Orthop Sports Phys Ther 1997;26(July):2–6.
[17] Robert H, Nouveau S, Gageot S, Gagnière B. Nouveau système de mesure des laxités sagittales du genou, le GNRB®. Application aux ruptures complètes et incomplètes du ligament croisé antérieur. Rev Chir Orthopédique Traumatol 2009;95(May):207–13.
[18] Küpper JC, Loitz-Ramage B, Corr DT, Hart DA, Ronsky JL. Measuring knee joint laxity: a review of applicable models and the need for new approaches to minimize variability. Clin Biomech Bristol Avon 2007;22(January):1–13.
[19] Jobbins B, Bird HA, Wright V. A Joint Hyperextensometer for the Quantification of Joint Laxity. Eng Med 1979;1(April (8)):103–4.
[20] Beighton P, Solomon L, Soskolne CL. Articular mobility in an African population. Ann Rheum Dis 1973;32(September):413–8.
[21] Boyle KL, Witt P, Riegger-Krugh C. Intrarater and interrater reliability of the beighton and horan joint mobility index. J Athl Train 2003;38:281–5.
[22] Junge T, Jespersen E, Wedderkopp N, Juul-Kristensen B. Inter-tester reproducibility and inter-method agreement of two variations of the Beighton test for determining Generalised Joint Hypermobility in primary school children. BMC Pediatr 2013;13:214.
[23] van Dongen PWJ, de Boer M, Lemmens WAJG, Theron GB. Hypermobility and peripartum pelvic pain syndrome in pregnant South African women. Eur J Obstet Gynecol Reprod Biol 1999;84(May):77–82.
[24] Perret C, Poiraudeau S, Fermanian J, Colau MM, Benhamou MA, Revel M. Validity, reliability, and responsiveness of the fingertip-to-floor test. Arch Phys Med Rehabil 2001;82(November):1566–70.
[25] Baltaci G, Un N, Tunay V, Besler A, Gerceker S. Comparison of three different sit and reach tests for measurement of hamstring flexibility in female university students. Br J Sports Med 2003;37(February):59–61.
[26] López-Miñarro PA, Andújar PS de B, RodrÑGuez-GarcÑa PL. A comparison of the sit-and-reach test and the back-saver sit-and-reach test in university students. J Sports Sci Med 2009;1(March (8)):116–22.
[27] Barbosa AR, Santarém JM, Filho WJ, Marucci M de FN. Effects of resistance training on the sit-and-reach test in elderly women. J Strength Cond Res Natl Strength Cond Assoc. 2002;16(February):14–8.
[28] Gachon B, Desseauve D, Fradet L, Decatoire A, Lacouture P, Pierre F, et al. [Changes in pelvic organ mobility and ligamentous laxity during pregnancy and postpartum. Review of literature and prospects]. Progres En Urol J Assoc Francaise Urol Soc Francaise Urol. 2016;(March):4.
[29] Cunningham FG, MacDonald PC, Gant NF, Leveno KJ, Gilstrap LC. Williams obstetrics 19th edition. 19th edition Norwalk, Conn: Appleton & Lange; 1993.

[30] Cakmak B, Ribeiro AP, Inanir A. Postural balance and the risk of falling during pregnancy. J Matern Fetal Neonatal Med 2015;27(July)1–3 0.
[31] Dumas GA, Reid JG, Wolfe LA, Griffin MP, McGrath MJ. Exercise, posture, and back pain during pregnancy. Clin Biomech Bristol Avon. 1995;10(March):98–103.
[32] Rudolph KS, Schmitt LC, Lewek MD. Age-related changes in strength, joint laxity, and walking patterns: are they related to knee osteoarthritis? Phys Ther 2007;87(November):1422–32.
[33] Zyroul R, Hossain MG, Azura M, Abbas AA, Kamarul T. Knee laxity of Malaysian adults: gender differentials, and association with age and anthropometric measures. Knee 2014;21(March):557–62.
[34] Carvalho MECC, Lima LC, de Lira Terceiro CA, Pinto DRL, Silva MN, et al. Low back pain during pregnancy. Rev Bras Anestesiol 2016;(May):21.