LISBOA
UNIVERSIDADE DE LISBOA

FACULDADE DE MEDICINA LISBOA

TRABALHO FINAL
MESTRADO INTEGRADO EM MEDICINA

Instituto de Anatomia

Predicting penile length increase after release of its suspensory ligament – an anatomical study

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JULHO'2021

RESUMO

Introdução: o tamanho do pénis é valorizado por muitos indivíduos, e atualmente existe a possibilidade de aumentar o seu comprimento cirurgicamente – todavia, o procedimento mais popular, a secção do ligamento suspensor do pénis, produz resultados pouco previsíveis, e não é isenta de riscos. **Objetivos:** este estudo tem como objetivo estabelecer correlações morfoclínicas entre variáveis anatómicas e clínicas e o aumento em comprimento do pénis flácido, após secção completa do ligamento suspensor, e que permitam prever, no pré-operatório, o grau de aumento em comprimento peniano espectável em cada caso individual. **Materiais e métodos:** foi realizado um estudo transversal experimental em 16 pénis de cadáveres humanos adultos, e colheram-se os seguintes dados: idade de morte, ascendência, altura, morfotipo, comprimento da porção livre do pénis antes da divisão do ligamento suspensor (L1) e a espessura do ligamento suspensor (W). Após a secção do ligamento suspensor do pénis, mediu-se a profundidade da sínfise púbica (D) e o comprimento da porção livre do pénis após o procedimento (L2). Coeficientes de correlação e múltiplos modelos de regressão linear foram utilizados para investigar relações entre estas variáveis. **Resultados e discussão:** foi possível obter um aumento do comprimento peniano em todos os indivíduos. Estabeleceram-se correlações entre L1 e L2, o aumento absoluto do comprimento peniano (S) e o aumento relativo do comprimento peniano (RS); e entre a altura e L2. O modelo linear generalizado indicou que W e o morfotipo, em conjunto com L1, também influenciam L2. **Conclusão:** é possível prever o aumento do comprimento do pénis previamente à cirurgia utilizando parâmetros anatómicos facilmente avaliáveis.

Palavras-chave

Pénis; Anatomia; Tamanho/Fisiologia de Órgão; Sexualidade; Procedimentos Cirúrgicos Urogenitais.

ABSTRACT

Introduction: penile size is a known concern amongst men, and nowadays they're being offered the possibility of having this organ surgically lengthened – however, the most popular procedure, the release of the suspensory ligaments of the penis, produces unpredictable results and comes with a number of possible risks. **Objectives:** the aim of this study is to establish morpho-clinical correlations between anatomically and clinically pertinent variables to penile lengthening surgery and the increase in length of the mobile flaccid penis after complete division of the suspensory ligament proper, to later be used for pre-op evaluation of men wishing to undergo this procedure. **Materials and methods:** an experimental cross-sectional study has been performed on 16 penises from adult cadavers, and the data collected included: age at death, ethnicity, body habitus, preservation method, height, length of the penis before ligamentolysis (L1), width of the suspensory ligament proper (W). Following the complete division of the suspensory ligament of the penis, the depth of the pubic symphysis (D) and the length of the penis after the procedure (L2) were measured. Correlation coefficients and multiple linear regression models were used to investigate relations between these variables. **Results and discussion:** penile lengthening was achieved in all individuals. Correlations were established between L1 and L2, the absolute length increase (S) and the relative length increase (RS); and between the height and L2. A generalized linear model indicated that W and the body habitus, along with L1, also influenced length gain. **Conclusions:** it is possible to predict the penile length increase pre-operatively using easily measurable anatomical parameters.

Keywords

Penis; Anatomy; Organ Size/Physiology; Sexuality; Urogenital Surgical Procedures.

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1 LIST OF ACRONYMS AND ABBREVIATIONS

D Depth of the pubic symphysis

DIFD Departamento de Investigação, Formação e Documentação do Instituto Nacional de Medicina Legal e Ciências Forenses

INMLCF Instituto Nacional de Medicina Legal e Ciências Forenses

L Length of the mobile flaccid penis

L1 Length of the mobile flaccid penis before the complete division of the suspensory ligament proper of the penis

L2 Length of the mobile flaccid penis after the complete division of the suspensory ligament proper of the penis

PMMA Polymethylmethacrylate

PTT Penile traction therapy

RS Relative penile length increase after the complete division of the suspensory ligament proper of the penis

S Absolute penile length increase after the complete division of the suspensory ligament proper of the penis

VT Vacuum therapy

W Width of the suspensory ligament proper of the penis

2 INTRODUCTION

2.1 Historical, social and psychological significance of penile size

Penile size has worried men throughout the ages (Bizic & Djordjevic, 2016; Chung & Kim, 2016; Dillon et al., 2008; Mertziotis et al., 2013; Vardi, 2006; Vardi et al., 2008; Vardi & Gruenwald, 2009; Vardi & Lowenstein, 2005), and this concern meets no geographical or cultural boundaries.

Innumerous references can be found regarding the most diverse methods employed around the world to achieve enhancement of the penile size. In India, the Sadhus holy men use weights to increase penile length (Vardi et al., 2008; Wylie & Eardley, 2007), and this practice is also present within the Cholomec tribe in Peru (Vardi et al., 2008) and the Caramoja tribe in Uganda (Bizic & Djordjevic, 2016). In the Topinama tribe of Brazil, men incite venomous snakes to bite their penis, inducing penile swelling that lasts up to six months (Wylie & Eardley, 2007).

With few exceptions, namely the ancient Greeks (Chung & Kim, 2016; Dillon et al., 2008; Panfilov, 2006), most cultures revere larger penises. The penis is perceived as a symbol of masculinity (Alter et al., 2011; Bizic & Djordjevic, 2016; Bogaert & Hershberger, 1999; Dillon et al., 2008; Drummond & Filiault, 2007; Kibby & Costello, 1999; Lehman, 1998; Lever et al., 2006; Nugteren et al., 2010; Stulhofer, 2006; Van Driel et al., 1998; Wylie & Eardley, 2007), sexual prowess (Alter et al., 2011; Bizic & Djordjevic, 2016; Panfilov, 2006; Van Driel et al., 1998), fertility (Bogaert & Hershberger, 1999; Drummond & Filiault, 2007; Lehman, 1998; Stulhofer, 2006; Wylie & Eardley, 2007), strength, intelligence, courage (Van Driel et al., 1998; Wylie & Eardley, 2007), power (Bogaert & Hershberger, 1999; Drummond & Filiault, 2007; Lehman, 1998; Stulhofer, 2006; Wylie & Eardley, 2007), stamina (Bogaert & Hershberger, 1999; Drummond & Filiault, 2007; Lehman, 1998; Stulhofer, 2006; Wylie & Eardley, 2007) and social status (Bogaert & Hershberger, 1999; Drummond & Filiault, 2007; Lehman, 1998; Stulhofer, 2006). The physical dimensions of the organ are directly associated with these traits, creating the notion that a larger penis makes a better man (Lever et al., 2006), which in turn has a negative impact on the self-esteem and mental health of men who perceive their penis as small (Ackard et al., 2000; Faith & Schare, 1993; Grov et al., 2010; Johnston et al., 2014; Lever et al., 2006; Spyropoulos et al., 2005; Vardi & Lowenstein, 2005). On the other hand, there is evidence that men who have larger penises feel better about their

bodies, report a more positive body image and greater satisfaction with their physical appearance, and feel sexually more competent and less unease with exposing their body during sexual activities (Francken et al., 2002; Johnston et al., 2014; Lever et al., 2006).

Presently, media has taken a strong role in highlighting this link between penis size and masculinity (Frederick et al., 2005; Lever et al., 2006; Nugteren et al., 2010). Pornography normalizes extraordinary penile dimensions, skewing people's insights on the size of male genitalia towards the larger, and unrealistic, end of the spectrum (Alter et al., 2011; Frederick et al., 2005; Lever et al., 2006), and exaggerates female's responses to their acting partner's oversized penis (Johnston et al., 2014). These misconstructions lead men to overestimate the average penis size and underestimate the size of their own penis (Lever et al., 2006) as well as misjudging the importance of penis size to women – who usually don't consider it an important issue (Francken et al., 2002), as most women tend to be satisfied with their partner's penis size (Lever et al., 2006), consider the average penis size close to ideal (Johnston et al., 2014) and very infrequently complain about the fact that their partner's penis is too small (Van Driel et al., 1998). It should be noted, however, that some studies did find that women tend to prefer penises with above-average dimensions (Francken et al., 2002; Prause et al., 2015), as well as misremember their partners attributes as smaller than they actually are – which may contribute to aggravate men's anxieties about their own penile size and explain why most men seeking to surgically lengthen their penises actually have average-sized genitalia (Prause et al., 2015).

These misconceptions create feelings of inadequacy in men, who become targets for an increasing number of advertisements on behalf of penile augmentation medications and techniques – including penile enlargement surgery, which is becoming increasingly popular (E Austoni et al., 2002; Lever et al., 2006; Littara et al., 2019; Spyropoulos et al., 2005; Vardi & Lowenstein, 2005).

As it was just mentioned, it is important to note that most men seeking penile augmentation surgery have average sized penises (Bizic & Djordjevic, 2016; Johnston et al., 2014; Lever et al., 2006; Mondaini et al., 2002; Prause et al., 2015; Van Driel et al., 1998; Vardi & Gruenwald, 2009; Wylie & Eardley, 2007). A 2006 study comprising a sample of 25594 men concluded that 45% of the individuals, overall, desired a larger penis. When considering only men who classified their penile size as "average", this

percentage still holds at 46%, and for those who classified their penis as “small” these figures jump to 91% (Lever et al., 2006).

Distress over penile dimensions may also be amplified in certain social situations, namely in changing rooms (Lever et al., 2006; Van Driel et al., 1998), saunas, nudist beaches and military inspections (Panfilov, 2006), and instigated by past experiences, such as hurtful comments about the size of their penis at the beginning of puberty (Lee, 1996). This may explain why many men worry about the size of their flaccid penis (Lever et al., 2006; Panfilov, 2006; Wylie & Eardley, 2007).

Finally, a small perceived or objectively measured penis size may be associated with low self-esteem, sexual dysfunction, depression and other mental disorders (Bizic & Djordjevic, 2016).

2.2 Penile anatomy and average penile size

The penis is constituted by a posterior (perineal), fixed and hidden portion, which is the root of the penis, and an anterior, mobile and visible portion, which corresponds to the body and glans penis. Generically, when we refer to the "size of the penis", we are referring to the dimensions of the mobile, anterior, visible portion of the penis.

Regarding the average penile size, there is significant geographical variability, as well as intra-community variability due to age – as penile length decreases with age after reaching adulthood (Habous et al., 2018) – and comorbidities, such as erectile disfunction and hormonal imbalances.

Currently, there is no consensus regarding the preferred method for the evaluation of penile size. Various and conflicting methods are reported in the literature. Different measuring instruments have been used, from rigid rulers to flexible measuring tapes – arguably these latter ones are superior, as they're able to follow the penis' natural curvature. Distinct measuring endpoints have also been used, with most studies measuring the penis from the pubo-penile skin junction to the meatus of the glans penis, whereas other studies elected other proximal points – for example, the pubic bone or the peno-scrotal junction – and/or distal points – such as the coronal sulcus or the middle glans point (Greenstein et al., 2020). Finally, it is clear that measuring the penis in its flaccid state yields different results from those that are obtained when the penis is measured in its erect state. The length of the flaccid penis is a poor predictor of the length of the erect penis (Wessells et al., 1996). However, as it was established in the previous subsection, one must keep in mind that the size of the flaccid penis is also a worrying subject to many men, so it should still be valued. On the other hand, measuring the size of the erect penis is not without its issues – it is often not possible in men with erectile disfunction, unless medications (such as phosphodiesterase type 5 inhibitors or prostaglandin E1) are used to induce erection, and those are considered invasive and come with the risk of inducing priapism. Even for men who don't suffer from erectile disfunction, visual and manual stimulation is often not effective in clinical settings. (Greenstein et al., 2020). Erection hardness is also a factor, that can be graded by the Erectile Hardness Grading Scale (Mulhall et al., 2006) and can influence the measurement of the erect penile length.

To overcome the limitations of measuring the length of the erect penis, the stretched flaccid length can be measured instead. It represents a good estimate of the length of the erect penis – at the cost of some reliability, since the stretched length is influenced by the amount of tension force applied – but avoids the issues that arise with trying to measure the erect penis (Greenstein et al., 2020; Veale et al., 2015).

While it is not easy to determine a set of standard measures for penile dimensions that fits all men worldwide, we took as reference the values ascertained in the largest and latest systematic review (Veale et al., 2015), which has drawn the following conclusions: the mean flaccid pendulous length is 9,16 cm; the mean stretched length is 13,24 cm; the mean erect length is 13,12 cm; the mean flaccid circumference is 9,31 cm; the mean erect circumference is 11,66 cm.

In the present study, the penises were measured with flexible, disposable rulers. As it was performed on cadavers, it was not possible to measure the erect length, and due to the lesser reliability and higher variability that measuring the stretched length could entail, it was decided to measure the length of the flaccid penis, which is still an important metric in penile lengthening surgery. Since most studies used these endpoints, the penises were measured from the pubo-penile skin junction to the tip of the glans penis, as described by Wessells et al. (Wessells et al., 1996).

2.3 Indications for penile enlargement surgery

Although it is widely accepted that patients with a truly small penis would be eligible candidates for penile enhancement surgery, no current consensus guidelines are available for the treatment of patients with a normal-sized penis.

Currently, the American Urological Association states that micropenis – a penis without congenital abnormalities which is less than 2,5 standard deviations below the mean in length, owing to an endocrinologic condition, or a penis which has less than 7,5 cm in stretched length – is the sole legitimate reason to seek penile enlargement surgery (*American Urological Association*, 2018).

However, a smaller penis can be secondary to other conditions, congenital and/or acquired, and penile lengthening surgery can be regarded as a reconstructive procedure for a number of causes of penile shortening, namely: buried penis, in which the penile shaft is hidden by the prepubic skin, which in obese adolescents is due to excessive abdominal fat and in infants and toddlers is owing to the penile skin not being attached to the deep fascia (Campbell & Gillis, 2017; Maizels et al., 1986; Oderda & Gontero, 2011); webbed penis, originated from trapping of the penoscrotal angle by the scrotal skin, tucking in the penis (Maizels et al., 1986); trapped penis wherein prepubic skin scarred by trauma traps the penile shaft (Campbell & Gillis, 2017; Maizels et al., 1986); post-surgical and/or non-surgical treatment of Peyronie's disease, of which penile shortening is a known side effect (Bizic & Djordjevic, 2016; Chevallier et al., 2013; Chung & Kim, 2016; Dillon et al., 2008; Falcone et al., 2020; Hall et al., 1995; Moncada-Iribarren et al., 2007; Oderda & Gontero, 2011; Veale et al., 2015); hormonal suppression, radiotherapy and surgical treatment of prostate cancer – namely radical retropubic prostatectomy (Bizic & Djordjevic, 2016; Chevallier et al., 2013; Chung & Kim, 2016; Dillon et al., 2008; Haliloglu et al., 2007; Munding et al., 2001; Oderda & Gontero, 2011; Savoie et al., 2003; Wylie & Eardley, 2007); erectile disfunction (Bizic & Djordjevic, 2016; Chevallier et al., 2013; Chung & Kim, 2016; Dillon et al., 2008; Wylie & Eardley, 2007); severe penile trauma (Bizic & Djordjevic, 2016; Shirong et al., 2000; Van Driel et al., 1998); penile cancer (Bizic & Djordjevic, 2016; Van Driel et al., 1998); priapism; Fournier's gangrene (Bizic & Djordjevic, 2016); lichen sclerosus (Bizic & Djordjevic, 2016; Kayes et al., 2012); and better fixation for condom catheter, particularly in wheelchair-dependent patients with spinal cord injury (Kabalin et al., 1990; Van Driel et al., 1998).

Yet, the most common requests for penile enhancement surgery are in patients with a normal penile size who: a) desire a larger penis for purely aesthetic reasons and want to enhance the appearance of their penis to meet certain social/cultural standards regarding penile aesthetics, without any underlying psychopathology; or b) have a subjective altered body perception, rather than an objective clinical assessment that their penis is small. This is otherwise known as penile dysmorphic disorder, a subtype of body dysmorphic disorder. There is a clinical entity designated “small penis syndrome”, which is a distressing and invalidating syndrome (Pastoor & Gregory, 2020) found in men with an average-sized penis but who feel it as small and in turn get anxious about it. It is defined by Wylie and Eardley as “an anxiety about the genitals being observed, directly or indirectly (when clothed) because of concern that the flaccid penis length and/or girth is less than the normal for an adult male, despite evidence from a clinical examination to counter this concern” (Wylie & Eardley, 2007).

A recent study employed and compared temporary methods of penile augmentation in patients with small penis syndrome, and a significant increase in satisfaction with penile appearance and sexual life was verified (Yang et al., 2020). This issue could be, more permanently, tackled by aesthetic surgery, following careful urological, psychosexual, psychological and psychiatric assessment (Wylie & Eardley, 2007).

Possible indications for penile enlargement surgery are summarized in Table 1.

Table 1 – Summary of the indications for penile enlargement surgery

Indications for penile enlargement surgery	
Small-sized penis, congenital/acquired	**Average-sized penis**
Micropenis	Aesthetic reasons
Buried penis	Penile dysmorphic disorder
Webbed penis	
Trapped penis	
Post correction of Peyronie's	
Post prostate cancer treatment	
Erectile disfunction	
Post severe penile trauma	
Post penile cancer treatment	
Post priapism treatment	
Fournier's gangrene	
Lichen sclerosus	
Better fixation for condom catheter	

2.4 Non-surgical and surgical techniques for penile lengthening

Non-surgical techniques for improving penile size comprise, among others, penile traction therapy (PTT) with penile extenders, vacuum therapy (VT) and injectable fillers – including polylactic acid, hyaluronic acid and polymethylmethacrylate (PMMA) microspheres. PTT seems to bring about significant, yet moderate (< 20 mm), increases in flaccid and stretched penile length, with reasonable patient satisfaction and minor complications, and seems to be useful for patients with erectile disfunction, who reported improvement in function at 9 months of treatment (Marra et al., 2020). VT appears to be useful in the context of the management of erectile disfunction and Peyronie's disease, with few drawbacks and modest efficacy (Romero-Otero et al., 2021). Fillers are usually injected between the dartos and the deep fascia of the penis and seem to cause significant increases in penile girth. Most complications were transient, including diminished penile tactile sensation after injection, but the use of PMMA microspheres lead to the appearance of irregularities in the penile skin (Marra et al., 2020; Romero-Otero et al., 2021).

The earliest and subsequently most studied surgical procedure used to lengthen the penis had its origins in 1971, when Kelley and Eraklis devised a technique to elongate the phallus of infants with bladder exstrophy. The key step consisted on the release of the suspensory ligaments of the penis (Kelley & Eraklis, 1971).

The method was then refined and applied to adults for aesthetic and reconstructive purposes: it has been combined with ancillary procedures, such as the V-Y (Alter et al., 2011; Chung & Kim, 2016; Dillon et al., 2008; Kayes et al., 2012; Li et al., 2006; Nugteren et al., 2010; Panfilov, 2006; Van Driel et al., 1998; Vardi & Gruenwald, 2009) and other kinds of advancement skin flaps (Edoardo Austoni et al., 1999; Kabalin et al., 1990; Moon, 2016; Nugteren et al., 2010; Vardi & Gruenwald, 2009), prepubic lipectomy (Bizic & Djordjevic, 2016; Maizels et al., 1986; Spyropoulos et al., 2005; Vardi et al., 2008; Vardi & Gruenwald, 2009), subcoronal approaches (Mertziotis et al., 2013), utilization of intracavernous cutaneous expanders (Edoardo Austoni et al., 1999), scrotal flaps and skin grafts (Shirong et al., 2000). Note that the release of the suspensory ligament of the penis recruits part of the root of the penis to the anterior mobile portion, conveying a lengthier appearance. Actually, the penis with its three components (root, body and glans), remains with the exact absolute size.

Novel, more invasive, techniques were created since then, mostly aiming at producing an actual increase in length of the penile components, such as corporoplastic augmentation with venous grafts (E Austoni et al., 2002), penile disassembly and glans detachment (Perovic & Djordjevic, 2000), sliding elongation (Egydio & Kuehhas, 2015; Rolle et al., 2012), flap reconstructions with local rhomboid flaps (Kramer & Jackson, 1986) and scrotal flaps (Xiao et al., 2014).

Nevertheless, the most widely used procedure is still the release of the suspensory ligaments of the penis, often combined with an inverted V-Y pubic skin plasty, with the aim of recruiting pubic skin for the penile body, now enlarged.

Possible complications include lesions of the neurovascular bundles of the penis (Kramer & Jackson, 1986), bulging of the penoscrotal transition (Campbell & Gillis, 2017; Panfilov, 2006), opening of the peno-pubic angle with horizontalization of the erect penis, penile instability (Alter et al., 2011), paradoxical penile shortening due to reattachment of the corpora in a more posterior position, decreased angle of elevation of the erect penis (Kayes et al., 2012; Vardi et al., 2008; Vardi & Gruenwald, 2009), hypertrophic wound scarring (Dillon et al., 2008), deep and superficial infections (Furr et al., 2018) and disfiguring advancement of suprapubic hairy skin (Dillon et al., 2008; Furr et al., 2018; Wylie & Eardley, 2007).

2.5 Anatomy of the suspensory ligamentous system of the penis

The suspensory apparatus of the penis comprises three main components: the fundiform ligament of the penis, the suspensory ligament proper and the inferior pubic ligament (Chen et al., 2017; Hoznek et al., 1998; Protogerou et al., 2011a). They are represented in Figures 1, 2 and 3.

According to the latest research (Chen et al., 2017) the fundiform ligament adheres to the posterior surface of the superficial fascia of the abdomen. It separates into two paramedian bundles that approach the corpora cavernosa, at the level of the lateral side of which they merge to the deep fascia of the penis bilaterally – note that this ligament does not have a direct connection to the tunica albuginea of the corpora cavernosa, nor the pubic symphysis. At the bottom of the corpus spongiosum, the two bundles come together and form the superior part of the scrotal septum. It is independent from the other two penile ligaments, and its role is to support the pendulous part of the penis in front of the pubis – its function is not significative in erection and its complete dissection should have little influence on the stability of the penis. Incomplete dissection of the fundiform ligament constitutes a step in penile elongation surgery through ligament release, in order to expose and gain access to the suspensory ligament proper (Chung & Kim, 2016; Panfilov, 2006).

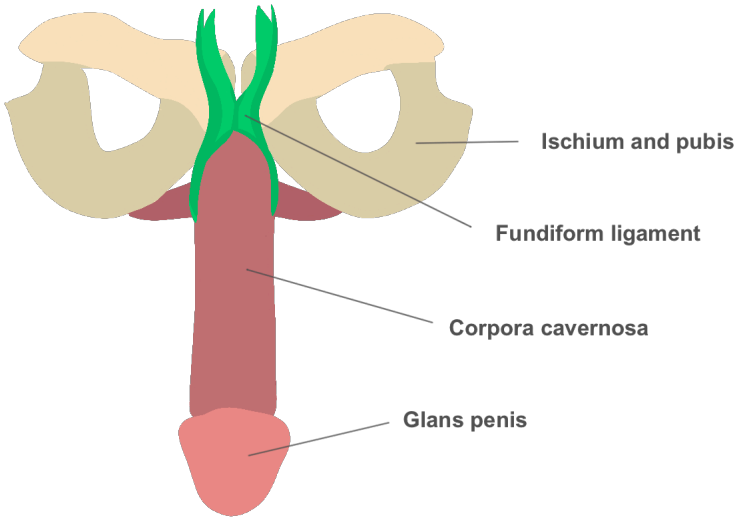

Figure 1 – Coronal view of the fundiform ligament (green), note that it embraces the circumference of the penis.

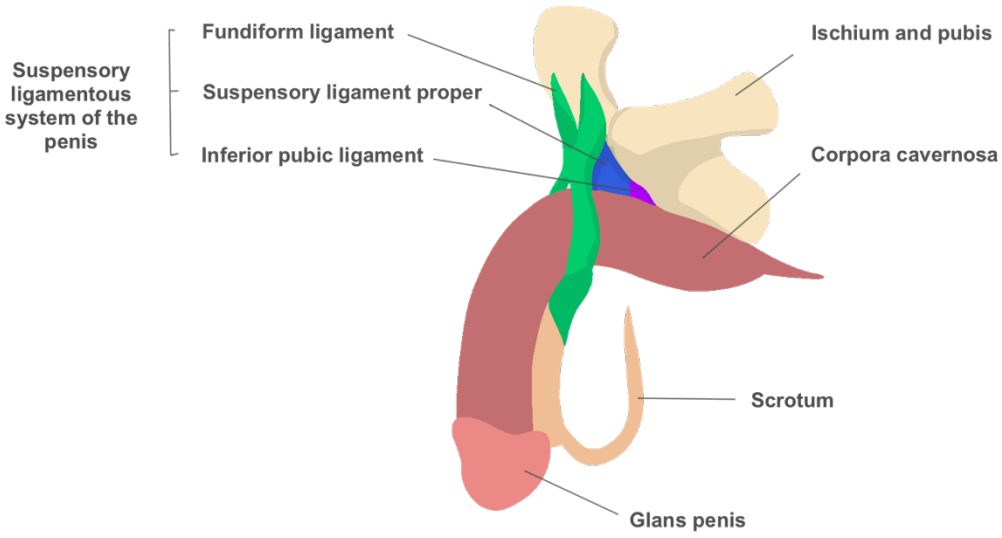

Figure 2 – anterolateral view of the suspensory ligamentous system of the penis. The fundiform ligament is represented in green, the suspensory ligament is represented in blue and the inferior pubic ligament in purple. Note that after encompassing the perimeter of the penis, the fundiform ligaments two bundles rejoin in the ventral aspect of the penis and constitute the superior part of the scrotal septum.

The suspensory ligament proper is located between the pubic symphysis and the corpora cavernosa. Posteriorly, it adheres to the inferior pubic ligament. Its superior margin adheres to the pubic symphysis, and due to this attachment, we can infer that the length of the suspensory ligament proper corresponds to the anteroposterior dimension of the pubic symphysis. Inferiorly, it attaches to the tunica albuginea of the corpora cavernosa. According to Chen et al., complete dissection of this ligament could result in penile instability and deformation, as well as erectile disfunction (Chen et al., 2017), though this hasn't been confirmed by objective data or other authors. The dimensions of the suspensory ligament proper, namely it's thickness/width and length/depth, and its implications for penile lengthening surgery, have yet to be studied. Dissection of the suspensory ligament proper should stop before the inferior border of the pubic arch, to avoid lesion to neurovascular structures destined to the penis (Protogerou et al., 2011a).

The inferior pubic ligament is situated between the inferior ramus of the pubis and the tunica albuginea of the corpora cavernosa. It attaches to the posteroinferior border of the pubic symphysis superiorly and it adheres to the posteroinferior border of the suspensory ligament anteriorly. Inferiorly it attaches to the tunica albuginea of the corpora cavernosa. It is rarely approached in penile lengthening surgery, and it serves a similar function to that of the suspensory ligament proper, although it may also be involved in the suspensory mechanism of the urethra (Steiner, 1994).

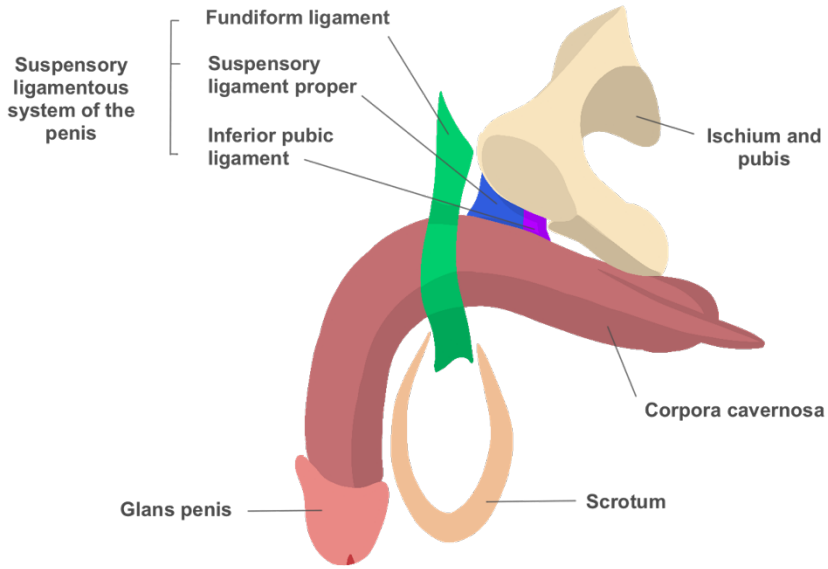

Figure 3 – sagittal view of the suspensory ligamentous system of the penis, offering another perspective on the relations between the different structures. The fundiform ligament is represented in green, the suspensory ligament proper is represented in blue, and the inferior pubic ligament is represented in purple.

2.6 Current issues with surgical lengthening of the penis

Several reviews have proposed that surgical procedures designed to enlarge the penis size may be associated with significant risks and complications.

Ligamentolysis is the most popular procedure used to achieve penile lengthening. However, the reported results are very variable and unpredictable, according to the literature – there are currently few validated ways to predict the outcome of the procedure, subjecting men who undergo through surgery to uncertainty regarding its results. For an adequate ponderation of the cost/benefit relation of the procedure and informed decision, it would be important to be aware of the predicted results for each individual case – not only for the prospective clients, but also for the surgeons own decision making and patient counseling.

So, our research question arises: will it be possible to determine parametric and other morpho-clinical evaluation criteria, capable of predicting the gains in penile length to be obtained?

Regarding anatomical parameters that might be predictors of the expected gain in penile length, Protogerou et al. proposed studying the anteroposterior dimension of the pubic arch, and the angle between the pubic rami and the horizontal plane. The anteroposterior dimension, depth or length of the pubic symphysis corresponds to the length of the suspensory ligament proper and the hidden part of the corpora cavernosa to which it attaches. They suggested that the deeper the pubic arch and the larger the angle between the pubic rami and the horizontal plane is (meaning, the more vertical it is), the bigger would be the expected gain in penile length (Protogerou et al., 2011b).

The thickness/width of the suspensory ligament of the penis might play a role too. We project that the thicker/wider the ligament is (meaning, the bigger the dimension in the coronal plane is), the greater the anticipated length gain.

Owning to how simple they are to access, we wanted to study whether the individuals' height might be relevant, as well as their age and body habitus.

We aim to find a correlation between easy to evaluate morphometric data, like the age, body habitus, height of the individual, the length of the suspensory ligament (measured by the depth of the pubic symphysis, D) and the width of the suspensory ligament proper (W) and the expected increase in length of the mobile flaccid penis (L), measured from

the pubo-penile junction to the tip of the glans, to use as a tool of decision making for both surgeon and patient, when considering this surgical procedure.

These parameters should be easy to measure preoperatively, via physical examination or using non-invasive imaging methods, such as classical X-ray imaging (to measure the depth of the pubic symphysis) and ultrasonography (to measure the width of the suspensory ligament proper).

The most relevant structures and measures are highlighted in Figure 4.

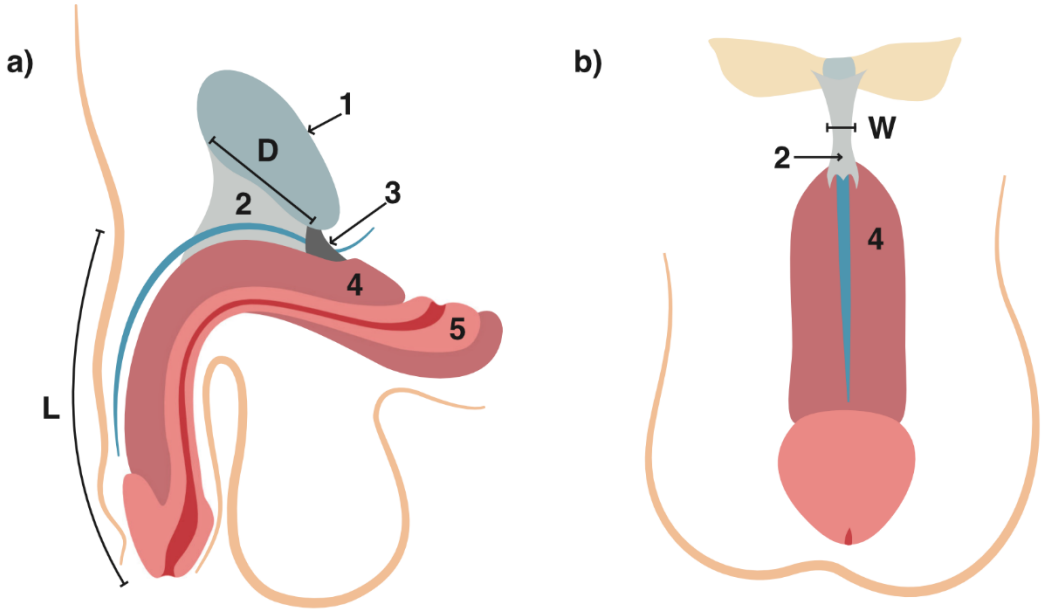

Figure 4 – Sagittal (a) and coronal (b) views of the relevant structures and measurements: pubic symphysis (1); suspensory ligament proper of the penis (2); inferior pubic ligament (3); corpus cavernosum (4); corpus spongiosum (5); depth of the pubic symphysis (D).

3 WORKING HYPOTHESIS

1. Division of the suspensory ligament of the penis results in an increase of the length of the mobile flaccid penis;
2. There is a correlation between the age and the length of the penis after dissection of the suspensory ligament proper (L2), the absolute length gain of the mobile flaccid penis after complete division of the suspensory ligament (S), and/or the relative length gain of the mobile flaccid penis after complete division of the suspensory ligament (RS);
3. There is a correlation between body habitus and the length of the penis after dissection of the suspensory ligament proper (L2), the absolute length gain of the mobile flaccid penis after complete division of the suspensory ligament (S), and/or the relative length gain of the mobile flaccid penis after complete division of the suspensory ligament (RS);
4. There is a correlation between the height of the individual and the length of the penis after dissection of the suspensory ligament proper (L2), the absolute length gain of the mobile flaccid penis after complete division of the suspensory ligament (S), and/or the relative length gain of the mobile flaccid penis after complete division of the suspensory ligament (RS);
5. There is a correlation between the individual's ethnicity and the length of the penis after dissection of the suspensory ligament proper (L2), the absolute length gain of the mobile flaccid penis after complete division of the suspensory ligament (S), and/or the relative length gain of the mobile flaccid penis after complete division of the suspensory ligament (RS);
6. There is a correlation between the length of the penis before dissection of the suspensory ligament proper (L1) and the length of the penis after dissection of the suspensory ligament proper (L2), the absolute length gain of the mobile flaccid penis after complete division of the suspensory ligament (S), and/or the relative length gain of the mobile flaccid penis after complete division of the suspensory ligament (RS);
7. There is a correlation between the depth of the pubic symphysis (D) and S the length of the penis after dissection of the suspensory ligament proper (L2), the absolute length gain of the mobile flaccid penis after complete division of the

suspensory ligament (S), and/or the relative length gain of the mobile flaccid penis after complete division of the suspensory ligament (RS);

8. There is a correlation between the width of the suspensory ligament proper (W) and the length of the penis after dissection of the suspensory ligament proper (L2), the absolute length gain of the mobile flaccid penis after complete division of the suspensory ligament (S), and/or the relative length gain of the mobile flaccid penis after complete division of the suspensory ligament (RS).

4 OBJECTIVES

4.1 General objectives

To establish parametric and non-parametric morpho-clinical correlations between anatomically and clinically pertinent variables to penile lengthening surgery and the increase in length of the mobile flaccid penis after complete division of the suspensory ligament proper.

4.2 Specific objectives

1. To register the age at death, ethnicity and body habitus of the individual;
2. To measure the height of the individual;
3. To measure the length of the mobile flaccid penis, before the complete division of the suspensory ligament of the penis (L1);
4. To measure the width of the suspensory ligament proper of the penis (W);
5. To fully dissect the suspensory ligament proper of the penis and measure the depth of the pubic symphysis (D);
6. To measure the length of the mobile flaccid penis, after the complete division of the suspensory ligament of the penis (L2);
7. To calculate the absolute length increase of the mobile flaccid penis (S);
8. To calculate the relative length increase of the mobile flaccid penis (RS);
9. To independently correlate the age, ethnicity, body habitus, height, depth of the pubic symphysis, and width of the suspensory ligament proper of the penis with the length of the mobile flaccid penis after the complete division of the suspensory ligament, the absolute length increase of the mobile flaccid penis and the relative length increase of the mobile flaccid penis;
10. To conclude about the existence of correlations between the aforementioned anatomical and clinical parameters and the expected increase in length of the mobile flaccid penis, aiming at a practical application in surgery.

5 METHODS

In order to obtain the required measurements to establish the above-said correlations, an anatomical dissection study modeled after a surgical protocol for penile lengthening through ligament release and V-Y advancement flap was performed.

5.1 General information

Firstly, essential data about each subject was recorded, namely: age at death; ethnicity (asian, black, latino or white) and body habitus (endomorph, mesomorph or ectomorph).

5.2 Height

The height of each individual was measured with the aid of an anthropometric rod and was recorded in centimeters.

5.3 Length of the mobile flaccid penis before ligamentolysis (L1)

The length of the flaccid penis was measured on the dorsal surface, in millimeters, from the pubo-penile junction to the meatus of the glans, with a disposable ruler, and then recorded.

5.4 Width of the suspensory ligament proper of the penis (W)

An inverted V incision was made at the pubo-penile junction, with the apex oriented superiorly. The superficial tissue and Scarpa's fascia were dissected and the suspensory ligament proper exposed. A photograph of the ligament was taken along with a segment of a disposable ruler, coplanarity to the anatomical structure, to set a scale, and its width was measured using the ImageJ program developed by the National Institute of Health, in millimeters, and recorded.

5.5 Surgical division of the suspensory ligament proper

The fundiform ligament was divided to expose the suspensory ligament proper. The suspensory ligament proper of the penis was dissected up to the inferior border of the pubic symphysis. A V-Y advancement flap was used to close the pubic incisions without tension, preventing penile advancement from being limited by shortage of skin coverage at the pubo-penile junction. The incisions were closed.

5.6 Depth of the pubic symphysis (D)

The fundiform ligament was divided, accordingly to the aforesaid surgical protocol, to expose the suspensory ligament proper. The suspensory ligament proper of the penis was dissected up to the inferior border of the pubic symphysis. The depth of the pubic symphysis was measured with a probe and a ruler, in millimeters, and recorded.

5.7 Length of the mobile flaccid penis after ligamentolysis (L2)

The flaccid penis was then measured again, as done when measuring it before the ligamentolysis, and its length was recorded in millimeters. The absolute and relative difference (S and RS) between the length of the flaccid penis before (L1) and after (L2) ligamentolysis is calculated and recorded, in mm and percentage, respectively.

5.8 Subjects and ethical considerations

The experimental cross-sectional study was performed on 16 penises from adult cadavers. The anatomical study took place during 20.10.2020 to 19.03.2021 at the National Institute of Legal Medicine and Forensic Sciences (INMLCF), Lisbon, Portugal. The dissections were performed by a student under the direct supervision of a tutor, senior plastic surgeon, experienced in performing penile augmentation surgery. The study was approved by the Department of Research, Training and Documentation (DIFD) of the INMLCF, and performed in accordance with the Declaration of Helsinki.

5.9 Statistical analysis

Statistical analysis was performed using the IBM SPSS® statistics software, version 27. Data was presented as means ± standard deviation, median, and range for numeric variables, and as absolute frequencies and percentages for categorical variables. Correlation coefficients (Pearson and Spearman) and general linear models/multiple linear regression models were used to investigate relations between variables. A significant level of $p \leq 0.05$ was used for statistical inference.

6 RESULTS

The descriptive statistics of the continuous and discrete variables were presented in Tables 2 and 3. Of note was the relative homogeneity of the sample, which is largely comprised of mostly caucasian males, with luso-africans representing just 12.5% of the dissected subjects. For that reason, ethnicity was excluded from the statistical models used.

Notice that this technique was successful in achieving its end goal, to produce an increase in penile length, in all individuals. The average length gain was 26,38 ± 14,83 mm, with a range of 4 to 60 mm.

Table 2 – Descriptive statistics of the continuous variables (L1 – length of the mobile flaccid penis before ligamentolysis; W – width of the suspensory ligament proper of the penis; D – depth of the pubic arch; L2 – length of the mobile flaccid penis after ligamentolysis; S – absolute difference between L1 and L2; RS – relative difference between L1 and L2)

Variable	Range (Min. – Max.)	Mean (Std. Deviation)
Age at death (years)	47 (41 – 88)	64.38 (13.109)
Height (cm)	21 (158 – 179)	167.19 (5.528)
L1 (mm)	100 (40 – 140)	103.62 (26.025)
W (mm)	2.360 (0.796 – 3.156)	1.78 (0.727)
D (mm)	40 (40 – 80)	60.20 (14.037)
L2 (mm)	70 (100 – 170)	130.00 (20.817)
S (mm)	56 (4 – 60)	26.38 (14.832)
RS (percentage)	146 (4 – 150)	31.86 (34.804)

Table 3 – Descriptive statistics of the discrete variables

Variable	Frequency	Percentage
Ethnicity		
Asian	0	0
Black	2	12.5
Latino	0	0
White	14	87.5
Total	**16**	**100**
Body habitus		
Endomorph	6	37.5
Mesomorph	8	50.0
Ectomorph	2	12.5
Total	**16**	**100**

Descriptive statistics of the penile length before ligamentolysis in mm (L1) between individuals with the same body habitus are presented in Table 4. Note that endomorph individuals had in average shorter penises than mesomorph individuals, who in turn had shorter penises that ectomorph individuals.

Table 4 – Penile length before ligamentolysis, in mm (L1) descriptive statistics, by body habitus

	Penile length before ligamentolysis, in mm (L1)		
Body habitus	**N**	**Mean (Std. Deviation)**	**Range (Min. – Max.)**
Endomorph	6	92.00 (33.793)	97 (40 – 137)
Mesomorph	8	109.50 (16.274)	50 (80 – 130)
Ectomorph	2	115.00 (35.355)	50 (90 – 140)
Total	**16**	**103.63 (26.025)**	**100 (40 – 140)**

The Pearson and Spearman correlation coefficients were presented in Tables 5 and 6.

The independent variable height produced statistically significant Pearson and Spearman correlation coefficients with the dependent variable L2 (the size of the penis after ligamentolysis – in mm).

The independent variable L1 (the size of the penis before ligamentolysis – in mm) produced statistically significant Spearman correlation coefficients with the dependent variables L2 and RS (the relative penile size increase), and statistically significant Pearson correlation coefficient with the dependent variables L2, S (the absolute penile size increase) and RS.

Table 5 – Spearman correlation coefficients between L2, S and RS and the remaining variables, minus ethnicity and body habitus. A value of $p \leq 0.05$ was used for statistical inference (L1 – length of the mobile flaccid penis before ligamentolysis; W – width of the suspensory ligament proper of the penis; D – depth of the pubic arch; L2 – length of the mobile flaccid penis after ligamentolysis; S – absolute difference between L1 and L2; RS – relative difference between L1 and L2)

	Nonparametric correlations (Spearman's ρ) – ρ (p)		
	L2	**S**	**RS**
Age at death	− 0.420 (0.105)	− 0.106 (0.696)	0.041 (0.879)
Height	**0.558 (0.025)**	0.179 (0.506)	0.047 (0.862)
L1	**0.811 (< 0.001)**	− 0.414 (0.111)	**– 0.669 (0.005)**
W	− 0.404 (0.136)	− 0.288 (0.298)	− 0.240 (0.389)
D	0.134 (0.633)	0.172 (0.541)	− 0.009 (0.975)

Table 6 – Pearson correlation coefficients between L2, S and RS and the remaining variables, minus ethnicity and body habitus. A value of $p \leq 0.05$ was used for statistical inference (L1 – length of the mobile flaccid penis before ligamentolysis; W – width of the suspensory ligament proper of the penis; D – depth of the pubic arch; L2 – length of the mobile flaccid penis after ligamentolysis; S – absolute difference between L1 and L2; RS – relative difference between L1 and L2)

	Parametric correlations (Pearson's r) – r (p)		
	L2	**S**	**RS**
Age at death	− 0.409 (0.116)	− 0.173 (0.523)	− 0.043 (0.874)
Height	**0.568 (0.022)**	0.142 (0.599)	− 0.104 (0.702)
L1	**0.822 (< 0.001)**	**− 0.601 (0.014)**	**− 0.782 (< 0.001)**
W	− 0.483 (0.068)	− 0.420 (0.119)	− 0.185 (0.509)
D	0.176 (0.531)	0.241 (0.388)	0.219 (0.433)

A generalized linear model, presented in Table 7, was used to investigate relations between multiple independent variables and the dependent variable L2. The independent variables that significantly influence L2 are L1 ($p < 0.001$), the width of the suspensory ligament of the penis (W) ($p = 0.004$) and the body habitus ($p = 0.02$).

Table 7 – Generalized linear model for the dependent variable L2. A value of $p \leq 0.05$ was used for statistical inference (L1 – length of the mobile flaccid penis before ligamentolysis; W – width of the suspensory ligament proper of the penis; L2 – length of the mobile flaccid penis after ligamentolysis)

Generalized linear model					
Source	**Type III sum of squares**	**df**	**Mean square**	**F**	**Sig.**
Corrected model	5827.921*	4	1456.980	25.768	<0.001
Intercept	3238.826	1	3238.826	57.283	<0.001
L1	3974.556	1	3974.556	70.295	**<0.001**
W	773.741	1	773.741	13.685	**0.004**
Body habitus	667.984	2	333.992	5.907	**0.02**
Error	565.412	10	56.541		
Total	257300.000	15			
Corrected total	6393.333	14			

*R squared = 0.912 (adjusted R squared = 0.876)

The variable L2 could be described by the following equations, with parameters estimated from the general linear model: $L_2 = 0.678 \times L_1 - 10.416 \times W + 2.370 + 82.747$ (if the individual was endomorph) and $L_2 = 0.678 \times L_1 - 10.416 \times W - 11.943 + 82.747$ (if the individual was mesomorph).

The penile length after ligamentolysis was greater if the individual was endomorph, as the body habitus variable adds 2.370 mm to L2, whereas if the individual was mesomorph, it subtracted 11.943 mm.

It should be noted that the influence of the body habitus stopped being statistically significative after computing these parameters ($p = 0.721$ for the parameter endomorph body habitus and $p = 0.079$ for the parameter mesomorph body habitus), which could have been a side effect of the low size of the sample.

Modeling for the dependent variable S yielded the same results, since L2 and S described each other linearly.

A generalized linear model targeting the dependent variable RS described it just in terms of L1, meaning that other variables had no statistically significant effect on RS.

7 DISCUSSION

7.1 Preamble

The crescent demand for penile augmentation surgery coupled with its risks creates the need for reliable ways to pinpoint the most likely surgical outcomes. Also, the results obtained with dissection of the suspensory ligament of the penis followed by V-Y skin plasty are also relatively unpredictable, with several articles reporting different intervals of gain in flaccid length, systematized in Table 8: Protogerou et al. report an average gain of 35 ± 13 mm (Protogerou et al., 2011a); Li et. al, a gain of 13 ± 9 mm (Li et al., 2006); Panfilov a gain of 15 to 48 mm, with an average of 20,42 mm (Panfilov, 2006); Shirong et. al, an increase of 35 to 65 mm (Shirong et al., 2000); and Klein, an increase of 26 to 91 mm (Klein, 1999).

Prior knowledge of the surgical outcomes could constitute valuable information for the patient who wished to undergo surgery, as it could help them decide whether or not they really want to proceed given the predicted results; and also, to the surgeons, who could provide better counseling to their patients regarding this procedure.

The results of this study indicate that this procedure was effective in achieving penile lengthening in all individuals, with an average length gain of 26,38 ± 14,83 mm and a range of 4 to 60 mm, in line with the results of the previously mentioned studies.

Table 8 – Summary of the reports of penile length increase, in mm, across studies performed by different authors. Hyphens indicate data that was not disclosed in the articles

	Range (Min. – Max.)	**Mean (Std. Deviation)**
Protogerou et al., 2011	–	35 (13)
Li et al., 2006	–	13 (9)
Panfilov, 2006	33 (15 – 48)	20,42 (–)
Shirong et al., 2000	30 (35 – 65)	–
Klein, 1999	65 (26 – 91)	–

7.2 Parametric and non-parametric correlation coefficients

The results indicated that the penile length after ligamentolysis (L2), the absolute length increase (S) and the relative length increase (RS) correlated most strongly with the length of the penis before the surgical procedure (L1) – in general, the longer the penis was before the procedure, the longer it would be afterwards, but the absolute and relative length increases would actually be smaller.

Without studying the full length of the penile components, as well as their relations with neighbor anatomical structures' measures (possibly with imaging methods) there was no way to determine why this is.

A reasonable assumption would be that men with a longer anterior mobile portion of the penis could have a relatively shorter posterior portion to free up with the dissection of the suspensory ligament, resulting in a smaller length increase. However, it could be far more likely that this result was influenced by the body habitus, as endomorph individuals showed in average shorter penile lengths than the other two groups, arguably due to part of the anterior portion of the penis being buried in the prepubic adipose tissue. The impact of this variable was further discussed in the following subsection.

There was also a positive correlation between the height and L2, but not with S or RS – suggesting that higher individuals attained a longer final penile size, but not necessarily through a greater absolute or relative length increase.

Statistically significant correlations between the other variables and L2, S and/or RS were not found.

7.3 Generalized linear model

Simple correlations were not enough to devise a way to assess the end penile length beforehand, so a generalized linear model was used to determine relationships between the penile length after ligamentolysis, and multiple other variables, and to estimate parameters for equations capable of approximating the former for a specific individual. Two equations were derived to this end, given the start penile length, the width of the suspensory ligament proper of the penis and the individuals body habitus. It should be recalled that this last parameter was statistically significative in the general linear model, but not when computing the equations' parameters, which was attributed to the small sample size.

Interestingly it seemed that subjects with an endomorph body habitus bore larger penile length increases compared to subjects with a mesomorph body habitus, which could be explained by taking into account the differences in the amount of prepubic adipose tissue between these individuals.

Considering that endomorph individuals had larger prepubic fat masses, these could partially obscure the anterior portion of the penis before the procedure, resulting in a shorter "measurable" penis – as supported by the results presented in Table 3. By not only dissecting the suspensory ligament proper of the penis, but also by performing a V-Y skin plasty, this hidden segment of the anterior portion of the penis (plus the mobilized segment of the posterior portion of the penis) could have been revealed and added to the overall penile length gain – explaining the greater penile length increase, and also validating the practice of prepubic lipectomy.

Mesomorph individuals, with smaller prepubic fat masses, did not have a significant measure of the anterior portion of the penis buried in the adipose tissue, and therefore did not experience comparable length gains.

An interesting implication of this fact is that weight loss by itself may produce some degree of "penile lengthening" by reducing the amount of prepubic fat and revealing segments of previously buried mobile penis in that tissue.

According to the equations, the width of the suspensory ligament, on the other hand, negatively impacts L2, meaning that the thicker the suspensory ligament proper is, the smaller the end penile length will be. The present study does not afford any explanation for this phenomenon.

Regarding L1, this variable positively influences L2, as one could logically deduce: the longer the initial penile size is, the longer the end penile size will be. However, as discussed in the previous subsection, penises that are longer to begin with tend to attain smaller absolute and relative length increases.

The parameters involved in these equations could be easily measured in-office: the penile length before the surgical procedure and the body habitus are easily evaluated in a physical examination, and the width of the suspensory ligament proper of the penis can be measured by non-invasive imaging methods, namely ultrasound imaging, as well as other methods such as computerized tomography and magnetic resonance imaging scans.

With these measurements, the surgeon could estimate a target penile size using the derived equations and communicate them to the patient, allowing them to make a more informed decision regarding the surgical procedure and its risks.

Although anatomical factors of better surgical prognosis – that is, a greater penile length increase – were identified, even individuals with less favorable anatomical conditions attained some level of penile length gain.

The reliability of these results could be limited by the small sample size, as well as the sample's homogeneity. Age and ethnicity-related effects could be exaggerated in these results. On the other hand, these correlations, as well as the generalized linear model, could yield vastly different results if the sample were larger and more diverse. This study was also effectuated in cadaver subjects, and these results may not apply to living individuals. A larger follow-up clinical study, maybe accessing new variables such as body fat percentage, would be beneficial to affirm or infirm this papers results, and to derive equations more reliable for living subjects.

8 CONCLUSIONS

Independently of the different intrinsic characteristics of the studied individuals, this penile lengthening technique always affords some degree of penile lengthening. There are statistically significant correlation coefficients between the individual's height and the penile length after ligamentolysis (L2), and between the length of the penis before ligamentolysis (L1) and L2, the absolute length increase (S) and the relative length increase (RS). Through a generalized linear model and parameter estimates, equations were derived that could approximate the end penile length by taking into account L1, the width of the suspensory ligament proper of the penis (W) and the individuals body habitus. While the present study pointed towards a possibility to predict the penile length increase after release of the suspensory ligament proper of the penis, larger and more diverse clinical trial with live patients could provide more reliable and statistically significant correlations and equations, that could be used confidently in clinical practice.

9 ACKNOWLEDGEMENTS

The author would like to thank: **Paulo Jorge Nogueira, PhD**, for providing statistical analysis consulting; **Pedro Henriques**, senior technician of Pathology, Cytology and Thanatology at the Institute of Anatomy of the Lisbon Faculty of Medicine, for providing logistic support and assistance; **Carlos dos Santos, MD, PhD**, National Institute of Legal Medicine and Forensic Sciences; **Vanda Abreu**, technician of Pathology, Cytology and Thanatology; **Carlos Costa**, technician of Pathology, Cytology and Thanatology; **David Valverde, MD**, National Institute of Legal Medicine and Forensic Sciences; and **Sara Travassos**, Faculty of Medicine of the University of Lisbon, for providing assistance during the dissections.

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11 TABLES

12 FIGURES