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Worldwide Temporal Trends in Penile Length: A Systematic Review and Meta-Analysis

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Purpose: Normative male genital measurements are clinically useful and temporal changes would have important implications. The aim of the present study is to characterize the trend of worldwide penile length over time.

Materials and Methods: A systematic review and meta-analysis using papers from PubMed, Embase, and Cochrane Library from inception to April 2022 was performed. PRISMA guidelines were used for abstracting data and assessing data quality and validity. Pooled means and standard deviations for flaccid, stretched, and erect length were obtained. Subgroup analyses were performed by looking at differences in the region of origin, population type, and the decade of publication. Metaregression analyses were to adjusted for potential confounders.

Results: Seventy-five studies published between 1942 and 2021 were evaluated including data from 55,761 men. The pooled mean length estimates were flaccid length: 8.70 cm (95% CI, 8.16–9.23), stretched length: 12.93 cm (95% CI, 12.48–13.39), and erect length: 13.93 cm (95% CI, 13.20–14.65). All measurements showed variation by geographic region. Erect length increased significantly over time (QM=4.49, df=2, p=0.04) in several regions of the world and across all age groups, while no trends were identified in other penile size measurements. After adjusting for geographic region, subject age, and subject population; erect penile length increased 24% over the past 29 years.

Conclusions: The average erect penis length has increased over the past three decades across the world. Given the significant implications, attention to potential causes should be investigated.

Keywords: Anatomy; Hormones; Meta-analysis; Penis

INTRODUCTION

As male sexual dysfunction diagnoses and treatments are common [1,2], penile size remains important [3]. Penile size has been suggested to associate with sexual strength, virility, and vitality in men [4], as well as a man's self-esteem [5].

The penis is formed during gestation under hormon-

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al influences and continues to grow through puberty [6]. Investigators have reported changes in normal male genital development over time as assessed by falling sperm counts, declines in serum testosterone levels, higher rates of testicular tumors, and increasing genital birth defects [7-10]. While the etiology of reported changes is uncertain, many have hypothesized environmental changes as potential culprits [7,11].

Penile size has been measured in several studies but no comprehensive study exists to examine geographic variation or temporal trend [12-14]. The aim of this systematic review and meta-analysis is to critically evaluate the literature to report the trend of penile length over time and in different geographic regions.

MATERIALS AND METHODS

1. Evidence acquisition

The protocol for this systematic review and meta-analysis was registered in PROSPERO (registration number: CRD42022335620). This meta-analysis was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The following research question was established based on the PICO criteria [15]: Has penile length changed over time globally? We performed a systematic review of the literature in PubMed, Embase, and Cochrane from inception to April 2022, to identify studies that evaluated penile size. Search terms included: "Penile Length" OR ("Width" OR "Circumference" OR "Dimension") AND ("Erect" OR "Flaccid" OR "Stretched"). The reference lists of the included studies were also screened for relevant articles. Seventy-five original articles were included and critically evaluated.

2. Selection of the studies and criteria for inclusion

This analysis was restricted to data collected from original articles that examined men's penile length. Studies were considered eligible if the quantitative measurement of penis size was measured by an investigator, the sample included ≥10 participants, participants were aged ≥17 years, and if they provided sample size, mean, and standard deviation (SD) of flaccid or erect length measured from the root (pubo-penile junction) of the penis to the tip of the glans (meatus) on the dorsal surface. Articles were excluded if they were based on a self-measurement and if they reported measurements done after major pelvic surgery. Abstracts and meeting reports were excluded from the analysis.

Two authors (FB and ME) independently screened the titles and abstracts of all articles. Abstracts and full-text articles were examined independently by five authors (FB, FDG, EM, ME, and FG) to determine whether or not they met the inclusion criteria. Final inclusion was determined by the consensus of all investigators. Selected articles meeting the inclusion criteria were then critically analyzed.

The following data were extracted from the included studies by using a standardized form: country and region of origin, publication year, sample size, participants' age, penile measurements, population description, and measurement technique.

3. Assessment of quality for studies included and statistical analysis

To assess the risk of bias (RoB), each report was reviewed using the National Institutes of Health (NIH) Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies [16]. The authors independently assessed the methodological quality based on sequence generation, allocation concealment, enrollment of control groups, incomplete outcome data, selective outcome reporting, and additional sources of bias. Publication bias was tested by visual assessment of the Deeks' funnel plot [17]. We first obtained the pooled mean and SD for every measurement category (*i.e.*, flaccid, erect, and stretched length). Then, we compared each study measurement with the pooled mean using the standardized mean difference (SMD) and 95% confidence intervals (CIs). Variability in the intervention effects as a consequence of clinical or methodological diversity among the studies was evaluated by form of heterogeneity [18]. Our results are graphically displayed as forest plots, with pooled means and SMD. Evaluation for presence of heterogeneity was done using [19]: (1) Cochran's Q-test with $p<0.05$ signifying heterogeneity; (2) Higgins I^2 test with inconsistency index (I^2)=0%–40%, heterogeneity might not be important; 30%–60%, moderate heterogeneity; 50%–90%, substantial heterogeneity; and 75%–100%, considerable heterogeneity. Subgroup analysis was performed by looking at differences in the regions of origin (*i.e.*, North America, South America, Europe, Africa), population type (volunteers, urology patients, prostate cancer [PCa] patients, others), and the decade of publication (1940–1979, 1980–1989, 1990–1999, 2000–

2009, 2010–2021). The QM statistics with accompanying p-values were used to determine the significance of subgroup differences [20]. Sensitivity analyses with and without each study were performed to investigate for any size-effect influences and outlier effects, but no major differences were observed. Metaregression was performed to adjust for preselected covariates (*e.g.*, age, region, patient population) using random-effects models. Statistical tests were performed using RStudio statistical software version 4.2.0 (The R Foundation for Statistical Computing, Vienna, Austria). All tests were two-sided, with a significance level set at <0.05.

RESULTS

1. Search results

The initial search yielded 12,531 articles (PubMed: 1,975; Cochrane: 3,435; and Embase: 7,121). Duplicate articles appearing in multiple databases were excluded (n=8,022). After abstract screening, 7,850 papers were excluded. Of the remaining 172 papers, 97 were further excluded as they either did not report penis measurements (n=63), reported measurements after major pelvic surgeries (n=12), or reported self-measurements (n=22). Full-text articles were then reevaluated and critically analyzed for the remaining 75 articles (Fig. 1). In all, 33, 22, and 64 papers reported data regarding measurements in flaccid, stretched, and erect length, respectively. RoB assessment according to NIH Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies for each of the individual studies is illustrated in Supplement Table 1.

2. Description of studies

The study characteristics of each article including patient description and dimensions recorded are summarized in Table 1 [3,12-14,21-89]. Of the seventy-five studies included, nineteen were conducted in North America [14,21-34], nineteen in Europe [3,12,35-51], five in South America [13,52-54], eight in Africa [55-61], twenty in Asia [62-77], one in Oceania [78], and three across multiple regions [79-81]. Twenty-three studies evaluated volunteers while thirty-six studies reported data from men evaluated for urological reasons. Fourteen studies investigated patients before prostate surgery and two evaluated cadavers. In total, 55,761 men were evaluated. In all, 40,251 (72.1%), 44,300 (79.4%), 18,481 (33.1%) men had data reporting flaccid, stretched, and erect length, respectively. The age ranged from 18 to 86 years with articles published between 1942 and 2021. Among the studies included, fourteen [21,32,34,37-40,44,53,60,62,69,79,81] and six [12,26,41,65,70,78] reported measurements obtained with penile injections and spontaneous erections, respectively.

3. Pooled means and SMD

Thirty-three studies reported flaccid length with measurements ranging from 5.20 cm to 13.80 cm. The pooled mean estimate under a random-effects model was 8.70 cm (95% CI, 8.16–9.23). Sixty-four studies analyzed stretched penile length with measurements ranging from 8.98 cm to 17.50 cm. The pooled mean es-

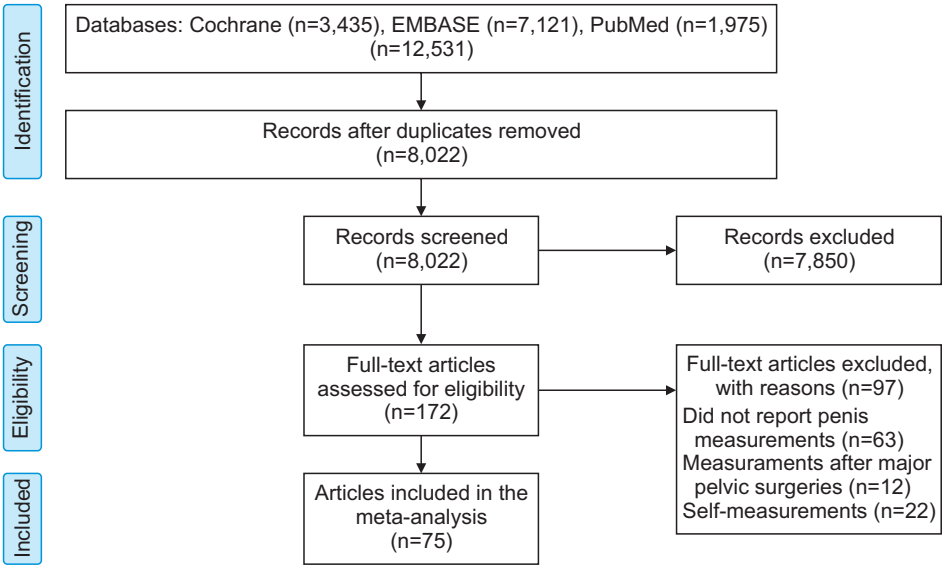

Fig. 1. PRISMA flow diagram.

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Table 1. Characteristics of studies assessing penile measuraments

Reference	Year	Country	Populations	Number	Age, y (range or average)	Measurement methods	Reported measuraments
Schonfeld and Beebe [22]	1942	USA	Volonteers	125	18–25	Patient measured 4 times in 4 mornings	Stretched
Kinsey et al [82]	1950	USA	Volunteers	2,578	18–21	Not listed	Stretched
Barry [24]	1980	USA	Men getting malleable prosthesis	23	26–66	Not listed	Stretched
Barry [23]	1981	USA	Men Getting IPP	110	24–55	Not listed	Stretched
Money et al [25]	1984	USA	Volunteers	65	36	Not listed	Stretched
Ajmani et al [55]	1985	Nigeria	Medical students	320	17–23	One examiner recorded measures several times	Flaccid
Chen et al [62]	1992	Taiwan	Men with ED	40	36–70	Not listed	Flaccid, erect
Bondil et al [35]	1992	France	Urology patients	905	53	A flexible centimetre ruler	Flaccid, stretched
Moreira de Goes et al [36]	1992	Belgium	Cadavers	17	-	Not listed	Flaccid, stretched
Siminoski and Bain [83]	1993	Canada	Volunteers	63	39.6	Not listed	Stretched
da Ros et al [84]	1994	Brazil	Volunteers	150	44.6	Not listed	Erect
Wessells et al [21]	1996	USA	Urology patients	80	54	One examiner	Flaccid, stretched, erect
Smith et al [78]	1998	Australia	Volunteers	184	-	Pubic bone to meatus	Erect
Bogaert and Hershberger [26]	1999	USA	Volunteers	3,228	30.6	Not listed	Flaccid, erect
Chen et al [37]	2000	Israel	Urology patients	55	47	One examiner, calipers	Flaccid, stretched, erect
Ansell [85]	2001	USA/Mexico	Volunteers	300	-	Not listed	Erect
Ponchietti et al [38]	2001	Italy	Volunteers	3,300	17–19	One examiner	Flaccid, stretched
Schneider et al [39]	2001	Germany	Volunteers	111	18–19	Using ruler	Flaccid, erect
Shah and Christopher [40]	2002	UK	Urology patients	104	54	Not listed	Stretched
Mondaini et al [3]	2002	Italy	Patients complaining of short penis	67	27	Undressed in normal air, before and after penile lenghtening procedures	Flaccid, stretched
Sengezer et al [41]	2002	Turkey	Volunteers	200	21.2	Measuring tape and a straight edged ruler	Flaccid, stretched, erect
Da Silva and Sampaio [52]	2002	Brazil	Cadavers	25	-	Not listed	Flaccid, stretched
Son et al [63]	2003	Korea	Volunteers	123	21.7	Not listed	Flaccid, stretched
Savoie et al [27]	2003	USA	PCa patients	124	59.1	Measured before anesthesia	Flaccid, stretched
Perugia et al [42]	2005	Italy	PCa patients	28	62.8	Not listed	Stretched
Spyropoulos et al [43]	2005	Greece	Urology patients	52	25.9	One examiner. Room temperature. Lying down, legs adducted. Circumference at base of shaft with measuring tape	Stretched
Orakwe et al [56]	2006	Nigeria	Volunteers	115	42.3	One investigator, 2 measurements, paper ruler	Stretched
Promodu et al [65]	2007	India	Urology patients	301	31.58	Three examiners	Flaccid, stretched, erect

Table 1. Continued 1

Reference	Year	Country	Populations	Number	Age, y (range or average)	Measurement methods	Reported measurements
Dalkin and Christopher [28]	2007	USA	PCa patients	42	-	Not listed	Stretched
Halioglu et al [87]	2007	Turkey	PCa patients	47	68.8	Not listed	Stretched
Köhler et al [88]	2007	USA	PCa patients	28	59	6 investigators	Stretched
Gontero et al [44]	2007	Italy	PCa patients	126	65.4	2 investigators, tape measure to 0.5cm	Flaccid, stretched
Mehraban et al [64]	2007	Iran	Volunteers	1,500	29.61	Circumference at mid-shaft	Stretched
Hosseini et al [66]	2008	Iran	Volunteers, urology patients	42	34.2	Not listed	Stretched
Kamel et al [57]	2009	Egypt	Urology patients	949	36	Not listed	Stretched
Savas et al [45]	2009	Turkey	Men with ED	42	52.1	One examiners, 2 measurements	Stretched
Schlomer et al [29]	2010	USA	Men with uretral strictures	100	55	Not listed	Stretched
Tomova et al [46]	2010	Bulgaria	Volunteers	310	18–19	Not listed	Flaccid
Choi et al [67]	2011	Korea	Urology patients	144	57.3	One examiner. Under aesthesia. Lying down, legs slightly abducted.	Flaccid, stretched
Nikoobakht et al [68]	2011	Iran	Patients complaining of short penis	23	26.4	Pubic bone to meatus	Flaccid, stretched
Engel et al [30]	2011	USA	PCa patients	127	56.5	Not listed	Stretched
Park et al [69]	2011	Korea	Volunteers	309	39.3	Not listed	Erect
Park et al [69]	2011	Korea	PCa patients	39	67.1	One examiner, paper ruler, uniformly measured force	Stretched
Aslan et al [47]	2011	Turkey	Volunteers	1,132	20.3	One examiner. Room temperature. Standing with the penis held parallel to the floor.	Flaccid, stretched
Awad et al [86]	2011	Jordan	Urology patients	271	44.6	Two examiners, lying down, legs slightly abducted. Measuring tape	Flaccid, stretched
Söylemez et al [48]	2011	Turkey	Volunteers	2,276	21.3	Not listed	Flaccid, stretched
Vasconcelos et al [53]	2012	Brazil	PCa patients	105	65	3 examiners, 3 measurements, stretched with rigid ruler	Stretched
Khan et al [49]	2012	UK	Urology patients	610	43	Two examiners. Room temperature. Lying down, legs adducted.	Flaccid, stretched
Chrouser et al [58]	2013	Tanzania	Circumcision patients	253	19-47	Not Listed	Stretched
Chen et al [70]	2014	China	Urology patients	5,196	40	Supine, straight edge ruler	Flaccid, stretched, erect
Berookhim et al [31]	2014	USA	PCa patients	118	58	Ruler, supine one examiner at a time	Stretched
Herbenick et al [14]	2014	USA	Volunteers	1,661	28.5	Not listed	Erect
Osterberg et al [32]	2014	USA	ED	20	61.5	Not listed	Stretched, erect
Shalaby et al [59]	2014	Egypt	Volunteers	2,000	31.6	Standing holding penis parallel to floor	Stretched
Caraceni et al [50]	2014	Italy	Men Getting IPP	19	68.9	Not listed	Flaccid, stretched

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Table 1. Continued 2

Reference	Year	Country	Populations	Number	Age, y (range or average)	Measurement methods	Reported measuraments
Brock et al [79]	2015	USA, Cada, Italy, Germany, France, Spain, Norway, Poland	PCa patients	423	57.9	Supine, paper ruler, supine, prior to anesthesia, one examiner at each site	Stretched
Habous et al [80]	2015	USA, UK, Saudi Arabia	Urology patients	201	49.6	Not listed	Stretched, erect
Habous et al [71]	2015	Saudi Arabia	Urology patients	778	43.7	Air conditioned consulting rooms at a costant temperature (21°), one operator, skin to tip, bone to tip, circumference	Stretched, erect
Yafi et al [33]	2015	USA	Urology patients	93	52	Not listed	Flaccid, stretched, erect
Gooran et al [72]	2016	Iran	Urology patients	380	34.7	Not listed	Stretched
Negro et al [51]	2016	Italy	Men Getting IPP	45	61	Not listed	Stretched
Canguven et al [73]	2016	Qatar	Urology patients	25	56,12	Not listed	Stretched
Kadono et al [74]	2017	Japan	PCa patients	102	64.4	Not listed	Stretched
Salama [60]	2018	Egypt	Urology patients	59	28.1	Not listed	Flaccid, stretched, erect
Salama [60]	2018	Egypt	Volunteers, ED patients	105	-	Not listed	Flaccid, stretched, erect
Alves Barboza et al [13]	2018	Brazil	Volunteers	900	18–86	Not listed	Stretched
Kadono et al [75]	2018	Japan	PCa patients	41	64.9	One examiner, pubopenile, ruler to 0.5 cm	Stretched
Sanches et al [54]	2018	Brazil	Urology patients	689	59.6	Rigid rule, penile tip to pubic bone	Stretched
Yafi et al [34]	2018	USA	ED	278	51.7	Not listed	Flaccid, stretched, erect
Kim et al [76]	2019	Korea	Men Getting IPP	342	58.3	Pubopenile skin to meatus on dorsal side	Stretched
Antonini et al [81]	2020	Italy, USA	Men Getting IPP	74	-	Pubic bone to meatus on dorsum, circ at base	Stretched, erect
Takure [61]	2021	Nigeria	Urology patients	251	57.3	Pubic arch to tip of glans	Flaccid, stretched
Nguyen Hoai et al [89]	2021	Vietnam	Urology patients	14,597	33.1	Tip of glans to pubic bone on dorsum	Flaccid, stretched
Su et al [77]	2021	China	PCa patients	45	68	Not listed	Flaccid, stretched
Di Mauro et al [12]	2021	Italy	Urology patients	4,685	19	Not listed	Flaccid, erect.

ED: erectile disfunction, PCa: prostate cancer, IPP: inflatable penile prosthesis.

timate under a random-effects model was 12.93 cm (95% CI, 12.48–13.39). Twenty studies analyzing erect length had measurements ranging from 9.50 cm to 16.78 cm. The pooled mean estimate under a random-effects model was 13.93 cm (95% CI, 13.20–14.65). Each study measurement was compared to the pooled mean to reveal the SMD estimate under a random-effects model (-0.05 cm; 95% CI, -0.21 to 0.12). There was evidence of heterogeneity between the studies (Q=2,986.24, df=26, p<0.0001; I^2=98.9%). The SMD estimates displayed a temporal trend with more recent studies displaying means higher than the pooled mean (Supplement Fig. 1). Supplement Fig. 2 and 3 reports all SMD for flaccid and stretched length.

4. Subgroup analyses

The pooled means and 95% CIs of all the subgroup analyses are summarized in Table 2. Significant differences were noted for geographic region for flaccid (QM=24.19, df=4, p<0.0001), stretched (QM=29.26, df=5, p<0.0001), and erect length (QM=22.86, df=6, p<0.0001). Differences between subject populations were not statistically significant for flaccid (QM=4.16, df=3, p=0.25), stretched (QM=1.12, df=3, p=0.77), and erect length (QM=1.11, df=2, p=0.58). No differences were observed when taking into consideration technique to achieve an erection (QM=2.29, df=1, p=0.13).

5. Metaregression analysis

There was no significant association was found between year of publication and stretched penile length (Fig. 2A). On the contrary, there was a significant association between year of publication and erect penile length (Fig. 2B) which remained significant after adjusting for geographic region, age, technique to achieve erection, and subject population (adjusted estimate: 0.11, p=0.034, Fig. 3). When the same analysis was performed investigating each region singularly, the same trend was observed in studies published in Asia (adjusted estimate: 0.17, p=0.005) and Europe (adjusted estimate: 0.16, p=0.04). Similar trends were also reported when analyzing only urology patients (adjusted estimate: 0.15, p=0.001) and volunteers (adjusted estimate: 0.07, p=0.02). In contrast, age was not associated with penile size: flaccid length (adjusted estimate: 1.84, p=0.079), stretched length (adjusted estimate: 1.93, p=0.372), and

Table 2. Pooled means and 95% CIs from subgroups analysises investigating decades, regions, and population type

Variable	Flaccid		Stretched		Erect	
	Mean	95% CI	Mean	95% CI	Mean	95% CI
Decade						
1940–1979	-	-	14.52	12.26–16.77	-	-
1980–1989	8.16	6.26–10.06	14.52	12.26–16.77	-	-
1990–1999	11.00	7.72–14.28	14.32	11.21–17.43	13.12	11.15–15.09
2000–2009	8.30	7.56–9.04	12.50	11.71–13.29	13.56	12.44–14.67
2010–2021	8.72	8.07–9.38	12.83	12.27–13.39	14.55	13.86–15.23
Region						
Africa	8.09	7.12–9.06	12.53	11.66–13.41	14.88	12.50–17.26
Asia	7.23	6.31–8.14	11.60	11.02–12.17	11.74	10.18–13.29
Europe	9.44	8.65–10.22	13.40	12.45–14.35	14.12	12.53–15.72
North America	9.82	8.78–10.86	13.75	12.79–14.70	14.58	13.68–15.48
Oceania	-	-	-	-	15.71	12.73–18.69
South America	11.00	7.72–14.28	15.60	14.34–16.86	14.50	11.40–17.60
Multiple Regions	-	-	12.13	10.53–13.73	15.33	13.45–17.21
Population Type						
Volunteers	8.44	7.70–9.17	13.08	11.94–14.23	14.33	13.26–15.40
Urology patients	8.64	7.84–9.43	12.93	12.41–13.44	13.66	12.67–14.65
PCa patients	7.86	5.91–9.81	12.50	11.32–13.67	-	-
Others	10.44	8.21–12.66	13.90	11.27–16.53	14.93	12.09–17.77

All measures in cm.
CI: confidence interval, PCa: prostate cancer.

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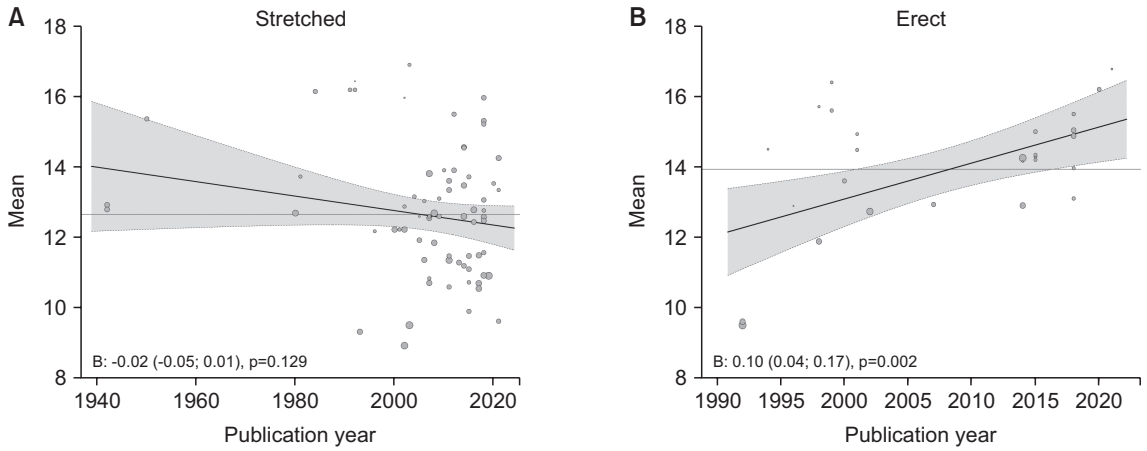

Fig. 2. Meta-regression model for mean (A) stretched length and (B) erect length over the year of publication.

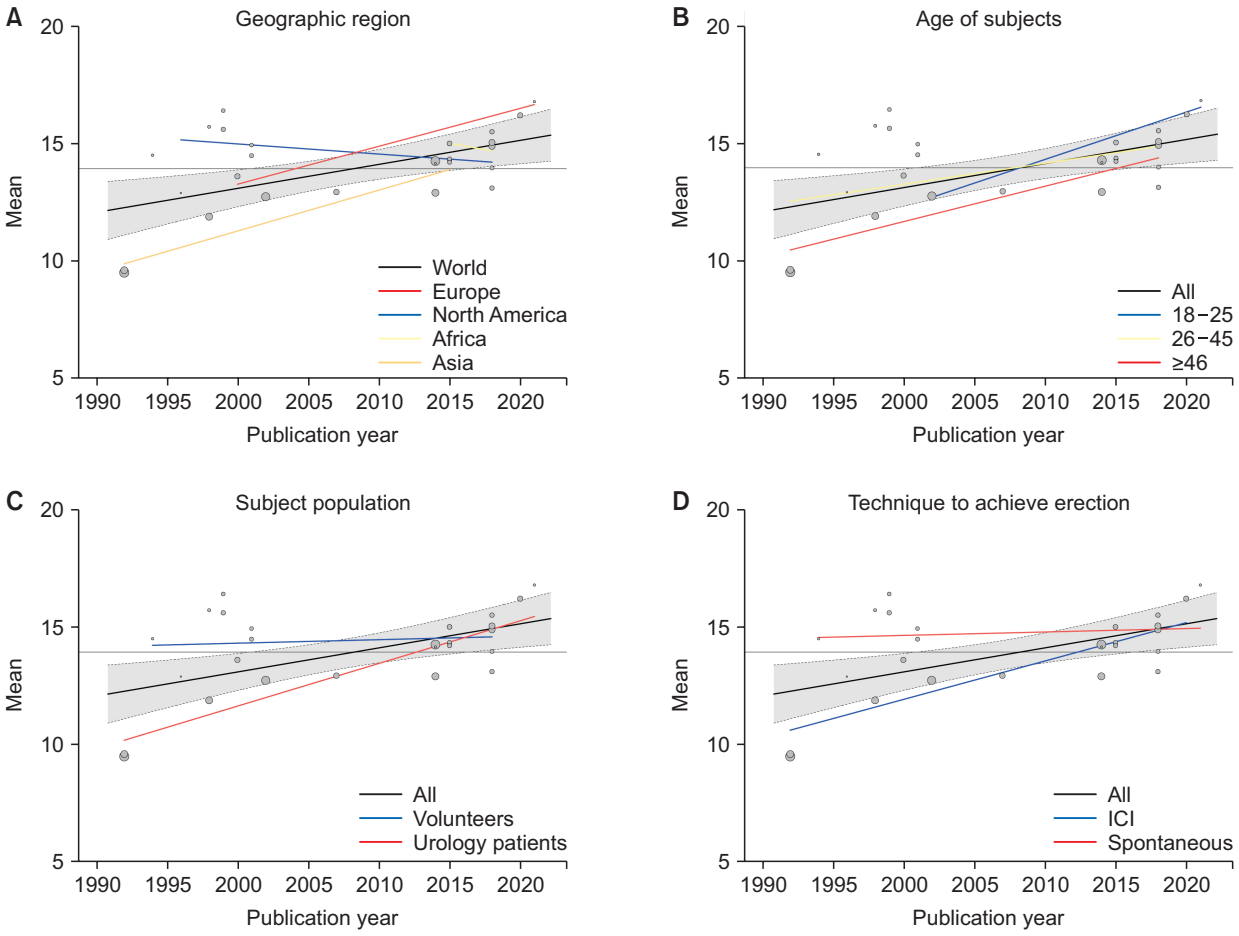

Fig. 3. Meta-regression model for mean erect length over the year of publication by (A) regions of origin, (B) age groups, (C) population type and (D) technique to achieve erection. ICI: intracavernosal injection.

erect length (adjusted estimate: 1.41, p=0.505). Using estimates from the metaregression model, erect penile length increased by 24% over the 29 years of observation was observed (from 12.27 cm to 15.23 cm).

6. Publication bias

The funnel plot for three CIs (90%, 95%, and 99% corresponding to shades white, gray and dark gray) for studies presenting flaccid length (Supplement Fig. 4A), stretched length (Supplement Fig. 4B), and erect length

(Supplement Fig. 4C). The Egger's test of asymmetry showed no significance for erect length (Z=0.85, p=0.40) and flaccid length (Z=0.56, p=0.57). On the contrary, there was significant assymmetry for stretched length (Z=2.09, p=0.04).

DISCUSSION

The current study identified an increase in the average erect penile length in men from 1992 to 2021. Importantly, the increase was seen across several geographic regions and subject populations. Moreover, when adjusting for relevant covariates, the point estimates remained similar. In contrast, no change was identified in stretched penile length or flaccid penile length. To our knowledge, this is the first study to examine temporal change in penile size. In addition, the current work identified significant differences in penile size measurements across different geographic regions. Moreover, it presents normative penile measurements based on data from more than 55,000 men.

A temporal trend was noted for erect length but not other penile length measurements. While erect length is fixed, investigators have noted the subjectivity and variability of stretched length. The goal of a stretched penile length measurement is to approximate the penile length during an erection. However, Schneider et al [39] compared younger (18–20 y) and older (48–60 y) men and found that older men had a significantly longer stretched penis, but no difference in erect lengths implying penile elasticity may change with age. Chen et al [37] also measured the forces required to stretch the penis to its full length using a specially developed gauge. In order to reach the erect length, a minimum tension force of 450 g a force during penile stretching is required. When measured, the clinician's force was lower (428 g of force) thus questioning the reliability of this method of measurement. Indeed, the current report noted significant asymmetry in stretched penile lengths suggesting clinical heterogeneity in reported lengths. Moreover, Habous et al [90] reported significant limitations of flaccid and stretched measurements in estimating erect length as well as marked inter-observer variation. Thus, estimating penile size in the flaccid state may be inaccurate whether stretched or not.

While erect lengths are consistent, erect lengths measurements can also create challenges. Different techniques have been described to measure the erect length including self-report, in office spontaneous erection, and in-office intracavernosal (*i.e.*, penile) injection. Because of their inherent biases, self-reported lengths should be regarded with caution. Studies attempting to analyze spontaneous erections in the clinic, on the other hand, have omitted numerous individuals who were unable to "perform" in this unnatural scenario [39]. The simplest technique to achieve an erection is penile injections which are routinely utilized to generate an erection in clinical settings [21,37,90]. Importantly, when the current analyses were adjusted for the technique to achieve erection, the point estimates remained similar.

The current report identified a significant difference in penile measurements across different geographical regions. Geographic variation is consistent with prior reports with other investigators also identifying longer measurements in sub-Saharan Africans, intermediate in Europeans, South Asians, and North Africans, and smaller in East Asians [91]. However, the cause for differences remains unknown and as migration continues, reported variations may lessen with time.

The etiology of the increase in erect penile length over time remains uncertain. It can be speculated that these changes may be linked with observations that pubertal milestones are occurring in younger boys than in the past [92]. Data suggests that earlier pubertal growth may be associated with increased body sizes including longer penile length [93-95]. The etiology of temporal changes in puberty remains unknown. Investigators have hypothesized sedentary lifestyle/obesity or increasing exposure to hormone-disrupting substances may play a role [96-98]. Indeed, emerging data suggest that diverse prenatal or postnatal exposures may influence pubertal timing [99-102]. Temporal declines in sperm counts and serum testosterone levels, higher rates of testicular tumors, and increasing genital birth defects have also been attributed to environmental and lifestyle exposures [7-10].

Certain limitations warrant mention. While measurement techniques were similar across studies, slight variations could contribute to differences. As has been suggested by other studies, the penile measurements may be affected by temperature, arousal state, body size and investigator factors [5,35,90]. In addition, volunteer bias may occur in some studies. Importantly, such limitations would be unlikely to consistently

change over time to lead to the identified trends. Finally, detailed geographic variation disparities were not taken into consideration in regional analyses because the majority of research did not provide precise information.

CONCLUSIONS

Our systematic review and meta-analysis suggest that the average erect penile length increased between 1992 and 2021. Given the important implications of genital development for urinary and reproductive function, future studies should attempt to confirm the trend and identify the etiology.

Conflict of Interest

The authors have nothing to disclose.

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Author Contribution

Conceptualization: FB, ME. Data curation: FB, SB, FDG, FG Formal analysis: FB Investigation: FB Methodology: FBF, ME. Supervision: ME. Validation: ME, AS Visualization: FB. Writing – original draft: FB. Writing – review & editing: EM, WM, SB, GF, EP, FM, AS, ME.

Supplementary Materials

Supplementary materials can be found *via* https://doi.org/10.5534/wjmh.220203.

REFERENCES

1. Sun AJ, Li S, Eisenberg ML. The impact of clostridium histolyticum collagenase on the prevalence and management of Peyronie's disease in the United States. World J Mens Health 2019;37:234-9.
2. Pozzi E, Capogrosso P, Boeri L, Cazzaniga W, Matloob R, Ventimiglia E, et al. Trends in reported male sexual dysfunction over the past decade: an evolving landscape. Int J Impot Res 2021;33:596-602.
3. Mondaini N, Ponchietti R, Gontero P, Muir GH, Natali A, Caldarera E, et al. Penile length is normal in most men seeking penile lengthening procedures. Int J Impot Res 2002;14:283-6.
4. Veale D, Miles S, Read J, Troglia A, Carmona L, Fiorito C, et al. Phenomenology of men with body dysmorphic disorder concerning penis size compared to men anxious about their penis size and to men without concerns: a cohort study. Body Image 2015;13:53-61.
5. Mautz BS, Wong BB, Peters RA, Jennions MD. Penis size interacts with body shape and height to influence male attractiveness. Proc Natl Acad Sci U S A 2013;110:6925-30.
6. P A A, Arbor TC, Krishan K. Embryology, sexual development [Internet]. Treasure Island (FL): StatPearls Publishing; c2022 [cited 2022 Jun 17]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK557601/.
7. Levine H, Jørgensen N, Martino-Andrade A, Mendiola J, Weksler-Derri D, Mindlis I, et al. Temporal trends in sperm count: a systematic review and meta-regression analysis. Hum Reprod Update 2017;23:646-59.
8. Lokeshwar SD, Patel P, Fantus RJ, Halpern J, Chang C, Kargi AY, et al. Decline in serum testosterone levels among adolescent and young adult men in the USA. Eur Urol Focus 2021;7:886-9.
9. Cheng L, Albers P, Berney DM, Feldman DR, Daugaard G, Gilligan T, et al. Testicular cancer. Nat Rev Dis Primers 2018;4:29.
10. Lankford JC, Mancuso P, Appel R. Congenital reproductive abnormalities. J Midwifery Womens Health 2013;58:546-51.
11. Skakkebaek NE, Rajpert-De Meyts E, Buck Louis GM, Toppari J, Andersson AM, Eisenberg ML, et al. Male reproductive disorders and fertility trends: influences of environment and genetic susceptibility. Physiol Rev 2016;96:55-97.
12. Di Mauro M, Tonioni C, Cocci A, Kluth LA, Russo GI, Gomez Rivas J, et al.; Trauma, Reconstructive Urology, Men's Health Working Parties of the European Association of Urology (EAU) Young Academic Urologists (YAU). Penile length and circumference dimensions: a large study in young Italian men. Andrologia 2021;53:e14053.
13. Alves Barboza R, da Silva EA, Ruellas T, Damião R. Anthropometric study of penile length in self-declared Brazilians regarding the color of the skin as white or black: the study of a myth. Int J Impot Res 2018;30:43-7.
14. Herbenick D, Reece M, Schick V, Sanders SA. Erect penile length and circumference dimensions of 1,661 sexually active men in the United States. J Sex Med 2014;11:93-101.
15. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. J Clin

Epidemiol 2009;62:e1-34.
16. National Heart, Lung, and Blood Institute. Study quality assessment tools [Internet]. Bethesda (MD): National Institutes of Health; c2021 [cited 2022 Jun 2]. Available from: https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools.
17. DerSimonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials 1986;7:177-88.
18. Mantel N, Haenszel W. Statistical aspects of the analysis of data from retrospective studies of disease. J Natl Cancer Inst 1959;22:719-48.
19. Melsen WG, Bootsma MC, Rovers MM, Bonten MJ. The effects of clinical and statistical heterogeneity on the predictive values of results from meta-analyses. Clin Microbiol Infect 2014;20:123-9.
20. Schwarzer G, Carpenter JR, Rücker G. Meta-analysis with R. Cham: Springer; 2015.
21. Wessells H, Lue TF, McAninch JW. Penile length in the flaccid and erect states: guidelines for penile augmentation. J Urol 1996;156:995-7.
22. Schonfeld WA, Beebe GW. Normal growth and variation in the male genitalia from birth to maturity. J Urol 1942;48:759-77.
23. Barry JM. Preoperative determination of inflatable penile prosthesis cylinder length. Urology 1981;18:82-3.
24. Barry JM. Clinical experience with hinged silicone penile implants for impotence. J Urol 1980;123:178-9.
25. Money J, Lehne GK, Pierre-Jerome F. Micropenis: adult follow-up and comparison of size against new norms. J Sex Marital Ther 1984;10:105-16.
26. Bogaert AF, Hershberger S. The relation between sexual orientation and penile size. Arch Sex Behav 1999;28:213-21.
27. Savoie M, Kim SS, Soloway MS. A prospective study measuring penile length in men treated with radical prostatectomy for prostate cancer. J Urol 2003;169:1462-4.
28. Dalkin BL, Christopher BA. Preservation of penile length after radical prostatectomy: early intervention with a vacuum erection device. Int J Impot Res 2007;19:501-4.
29. Schlomer BJ, Dugi DD 3rd, Valadez C, Morey AF. Correlation of penile and bulbospongiosus measurements: implications for artificial urinary sphincter cuff placement. J Urol 2010;183:1474-8.
30. Engel JD, Sutherland DE, Williams SB, Wagner KR. Changes in penile length after robot-assisted laparoscopic radical prostatectomy. J Endourol 2011;25:65-9.
31. Berookhim BM, Nelson CJ, Kunzel B, Mulhall JP, Narus JB. Prospective analysis of penile length changes after radical prostatectomy. BJU Int 2014;113:E131-6.
32. Osterberg EC, Maganty A, Ramasamy R, Eid JF. Pharmacologically induced erect penile length and stretched penile length are both good predictors of post-inflatable prosthesis penile length. Int J Impot Res 2014;26:128-31.
33. Yafi FA, Libby RP, McCaslin IR, Sangkum P, Sikka SC, Hellstrom WJ. Failure to attain stretched penile length after intracavernosal injection of a vasodilator agent is predictive of veno-occlusive dysfunction on penile duplex Doppler ultrasonography. Andrology 2015;3:919-23.
34. Yafi FA, Alzweri L, McCaslin IR, Libby RP, Sangkum P, Sikka SC, et al. Grower or shower? Predictors of change in penile length from the flaccid to erect state. Int J Impot Res 2018;30:287-91.
35. Bondil P, Costa P, Daures JP, Louis JF, Navratil H. Clinical study of the longitudinal deformation of the flaccid penis and of its variations with aging. Eur Urol 1992;21:284-6.
36. Moreira de Goes P, Wespes E, Schulman C. Penile extensibility: to what is it related? J Urol 1992;148:1432-4.
37. Chen J, Gefen A, Greenstein A, Matzkin H, Elad D. Predicting penile size during erection. Int J Impot Res 2000;12:328-33.
38. Ponchietti R, Mondaini N, Bonafè M, Di Loro F, Biscioni S, Masieri L. Penile length and circumference: a study on 3,300 young Italian males. Eur Urol 2001;39:183-6.
39. Schneider T, Sperling H, Lümmen G, Syllwasschy J, Rübben H. Does penile size in younger men cause problems in condom use? A prospective measurement of penile dimensions in 111 young and 32 older men. Urology 2001;57:314-8.
40. Shah J, Christopher N. Can shoe size predict penile length? BJU Int 2002;90:586-7.
41. Sengezer M, Oztürk S, Deveci M. Accurate method for determining functional penile length in Turkish young men. Ann Plast Surg 2002;48:381-5.
42. Perugia G, Liberti M, Vicini P, Colistro F, Gentile V. Use of local hyperthermia as prophylaxis of fibrosis and modification in penile length following radical retropubic prostatectomy. Int J Hyperthermia 2005;21:359-65.
43. Spyropoulos E, Christoforidis C, Borousas D, Mavrikos S, Bourounis M, Athanasiadis S. Augmentation phalloplasty surgery for penile dysmorphophobia in young adults: considerations regarding patient selection, outcome evaluation and techniques applied. Eur Urol 2005;48:121-7; discussion 127-8.
44. Gontero P, Galzerano M, Bartoletti R, Magnani C, Tizzani A, Frea B, et al. New insights into the pathogenesis of penile shortening after radical prostatectomy and the role of postoperative sexual function. J Urol 2007;178:602-7.
45. Savas M, Yeni E, Ciftci H, Topal U, Utangac M, Verit A. Is penile length a factor in treatment of erectile dysfunction with PDE-5 inhibitor? J Androl 2009;30:515-9.
46. Tomova A, Deepinder F, Robeva R, Lalabonova H, Kumanov P, Agarwal A. Growth and development of male external gen-

italia: a cross-sectional study of 6200 males aged 0 to 19 years. Arch Pediatr Adolesc Med 2010;164:1152-7.
47. Aslan Y, Atan A, Omur Aydın A, Nalçacıoğlu V, Tuncel A, Kadıoğlu A. Penile length and somatometric parameters: a study in healthy young Turkish men. Asian J Androl 2011;13:339-41.
48. Söylemez H, Atar M, Sancaktutar AA, Penbegül N, Bozkurt Y, Onem K. Relationship between penile size and somatometric parameters in 2276 healthy young men. Int J Impot Res 2012;24:126-9.
49. Khan S, Somani B, Lam W, Donat R. Establishing a reference range for penile length in Caucasian British men: a prospective study of 609 men. BJU Int 2012;109:740-4.
50. Caraceni E, Utizi L, Angelozzi G. Pseudo-capsule "coffin effect": how to prevent penile retraction after implant of three-piece inflatable prosthesis. Arch Ital Urol Androl 2014;86:135-7.
51. Negro CL, Paradiso M, Rocca A, Bardari F. Implantation of AMS 700 LGX penile prosthesis preserves penile length without the need for penile lengthening procedures. Asian J Androl 2016;18:114-7.
52. Da Silva EA, Sampaio FJ. Urethral extensibility applied to reconstructive surgery. J Urol 2002;167:2042-5.
53. Vasconcelos JS, Figueiredo RT, Nascimento FL, Damião R, da Silva EA. The natural history of penile length after radical prostatectomy: a long-term prospective study. Urology 2012;80:1293-6.
54. Sanches BC, Laranja WW, Alonso JC, Rejowski RF, Simões FA, Reis LO. Does underestimated penile size impact erectile function in healthy men? Int J Impot Res 2018;30:158-62.
55. Ajmani ML, Jain SP, Saxena SK. Anthropometric study of male external genitalia of 320 healthy Nigerian adults. Anthropol Anz 1985;43:179-86.
56. Orakwe JC, Ogbuagu BO, Ebuh GU. Can physique and gluteal size predict penile length in adult Nigerian men? West Afr J Med 2006;25:223-5.
57. Kamel I, Gadalla A, Ghanem H, Oraby M. Comparing penile measurements in normal and erectile dysfunction subjects. J Sex Med 2009;6:2305-10.
58. Chrouser K, Bazant E, Jin L, Kileo B, Plotkin M, Adamu T, et al. Penile measurements in Tanzanian males: guiding circumcision device design and supply forecasting. J Urol 2013;190:544-50.
59. Shalaby ME, Almohsen AE, El Shahid AR, Abd Al-Sameaa MT, Mostafa T. Penile length-somatometric parameters relationship in healthy Egyptian men. Andrologia 2015;47:402-6. Erratum in: Andrologia 2016;48:986.
60. Salama N. Penile dimensions of diabetic and nondiabetic men with erectile dysfunction: a case-control study. Am J Mens Health 2018;12:514-23.
61. Takure AO. Penile length of men attending urology outpatient clinic in Southwest Nigeria. Pan Afr Med J 2021;39:155.
62. Chen KK, Chou YH, Chang LS, Chen MT. Sonographic measurement of penile erectile volume. J Clin Ultrasound 1992;20:247-53.
63. Son H, Lee H, Huh JS, Kim SW, Paick JS. Studies on self-esteem of penile size in young Korean military men. Asian J Androl 2003;5:185-9.
64. Mehraban D, Salehi M, Zayeri F. Penile size and somatometric parameters among Iranian normal adult men. Int J Impot Res 2007;19:303-9.
65. Promodu K, Shanmughadas KV, Bhat S, Nair KR. Penile length and circumference: an Indian study. Int J Impot Res 2007;19:558-63.
66. Hosseini J, Tavakkoli Tabassi K. Surgical repair of posterior urethral defects: review of literature and presentation of experiences. Urol J 2008;5:215-22.
67. Choi IH, Kim KH, Jung H, Yoon SJ, Kim SW, Kim TB. Second to fourth digit ratio: a predictor of adult penile length. Asian J Androl 2011;13:710-4.
68. Nikoobakht M, Shahnazari A, Rezaeidanesh M, Mehrsai A, Pourmand G. Effect of penile-extender device in increasing penile size in men with shortened penis: preliminary results. J Sex Med 2011;8:3188-92.
69. Park KK, Lee SH, Chung BH. The effects of long-term androgen deprivation therapy on penile length in patients with prostate cancer: a single-center, prospective, open-label, observational study. J Sex Med 2011;8:3214-9.
70. Chen XB, Li RX, Yang HN, Dai JC. A comprehensive, prospective study of penile dimensions in Chinese men of multiple ethnicities. Int J Impot Res 2014;26:172-6.
71. Habous M, Tealab A, Williamson B, Binsaleh S, El Dawy S, Mahmoud S, et al. Erect penile dimensions in a cohort of 778 Middle Eastern men: establishment of a nomogram. J Sex Med 2015;12:1402-6.
72. Gooran S, Narouie B, Faraji Shovey M, Fazeli F, Dialameh H, Sharifi A, et al. Comparing the length of penile mucosa in men with and without premature ejaculation. Urologia 2016;83:36-9.
73. Canguven O, Talib RA, El-Ansari W, Shamsoddini A, Salman M, Al-Ansari A. RigiScan data under long-term testosterone therapy: improving long-term blood circulation of penile arteries, penile length and girth, erectile function, and nocturnal penile tumescence and duration. Aging Male 2016;19:215-20.
74. Kadono Y, Machioka K, Nakashima K, Iijima M, Shigehara K, Nohara T, et al. Changes in penile length after radical prosta-

tectomy: investigation of the underlying anatomical mechanism. BJU Int 2017;120:293-9.
75. Kadono Y, Nohara T, Kawaguchi S, Sakamoto J, Makino T, Nakashima K, et al. Changes in penile length after radical prostatectomy: effect of neoadjuvant androgen deprivation therapy. Andrology 2018;6:903-8.
76. Kim KS, Bae WJ, Kim SW, Lee MY. Experience with AMS 700 LGX penile prostheses for preserving penile length in Korea. BMC Urol 2019;19:6.
77. Su HC, Gu XF, Zhu Y, Dai B, Qin XJ, Lin GW, et al. [Changes in the penis size of prostate cancer patients after radical prostatectomy and its influencing factors]. Zhonghua Nan Ke Xue 2021;27:522-5. Chinese.
78. Smith AM, Jolley D, Hocking J, Benton K, Gerofi J. Does penis size influence condom slippage and breakage? Int J STD AIDS 1998;9:444-7.
79. Brock G, Montorsi F, Costa P, Shah N, Martinez-Jabaloyas JM, Hammerer P, et al. Effect of tadalafil once daily on penile length loss and morning erections in patients after bilateral nerve-sparing radical prostatectomy: results from a randomized controlled trial. Urology 2015;85:1090-6.
80. Habous M, Muir G, Tealab A, Williamson B, Elkhouly M, Elhadek W, et al. Analysis of the interobserver variability in penile length assessment. J Sex Med 2015;12:2031-5.
81. Antonini G, De Berardinis E, Busetto GM, Del Giudice F, Chung BI, Conti SL, et al. Postoperative vacuum therapy following AMS™ LGX 700® inflatable penile prosthesis placement: penile dimension outcomes and overall satisfaction. Int J Impot Res 2020;32:133-9.
82. Kinsey AC, Pomeroy WR, Martin CE. Sexual behavior in the human male. 1948. Am J Public Health 2003;93:894-8.
83. Siminoski K, Bain J. The relationships among height, penile length, and foot size. Ann Sex Res 1993;6:231-5.
84. da Ros C, Teloken C, Sogari P, Barcelos M, Silva F, Souto C. Caucasian penis: what is the normal size? J Urol 1994;151(Pt 2):323A-325A.
85. Ansell. The penis size survey [Internet]. Richmond: Ansell [cited 2019 Oct 12]. Available from: http://esvc000171.wic049u.server-web.com/education/research.htm
86. Awad A, Alsaid B, Bessede T, Droupy S, Benoît G. Evolution in the concept of erection anatomy. Surg Radiol Anat 2011;33:301-12.
87. Haliloglu A, Baltaci S, Yaman O. Penile length changes in men treated with androgen suppression plus radiation therapy for local or locally advanced prostate cancer. J Urol 2007;177:128-30.
88. Köhler TS, Pedro R, Hendlin K, Utz W, Ugarte R, Reddy P, et al. A pilot study on the early use of the vacuum erection device after radical retropubic prostatectomy. BJU Int 2007;100:858-62.
89. Nguyen Hoai B, Pham Minh Q, Nguyen Cao T, Sansone A, Colonnello E, Jannini EA. Data from 14,597 penile measurements of Vietnamese men. Andrology 2021;9:906-15.
90. Habous M, Muir G, Soliman T, Farag M, Williamson B, Binsaleh S, et al. Outcomes of variation in technique and variation in accuracy of measurement in penile length measurement. Int J Impot Res 2018;30:21-6.
91. Lynn R. Rushton's *r–K* life history theory of race differences in penis length and circumference examined in 113 populations. Personal Individ Differ 2013;55:261-6.
92. Brix N, Ernst A, Lauridsen LLB, Parner E, Støvring H, Olsen J, et al. Timing of puberty in boys and girls: a population-based study. Paediatr Perinat Epidemiol 2019;33:70-8.
93. Mills JL, Shiono PH, Shapiro LR, Crawford PB, Rhoads GG. Early growth predicts timing of puberty in boys: results of a 14-year nutrition and growth study. J Pediatr 1986;109:543-7.
94. Limony Y, Kozieł S, Friger M. Age of onset of a normally timed pubertal growth spurt affects the final height of children. Pediatr Res 2015;78:351-5.
95. Busch AS, Højgaard B, Hagen CP, Teilmann G. Obesity is associated with earlier pubertal onset in boys. J Clin Endocrinol Metab 2020;105:dgz222.
96. Euling SY, Selevan SG, Pescovitz OH, Skakkebaek NE. Role of environmental factors in the timing of puberty. Pediatrics 2008;121 Suppl 3:S167-71.
97. Ohlsson C, Bygdell M, Celind J, Sondén A, Tidblad A, Sävendahl L, et al. Secular trends in pubertal growth acceleration in Swedish boys born from 1947 to 1996. JAMA Pediatr 2019;173:860-5.
98. Aksglaede L, Olsen LW, Sørensen TI, Juul A. Forty years trends in timing of pubertal growth spurt in 157,000 Danish school children. PLoS One 2008;3:e2728.
99. Roth CL, DiVall S. Consequences of early life programing by genetic and environmental influences: a synthesis regarding pubertal timing. Endocr Dev 2016;29:134-52.
100. Monteilh C, Kieszak S, Flanders WD, Maisonet M, Rubin C, Holmes AK, et al. Timing of maturation and predictors of Tanner stage transitions in boys enrolled in a contemporary British cohort. Paediatr Perinat Epidemiol 2011;25:75-87.
101. Main KM, Schmidt IM, Skakkebaek NE. A possible role for reproductive hormones in newborn boys: progressive hypogonadism without the postnatal testosterone peak. J Clin Endocrinol Metab 2000;85:4905-7.
102. Grumbach MM. A window of opportunity: the diagnosis of gonadotropin deficiency in the male infant. J Clin Endocrinol Metab 2005;90:3122-7.