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**Penile Measurements in Tanzanian Males:  
Guiding Circumcision Device Design and Supply Forecasting**

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**Keywords: male circumcision, HIV, Africa, penis**

**ABSTRACT**

**Purpose:** Voluntary medical male circumcision (VMMC) has been shown to reduce men's risk of HIV infection through heterosexual intercourse by ~60% in clinical trials and 73% in post-trial follow-up. In 2007, WHO and UNAIDS recommended countries with low circumcision rates and high HIV prevalence expand VMMC programs as part of their national HIV prevention strategies. Devices for adult/adolescent male circumcision could accelerate the pace of VMMC scale-up. Detailed penile measurements of African males are required for device development and supply size forecasting.

**Materials and Methods:** Consenting males undergoing VMMC at three health facilities in Tanzania's Iringa region underwent measurement of the glans, shaft and foreskin of the penis. Age, Tanner stage, height and weight were recorded. Measurements were analyzed by age categories. Correlations between penile parameters and height, weight and body mass index (BMI) were calculated.

**Results:** In 253 Tanzanian males ages 10–47 years, the mean (SD) penile length of adults was 11.5 (1.6) cm; shaft circumference was 8.7 (0.9) cm; and glans circumference was 8.8 (0.9) cm. As expected, given the variability of puberty, measurements of younger males varied significantly. Glans circumference was highly correlated with height ( $r=0.80$ ,  $p<.001$ ) and weight ( $r=0.81$ ,  $p<.001$ ). Stretched foreskin diameter was moderately correlated with height ( $r=0.68$ ,  $p<.001$ ) and weight ( $r=0.71$ ,  $p<.001$ ).

**Conclusions:** This descriptive study provides penile measurements of males seeking VMMC services in Iringa, Tanzania. It is the first study in a sub-Saharan African population that provides sufficiently detailed glans and foreskin dimensions to inform VMMC device development and size forecasting.

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## INTRODUCTION

After three randomized control trials indicated male circumcision reduces heterosexual male HIV acquisition by ~60%, the World Health Organization (WHO) and the Joint UN Programme on HIV/AIDS (UNAIDS) recommended rapid scale-up of voluntary medical male circumcision (VMMC) programs in 14 African countries with low circumcision rates and high HIV prevalence.<sup>1-4</sup> Subsequent studies have shown prevention effect of up to 73%.<sup>5</sup> In addition to averting millions of HIV infections, expanding VMMC could potentially save up to \$16 billion in healthcare costs.<sup>6</sup> As of March 2012, over a million PEPFAR (President's Emergency Plan for HIV/AIDS Relief) funded circumcisions had been performed in East and southern Africa.<sup>7</sup> Unfortunately, this is only a fraction of the circumcisions recommended by UNAIDS.<sup>1</sup>

Strategies to increase VMMC efficiency have included streamlining logistics and expanding the role of non-physician healthcare providers.<sup>8</sup> Another approach is to use medical devices rather than surgery for VMMC, reducing both human resource and infrastructure requirements.<sup>9</sup> Male circumcision devices have a successful track record in newborn circumcision.<sup>10</sup> Two adult VMMC devices, the Shang Ring<sup>TM</sup> and the PrePex<sup>TM</sup> are currently undergoing the WHO approval process.<sup>11-13</sup> Both devices include inner and outer compression rings, are single use and disposable, and come in multiple adult sizes.<sup>12, 13</sup> At present neither device has been studied in African males under age 18. Many countries, including Tanzania, have high demand for VMMC among adolescents and young adults, who have the most natural penile size variability. . Since 2009, the Ministry of Health has performed over 100,000 circumcisions in the Iringa and Njombe regions of Tanzania 76% of them in males ages 19 and younger. Since "one-size-fits-all" devices are not currently available, penile size distribution in target populations has significant implications for device development, manufacturing, and supply chain forecasting.

Engineers developing or refining VMMC devices require design specifications which include glans and foreskin parameters. This data dictates which designs are most universally applicable, whether the device requires multiple sizes or is adjustable, and what are clinical exclusion criteria for males whose anatomy is inappropriate for device use. Correct device fit and function are essential for safe and effective VMMC, both intra-operatively and postoperatively. Devices are designed to accommodate a range of anatomic variations of the foreskin and glans, maintain appropriate intraoperative functionality, and prevent penile injury. Postoperative safety and acceptability are also critical, as most adult devices are designed to be left in place several days. A device that is too large could detach prematurely, leading to bleeding or infection. A device that is too small could cause discomfort (affecting acceptability), excessive edema, or pressure necrosis. A 2009 VMMC trial in young South African males randomized the TaraKLamp<sup>TM</sup> device vs. usual surgical technique, but the trial was aborted early due to higher rates of adverse events in the device arm.<sup>14</sup> The design of an individual device dictates which penile parameters correlate with device size, and all currently require a measurement tool to aid in size selection. Accurate forecasting of device sizes will be critical for programs to efficiently provide large numbers of VMMCs.

For disposable devices available in a range of sizes, manufacturing and supply forecasting are dependent on accurate predictions of device sizes required by target communities. Procurement of inaccurate sizes can lead to stockouts in popular sizes, impeding access to VMMC services, while overstocks of infrequently used sizes can increase warehousing costs. In low income countries where VMMC devices must be imported and where patients often face financial and geographic barriers to obtaining VMMC services, there are far-reaching implications if programs must deny or delay services due to commodity stockout.

Navigating a device through the process of designing, refining, testing, and satisfying regulatory requirements is expensive and the data collected is often considered proprietary by device companies who are not incentivized to publish information that might be useful to competitors. Consequently little published literature exists regarding tissue properties and penile size variations required for device refinement. Most publications (Table 1) describing penile measurements focus on adult dimensions such as penile length or girth, which are relevant to penile augmentation surgery, rather than foreskin and glans parameters, which are important for VMMC device development and sizing. Only two publications report penile parameters in Sub-Saharan Africans, and the data collected is inadequate to inform design or sizing.<sup>15, 16</sup>

Some prior studies have shown weak correlations between penile length and somatometric parameters such as height and BMI (Table1).<sup>17-21</sup>. It is not known whether there are correlations between glans/foreskin measurements and somatometric parameters.

Our main study objective was to provide detailed penile and foreskin dimensions to inform device development and size forecasting in a location where VMMC programs are being expanded. A secondary objective was to explore the relationship between selected somatometric parameters and penile dimensions for clinical or programmatic implications.

## **MATERIALS AND METHODS**

This study was conducted at health facilities serving peri-urban and rural areas of Iringa region, which has Tanzania's highest HIV prevalence, low circumcision prevalence, and an active VMMC program.<sup>22, 23</sup>

### **Participants and Informed Consent**

Males ages 10–49 years presenting for VMMC at three health facilities during July and September 2011, and meeting eligibility criteria were invited to participate. Sample size calculations used weighted data from the published literature where we calculated a mean midshaft penile circumference of 9.55 cm and, using weighted standard deviations, found that with a sample of 50 to 75 men in an age group, precision is  $\pm 0.28$  cm to  $\pm 0.23$  cm with a 95% confidence interval. This degree of precision was deemed acceptable for design purposes by device engineers. Using a quota sampling method, initial sample size goals for each age group (10-13, 14-17, and 18-49) were 50-75 each.<sup>24</sup> This was subsequently increased to 125 among adults (aged 18-49) in order to accrue enough mature males (Tanner 5) to achieve our desired precision.

Informed consent was obtained by research assistants who received ethics training. Verbal assent was required from all participants over age 17 and written informed consent from a parent or guardian for participants under 17. Age was self-reported as Tanzania has no national identification cards.

### **Clinical and Measurement Procedures**

Data collectors included five Tanzanian doctors and nurses with VMMC experience, who had a two-day orientation to the study. The training established intra-individual reproducibility as well as utilized repeated measures of inter-rater reliability against a gold standard.

Participant's age, height and weight were measured before surgery. BMI was calculated as body weight (kilograms) divided by the square of height (meters). In adults, normal BMI is defined as 18.5 to 24.9, underweight as  $<18.5$ , overweight as 25–29.9 and obese as  $>30$ . Penile measurements were obtained after administering local anesthesia, immediately before surgery.

After manual reduction of any suprapubic fat, gentle traction was applied at the corona. Stretched penile length (cm) was measured from the penopubic junction to the most distal glans using a ruler; glans length (cm) from corona to distal glans was also recorded. Length from the corona to the distal edge of the reduced foreskin (cm) in the relaxed state was measured using a ruler. Unstretched shaft circumference at both the corona and distal shaft (cm) was measured with a tape measure. The distal foreskin stretched diameter was measured (cm) by inserting the inside jaws of a vernier caliper inside the opening of the reduced foreskin and gently separating until skin was taut transversely, insuring the foreskin did not roll off. Foreskin thickness under tension (mm) was measured by placing the caliper's fixed jaw flush along the longitudinal penile axis with the tip at the corona, and then reducing the foreskin over the both the glans and the caliper jaw. The jaws were then approximated until the foreskin would not slide out, taking care not to overcompress the tissue while measuring. Phimosis, the inability to retract the foreskin without trauma, can affect some penile measurements so if the patient was noted to have phimosis and/or an erection during measurements, this was recorded along with estimated Tanner stage.

### Statistical Analysis

For continuous variables, the mean, median, interquartile range (IQR) and standard deviation were calculated. For categorical variables, percentages and frequencies were calculated. Results were analyzed by age category. Given estimated variation in pubertal onset, data from the younger two age categories were plotted in a similar fashion to a growth curve (measurements vs. age).

Participant height and weight were measured in order to examine correlations with penile parameters. Pearson correlations were calculated for penile and somatometric parameters. Pearson correlations are considered very high when 0.9–1.0, high if 0.7–0.9, moderate if 0.5–0.7, low if 0.3–0.5 and weak when 0–0.3. Scatterplots of continuous measurements were made with locally weighted scatterplot smoothing (lowess). Statistical analyses were performed in Stata 11.0 (Stata, College Station, Texas).

### Ethical Oversight

Ethical approval was obtained from the National Institute for Medical Research in Tanzania and the Institutional Review Board of the Johns Hopkins Bloomberg School of Public Health.

## RESULTS

Overall, 253 males aged 10–47 years were enrolled at VMMC sites (52 aged 10-13, 107 aged 14-18, and 93 adults aged 19-47). The median (IQR) stretched penile length among adults was 11.5 cm (10.7-12.3). Glans length was 2.9 cm (2.6-3.2) and shaft circumference was 8.5 cm (8.1-9.0) (Table 2). Circumference at the coronal ridge was 8.8 cm (8.2-9.4), stretched diameter of distal foreskin was 4.6 cm (4.2-4.9), foreskin thickness was 1.4 mm (1.2-1.8) and the distance from coronal ridge to the distal tip of foreskin was 3.3 cm (3.0-3.6). As expected, penile parameters varied widely among males ages 10–18 (Figure 1), given variability in age and sexual maturation.

Among adults (n=61), median (IQR) BMI was 20.8 (19.8-22.3) (Table 3). In our data, 84% of adults were normal weight, 7% underweight, 8% overweight and 2% obese. There were no obese boys and 2.6% were overweight. The majority of males <19 fell beneath the 50<sup>th</sup> percentile of the WHO age-specific BMI curve.<sup>25</sup> Figure 2 shows age-specific BMI measurements.

Glans and foreskin measurements are critical to device fit. Distal foreskin stretched diameter was moderately correlated with patient height ( $r=0.68$ ,  $p<.001$ ) and weight ( $r=0.71$ ,  $p<.001$ ) (Table 4). Glans circumference was highly correlated with patient height ( $r=0.80$ ,  $p<.001$ ) and weight ( $r=0.81$ ,  $p<.001$ ) (Table 4 and Figure 3).

As expected, progression in sexual maturity according to Tanner staging increased with age (Figure 4). However, by age 19, only 69% of males were Tanner 5, suggesting these adults were not all sexually mature.

A subset analysis of age and Tanner stage showed that 18-year-olds were more variable in Tanner staging than adults. Thus they were placed in the pubertal for analysis which accords with WHO definitions for adolescents.<sup>25</sup> Thus, the three age categories used in this study were pre/peri-pubertal (10–13), pubertal (14–18), and adult (19–49).

The phimosis rate was low (1.6%, 4/254). Penile parameters collected during erections were removed during analysis. This affected one data point from each of six participants; each was recoded as “missing.”

## DISCUSSION

This study describes penile measurements of the foreskin and glans in Tanzanian VMMC clients in Iringa, Tanzania to inform device development and size forecasting for device-based VMMC programs. These data augment currently available literature on penile dimensions, providing more detailed measurements than previously available in a population where VMMC is being scaled up.

Mean adult stretched penile length among this sample [11.5 +/- 1.6 cm] is near the lower end of the spectrum of other studies. In the world literature, length varied from 9.6 to 16.7 cm.<sup>15, 17, 18, 20, 21, 26, 27</sup> Our findings differ from published studies in West Africa.<sup>15, 16</sup> There are several potential explanations, including delayed puberty, stunted growth/ poor nutrition, and a preponderance of young adults in the adult category. Environmental and genetic factors might play a role. The study population may experience later puberty relative to high-income countries. More than 30% of the adults in this study had not yet attained sexual maturity (Figure 3) and may not have yet achieved their adult penile size. Similarly, a 1985 Nigerian study, found that only 47% of males reached full maturity by age 19 (89% by age 21).<sup>16</sup> In contrast, a U.S. study found 91% of males showed mature pubic hair patterns by age 18.<sup>28</sup> Nutritional status affects both somatometric parameters and pubertal onset.<sup>29</sup> Tanzania's 2010 Demographic and Health Survey found 52% of children under 5 were stunted, reflecting chronic under-nutrition.<sup>23</sup> There is evidence that adolescent males in rural sub-Saharan Africa may be more underweight than those in urban areas.<sup>30</sup> Finally, the majority of adult males in this study were young (69% were < 25 years old), which reflects the underlying age distribution of adult men seeking VMMC. The preponderance of young adults in the “adult” group magnifies any contribution of stunting or delayed sexual maturity discussed above.

The findings are operationally relevant for device supply forecasting in a demand-driven, device-based VMMC program. All devices under development are produced in multiple sizes. Countries implementing device-based VMMC programs need to locally assess penile parameters and age distribution to establish appropriate quantities and range of device sizes to order. Of note, once a program has chosen a device, the local assessment can focus on the 1-2 penile parameters relevant to that device. Accurate device size forecasting will lead to more efficient use of resources for VMMC services as well as avoiding potential adverse clinical events from inappropriately sized devices.

Previous literature, focusing on adults, has shown variable correlations between penile parameters and height, weight and BMI (Table 1). In this study, the most important parameters related to device fit (glans length, circumference at corona, and distal stretch diameter of foreskin) were correlated with both height and weight. High correlation (0.8) existed between the circumference at the coronal margin and patient height (Table 4, Figure 4).. Practically, this could mean measuring height in lieu of a genital sizing exam to help predict circumcision device size. These correlations should be confirmed by future studies.

### **Limitations**

Results of this study are not necessarily generalizable. Penile dimensions can vary based on age, race, and environmental factors.

The adult category was disproportionately comprised of younger males, reflecting the demographic seeking VMMC services. Less physically mature adults may be overrepresented.

In this study, age was based on self-report, since national IDs are not required.

### **CONCLUSIONS**

Penile parameters measured in this study were more detailed than any previous evaluation in a rural/peri-urban sub-Saharan African population and will be useful for device design and supply forecasting. Differences between this study and previous literature highlights the need to assess penile dimensions among target populations in the implementation plans of device-based VMMC programs.

Some somatometric measurements were found to be correlated with penile dimensions. This finding may increase device-based VMMC program efficiency by providing an alternative non-genital method for estimating device size.

Penile measurements should be assessed in additional settings (urban locations, other countries, etc.) to establish generalizability.

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## REFERENCES

1. **New Data on Male Circumcision and HIV Prevention: Policy and Programme Implications**, Geneva: World Health Organization, UNAIDS, 2007  
Accessed on 2/1/12 at:  
[http://libdoc.who.int/publications/2007/9789241595988\\_eng.pdf](http://libdoc.who.int/publications/2007/9789241595988_eng.pdf).
2. **Auvert, B., Taljaard, D., Lagarde, E. et al.:** Randomized, controlled intervention trial of male circumcision for reduction of HIV infection risk: the ANRS 1265 Trial. *PLoS Med*, 2: e298, 2005
3. **Bailey, R. C., Moses, S., Parker, C. B. et al.:** Male circumcision for HIV prevention in young men in Kisumu, Kenya: a randomised controlled trial. *Lancet*, 369: 643, 2007
4. **Gray, R. H., Kigozi, G., Serwadda, D. et al.:** Male circumcision for HIV prevention in men in Rakai, Uganda: a randomised trial. *Lancet*, 369: 657, 2007
5. **Gray, R., Kigozi, G., Kong, X. et al.:** The effectiveness of male circumcision for HIV prevention and effects on risk behaviors in a posttrial follow-up study. *AIDS*, 26: 609, 2012
6. **Njeuhmeli, E., Forsythe, S., Reed, J. et al.:** Voluntary medical male circumcision: modeling the impact and cost of expanding male circumcision for HIV prevention in eastern and southern Africa. *PLoS Med*, 8: e1001132, 2011
7. **Reed, J. B., Njeuhmeli, E., Thomas, A. G. et al.:** Voluntary medical male circumcision: an HIV prevention priority for PEPFAR. *J Acquir Immune Defic Syndr*, 60 Suppl 3: S88, 2012
8. **Lissouba, P., Taljaard, D., Rech, D. et al.:** A model for the roll-out of comprehensive adult male circumcision services in African low-income settings of high HIV incidence: the ANRS 12126 Bophelo Pele Project. *PLoS Med*, 7: e1000309, 2010
9. **McIntyre, J. A.:** Can devices for adult male circumcision help bridge the implementation gap for HIV prevention services? *J Acquir Immune Defic Syndr*, 58: 506, 2011
10. **Grossman, E., Posner, N. A.:** Surgical circumcision of neonates: a history of its development. *Obstet Gynecol*, 58: 241, 1981
11. **Framework for the clinical evaluation of adult devices for male circumcision** Geneva: World Health Organization, 2012  
Accessed on December 5th, 2012 at:  
[http://apps.who.int/iris/bitstream/10665/75954/1/9789241504355\\_eng.pdf](http://apps.who.int/iris/bitstream/10665/75954/1/9789241504355_eng.pdf).
12. **Mutabazi, V., Kaplan, S. A., Rwamasirabo, E. et al.:** HIV prevention: male circumcision comparison between a nonsurgical device to a surgical technique in resource-limited settings: a prospective, randomized, nonmasked trial. *J Acquir Immune Defic Syndr*, 61: 49

13. Li, H. N., Xu, J., Qu, L. M.: [Shang Ring circumcision versus conventional surgical procedures: comparison of clinical effectiveness]. *Zhonghua Nan Ke Xue*, 16: 325
14. Lagarde, E.: High rate of adverse events following circumcision of young male adults with the Tara KLamp technique: a randomised trial in South Africa. *SAMJ*, 99: 163, 2009
15. Orakwe, J. C., Ogbuagu, B. O., Ebu, G. U.: Can physique and gluteal size predict penile length in adult Nigerian men? *West Afr J Med*, 25: 223, 2006
16. Ajmani, M. L., Jain, S. P., Saxena, S. K.: Anthropometric study of male external genitalia of 320 healthy Nigerian adults. *Anthropol Anz*, 43: 179, 1985
17. Soylemez, H., Atar, M., Sancaktutar, A. A. et al.: Relationship between penile size and somatometric parameters in 2276 healthy young men. *Int J Impot Res*, 24: 126, 2011
18. Mehraban, D., Salehi, M., Zayeri, F.: Penile size and somatometric parameters among Iranian normal adult men. *Int J Impot Res*, 19: 303, 2007
19. Aslan, Y., Atan, A., Omur Aydin, A. et al.: Penile length and somatometric parameters: a study in healthy young Turkish men. *Asian J Androl*, 13: 339, 2010
20. Promodu, K., Shanmughadas, K. V., Bhat, S. et al.: Penile length and circumference: an Indian study. *Int J Impot Res*, 19: 558, 2007
21. Ponchietti, R., Mondaini, N., Bonafe, M. et al.: Penile length and circumference: a study on 3,300 young Italian males. *Eur Urol*, 39: 183, 2001
22. Tanzania Commission for AIDS (TACADIS), Zanzibar AIDS Commission (ZAC), National Bureau of Statistics, Office of the Chief Government Statistician, and Macro International Inc: Tanzania HIV/AIDS and Malaria Indicator Survey 2007-08., Dar es Salaam, Tanzania, 2008  
Accessed on December 5<sup>th</sup>, 2012 at:  
<http://www.tac aids.go.tz/dmdocuments/THMIS%202007-08.pdf>
23. Tanzania Demographic and Health Survey 2010, Dar es Salaam, Tanzania: National Bureau of Statistics (NBS) [Tanzania] and ICF Macro, 2011  
Accessed on December 5<sup>th</sup>, 2012 at:  
[http://www.measuredhs.com/pubs/pdf/FR243/FR243\[24June2011\].pdf](http://www.measuredhs.com/pubs/pdf/FR243/FR243[24June2011].pdf)
24. Fisher, A., Foerit, J: *Designing HIV Intervention Studies: An Operations Research Handbook*. Washington, DC: Population Council, 2002
25. de Onis, M., Onyango, A. W., Borghi, E. et al.: Development of a WHO growth reference for school-aged children and adolescents. *Bull World Health Organ*, 85: 660, 2007
26. Son, H., Lee, H., Huh, J. S. et al.: Studies on self-esteem of penile size in young Korean military men. *Asian J Androl*, 5: 185, 2003

27. Bondil, P., Costa, P., Daures, J. P. et al.: Clinical study of the longitudinal deformation of the flaccid penis and of its variations with aging. *Eur Urol*, 21: 284, 1992
28. Karpati, A. M., Rubin, C. H., Kieszak, S. M. et al.: Stature and pubertal stage assessment in American boys: the 1988-1994 Third National Health and Nutrition Examination Survey. *J Adolesc Health*, 30: 205, 2002
29. Parent, A. S., Teilmann, G., Juul, A. et al.: The timing of normal puberty and the age limits of sexual precocity: variations around the world, secular trends, and changes after migration. *Endocr Rev*, 24: 668, 2003
30. Omigbodun, O. O., Adediran, K. I., Akinyemi, J. O. et al.: Gender and rural-urban differences in the nutritional status of in-school adolescents in south-western Nigeria. *J Biosoc Sci*, 42: 653, 2010

**ABBREVIATIONS KEY****BMI = body mass index****ht = patient height****IFL = index finger length****IQR = interquartile range****PEPFAR=President's Emergency Plan for HIV/AIDS Relief****PSC = penile shaft circumference****SPL = stretched penile length****UNAIDS=Joint UN Programme on HIV/AIDS****VMMC = voluntary medical male circumcision****wt = patient weight****WHO = World Health Organization**

Table 1. Summary of selected literature on penile measurements and correlations

Author, year	Country	Number of males	Age	Stretched penile length in cm (SPL)	Penile shaft circumference in cm (PSC)	Positive correlations* (statistically significant)	Negative correlation* (statistically significant)	No correlation* (or not statistically significant)
Ajmani et al, 1985	Nigeria	320	17-23	NA	8.83			
Bondil et al, 1992	France	905	17-91	16.7	NA			
Ponchietti et al, 2001	Italy	3,300	17-19	12.5	10.0	SPL with ht (r=0.22), PSC with ht (r=0.16)	SPL with wt (r=-0.14) and with BMI (r=-0.17) and PSC with wt (r=-0.004) and with BMI (r=-0.58)	
Son et al, 2003	Korea	123	19-27	9.60	8.50			
Orakwe, 2006	Nigeria	115	30-65	13.4	NA	SPL with gluteal size		no correlation between SPL and BMI
Mehraban et al, 2007	Iran	1,500	20-40	11.58	8.66	PSC with ht (r=0.18) and with wt (r=0.21) and with IFL (r=0.46). SPL with ht (r=0.31) and with wt (r=0.18) and with IFL (r=0.23)		

Promodu et al, 2007	India	301	18-60	10.88	9.14	PSC with ht (r=0.25) and with wt (r=0.33) and with BMI (r=0.22)	SPL with wt (r=-0.21) and with BMI (r=-0.27)	SPL with ht (r=0.09)
Aslan et al, 2010	Turkey	1,132	19-30	13.7	NA	SPL with ht (r=0.16) and with wt (r=0.21) and with BMI (r=0.21)		

Key: ht=patient height; IFL=index finger length; PSC=penile shaft circumference; SPL=stretched penile length; wt=patient weight

Note: \*r values (correlation) provided if cited in study

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**Table 2. Penile measurements by age category**

Measurement variable	Age 10-13 (n=52)		Age 14-18 (n=107)		Age 19-49 (n=93)	
	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)
Stretched penile length (cm) L1	7.5 (6.4-8.3)	7.4 (1.5)	10 (8.3-1.2)	9.7 (2.0)	11.5 (10.7-12.3)	11.5 (1.6)
Glans length (cm) L2	1.8 (1.5-1.9)	1.7 (0.4)	2.5 (2.1-2.8)	2.4 (0.5)	2.9 (2.6-3.2)	2.9 (0.4)
Girth/circumference of shaft proximal to corona (cm) C1	5.5 (5.0-6.0)	5.6 (0.8)	7.9 (7.0-8.5)	7.6 (1.3)	8.5 (8.1-9.0)	8.7 (0.9)
Girth/circumference at coronal ridge/margin (cm) C2	5.5 (5.0-5.8)	5.5 (0.9)	7.9 (6.9-8.7)	7.6 (1.4)	8.8 (8.2-9.4)	8.8 (0.9)
Foreskin stretched diameter at most distal end (cm) F2	2.6 (2.3-3.0)	2.7 (0.6)	4.0 (3.3-4.5)	3.9 (0.9)	4.6 (4.2-4.9)	4.6 (0.7)
Foreskin thickness under tension (mm) F3	1.1 (1.0-1.2)	1.2 (0.3)	1.3 (1.2-2.0)	1.5 (0.5)	1.4 (1.2-1.8)	1.5 (0.5)
Distance from the coronal ridge to the distal edge of the foreskin (cm) F5	2.5 (2.0-2.8)	2.5 (0.6)	3 (2.6-3.4)	3.0 (0.6)	3.3 (3.0-3.6)	3.3 (0.6)

IQR = interquartile range (25%ile to 75%ile) SD=standard deviation

**Table 3. Somatometric measurements by reported age group**

Measurement variable	Age 10-13 (n=47)		Age 14-18 (n=90)		Age 19-49 (n=61)	
	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)
Height (cm)	135 (123.0-140.0)	133.3 (0.9)	152.0 (146.0-158.0)	151.5 (9.7)	165 (161.0-170.0)	164.6 (7.6)
Weight (kg)	30.0 (26.0-32.0)	29.5 (5.0)	44.0 (39.0-50.0)	44.1 (8.4)	59 (51.0-61.0)	57.7 (7.1)
Body Mass Index (kg/m <sup>2</sup> )	16.5 (15.3-17.9)	16.5 (1.8)	19.1 (17.3-20.4)	19.1 (2.3)	20.8 (19.8-22.3)	21.3 (2.7)

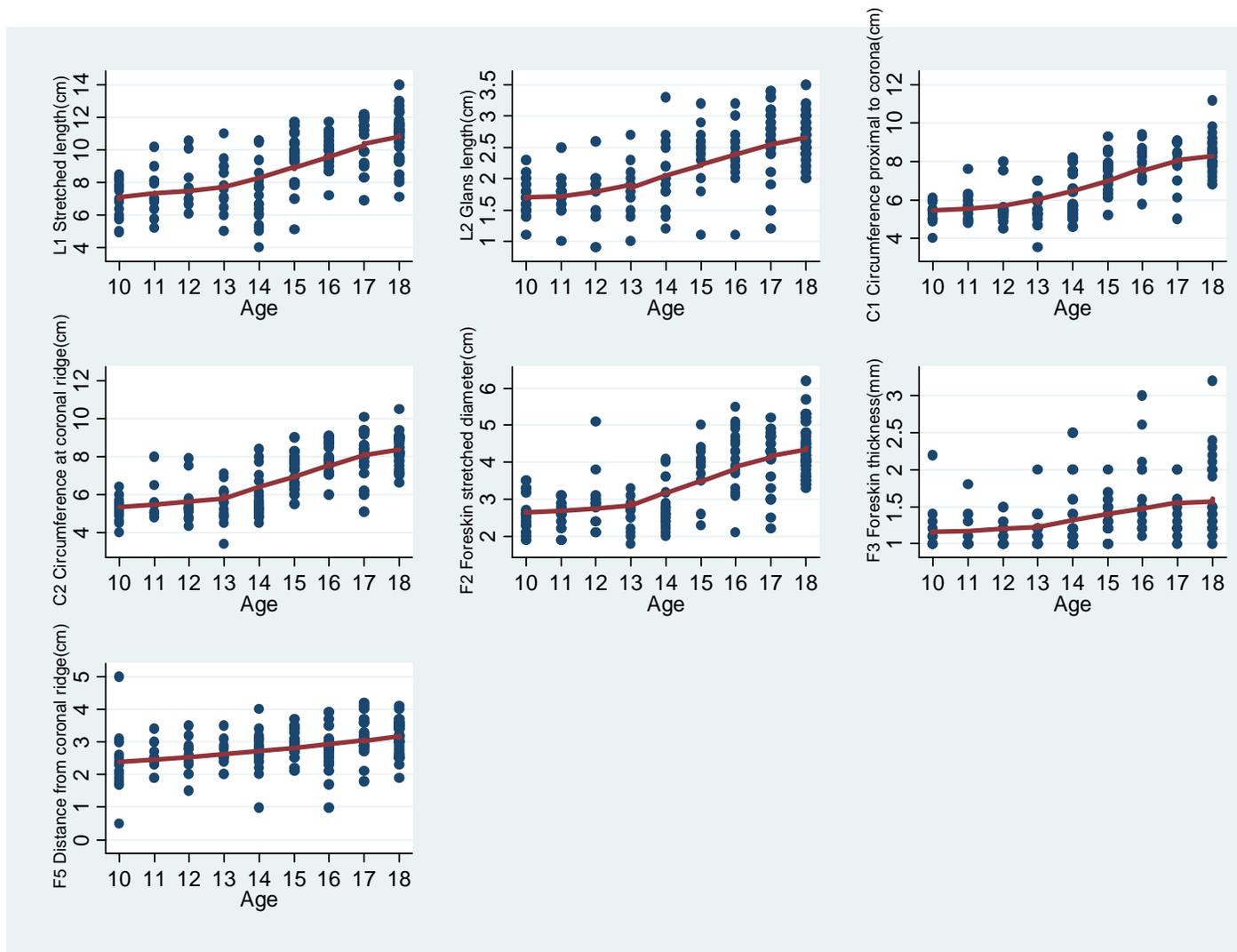
Note: N=198. Not all patients had data on height and weight available

**Table 4. Pearson correlations of penile and somatometric measurements<sup>a, b</sup>**

<b>Measurement variable</b>	<b>Height (cm)</b>	<b>Weight (kg)</b>	<b>Body mass index (kg/m<sup>2</sup>)</b>
Stretched penile length (base to tip of glans) (cm)	0.69	0.73	0.55
Glans length (coronal ridge to tip) (cm)	0.68	0.71	0.50
Girth/circumference of shaft just proximal to the corona with foreskin retracted (cm)	0.78	0.78	0.57
Girth/circumference at coronal ridge/margin with foreskin retracted (cm)	0.80	0.81	0.59
Foreskin stretched diameter at most distal end (cm)	0.68	0.71	0.53
Foreskin thickness under tension (mm)	0.27	0.30	0.18*
Distance from coronal ridge to distal edge of the foreskin (cm)	0.49	0.49	0.32

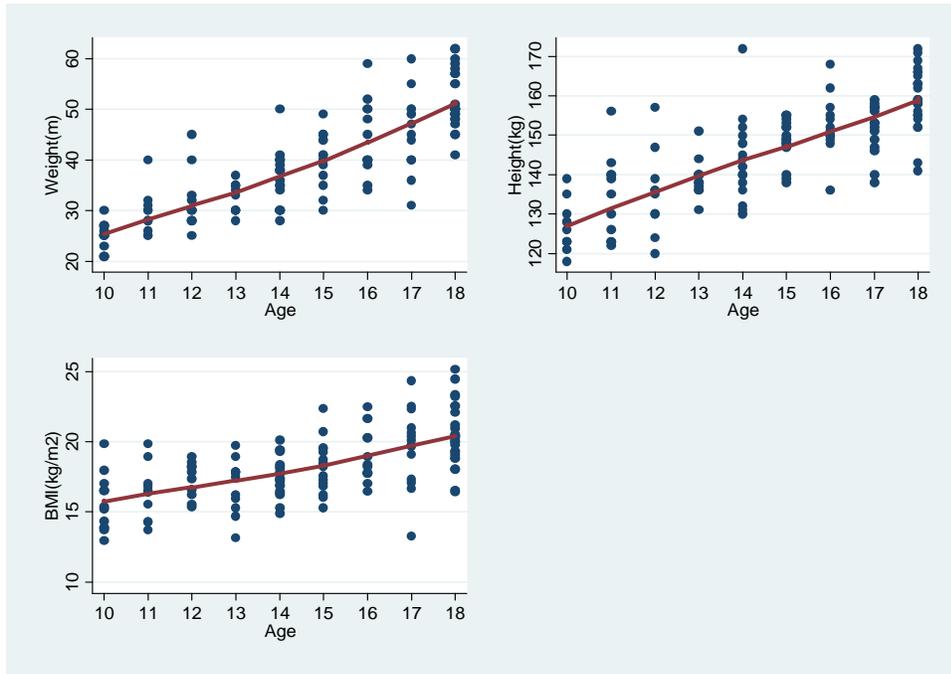
<sup>a</sup> All results presented are significant at p-value <.001 except where noted; \* p<.05

<sup>b</sup> Pearson correlations are considered very highly correlated when 0.9 to 1, high if 0.7 to 0.9, moderate if 0.5 to 0.7, low if 0.3 to 0.5, and little if any correlation when 0 to 0.3.

**Figure 1. Penile parameters by year of age for non-adults (n=159)**

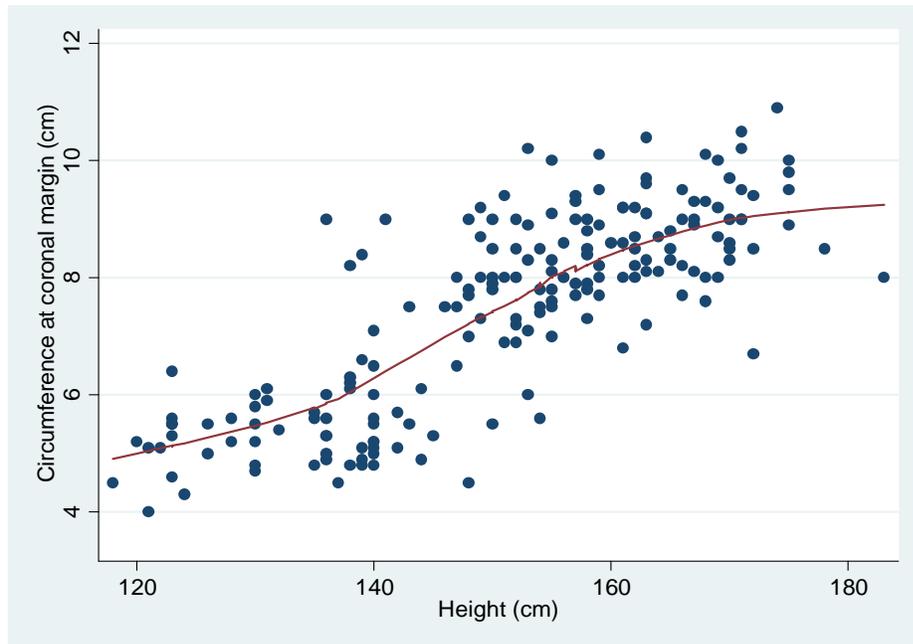
**Note: line represents locally weighted scatterplot smoothing (lowess)**

Figure 2. Somatometric parameters by year of age for non-adults (n=159)



Note: line represents locally weighted scatterplot smoothing (lowess)

**Figure 3. Scatterplot of circumference at coronal margin (cm) vs. patient height (cm)**



**Note: line represents locally weighted scatterplot smoothing (lowess)**

**Figure 4. Tanner staging (sexual maturity) distribution by age category**