A unified pelvic floor conceptual model for studying morphological changes with prolapse, age, and parity

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Several 2-dimensional and 3-dimensional measurements have been used to assess changes in pelvic floor structures and shape. These include assessment of urogenital and levator hiatus dimensions, levator injury grade, levator bowl volume, and levator plate shape. We argue that each assessment reflects underlying changes in an individual aspect of the overall changes in muscle and fascial structures. Vaginal delivery, aging, and interindividual variations in anatomy combine to affect pelvic floor structures and their connections in different ways. To date, there is no unifying conceptual model that permits the evaluation of how these many measures relate to one another or that reflects overall pelvic floor structure and function. Therefore, this study aimed to describe a unified pelvic floor conceptual model to better understand how the aforementioned changes to the pelvic floor structures and their biomechanical interactions affect pelvic organ support with vaginal birth, prolapse, and age.

In this model, the pelvic floor is composed of 5 key anatomic structures: the (1) pubovisceral, (2) puborectal, and (3) iliococcygeal muscles with their superficial and inferior fascia; (4) the perineal membrane or body; and (5) the anal sphincter complex. Schematically, these structures are considered to originate from pelvic sidewall structures and meet medially at important connection points that include the anal sphincter complex, perineal body, and anococcygeal raphe. The pubovisceral muscle contributes primarily to urogenital hiatus closure, whereas the puborectal muscle is mainly related to levator hiatus closure, although each muscle contributes to the other. Dorsally and laterally, the iliococcygeal muscle forms a shelflike structure in women with normal support that spans the remaining area between these medial muscles and attachments to the pelvic sidewall. Other features include the levator plate, bowl volume, and anorectal angle. The pelvic floor conceptual model integrates existing observations and points out evident knowledge gaps in how parturition, injury, disease, and aging can contribute to changes associated with pelvic floor function caused by the detachment of one or more important connection points or pubovisceral muscle failure.

Key words: levator ani avulsion, levator ani muscle, levator bowl volume, levator hiatus, pelvic floor conceptual model, pelvic floor muscle injury, pelvic floor shape, pelvic organ prolapse, urogenital hiatus

Introduction

The female pelvic floor is composed of muscles and connective tissues supporting the abdominopelvic organs and closing the pelvis caudally. We shall see that 1-dimensional, 2-dimensional (2D), and 3-dimensional (3D) measurements have been used to describe the morphology of different aspects of the floor along with grading systems for assessing levator muscle injury.[1,2] To date, there is no unifying conceptual model that allows us to evaluate how these many different measures relate to one another or how they reflect overall pelvic floor function.

The pelvic floor forms a shelflike structure with a ventral opening at the bottom of the abdominopelvic cavity

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Received Aug. 24, 2023; revised Nov. 21, 2023; accepted Nov. 23, 2023.

J.O.D. and S.M. share first authorship.

The authors report no conflict of interest.

J.O.D. and J.A.A.M. receive funding from the National Institutes of Health (NIH; grant number: RC2 DK122379). L.C. receives funding from the NIH (grant number: R01 HD094954). The NIH played no role in the study design; collection, analysis, and interpretation of data; writing of the report; or decision to submit the article for publication.

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0002-9378 • • https://doi.org/10.1016/j.ajog.2023.11.1247

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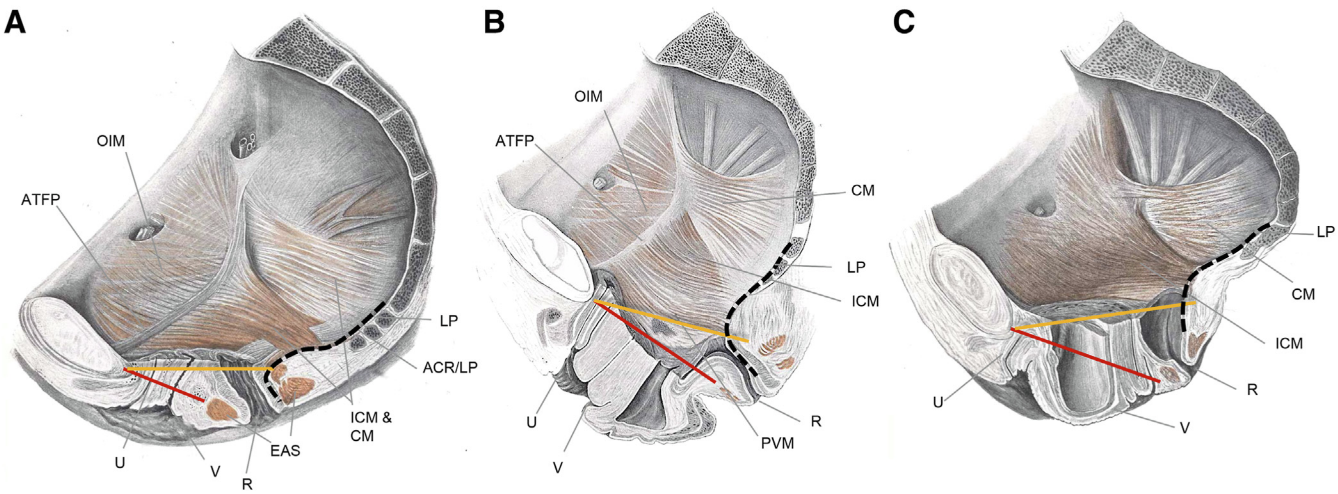
FIGURE 1
Illustrations drawn from cadaver dissection of the female pelvic floor



A, Left lateral view of a normal pelvic floor after removal of the upper pelvic organs. **B and C,** Midsagittal view of 2 women with pelvic organ prolapse. *Red lines* represent the urogenital hiatus, *yellow lines* represent the levator hiatus, and the *black dotted line* represents the levator plate. The 3 different images were chosen to illustrate that the pelvic floor changes seen with prolapse are different in different individuals (note the levators sagging downward in **B**, whereas they are more horizontal in **C**). Adapted from Halban and Tandler.[3]

ACR, anococcygeal raphe; *ATFP*, arcus tendinous fascia pelvis; *CM*, coccygeus muscle; *EAS*, external anal sphincter; *ICM*, iliococcygeal muscle; *LP*, levator plate; *OIM*, obturator internus muscle; *PVM*, pubovisceral muscle; *R*, rectum; *U*, urethra; *V*, vagina.

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(Figure 1). It counteracts the forces placed on the pelvic organs by the weight and inertial forces of the abdominal contents and the intra-abdominal pressure associated with daily activities. Muscle action serves to close the opening (hiatus) in its anterior portion, helps maintain urinary and fecal continence, is involved in sexual function, and allows for childbirth. It primarily consists of the levator ani muscle (LAM) and its fascial coverings that span the bony pelvic canal. The medial portions arise from the pubic bones to close the hiatuses through which the pelvic organs pass by attaching to the lower portions of pelvic viscera and interacting with the perineal body and membrane. In this role, the LAM prevents excess force from being applied to the ligaments and fascial structures that connect the pelvic organs to the pelvic walls.[4]

Anatomic consensus[5] recognizes that the LAM has 3 components: pubococcygeus (also known as the pubovisceralis [PVM][1]), puborectalis (PRM), and iliococcygeus (ICM). The urogenital hiatus (UGH) lies between the pubis and perineal body and is flanked by the PVM; the levator hiatus (LH) has the same ventral and lateral borders but extends to behind the anorectal angle. Dorsal and lateral to the PRM and PVM, the ICM closes the "pelvic floor bowl" and forms a shelflike structure ("shelf") from the anal canal to the sacrum and coccyx. Of note, 2 examples of prolapse-associated changes in pelvic floor shape and hiatus configuration can be seen by comparing cadaveric dissection of an individual with normal support (Figure 1, A) and 2 individuals with advanced pelvic organ prolapse (Figure 1, B and C). With prolapse, the levator plate is more vertically oriented in Figure 1, C, and the UGH and LH are larger in Figure 1, B. In addition, descent of the entire pelvic floor and deepening of the bowl-like shape formed can easily be seen in Figure 1, B, but not to the same degree in Figure 1, C.

Various measurements to assess structural alterations in the pelvic floor have been developed over the last 30 years using ultrasound and magnetic resonance imaging (MRI). Each measurement has been described to reflect a specific dimension or shape in 4 domains:

1. Anterior-posterior (AP) and transverse diameters and area of the LH and UGH.[6]
2. Levator plate angle and shape,[7–11] which refer to the inclination and shape of the midsagittal aspect of the levator ani behind the rectum represented by the decussation of the iliococcygeal muscles in the midline (anococcygeal raphe).
3. Levator bowl volume, an MRI measure of the 3D space contained between the LAM and a plane based on the sacrococcygeal junction-to-inferior pubic point reference line that reflects the overall downward displacement of the pelvic floor.[12] Other simple measures have been used as surrogates for bowl volume (M-Line, H-line, midsagittal area[13–15]) and measures of its shape (V-U index).[16]
4. Variations in the rimlike upper margin of the levator ("rim") that attaches to the pelvic walls have also been studied because a larger area that must be

[1]We have chosen to use the term pubovisceral muscle rather than pubococcygeal muscle listed in *Terminologia Anatomica* (TA) because the former term reflects the origin and insertion and the TA term was selected on evolutionary terms and misrepresents what the muscle does.

spanned by the muscles would mean a given abdominal pressure would exert a great force on its surface.[17]

In addition, recent studies have focused on the perineal membrane around the UGH, which maintains its closure via its interconnections with the LAM and the perineal body.[18]

This study aimed to describe a unified conceptual model to better understand how the aforementioned changes to the pelvic floor structures and their biomechanical interactions affect pelvic organ support with vaginal birth, prolapse, and age. This framework—the pelvic floor conceptual (PFC) model—integrates existing data, examines the pelvic floor's structures and their relationship to each other, and helps to identify knowledge gaps. Here, we will first present an overall framework for understanding pelvic floor deformation and then consider biomechanical hypotheses for the effect of different changes on pelvic organ support.

Visual displaying of shape variation

Examples of variations that occur in pelvic floor shape are shown as levator bowl volumes in Figure 2, A—D. To aid the visualization of the shape changes to the pelvic floor structures, we used isocurves similar to those used for 2D rendering of 3D shapes. Figure 2, E, shows lines outlining bowl volumes from a nullipara (in black lines) and prolapse (in red lines). The lines represent the different elements of shapes or structures. The changes in levator shape and hiatal configuration area reflect changes in these individual elements of the levator ani and perineal complex. It is evident that the structures involved in these shape changes are all intimately connected and that alterations in 1 aspect of this system affect all other parts.

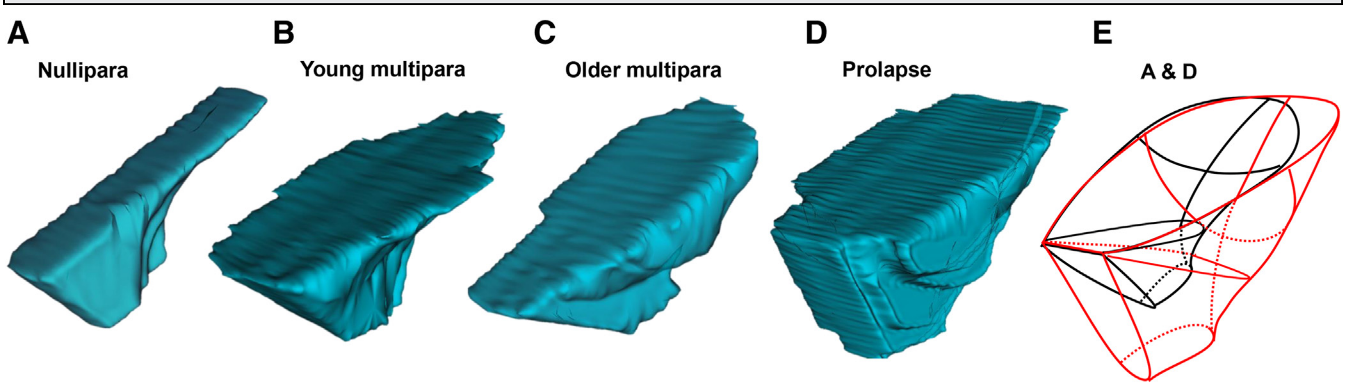
Toward development of a pelvic floor conceptual model

The depth of existing evidence for the different elements of the pelvic floor structural complex varies greatly. For example, most research concerning the LAM's role in pelvic organ support has focused on quantifying levator injury[19—21] and assessing the size of the LH and UGH through which prolapse occurs. This includes recent high-level evidence establishing the importance of an enlarged UGH in pelvic organ prolapse occurrence.[6] However, hiatal size and levator injury do not capture all aspects of pelvic floor configuration. Only a small portion of hiatal enlargement is associated with muscle defect, and half of the women with prolapse do not have substantial levator damage.[22,23] This suggests that mechanisms other than muscle injury play a role, such as the overall downward displacement of the muscles that occurs with aging.[16] Each change is a consequence of alterations in the muscular and fascial structures and the loads placed upon them. For example, the pubic portions of the levator ani constrict the hiatuses, and the ICM creates a dorsal and lateral floor or shelf spanning the lateral and posterior aspects of the pelvic canal; along with their superior fascia, they support the organs. Therefore, an overall conceptual framework is needed to evaluate how these various individual metrics relate to one another and to the overall changes in LAM shape during the life span. The Appendix provides an example of such a conceptual framework assessment, summarizing the degree of association between patient-specific variables and their effect on the structures, which is currently based on expert opinion only.

The pelvic floor conceptual model

The PFC model is composed of a "structural" model (Figure 3, A) that relates the essence of the important anatomic structures with their connections and an "interactions" model (Figure 3, B) that schematically displays how 1 structure or element might be associated with another. These 2 models capture essential anatomy, geometry, and points of connection for the pelvic

FIGURE 2
The 3D levator bowl models



The top row shows sample 3D levator bowl models. **A,** Nulliparous young patient. **B,** Multiparous young patient. **C,** Nulliparous older patient. **D,** Older multiparous patient affected by pelvic organ prolapse. **E,** Superimposed conceptual model of the bowl volumes in **A** and **D** using isocurves. Isocurves are the 3D curves representing the contour on 3D surfaces that are widely used in computer graphics and 3D model rendering.

3D, 3-dimensional.

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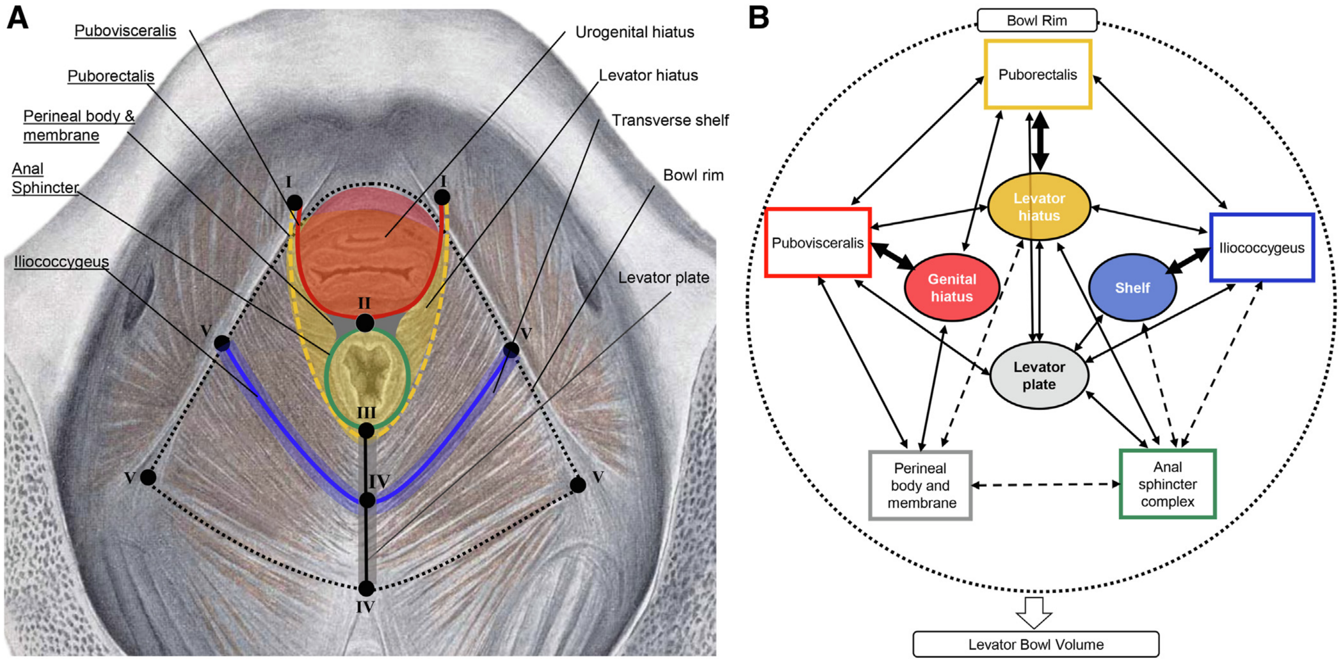
FIGURE 3
PFC model



A, Illustrations drawn from cadaver dissection of the female pelvic floor from above, after removal of the upper pelvic organs showing the structures (*underlined*), elements, and connection points (*black dots*) of the proposed PFC model. **B,** A schematic view of all the different connections among the different elements (in *circles*) and anatomic structures (in *rectangles*), shown as *color-coded solid lines* relating to the structures shown in **A**. *Bold arrows* indicate well-known relationships between 2 elements, whereas *dashed lines* show less studied or less known connections.

PFC, pelvic floor conceptual.

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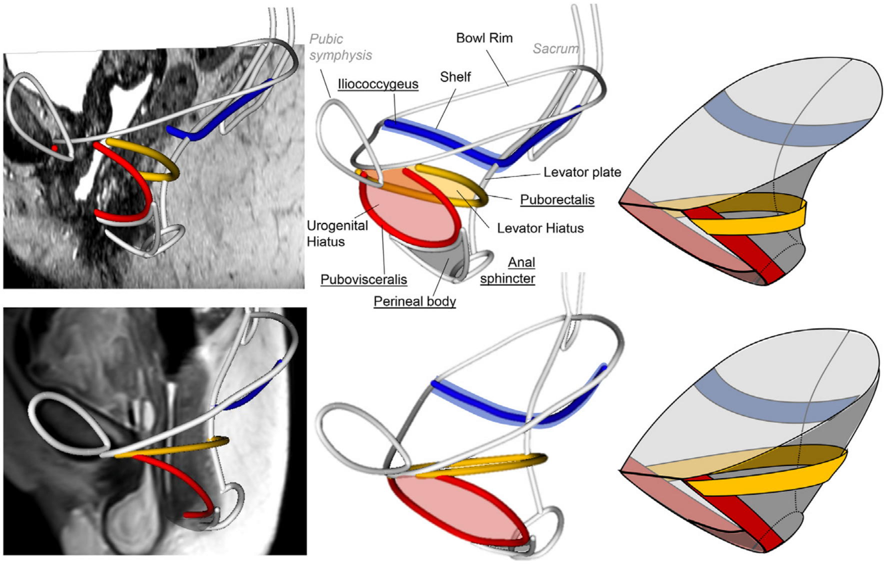
floor elements and the ways that they may affect one another. The structural model (Figure 3, A) is biomechanically based, whereas the interaction model (Figure 3, B) serves as a template to assess the presence and strengths of the associations among various measurements based on evolving data. These models show how the results of different measurements can be synthesized both functionally and statistically into an overall understanding. Moreover, it can point toward knowledge gaps in our current understanding as we seek to determine how parturition, injury, disease, and aging contribute to changes associated with pelvic floor function.

A visual display of our conceptual framework is shown in Figure 4 and the Video, demonstrating the primary structural "elements" that can be measured. These elements have been studied previously[6–17] and are represented here as lines, which were taken directly from the MRI scans using 3D Slicer, a free open-source software application for medical image computing.[24] The difference between the 2 models shown is noteworthy. For example, the blue line representing the ICM has a different shape in the woman with advanced prolapse (bottom), resulting in a concave "U" shape of the bowl. In addition, the enlarged hiatal size with prolapse is visible. Of interest, the ring representing the inside of the anal sphincter is also enlarged—something not typically remarked on with prolapse—thus illustrating how the PFC model (provided below) may identify novel aspects of pelvic floor deformation not previously considered. Each element captures singular changes happening in the region of corresponding anatomic structures, but all elements are part of the overall shape change that occurs with aging, parity, and other disease processes that eventually lead to pelvic floor support failure. Although each element can be analyzed "independently," there are important connection points between the different structures.

Figure 5 lists the anatomic structures (eg, PVM), their connection points, and the "measurable" elements (eg, UGH) that compose the PFC model.[25–31] These elements and connections are based on primary published anatomic observations. For example, the levator plate, a term coined by Halban and Tandler,[3] corresponds to the posterior segment where the LAM unites with its ICM counterpart. Anatomically, it is bounded by the midline iliococcygeal raphe, a characteristic feature easily recognizable on midsagittal MRI scans.

For each structure and element, several measurements have been described (Figure 5, "features"). For example, the UGH is most often measured using an AP diameter but also has a transverse diameter, area, and

FIGURE 4
Structural elements of the proposed conceptual model



Examples of the proposed conceptual model from 3D MRI reconstructions from specific subjects made on the 3D Slicer.[23] The top row shows a woman with normal support; the bottom row shows a woman with pelvic organ prolapse. The left panels show an MRI midsagittal view with the 3D model superposed. The central panels show a 3D view of the model and its orientation compared with the pelvic bones. In the right panels, the key muscles are represented as bands. The anatomic structures (*underlined*) include the levator ani muscle subdivisions (PVM, PRM, and ICM), the perineal body and membrane, and the anal sphincter ring. The structural elements include the levator hiatus and urogenital hiatus, the levator plate, the transverse shelf, the bowl "rim," and the bowl itself.

3D, 3-dimensional; *ICM*, iliococcygeus; *MRI*, magnetic resonance imaging; *PRM*, puborectalis; *PVM*, pubovisceral muscle.

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shape.[6] A unilateral injury might result in an asymmetric shape without necessarily altering the UGH area or length.[32] Similarly, a woman with a bilateral avulsion might have a wider hiatus than a woman with a similar AP diameter but who has intact but stretched muscles. Another example is the age-related lateral sagging and posterior ballooning of the levator plate, which is interconnected with the ICM shape change.[16] Except for birth trauma, it is currently unknown whether the changes to the levator plate are due to changes in the ICM or vice versa.[10] Similar bowl volumes or hiatal dimensions could be the result of different adaptational mechanisms, so we cannot currently establish the original cause of pelvic floor shape changes.

Figure 6 illustrates 6 areas of pelvic floor structural deformation: (1) the UGH, (2) the LH, (3) the levator plate, (4) the transverse shelf, (5) the bowl "rim" size, and (6) the levator ani avulsion. For each example in the diagram, the dotted red line represents the normal state, and the solid red line demonstrates the imposed changes. It can immediately be seen that alterations in any 1 aspect have consequences for the others. For example, to change the levator plate angle, the puborectal muscle needs to lengthen, the anal sphincter complex needs to stretch, or both.

Principal component analysis (PCA) can be employed to perform statistical shape analysis for characterizing alterations in the pelvic floor shape. This technique determines what aspect of shape variation is the most influential (PC1) in capturing the observed variation, then the second most influential (PC2), etc. This approach allows us to determine the strongest aspects of pelvic floor shape variation so that they can be evaluated relative to factors, such as age, parity, muscle injury, and prolapse.

Figure 7 provides 1 example of the use of PCA[7] to investigate how pelvic floor shape can be analyzed independent of differences in size. It compares levator plate shape in women with and without recurrence after prolapse surgery. The raw data of the actual shapes, scaled to be of similar size, are shown. PCA identified 2 primary ways in which the shape varied (PC1 and PC2). PC1 shows rotation from the sacrococcygeal joint, and PC2 indicates caudal-cranial descent. Each component is defined as the degree of variation from the mean and allows for a quantitative comparative analysis between women with normal support after surgery and those who have experienced postoperative failure and prolapse recurrence.[7] Our results showed that 61% of the shape change was due to levator plate rotation (PC1) and that 30% of the shape change was due to cranial descent (PC2); the remaining 9% of the shape variation was not characterized by these measures.[7] Only PC1 differed between women with and without recurrence.

Biomechanical consequences of pelvic floor changes

The pelvic organs are attached to the pelvic sidewalls by connective tissue; therefore, changes in the pelvic floor affect these fascial attachments.[33,34] There are 2 mechanical ways in which changes in the pelvic floor can affect organ support (Figure 8).

The first mechanism has to do with forces generated by pressure differentials between intra-abdominal and atmospheric pressure when the hiatuses fail to close and the vaginal wall becomes exposed to that pressure.[4,33,34] This creates a downward force that places abnormal stresses on the connective tissues that attach pelvic organs to the pelvic sidewall, leading to subsequent tension on the apical ligaments and paravaginal attachments.[35]

The second mechanism results from the overall downward movement of the pelvic organs as the floor is displaced caudally.[9] Hiatal enlargement shifts the levator plate to a more dorsal direction, which, in association with a caudal shift of the organs, results in increased connective tissue attachment loading and stretch. It is well known that the opening of the pelvic floor and descent are related, but not all individuals will have the same combination of changes. To understand the biomechanical consequences of pelvic floor dysfunction, each phenomenon needs a separate assessment, followed by an evaluation of the interactions.

Muscle function, fascia covering, and levator shape

The shape of the pelvic floor as a unit derives from the LAM's structural and histological integrity,[36,37] its anatomic cross-sectional area perpendicular to the fiber direction, and its activation by the sophisticated neural control mechanisms that govern its "resting" tone, reflex activation, and voluntary contraction.[38] As the muscle relaxes, its superficial fascia can also help resist the

FIGURE 5
Structures, elements, and connection points of the pelvic floor conceptual model

Anatomical Structure	Anatomical Features	*Connection Points*	Measurements	Measurement Features
Pubovisceral Muscle (L,R)[24,25]	▪Length ▪Shape ▪Thickness ▪Defect/avulsion ▪Symmetry	***I. Pubic bone origins (L,R)***	**Urogenital Hiatus**	▪Antero-posterior diameter ▪Transverse diameter ▪Area ▪Shape ▪Symmetry
Puborectal Muscle (L, R)[24,25]	▪Length ▪Shape ▪Thickness ▪Symmetry	***II. Perineal body***	**Levator Hiatus**	▪Antero-posterior diameter ▪Transverse diameter ▪Area ▪Shape (V-U index) ▪Symmetry
Iliococcygeal Muscle (L, R)[24,25]	▪Length ▪Shape ▪Thickness ▪Symmetry	***III. Anal sphincter complex***	**Levator Plate**	▪Shape ▪Angle ▪PC1 – PC2
Perineal Membrane[26,27] Perineal Body[28,29]	▪Position ▪Injury • swinging door • midline separation • dorsal spreading • stretching	***IV. Levator plate/ anococcygeal raphé connections***	**Transverse Shelf**	▪Shape ▪Depth ▪Length
			Bowl Rim	▪Antero-posterior diameter ▪Transverse diameter ▪Area ▪Shape
Anal Sphincter Complex[30]	▪Position ▪Shape	***V. Ischial spines/ ATLA (L,R)***	**Levator Bowl Volume**	▪Shape ▪Depth ▪Volume

Connection points are enumerated I to V as shown in Figure 4.

L, left; *R*, right.

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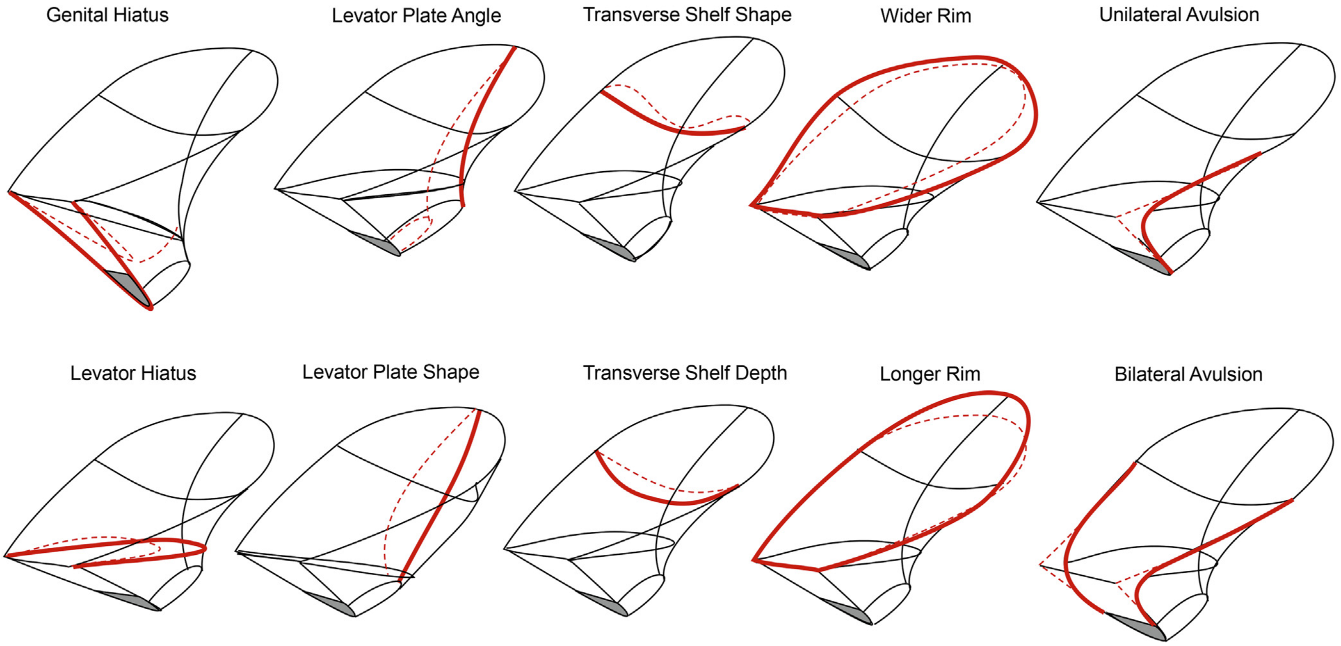
FIGURE 6
Areas of possible structural deformationin the conceptual model



The *dotted line* represents the normal configuration. The *solid red line* indicates an example of a structural alteration from the normal configuration.

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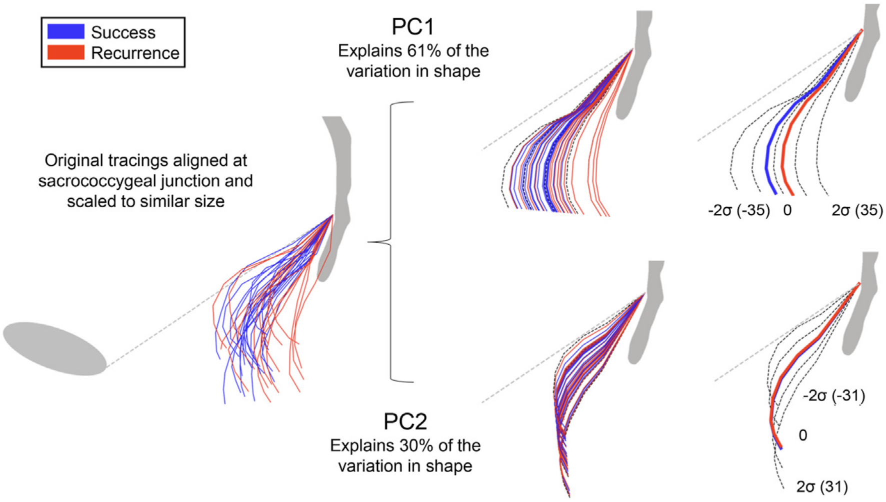
FIGURE 7
Levator plate shape variations



Variations in 16 women with postoperative failure (*red*) and 19 women with normal postoperative support are shown. On the right, the analysis identified 2 main modes of shape variations (PC1 and PC2). At rest, PC1 accounted for 61% of shape variation, and PC2 accounted for an additional 30% of variation. The PC1 scores differed significantly between the success and recurrence groups, whereas PC2 score distributions were similar between groups.

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downward forces placed on it by static and dynamic loads. Thus, unlike muscles of the arms and legs, whose elongation is typically limited by the joint's range of movement, the pelvic floor's descent is limited by the stretch of its connective covering. It is beyond the scope of this article to review all of these important information, but we will highlight a few examples.

The accumulation of cellular and molecular damage with aging creates a progressive loss of muscle physiological integrity, leading to impaired function.[39] Specifically, age-related modifications to the LAM are a result of cellular senescent changes, chronic inflammation, repetitive mechanical stress, and myogenic and neurogenic changes.[38] Previous studies on cadaveric tissue specimens found a significant increase in LAM intramuscular collagen with aging and a reduction in its cross-sectional area.[40]

The maximal isometric force that the LAM can generate is affected by the integrity of its pubic bone and arcus tendineus levator ani origins and whether the force transmission is normal or abnormal because of injury and compensated for by lateral force transmission to adjacent structures. Effects of birth-related injury and other factors altering the muscle's structure (such as connective tissue impairment, neuropathic injury, and aging) result in an altered muscular line of action and length-tension relationship.

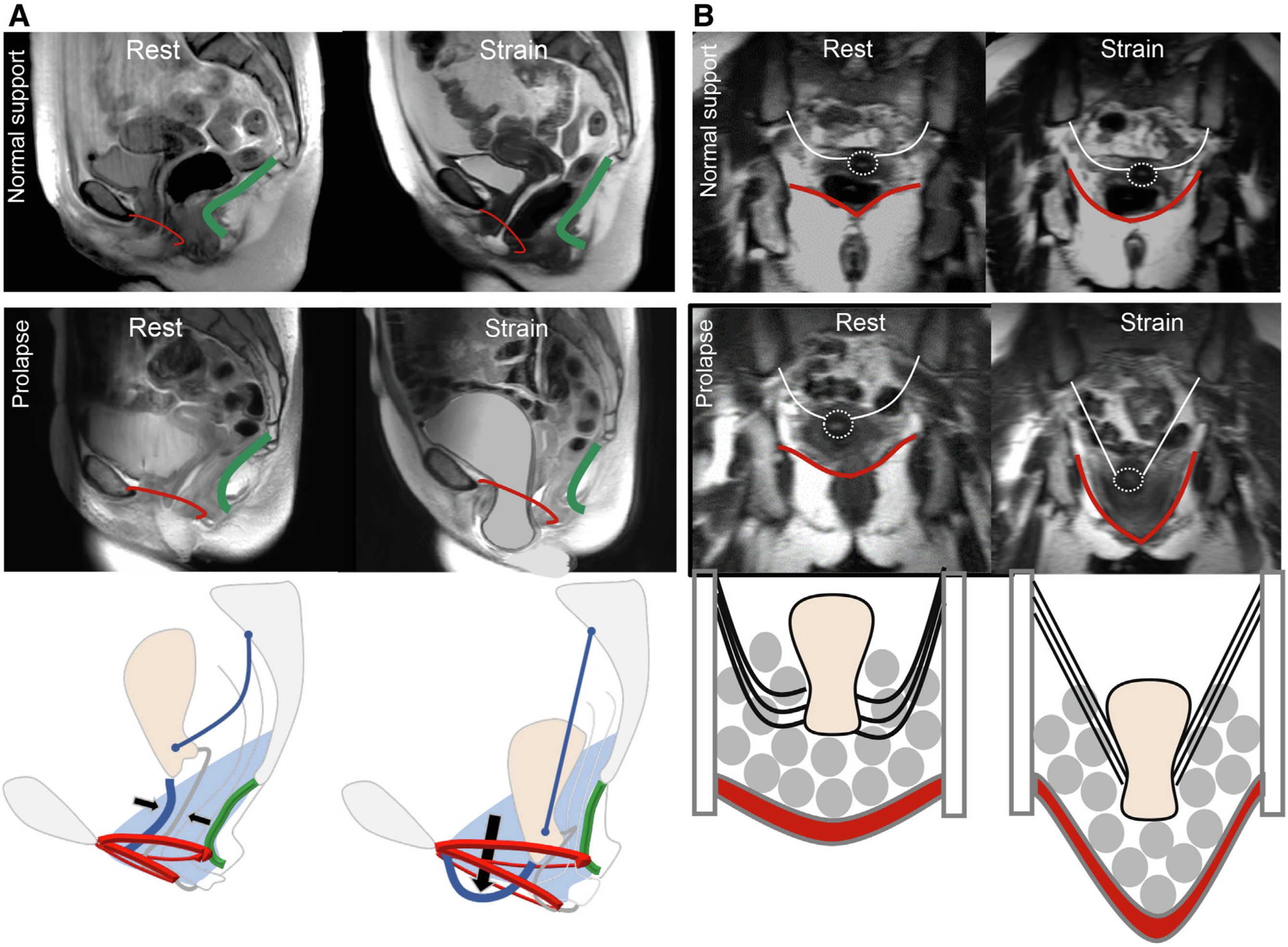
Last, the framework includes the bowl "rim," which can be considered as a function of bony pelvic dimensions. There are several theories as to how different bony pelvis dimensions predispose women to pelvic floor dysfunction. For example, a larger pelvis might be associated with pelvic floor dysfunction because of larger caudal forces for a given intra-abdominal pressure on the larger cross-sectional area.[17,41,42] Conversely, a larger bony pelvis and pelvic floor may undergo less stretching and be at lower risk of injury during vaginal birth.[43] Our understanding of these mechanisms is still limited. Furthermore, the biomechanics and interaction of different forces and support structures are poorly understood. The PFC model does not yet account for muscle strength but rather shows how muscles can affect pelvic floor shape and, consequently, its function.

Factors that can alter pelvic floor morphology

Aging and parity are key risk factors for prolapse[44] and are highly correlated to shape and dimensional changes of different pelvic floor structures. For example, aging, in the absence of childbirth, is associated with increased levator bowl volume and a downward posterior and lateral sagging of the levators.[16] Levator bowl volume increases with age independent of childbirth changes to the UGH; this increase is reflected in a change in the shape of the levator muscles ("V-U index")[16] and of the levator plate on both the ventral-dorsal and cephalic-caudal directions.[7] Vaginal parity is associated with an increase in GH size that might occur without necessarily changing the posterior aspects of the bowl, as the hiatal area only explains 56% of bowl volume change[15]—suggesting that 2 interrelated but different phenomena are involved. Both these changes result in an increased tension on apical and paravaginal ligaments, leading over time to impaired support.

The PFC model principally examines the shape changes arising from prolapse. Knowledge gaps still exist related to the histological, cell-level, and molecular changes of the various pelvic floor structures—including the extracellular matrix composition and collagen polymorphisms in the connective tissues. In prolapse recurrence, potential mechanisms involve generalized descent and ballooning of the levators and hiatal enlargement. However, current surgical techniques fail to address these changes directly, thus explaining at least a portion of the current recurrence rate of 30%.[44] Studies on how to identify individual failure patterns are lacking, although efforts are being made to understand specific failure sites.[45] In the era of personalized medicine, a quantitative framework identifying individual pelvic floor failure sites is necessary for informed decision-making regarding which surgery fits the individual needs

FIGURE 8
Biomechanical consequences of pelvic floor changes



A, Midsagittal scans from 2 different women at rest and strain. The top row shows a magnetic resonance image of a woman with normal support at rest and maximal Valsalva maneuver (strain). The middle row shows a woman with uterine prolapse at rest and maximal Valsalva maneuver. The bottom row shows a schematic model simulating the changes in hiatus size and levator plate angle that happen with prolapse. *Red circles* simulate the hiatuses, and *green bands* simulate the levator plate. **B,** Coronal scans from 2 different women at rest and strain. The bottom row shows a model simulating the tension on the apical ligaments in the case of impaired support at rest and maximal Valsalva maneuver. *Gray circles* simulate intra-abdominal pressure effect on the muscles (*red band*).

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of each patient. In the future, the development of surgical planning platforms based on biomechanical models may aid in predicting outcomes following different surgical treatment strategies, such as the decision about whether to correct an enlarged hiatus or a deepened levator bowl.

Conclusions

The PFC model was defined to include 5 anatomic structures, 10 schematic connection points of 5 different types, 2 hiatuses, and several important measurable elements. It provides a conceptual framework to test hypotheses involving the interactions of these structural supports in pelvic floor research. It illustrates how changes to any 1 structure and its connections require an understanding of how this alteration affects other parts of the system. In addition, it permits the study of how vaginal delivery, aging, interindividual anatomic variation, or different combinations of these factors are involved. Such insights are needed to better understand the structural and functional implications of how the pelvic floor resists the loads imposed on it during the life span. ■

ACKNOWLEDGMENTS

We thank Sarah Block, BGS for assistance in preparing the manuscript for submission and Jennifer LaCross, PhD for helping with the video editing and voice-over.

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SUPPLEMENTAL TABLE

Sample framework for assessing the strength of existing literature on degree of associations of different structures and patient-specific variables[a]

Structure	Age	Parity	Prolapse	Prolapse surgical failure
Urogenital hiatus	+[1]	+++[1]	+++[1,2]	++[1,3,4]
Levator hiatus	++[1]	+++[1]	+[1]	+++[1,4]
Levator plate	—	—	+[1,5]	++[4]
Pubovisceral muscle or levator injury	+[1,6]	+++[1,6]	++[1,7]	—
Puborectal muscle	—	—	—	—
Iliococcygeal muscle	—	—	—	—
Levator bowl volume	++[1,8]	++[1,9]	++[1,8,10]	—
Bowl rim or bony pelvis	—	—	+[11]	—
Perineal body and membrane	—	++[2,12]	+[13]	—
Anal sphincter complex	—	—	—	—

Legend: +++, state-of-the-art review; ++, multiple studies; +, 1 article, knowledge gap.

[a] Currently based on expert opinion, not evidence based.

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