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DOES POSTURE AFFECT MICTURITION?

Thesis submitted by

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And finally Dr Jay Iyer, a student that a teacher can only hope for, a colleague one could only wish for and a friend one could only dream for, I am truly grateful.
ABSTRACT

Posture during toileting and its effect on toileting has been under scrutiny for more than 7000 years. With the advent of the western toilet in the 19th century and a more closeted approach to toileting, the effects of posture became even more important to study because the visual one to one education of children, regarding toileting became less and less. Wennergren in her study of children demonstrated the value of foot support to relax the pelvic floor during urination in children. [1] Moore in her study showed that a majority of British women will not sit on the toilet outside their house and would ‘hover’ to pass urine. [2] A Taiwanese study showed a similar trend except that young students would precariously perch in a squat over a western toilet than sit on it for hygiene reasons. [3] All these studies stimulated the generation of this thesis.

PRINCIPAL OBJECTIVES AND SCOPE OF THE STUDY

The principal objectives of these investigations were to study

- The effect of the ‘lean forward’ position on the western toilet (WT) compared to the ‘sit upright position’ during micturition.
- The effect of the ‘raised knee’ position on the western toilet compared to the ‘lean forward’ position during micturition.
- The effect of squatting on a custom built Asian toilet compared to ‘lean forward’ position on the western toilet.

What was learnt led to numerous ‘sub-studies’ on squatting which included -

- Study of squatting in volunteers leading to a ‘squatability’ index
- Study of school children and their ability to squat
- Study of abdominal pressures in squatting and sitting positions at rest and during Valsalva manoeuvre.
- Study of the levator hiatus during squatting and lying down at rest.
- Possible design of a retro fit device to aid toileting on the western toilet called Duneze.
METHODOLOGY

All toileting parameters were studied using uroflowmetry which was used as standard, as in previous studies. [1-6]

Support for Uroflowmetry, which is a simple non-invasive measurement of urine flow over time and an indication in screening for voiding difficulty, as a screening test for voiding dysfunction has become stronger over time, [7-9] measuring some of the key components of the micturition process. [10] An abnormally slow urine flow suggests a provisional diagnosis of voiding difficulty subject to test repetition, post-void residual bladder volume (PVRBV) measurement and possible voiding cystometry.

Post Void Residual Urine Volume Measurement of post void residual urine volume (PVRBV), the amount of residual urine in the bladder after a voluntary void, is another non-invasive screening test for evaluating voiding dysfunction. Most urologists agree that volumes of 50 mL to 100 mL constitute the lower threshold defining abnormal residual urine volume PVRBV measurement. There are 2 methods of measuring PVRBV: sterile catheterization and bladder ultrasound. Although sterile catheterization provides a urine sample, there are many disadvantages associated with the procedure: it causes patient discomfort, carries a risk of urethral trauma and introducing an UTI, is time-consuming, and may not be necessary. [11]

In contrast, bladder ultrasound can be performed with a portable device. It is non-invasive and time-efficient, minimizes medical waste and supplies, and determines when catheterization is medically appropriate. However, a urine specimen cannot be obtained during this procedure. Portable 3-dimensional ultrasound devices have been shown to provide highly accurate measurement of bladder volume. Coombes and Millard compared the BladderScan™ BVI 2500 series (Diagnostic Ultrasound, Bothell, Wash) with catheterization for the measurement of bladder volume with no significant difference in estimates being demonstrated. The overall accuracy (94%), sensitivity (97%), and specificity (91%) of the BVI 2500+ were encouraging. [11] The current accuracy of modern uroflowmeters in measuring urine voided over time (flow rate) is approximately ± 2–5%, despite the fact that a variety of different physical measurement principles are being used. This accuracy compares favourably with the ± 20–25% for the most accurate ultrasonic techniques for PVR measurement with the potential error using urethral catheterisation being much higher. [12]
After obtaining Institutional ethics approval for all studies, volunteers recruited from nursing staff and medical students participated in these studies coached either by Audrey Corstiaans (AC) or Professor Ajay Rane (AR).

SUMMARY OF RESULTS

STUDY ONE:

There was a statistically significant difference in the peak and average urine flow rates in the lean forward position when compared to the sit back posture (p<0.0054 and p<0.0097 respectively).

STUDY TWO:

There was a statistically significant difference in uroflowmetric parameters i.e. the peak (p=0.01) and average flow rates (p=0.043), when tested in the lean forward position as compared to the knee raised position respectively. Hence the importance of knee raising or leaning forward with feet stability was deemed equally important when toileting.

STUDY THREE:

This was the most challenging of studies. In summary, only 46% of our volunteers from a cohort of 125 could actually squat (with feet flat for more than 30 seconds). [13] Although not statistically significant, in volunteers who could squat there was a trend to better urine flows especially the “time to maximum flow” (p=0.003) in the squatting position when compared to the lean forward position.

The results of the Study One encouraged us to consider the possibility that an alternative position during toileting would be beneficial in effecting voiding. This lead to the evaluation of Uroflowmetric parameters in the lean forward and raised knee position (Study Two). Encouraged by the results of Study Two we raised the bar even higher and asked patients to squat during the act of voiding. Although no firm conclusions could be drawn from this study the main challenge arose from the fact that less than half of our volunteers could not squat.
PRINCIPAL CONCLUSIONS

The main conclusions derived from these studies are
- Posture on the toilet affects bladder function
- On the western toilet the lean forward position with foot support is the most optimal
- Squatting position is difficult to assume in a majority of the population who do not routinely use squat toilets.
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CHAPTER 1

GENERAL INTRODUCTION
Posture during micturition and defaecation has been a topic of discussion for centuries. There is a huge body of anecdotal and unscientific literature on this topic. This introduction reflects on this data, and an attempt is made to scientifically study posture, and it’s effect on micturition, in subsequent chapters. Two-thirds of humanity uses the squatting position to answer the call of nature. This fact has generated intense debate both in Orient and the Occident whether the traditional squatting position over the toilet is superior in achieving bowel evacuation to the “more evolved” sitting posture adopted by Western Cultures. In the yogic scriptures of Patanjali, 7000 years ago, there is a description on the use of a Hatha Yoga technique called ‘Mahabandha’ for control of anal and urethral canals through perineal pressure by the heel of the left foot. [14] The lotus position and heel pressure on the perineum to defer micturition are also well enshrined in the teachings of Tai-Chi.

Although squatting is the most natural and effective posture for evacuation, the body is able to use other positions in emergencies (like a broken leg). For thousands of years, kings and queens have adopted other positions to distinguish themselves from the “commoners”. [15] Then, in the mid-nineteenth century, at the beginning of the Industrial Revolution, indoor plumbing became universally available. The early industrialists decided (rather arbitrarily) to install throne-like toilets everywhere – to allow ordinary people to feel like kings and queens. Knowing nothing about physiology, they sincerely believed that they were improving people’s lives. Those who felt uncomfortable with this decision were forced to keep silent. (In Victorian England, bodily functions were considered unmentionable). From Great Britain, the most influential country in the world at the time, the fad quickly spread to the rest of Europe, and to North America and Australia. No country wanted to seem “backward” at a time when the world was making such rapid “progress.” [15] Until just a few years ago, the taboo on discussing this subject kept most of the western world in the dark about how the human body was designed to function.

The ignorance of the medical profession has been especially regrettable – and has caused much needless suffering. [15] Naylor and Mulley from St Luke’s at Leeds addressed the issue of western commodes and the attitudes of users and carers to them. [16] This study highlighted the existing ignorance amongst carers about the use of commodes and other appliances in aiding toileting.
TOILETTING – A PRIVATE BUT FASCINATING FUNCTION [17]

Toileting has fascinated people the world over. In vernacular English alone there are more than three hundred different names for it like loo, john, dunny, bathroom, WC, washroom, toilet, facilities, little boys' room etc. Taboo subjects like death, drugs and sex have all provoked deep interest throughout the ages. Toilets are no different. They are indeed a bay window to civilisations and populations. Often they reflect development or lack of, in a given country or region. Toilets are ubiquitous; they transcend all ages, races, religions and social class. Every one of us has to obey the call of nature.

Some may say the act is philosophical – emptying the body empties the head! Many people use the toilet to get peace of mind or generate great ideas. Records in the Old Testament tell us of Moses telling his people 'to go abroad and when they ease themselves, to dig, turn back and cover what has cometh from thee'. Although there was no knowledge of bacteria and sanitation, it was the smell of excrement that drove civilisations to do the ‘job’ away from living space and this by itself may have limited the spread of disease.

The oldest known flush toilet dates to the 18th Century BC in Knossos, Crete, home of King Minos. Sewage disposal was quite rigorous in Jerusalem and Rome. In 800 BC Cloaca Maxima was the first known sewer with running water. The Middle Ages though, saw a fall in sanitation and this contributed to the bubonic plague called Black Death in Europe. Chamber pots were standard in use and the contents usually heaved out of the window with a warning cry “guardez l’eau” in French meaning – watch the water – the word loo remains slang for toilets in Britain.

As the Middle Ages drew to a close, science made the connection between disease and poor sanitation which led to sewers and proper disposal. In 1596, Sir John Harington is known to have designed the first flush toilet for Queen Elizabeth I in Richmond Palace. She is rumoured not to have used it because of the noise! Thomas Crapper dubiously has been given the kudos of inventing the toilet. Far from it Crapper and Co. had their name on a lot of porcelain toilets and American soldiers stationed in the UK during WWI used the word Crapper or Crap when they excused themselves - this word still remains in use! In 1775 Alexander Cummings patented the flush toilet and since then there has been no great changes in the toilet except in bowl design, cistern shapes and the quantity of water used. In a brief tour of the toilets of the
Fig 1(i) “guardez l’eau” – watch the water!

Fig 1(ii) Thomas “Crapper” advt

Fig 1(iii) Ornate Porcelain toilet (Victorian England)
world, I have picked some geographically salient features continent by continent to describe the effects of population affluence, geography and traditions on toilet designs.

**NORTH AMERICAS**

The most obvious feature in North American toilets is the amount of water they use; it is the largest amount in the world per flush. The 102nd U.S. Congress legislated through the Energy Policy Act of 1992 (that came into effect on 1st January 1994) that cisterns used no more than 6 litres per flush down from a whopping 19-26 litres per flush. Visitors often complain about the splash back effect due to a high water level. Another important feature is the crescent moon which was cut on top of the doors of outhouses to let light in. This continues to be used even though electricity is ubiquitous. Americans usually avoid the word toilet, and they ask for bathroom, washroom or restroom when they need to go. Amazing toilet designs from North America include toilets in submarines, the international space station, l’urinette (The standing loo for women) in Quebec amongst many others.

**CENTRAL AND SOUTH AMERICA**

Impoverishment meant that typically the restrooms or ‘banos’ are small and dirty. There are people who man some for a fee and keep them clean. Of note are the Kuna Indian toilets – which have a narrow plank walk right up to the Pacific Ocean and they let the tides do the cleaning act. Most toilets in this region have thatched palm frond roofs and no sewer systems.

**EUROPE**

Europe seems to be the heart of toilet varieties. Sewerage is universal but the toilet designs and etiquettes are vastly variable. Many are quite exotic and ergonomically designed. [18] Most European countries require you to pay to use facilities in public buildings. Madame Pipi in French or ‘Klofrau’ in German needs to be handed the money before you enter. Perhaps the more scary aspect for the unwary traveller is the Squat toilets in France and southern Europe. Long haired beginners are urged to tie up their hair and require reasonable athletic prowess to squat and avoid splashing trousers, shoes and feet!
Fig 1(iv) NYC-“CBGB”- Punk Heaven

Fig 1(v) Colca Canyon Andes-home of the “Condor”

Fig 1(vi) Atacama Desert-Humberstone Route 16
Fig 1(vii) London-“Pink eggs are for girls, blue …

Fig 1(viii) Brussels-Square Maurice Raindorf
AFRICA

It is obviously assumed that the first act of toileting took place in Africa. Landscape, wild life, dress and customs and economic disparity dictate the types of toilets in this continent. Squat toilets are commoner in North Africa and they get more and more infrequent as one goes south. A door in front of an African toilet is usually without hinges and brightly painted. It is simply propped against the entrance. A clever adaptation in African toilets is the use of the suns’ searing heat to ventilate the toilet. A ventilation pipe runs from the pit below the toilet through the roof. The outer portion of the pipe gets heated by the sun, which causes air and odours from the latrine to be sucked up and expelled from the top of the pipe. Perhaps most relevant is the difference in toilets during apartheid with opulence for the white men and dank, stinky holes for the non – whites.

OCEANIA

The lingo of the ‘dunny’ and the ‘long drop’ is very specific to Australia and New Zealand. The dual flush toilet is the hallmark for this region. Small flush and big flush for respective jobs! Tales of the outback dunny are plenty with snakes, red back spiders, bats, wombats and even crocs abiding in some dunnies!!

One of the common myths is the direction of the swirl of water in the toilet. The myth is that it swirls in the opposite direction down under. The reality is water does not swirl the other way down under. The direction in which the water swirls depends purely on technicalities like bowl shape and piping. Only in very large bodies of water is the Coriolis effect perceptible. Even a toilet a few kilometres in diameter will not be enough to demonstrate this effect!

Australia is unique in that it has a National Public Toilet Map. Another unique fact for manufacturers for Australian toilets – whilst all over the world these are tested by stuffing condoms with sausages of various sizes and flushed the Australians insist on golf balls stuffed in a condom for testing!!

Finally the town of Dunedoo in NSW is split in half – with a pro Big Dunny group and an anti-Big Dunny group!
Fig 1(ix) Alscot Park Manor-England

Fig 1(x) Toilet Apartheid!
Fig 1(xi) All sheep no humans- Kiwiland!

Fig 1(xii) Inside the leading Dunny- Silverton, NSW

Fig 1(xiii) Duneedoo Caravan Park, NSW-
A dunny that bitterly divided a village!
ASIA

This continent has perhaps the most varied in cultures and therefore toileting habits. Most Asians use squat toilets. But that’s where the similarity ends. Japanese squat toilets require guest to change footwear before entering the toilet and changing back when exiting. They use plenty of flushable toilet paper.

Chinese use squat toilets but facial tissue paper is used to wipe and flush. The Thai use toilet paper but it must be tossed in the bin next to the toilet. The Indians and Turks prefer washing with their left hand as a substitute for toilet paper.

In India though only a third of the population uses sewered facilities, the rest do it in the open – this has serious health and sanitation consequences and a Non Government Organisation called Sulabh Sanitation is making progress in improving this public health issue.

Finally flushing mechanisms vary considerably. In some there are sensors, buttons, and jets whereas in others there are chains and knobs, and then there is the humble bucket and the floating mug!
Fig 1(xiv) Odoriferous home next to public toilet - India

Fig 1(xv) Hutongs (communal toilets) - Beijing

Fig 1(xvi) Japanese toilet
Toilets from Ancient Times

Pictures of ancient public toilets tend to confuse westerners, who assume that they were used in the sitting position. This impression is often reinforced by the pose of a comical tourist. But, in reality, these are squat toilets. They are elevated, not for sitting, but because there is an open sewer underneath. The cut-outs in the vertical wall allow people to clean themselves with water, which is done from the front when squatting.

Photo courtesy of Toilets of the World [17]

The ancient Romans used the posture shown below on the left. (Togas were more convenient than trousers, and provided some degree of privacy.) The last picture shows a typical tourist. He might be surprised to learn that, except for royalty and the disabled, everyone used the squatting position until the second half of the 19th century.

Highlights in the Evolution of Toilet System – 2500 BC to the 21st Century [19]

2500 BC: In Mohenjo – Daro, there existed highly developed drainage system where waste water from each house flowed into the main drain.
1000 BC: In the Bahrain Island in the Persian Gulf, flush type toilet was discovered.
   69 AD: Vespasianus for the first time levied tax on toilets.
1214 AD: Construction for the first time of public toilets manned by scavengers in Europe.
1596 AD: JD Harrington invents W.C.
1668 AD: Edict issued by Police Commissioner Paris, construction of toilets in all houses.
1728 AD: Architect J.F. Brondel argues that attached toilet is ideal.
1739 AD: First separate toilet for men and women appear at a ball in Paris.
1824 AD: First Public Toilet in Paris.
1859 AD: Toilet of Queen Victoria is decorated with gold.
1883 AD: First Ceramic Toilet by Thomas Turiferd for Queen Victoria.
1889 AD: Sewage Treatment for the first time in the world (U.K.).
1959 AD: All surface Toilets abandoned (Paris).
Fig 1(xvii)-Toilets from Ancient times
URINARY INCONTINENCE

In the larger cities of Asia, many residents have abandoned their traditional customs, believing that the West is more progressive and somehow “superior.” By adopting western toilets, they have unwittingly introduced new diseases into their society. A recent article in the Malaysian newspaper The Star (March 30, 2003) discusses one such ailment:

“To squat or not to squat?” That is the question. Actually, your toileting technique may have an effect on urinary incontinence. There is evidence to show that the Asian technique of using the toilet goes a long way to maintaining better pelvic health than the Western technique. [13]

A study done in Hong Kong showed that city-dwelling women had more urinary incontinence and bowel problems than country dwelling women who attributed the basic differences in these women, not to their body weight, or how many children they had, but to their toileting habits. [20] In general, women in urban areas use the “sit” method while the rural women use “squat” toilets.

‘Natures’s Platform’ suggests that squatting causes the angle of the pelvis to change and exert higher pressure on the ano-rectum.. When sitting, appropriate relaxation of the pelvic muscles does not occur nor is the angle of the pelvis correct. This further emphasises health gains from adopting the squatting position.[15]

The above view is shared by Dr. Stuart Stanton, Chairman of the Continence Foundation and Consultant Urogynaecologist at St. George’s Hospital, London.’ “Squat” toilets are an excellent way for women to exercise their perineum and pelvic floor muscles and control their urinary stream from the age of 2½-3 years onwards. Reports from the developing world suggest that urinary incontinence is much less in women who squat.’ [15]

A brief explanation of why sitting toilets increase the risk of incontinence could be as follows:

The pelvic floor is a hammock of muscles that supports the abdominal contents, the bladder, rectum and the uterus. Western toilets force the user to strain when evacuating, repeatedly subjecting the pelvic floor to unnatural pressure. The downward pressure constitutes a chronic repetitive stress injury that stretches and weakens the pudendal nerve, responsible for bladder control.
71 women who had delivered at St. Bartholomew’s Hospital, London, were studied by electrophysiological measurements performed on the innervations of the external anal sphincter muscle. Manometry was also performed. [21-25]

The investigations were carried out 2-3 days after delivery and repeated in 70% of these women 2 months later. Faecal and urinary incontinence developing after vaginal delivery had always been thought to be due to direct sphincter division or muscle stretching. However the results of this study suggest that in most cases this incontinence results from damage to the innervations of the pelvic floor muscles. [26]

To maintain continence, the brain needs to constantly monitor the pressure within the bladder and issue commands to the urethral sphincter muscle. Both functions are impaired when the pudendal nerve is weakened by the descent of the pelvic floor.

The following statistics from FocusOnUrology.com [27] show how frequently this occurs:

- 17 million Americans are incontinent.
- Women experience incontinence twice as often as men. (The gynaecological disorders section explains why.)
- 1 in 4 women age 30-59 has experienced an episode of incontinence.
- $16.4 billion is spent every year on incontinence-related care
- $1.1 billion is spent every year on disposable products for adults.
- 50% or more of elderly persons living at home or in long-term care facilities are incontinent.

FocusOnUrology.com attributes incontinence mainly to childbirth, weakened pelvic muscles, hormonal changes associated with menopause, and (in men) prostate surgery. Due to their cultural conditioning, women do not often mention the use of the reclining posture for childbirth. The modern toilet has made women incapable of prolonged squatting, the position designed by nature to protect the pelvic floor during delivery. [28]
Nor does the website FocusOnUrology.com mention the direct effect of using a sitting toilet, which causes the pelvic floor to be pushed downwards each time one strains to evacuate.

Based on a conservative estimate that the average person strains four times for each daily evacuation, by the age of 50 the unsupported pelvic floor has been stretched 73,000 times. BA Sikirov discusses straining forces on bowel elimination and its effects on pelvic floor structures. [29] D Sikirov gives a comparison of straining during defaecation in three positions and its implications for human health. [30]

An unnatural manoeuvre repeated so many times inevitably causes a “repetitive stress injury.” The pudendal nerve is the main casualty of this unintentional abuse, which renders over 50% of elderly Americans incontinent.

An article entitled “The Descent of Women – a Silent Epidemic” by University of Adelaide researchers, in the first comprehensive study of its kind in the world, have found a remarkably high prevalence of pelvic floor disorders in the general population. Most of these complaints were still common among women who had never had a vaginal birth. According to Professor MacLennan, the survey highlights the high prevalence and major social impact of pelvic floor prolapse and incontinence in our society. In his opinion it is a silent epidemic which to some extent is unavoidable, as women continue to give birth and also because those with the problem are often embarrassed to talk or seek help about it. [31]

But research by Mr Wallace Bowles on the relevance of the squatting posture has brought a new understanding of how to prevent (and, in many cases, correct) these disorders. Most people with urinary incontinence experience a noticeable improvement within several weeks of commencing to squat for defaecation with complete correction within about 3 months. [32] Anecdotally, a number of women who squat, habitually, for bowel movements and who have experienced pelvic floor trauma and incontinence after the birth of their baby, have regained their continence within about six weeks when they continue to adopt the squat posture for bowel evacuation. Squatting has been linked to prevention of bowel cancer as well. [33]

Even children are susceptible to pelvic floor nerve stretch injury. An article entitled “My Child, My Teacher” was published in the Spring 1998 issue of New Vegetarian and Natural Health Magazine. Focusing on the benefits of squatting for children, the article contains numerous reports of bedwetting corrected by this simple change of habit. [34]
A study carried out in Iran attempted to objectively assess the impact of ethnic habits on defecographic measurements. [35] This study emphasises the importance of the wider anorectal angle resulting from defaecating in a squatting type toilet versus the Western toilet.

Kate Moore and colleagues studied the phenomenon of “Crouching over the toilet seat” and its prevalence in British gynaecological outpatients and its effect upon micturition. This study highlighted the phenomenon of “hovering over the toilet seat” as opposed to actually being seated upon it and its effect on uroflowmetry measurements and bladder residuals.

Given the foregoing background I have attempted to study the effects of posture and its possible impact on micturition.
Chapter 1  General introduction

Chapter 2  Hypothesis, study parameters and justifications

Chapter 3  Physiology of Pelvic structures during toileting
  3a.  Physiology of Micturition
  3b.  Physiology of Defaecation

Chapter 4  Epidemiology of Incontinence

Chapter 5  The Perfect Pee Study

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Chapter 8  Inventions to aid squatting

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CHAPTER 2

HYPOTHESES, STUDY PARAMETERS AND JUSTIFICATIONS
HYPOTHESES

1. Posture on the western toilet in the lean forward position and the upright position makes no difference to voiding parameters.
2. Posture on the western toilet with knee elevation and the lean forward position makes no difference to voiding parameters.
3. Squatting posture on a custom designed toilet and the lean forward position on the western toilet make no difference to voiding parameters.
4. Squatting posture for toileting is possible in all volunteers.
5. All school going children irrespective of gender can adopt the squatting position for toileting in a western setting.
6. There is no difference in abdominal pressures at rest or during Valsalva manoeuvre in the sitting or squatting position.
7. There is no difference in the levator hiatus on scan in the sitting or squatting position at rest or during Valsalva manoeuvre.

STUDY PARAMETERS

Study parameters included mainly the use of Uroflowmetric data on volunteers, cystometry, vaginal manometry and 3D/4D trans-perineal ultrasound.

Uroflowmetry, the simple, non-invasive measurement of urine flow over time during micturition, has a long history, clear definitions, and a clear purpose in screening for voiding difficulty. Most importantly technical accuracy is reproducible. [36, 37] Support for its use as a screening test for voiding dysfunction has become ever stronger over time. [7, 9] It is recognised as a simple, non-invasive test measuring some of the key final outcomes of the micturition process. [10] Abnormally slow urine flow represents a provisional diagnosis of voiding difficulty subject to test repetition, post-void residual (PVR) measurement and possible voiding cystometry. The current accuracy of modern uroflowmeters in measuring urine voided over time (flow rate) is around ± 2–5%, despite the fact that a variety of different physical principles are being used. This accuracy compares favourably with the ± 20–25% for the most accurate ultrasonic techniques for PVR measurement with the potential error using urethral catheterisation being much higher. [12]
Data interpretation remains the key issue limiting the clinical value of uroflowmetry. This involves an understanding of the normality, relevance and diagnostic potential of the data obtained. The main three clinically relevant parameters are the voided volume and the maximum (MUFR) and average (AUFR) urine flow rates. [38] The voided volume is the area under the urine flow curve. MUFR, the maximum measured value of the urine flow rate, and AUFR, the voided volume divided by the time over which measurable flow occurs (flow time), are different numerical interpretations of the urine flow curve. The clinical use of either flow rate is equally valid. The need for a completely private environment in which women can void for uroflowmetry has long been emphasised as essential. [8] The use of modern uroflowmeters with the levels of accuracy cited above is assumed. Sitting rather than hovering over the toilet to void gives a better urine flow. [2]

Traditionally recommended lower limits of normality in women for the MUFR range between 12 ml/s [39] and 20 ml/s [40] provided 150 ml or sometimes 200 ml has been voided. All these values have been deemed as arbitrary. [41] The strong dependency of urine flow rates on voided volume is recognised most directly and over the widest range of voided volumes by the use of nomograms. The Liverpool (Uroflow) Nomograms [42], published in 1989, using the uroflowmetry data from 249 asymptomatic female volunteers, have become an established reference (Fig. 1 for MUFR, Fig. 2 for AUFR). Under the 10th centile of the nomogram has been determined as having the most useful discriminatory ability (sensitivity 81%, specificity 92%) for the diagnosis of voiding difficulty [43], confirming the findings of a previous study. [44]

All women participating in the study had been given an information leaflet and telephone instructions by a practice nurse or secretary both at the initial booking and at confirmation of the appointment that (i) they should come with a comfortably full bladder; (ii) they should eat and drink normally; (iii) they should not empty their bladder in the hour prior to their appointment. Free uroflowmetry would then be likely to occur 60–90 min following their last void, in an effort to optimise the presenting bladder volume. The clinical and academic utility of reference to nomograms (Fig 2(i), (ii))

The overall advantages of referring raw uroflowmetry data to established nomograms are: (i) automatic correction of urine flow rates for voided volume; (ii) immediate validation of interpretation for around 89% voided volumes from uroflowmetry studies; (iii) clear delineation of normality over the same range; (iv) the use of centile rankings allows the uroflowmetry data of different populations to be compared; (v) it overcomes
the dangers of referencing urine flow rates to any one voided volume: e.g. an MUFR of 15 ml/s might be just on the 10th centile Liverpool Nomogram at 200 ml though well below the 5th centile at 400 ml voided volume.

Urine flow traces are complementary to urine flow rates, though their statistical utility is limited by the fact that they cannot be numerically represented except by the flow data. However, abnormally slow but continuous urine flow traces might be due to either a urethral obstruction or to poor detrusor function with pressure flow studies needed to determine the cause. Abnormally interrupted but otherwise normal urine flow might indicate voluntary urethral sphincter contraction, though if it is slow and there is associated abdominal straining to achieve this urine flow, it might again indicate poor detrusor function. Detrusor sphincter dyssynergia is where there is discoordination of the detrusor contraction and urethral relaxation. Generally, urine flow is slow, only occurring with urethral relaxation, with longer interruptions to flow. There is some deterioration in urine flow rates in symptomatic women with age [43, 44] with increasing prolapse with age accounting for much of that deterioration.

In summary, Uroflowmetry is the study of voiding velocity and our Unit measures this electronically. Since Uroflowmetry is usually used to determine obstructive voiding, mean flow rates do not have as much significance as maximal flow rates. Fig 2 (iii) demonstrates a study from a 21-year-old woman with factors that define a normal uroflowmetry. The findings are a bell shaped curve with peak flow rate >25 ml/s and a total flow time <20s. The peak flow rate is reached in <10s and there is no residual urine. An important calculation in uroflowmetry that is not given its due is the residual urine. We consider a residual of < 50 mls as normal but necessarily evaluate this in relation to the volume voided. The test is highly volume dependent and peak flow rates will increase as the volume rises in normal women.

**JUSTIFICATION**

For our studies we used uroflowmetry as a minimally invasive and accurate investigation tool which was easy to administer. We followed the example of Moore et al. [2] when they performed studies on women sitting or ‘hovering’ over toilets. Following our first study, numerous studies have utilised uroflowmetry to study the effect of posture during micturition.
Fig 2(i) Liverpool Normogram for the maximum urine flow rate. Reproduced with permission. The equation for MUFR:
\[ \ln(MUFR) = 0.511 + 0.505 \times \ln(\text{voided volume}) \]
Root mean square error = 0.340

Fig 2(ii) Liverpool Normogram for the average urine flow rate. Reproduced with permission. The equation for AUFR:
\[ \sqrt{AUFR} = -0.21 + 0.869 \times \ln(\text{voided volume}) \]
Root mean square error = 0.640
Bowel studies are inherently difficult to conduct and recruitment for such studies produce small numbers. [29, 35] No new studies have been reported since the mid-nineties.

URODYNAMICS [45-47]

Multichannel Urodynamic evaluation of the female urinary tract involves urethrocystometry, urethral closure pressure profile and voiding pressure studies. Integrating these tests and performing them at various states of bladder fullness as well as in different positions can allow the urodynamicist to obtain a great deal of useful information.

Urodynamics can be used to help counsel patients and to guide treatment plans. For instance, patients who void with a weak or absent detrusor contraction are at an increased risk of postoperative urinary retention after a tension free vaginal sling and patients with a low maximum urethral closure pressure are more likely to have persistent stress incontinence following a transobturator versus a retropubic midurethral sling. As these scenarios indicate, the function of the urethral sphincter and detrusor muscle may affect the decision process when implementing a treatment plan, as well as influencing the counselling of patients on expectations and outcomes. The benefits of the urodynamic evaluation should outweigh the risks, which include time, cost, invasiveness, discomfort for the patient, and the risk of an iatrogenic urinary tract infection.

In our Unit, multichannel urodynamic testing was carried out using a Laborie device (Laborie Medical Technologies) and MediPlus 5400 urethral and abdominal catheters. All procedures were performed in a supine dorsal position with normal saline at room temperature. The filling rate was 50 cm$^3$/min unless this provoked urinary urgency. The abdominal pressure transducer was placed vaginally. Prolapse to or beyond the hymen was reduced manually or rarely a pessary was used for the purpose. Provocative manoeuvres, including water stimulation and cough, were used in an effort to provoke detrusor overactivity or demonstrate stress incontinence. Urethral pressure profilometry was performed manually at a rate of approximately 1 mm/s. Both static and dynamic profiles were performed at cystometric capacity. Recorded urodynamic parameters in addition to the urodynamic tracings were from the uroflowmetry (voided volume, post void residual, maximal and average flow rate, voiding time), cystometrogram (first sensation, first desire to void, strong desire, urgency, capacity, fill rate, detrusor
overactivity, detrusor overactivity incontinence, urodynamic stress incontinence) and urethral pressure profilometry. Any pertinent documentation regarding sensory urgency or leakage during testing was included. Our unit also performs flexible cystoscopy at the end of urodynamics thus providing an anatomic assessment of the bladder that complements its functional assessment by urodynamics and uroflowmetry.

We also used 3 D/4D ultrasound for examining the levator hiatus on lying and squatting to analyse its effect on the puborectalis. [48, 49]
Fig 2(iii) Diagram of a urine flow recording with International Continence Society recommended nomenclature.
Basic elements of Maximum flow, mean flow, total flow time, and total voided volume.
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CHAPTER 3

PHYSIOLOGY OF PELVIC STRUCTURES DURING TOILETING
CHAPTER 3a

PHYSIOLOGY OF MICTURITION
INTRODUCTION

The lower urinary tract has two essential functions: the low-pressure storage of urine in a continent reservoir, and the timely expulsion of stored urine in a coordinated, efficient, and complete fashion. These two mutually exclusive functions are ultimately determined by the activity of the smooth and striated musculature of the bladder, urethra, and external urethral sphincter under the control of various neural circuits in the brain and spinal cord. Although a result of complex interplay between both the central and peripheral nervous systems, these functions are also influenced by several anatomic factors such as integrity of the pelvic floor support and dynamic relationship of the bladder and its outlet to various points in the bony pelvis and adjacent organs during voiding. [50]

PROPERTIES OF DETRUSOR MUSCLE AND BLADDER WALL

A. Excitation-Contraction Coupling

The process of force generation of muscle in response to ligand binding has been termed excitation-contraction coupling. It is a very complex process that results from molecular changes induced by a neurotransmitter crossing the postsynaptic cleft. Smooth muscle cell morphology differs from that of striated muscle in that the major contractile protein in smooth muscle is actin, whereas myosin predominates in striated muscle. Nevertheless, force is ultimately generated by interaction of these two myofilaments. Cardiac muscle and striated muscle have been studied to a much larger extent than smooth muscle, but much of what we know about smooth-muscle physiology comes from the fields of gastroenterology and obstetrics. The molecular and neurological events leading to smooth-muscle contraction are shown in Figure 3a (i),(ii) & (iii).
Fig 3a(i) Molecular events leading to smooth muscle contractions

Fig 3a(ii) Sympathetic nervous system events at neuromuscular junction
B. Compliance

The ability of the bladder to accommodate increasing volumes of urine at low pressures is termed bladder compliance. In mathematical terms, it is measured as a change in unit volume per change in pressure \((C = \Delta V/\Delta P)\). A bladder that can hold large volumes of urine at low pressures is “highly” compliant. At physiologic rates of filling (<10 ml/min), bladder pressure rarely rises above 10 cm H2O up to a capacity of 400–500 cc. This phenomenon is unique to the bladder as an organ if one considers that bladder smooth muscle must undergo a 100–200% displacement in slack length to create this kind of compliance. Compliance is a product of both the neuromechanical and viscoelastic properties of the bladder wall. The fact that even acutely denervated bladders maintain adequate compliance underscores the importance of the passive viscoelastic properties in maintaining adequate bladder compliance. [50]

The human bladder wall is composed of detrusor smooth muscle interspersed with islands of connective tissue or extracellular matrix (ECM). The ECM is composed of proteins such as collagen, proteoglycans, elastin, and many other molecules that are now being identified. Because bladder muscle does not have a “skeleton” on which to exert force, these ECM proteins are extremely important with regard to energy transmission. They are also crucial to compliance, and any alteration in the composition of the ECM can result in decreased compliance. Such alterations can occur with chronic inflammation, injury, obstruction, or chronic denervation and typically result in increased collagen content and fibrosis. There is no agreement yet on the definition of abnormal compliance values. Ghoniem suggested that a value of, 10 ml/cm H2O is severely impaired compliance and dangerous to the upper urinary tracts, 10–20 ml/cm H2O is moderately impaired and >20 ml/cm H2O is normal. [50]

LOWER URINARY TRACT INNERVATION

The pelvic and hypogastric nerves supply the bladder and urethra with efferent parasympathetic and sympathetic neurons, and both convey afferent (sensory) neurons from these organs to the spinal cord. The storage phase of micturition is controlled primarily by sympathetic and voiding phase by parasympathetic, vesicourethral innervation. The somatic innervation is important mainly in regard to the musculature of the pelvic floor and the external or striated urethral sphincter (EUS), and is supplied via efferents in the pudendal nerve. [51-53]
A. Parasympathetic Supply
The parasympathetic efferent supply is classically described as originating in the intermediolateral region of the gray matter of the spinal cord segments S 2–4 and emerges as preganglionic fibres in the ventral roots and exits as the pelvic nerve. This nerve courses deep in the pelvis on each side of the rectum as three or four trunks in human. Bilaterally, at a variable distance from the bladder and urethra, the pelvic and hypogastric nerves meet and branch to form the pelvic plexus, sometimes known as the inferior hypogastric plexus, or plexus of Frankenhauser. This is a plexus of freely interconnected nerves in the pelvic fascia that is lateral to the rectum, internal genitalia, and lower urinary organs. Divergent branches of this plexus innervate these pelvic organs. The hypogastric and pelvic nerves also carry afferent autonomic nerve impulses to synapses in the dorsal column of the lumbosacral spinal cord. [51, 52]

B. Sympathetic Supply
The sympathetic innervation to the lower urinary tract originates in the intermediolateral nuclei of the thoracolumbar spinal cord in segments from T11 through L2 or L3. They traverse the lumbar sympathetic ganglion and join the presacral nerve (superior hypogastric plexus). The hypogastric plexus lies anterolateral to the great vessels at the level of third lumbar to first sacral vertebrae and gives rise to the left and right hypogastric nerves which are really elongated nerve plexuses. These nerve plexuses join the pelvic nerves to form the plexuses of Frankenhauser, from which they spread out to innervate the pelvic organs. [54] As demonstrated by Gilepsie, two nerve bundles extended from the inferior hypogastric plexus (plexus of Frankenhauser), each accompanied by artery derived from the vaginal artery. [55] The first bundle (vesicoureteric plexus) parallels the inferior border of the ureter until it reaches the cardinal ligament, from where, some fibres supply the dorsum of the bladder, while the remaining nerve fibres continue to parallel the ureter to pierce the bladder at the level of the interureteric ridge of the trigone. The destruction of this plexus (vesicoureteric plexus) was found effective in the treatment of women with hypersensitive bladder disorders. The second nerve bundle passes downward to the junction of the urethra with the anterior wall of the vagina. However, more anatomical dissections are needed for this area.

Classically, the autonomic nervous system has been regarded as a two-neuron system composed of two neuron models; preganglionic and postganglionic neurons Figure 3 a(ii). Elbadawi has extensively reviewed the anatomic aspects of the contemporary modifications of classical autonomic nervous system. [56-60] He stated that the
muscular innervation of the lower urinary tract is derived exclusively from postganglionic neurons of what is called the urogenital short neuron system. Although paraganglia and preganglia exist, actual innervation predominantly emanates from peripheral ganglia that are at a short distance from, adjacent to, or within the organs they innervate, thus the name short. The ganglia are composed of three cell types: cholinergic principal neurons, adrenergic principal neurons, and small intensely fluorescent (SIF) cells. The SIF cells are thought to play an important role in modulation of interganglionic vasomotor function and ganglionic transmission. In addition, there are complex intraganglionic networks of cholinergic and adrenergic fibres. Thus, there is a wide variety of modulating synaptic relays. In addition, postganglionic neurons do not necessarily terminate in the peripheral end organ, but many actually terminate within the ganglia of some systems.

C. Somatic Supply

The somatic supply arises from motor neurons in the anterior horn of S2, S3, and S4, clustered in an area known as Onuf’s nucleus. There are contradictory views of the neural supply of the striated sphincter. The EUS is composed of an extramural and intramural component that differs physiologically and will be discussed later. However, most authors agree that the striated sphincter, including both components, is innervated only through motor end plates, implying purely somatic innervation, through there may be differences in opinions regarding the actual nerve trunks carrying these fibres. [53, 61] Hollabaugh et al. described an intrapelvic branch of the pudendal nerve that joins the pelvic nerve branch at the level of the proximal urethral sphincter. [62] The morphologic evidence of autonomic innervation of the striated sphincter has not been definitively demonstrated in other species or in human. However, Elbadawi and Atta [60] reported that there is evidence for triple innervation (somatic plus cholinergic and adrenergic autonomic) of the intramural striated sphincter of the male cat. This finding is supported by electrophysiological studies. [63] These conclusions are applicable only to the intramural portion of the striated sphincter.
NEUROTRANSMISSION AND RECEPTORS

A. General
In both the parasympathetic and sympathetic systems, the preganglionic neurotransmitter is acetylcholine, which affects nicotinic cholinergic receptors. The primary postganglionic parasympathetic neurotransmitter is also acetylcholine, which affects muscarinic cholinergic receptors, while the postganglionic sympathetic neurotransmitter is a catecholamine, norepinephrine, which affects the adrenergic receptors. Newer scientific data are supporting the existence of many other neurotransmitters and receptors responsible for lower urinary tract function. These include ATP, nitric oxide (NO), dopamine, serotonin, glutamine, gamma amino butyric acid (GABA), various neuropeptides, and prostanoids.

SENSORY INNERVATION

Afferent nerve fibres have been demonstrated in the pelvic, pudendal, and hypogastric nerves. [64] In the cat, the afferents subserving the sensation of distension (and active therefore in evoking micturition) are more prominent in muscularis propria layer and are distributed evenly to all regions of the bladder, but the afferents subserving the sensations of pain and conscious touch are more prominent in the submucosa in the regions of trigone and anterior bladder neck. Both pelvic and hypogastric afferent pathways carry nociceptive afferents, whereas afferent pathways from the striated sphincter and from the urethra transmit sensations of temperature, pain, wall distension (urethra), urine passage, and travel in the pudendal nerve. [64] Anatomical and electrophysiological studies have shown that sacral afferent fibres projecting from the bladder to the spinal cord are either myelinated (A-delta with fast conduction up to 30 m/sec) or unmyelinated (C-fibres with slow conduction 0.3 m/sec). [65, 66] Figure 3a (iv) represents a schematic of sensory pathways.

In humans, capsaicin-sensitive nerves have been postulated. A concentration-dependent reduction in first sensation and bladder capacity occurs following acute administration of intravesical capsaicin. It causes desensitization of C-fibre sensory afferents inducing reversible suppression of sensory neuron activity. These pharmacological data support the use of capsaicin or other neurotoxins to treat painful bladder disorders. [67]
Fig 3a(iii) Parasympathetic nervous system events at neuromuscular junction
(Ach- Acetylcholine; M1- Muscarinic; NE- Norepinephrine; CCF- Cleveland Clinic Foundation)

Fig 3a(iv) Sensory innervation of the bladder and central afferents
Resiniferatoxin (RTX), a substance isolated from the cactus plant Euphorbia resinifera, is 1000 times more potent than capsaicin. In contrast, however, RTX has weaker initial excitatory effects than capsaicin on bladder afferents thus eliciting less discomfort. This agent holds significant promise as an alternative to capsaicin in the treatment of both painful bladder disorders as well as detrusor hyperreflexia. [68, 69]

**PHYSIOLOGY OF THE EXTERNAL URETHRAL SPHINCTER (EUS)**

There are two types of muscle fibres in the striated sphincter or EUS. The first one is the strongly reactive fast-twitch muscle fibres, and the second is the weekly reactive slow-twitch muscle fibres. Speed of contraction seems to correlate with histochemical reaction for ATP. Resistance to fatigue is directly related to the intensity of oxidative enzyme staining in the same fibres. Slow-twitch fibres are high in oxidative enzyme activity and relatively fatigue resistant. Fast-twitch fibres may be fatigable or relatively fatigue resistant. [70] The entire intramural (intrinsic) striated sphincter is composed of slow-twitch fibres, whereas the extramural (extrinsic) component consists of both slow-twitch and fast-twitch fibres.

Teleologically, this would be convenient because the intramural striated component would then consist of specialized fibres functionally capable of maintaining tension over prolonged time periods without fatigue. The structure of the extramural component might be related to a role played by this muscle in activity supporting the pelvic viscera and that the slow-twitch fibres are responsible for (background activity) during electromyographic recording. The fast-twitch population of the extramural component is functionally associated with rapid, forceful muscle contraction. It is these fibres then that are recruited to increase the force and speed of contraction of the levator ani during those events that might otherwise cause stress incontinence by raising intra-abdominal pressure. [71]

The fast-twitch fibres (fatigable) can convert to slow-twitch fibres by physiotherapy (e.g., electrical stimulation). This is also a theoretical advantage of pelvic floor exercises and behavioural modifications. Some authors explain the success of these therapies for the treatment of urinary incontinence on the basis of changes in the oxidative characteristics of striated muscle. However, other authors have shown that these types of therapies more successfully treat urge incontinence rather than stress incontinence, raising doubt as to the validity of alterations in muscle morphology. [72]
CENTRAL NERVOUS CONNECTIONS OF THE LOWER URINARY TRACT

It has yet to be resolved whether voiding is the result of a segmental reflex arc that is facilitated and inhibited by supraspinal neurologic pathways, or a long routed reflex that is integrated at higher nervous system levels. [73, 74] However, in the cat, it appears that the most fundamental micturition reflex is a spinal reflex occurring largely in the sacral micturition centre (SMC) at S 2–4. [75] The spinal cord itself has complex patterns of facilitation and inhibition that take place among the ascending and descending pathways at the spinal cord level. Above the level of the cord, the (Pontine Micturition Centre (PMC) is located. It is the most important facilitative motor centre for micturition, and it is believed that this centre serves as the final common pathway for all bladder motor neurons. The region is known as Barrigton’s centre and is present in the anterior pons. The cerebellum serves as a major centre for coordinating pelvic floor relaxation and force of detrusor contraction. There are extensive cerebellar interconnections with the brainstem reflex centres. [74, 76]

Above this level, the basal ganglia exert inhibitory function on detrusor contractility. Consequently, detrusor hyperactivity is frequently seen in Parkinson’s disease. The cerebral cortex, particularly the frontal lobes and genu of the corpus callosum, exerts primarily inhibitory influences on the micturition reflex. Thus, facilitative influences that release inhibition occur in the upper cortex and permit the anterior PMC to send efferent impulses through the spinal cord allowing a sacral micturition reflex to occur with resultant bladder emptying. Any lesion in these centres can produce a disturbance in bladder function characterized by a reflex coordinated contraction with complete emptying. [74, 76] A simplified overview of micturition reflexes is shown in Figures 3a (v) & (vi).

A. Bradley’s Loop Concept
Most of the micturition reflex requires a balanced contribution by all four loops.

Loop I: Cerebral-Brainstem Circuit
This loop consists of pathways to and from the frontal lobes to the pontine mesencephalic reticular formation, with contribution from the thalamic nuclei in the basal ganglia and cerebellum. This loop coordinates volitional control of micturition. It matures during infancy, and may account for voluntary control over the micturition reflex in the childhood. This loop integrity can be demonstrated during cystometry by asking the patient to voluntarily suppress detrusor contraction. Interruption of this circuit
severs the micturition reflex from volitional control, e.g., in brain tumours, trauma, cerebrovascular disease. [77]

**Loop II: The Brainstem Sacral Loop**
This loop consists of pathways from the brainstem (pontine-mesencephalic reticular formation) to the sacral micturition area. Additionally, sensory afferents from the bladder musculature travel directly in the spinothalamic tract to the brainstem without synapsing in the sacral micturition area. These sensory afferent fibres are responsible for the normal sensation of desire to micturate. Loop II is responsible for the occurrence of a coordinated detrusor reflex of adequate duration to produce total evacuation of the intravesical content. Partial interruption of loop II, as in spinal cord injury, results in detrusor reflex of low threshold and the presence of post void residual urine. While abrupt and complete interruption (in spinal shock) produces areflexia and urinary retention; with recovery, uninhibited detrusor reflex contractions appear in the cystogram. [78, 79]

**Loop III: Vesical-Sacral Sphincter Loop**
This loop consists of the detrusor nuclei and pudendal nuclei in the gray matter of the sacral spinal cord with their neurons. Sensory afferents in the detrusor muscle travel the detrusor nucleus and influence the closely located pudendal motor nucleus. Pudendal motor neurons terminate in the striated muscular component of the urethral sphincter. Loop III provides the circuit for coordination of detrusor and urethral muscular activity during voiding. Dysfunction of this loop will be manifested in electromyographic recording as either detrusor sphincter dyssynergia or uninhibited sphincter relaxation. [80]
Fig 3a(v) Motor supply to the bladder and parasympathetic events
Fig 3a(vi) Overview of Micturition reflexes
**Loop IV: Cerebral-Sacral Loop**

This loop consists of two components: (a) supraspinal and (b) segmental innervation of the peripheral striated muscle. The supraspinal component consists of sensory pathways originating from muscle spindles and tendon organs in the pelvic floor musculature. These axons course through the posterior column and synapse in the thalamus, to reach the pudendal area of the sensorimotor cortex. From there, the motor fibres originate and travel to terminate by synapsing on motor neurons on the pudendal nucleus in the spinal cord. The segmental portion of the loop consists of sensory axons arising from the muscle spindles and tendon organs, which end by synapsing on pudendal motor neurons. The pudendal neurons give origin to efferent axons to innervate the pelvic floor musculature and to regulate the sensitivity of spindle stretch receptors. Electromyographic evidence of voluntary contraction of the external sphincter demonstrates an intact loop IV. [81, 82]

**B. Integral Theory of Voiding Reflexes**

Mahoney et al. described another concept of micturition as a reflex event that occurs largely in the peripheral autonomic nervous system, permitted to do so by the central nervous system. They proposed 12 reflexes operating among bladder, urethra, brainstem micturition centre, and spinal cord micturition centre. These reflexes could be grouped into four groups according to their function.

1. **Storage-Favouring Reflexes (Four Reflexes)**

   a. **Sympathetic-Detrusor Inhibition Reflex (SDIR).** The afferent is the pelvic nerve; the efferent is the hypogastric nerve. This reflex is activated by bladder wall stretch during filling and its function is to inhibit detrusor contraction.

   b. **Sympathetic Sphincter Constrictor Reflex (SSCR).** This reflex consists of the same stimulus and pathway as SDIR, but the target organ is the smooth muscle component of the urethral sphincter. It produces an increase in the tone of the sphincter during bladder filling. Together, these two reflexes comprise the “sympathetic stabilizing reflexes” favouring continence of urine.

   c. **Perineodetrusor Inhibitory Reflex (PDIR).** Stimulation of the stretch receptors of the perineum and pelvic floor muscles produces impulses that travel through pudendal nerve afferents to the SMC. Efferent impulses travel via the pelvic nerve, and the function is inhibition of the detrusor contraction.
d. **Urethrosphincteric Guarding Reflex (USGR).** The stimulus is an increase in mural tension in the trigone and bladder neck during filling or escape of urine into proximal urethra. The afferent limb is via the pelvic nerve to the SMC, and the efferent is via the pudendal nerve to the striated component of the external urethral sphincter producing contraction.

2. **Initiation of Micturition Reflexes (Two Reflexes)**
   a. **Perineobulbar Detrusor Facilitative Reflex (PBDFR).** The stimulus is the voluntary contraction of the diaphragm and abdominal wall muscles with simultaneous relaxation of the pelvic floor muscles. The impulse travels through the pudendal nerve and other somatic nerves cranially to the brainstem and brain cortex, which in turn produce stimulation of the SMC.

   b. **Detrusodetrusor Facilitative Reflex (DDFR).** An increase in detrusor mural tension produces an impulse that travels via the pelvic nerve to the PMC. The PMC sends facilitative impulses via the lateral reticulospinal tract to the SMC. From here, stimulatory impulses are sent to the detrusor muscle via pelvic nerve efferents producing a detrusor contraction.

3. **Intramicturition Reflexes (Five Reflexes)**
   These reflexes are concerned with maintaining a strong detrusor contraction with synchronous relaxation of the sphincter during the voiding phase to provide complete and efficient emptying of the bladder.

   a. **Detrusourethal Inhibitory Reflex (DUIR).** The impulse from the detrusor stretch receptors travels via the pelvic nerve to the SMRC producing stimulation, then via the pelvic nerve again to the bladder neck and smooth muscle component of the external urethral sphincter producing relaxation.

   b. **Detrusosphincteric Inhibitory Reflex (DSIR).** An inhibitory impulse via the pelvic nerves to the “pudendal nucleus” producing relaxation of the striated component of the external urethral sphincter is generated in response to a stimulus from the stretch receptors in the detrusor muscle.

   c. **Urethrodetrusor Facilitative Reflexes (UDFR).** Both of these reflexes originate in the proximal urethra and produce detrusor contractions via efferents from the SMC. There are two reflex pathways proposed, one with a brainstem component and one without.
Both may act to cause a detrusor contraction in response to the presence of urine in the proximal urethra.

d. Urethro sphincteric inhibitory reflex (USIR). This reflex has both its afferent and efferent limbs in the pudendal nerves. It is responsible for the prompt synchronous relaxation of the external sphincter at the onset of micturition and is additive to the effect of the DSIR in this regard.

4. Micturition Cessation Reflex (One Reflex)
   a. Perineobulbar detrusor inhibitory reflex (PBDIR). At the end of micturition, inhibitory impulses from the stretch receptors in the perineum and pelvic muscles travel to the brainstem. Efferent inhibitory impulses are then sent to the SMC, thus re-establishing the storage reflexes (Group I).

SUMMARY

Much controversy still abounds regarding the exact processes of the micturition cycle, but most experts would agree that it involves two relatively discrete phases: (a) bladder filling and storage, and (b) bladder emptying. From a clinical standpoint, most disorders of voiding can be categorized into a failure of either one of these discrete processes, although quite often there is a combination of the two. While some of the basic concepts of pathways and neural circuits have been around for decades, our understanding of the details of these pathways and circuits has grown tremendously in the past several years. With the advent of functional MRI and PET scanning, as well as the continued discovery of new neurotransmitters and receptors, this knowledge base will continue to develop allowing more effective diagnosis and treatment of voiding dysfunction well into the future.
CHAPTER 3b

PHYSIOLOGY OF DEFAECATION
ANORECTAL ANATOMY AND INNERVATION

Although the rectum is in direct continuity with the colon, the longitudinal muscle layer within this region is not organized into teniae; rather, it forms a continuous outer layer, uniformly encircling the rectum, and insinuating between the internal and external anal sphincters to the distal end of the anal canal. The narrowed distal rectum, or anorectal junction, is formed by the longitudinal muscle coat of the rectum, which is joined by the sling fibres of the puborectalis muscle, attachments of the levator ani muscles, and proximal margins of the internal and external anal sphincters. [83]

The puborectalis and levator ani muscles have important roles in maintaining continence and in defecation. These striated muscles form part of the pelvic floor and are in a state of constant tone that serves to pull the rectum anteriorly and elevate it, thereby reducing the anorectal angle; this mechanical effect tends to prevent entry of stool into the upper anal canal. The internal anal sphincter is a thickened band of smooth muscle, with relatively high spontaneous tone, that is in continuity with the circular smooth muscle of the rectum. By contrast, the external anal sphincter is a striated muscle and is located distal to, but partly overlying, the internal sphincter. The external sphincter also has a high resting tone, but unlike that of its internal counterpart, its tone can be influenced by voluntary efforts, to help maintain continence. [83]

The sources of innervation of the internal and external anal sphincters are different. The internal sphincter directly receives a powerful inhibitory innervation from intrinsic, enteric inhibitory motor neurons and also extrinsic input from lumbar sympathetic and sacral parasympathetic nerves that project via the pelvic plexus ganglia. The external anal sphincter and other pelvic floor muscles are innervated, through the pudendal nerve (S3-S4), by motor neurons with cell bodies in the spinal cord. The rectum and proximal anal canal are richly supplied with sensory receptors that respond to rectal stretch and the composition of the intraluminal contents. These receptors are important for detecting rectal filling, triggering sensations of urgency, facilitating rectal accommodation, and differentiating the composition (stool or gas) of rectal content
THE ENTERIC NERVOUS SYSTEM

Direct neuronal control of colonic motility is mediated mostly by the enteric nervous system (ENS). Although the ENS is capable of expressing a diverse repertoire of motor patterns, its functions are modulated by sympathetic, parasympathetic, and extrinsic afferent pathways {Fig 3b (i)}. The ENS is by far the largest component of the autonomic nervous system, with considerably more neurons than those of the parasympathetic and sympathetic divisions combined. The nerve cell bodies of the ENS are located in plexuses of myenteric ganglia (Auerbach's plexus), which lie between the longitudinal and the circular muscle layers of the muscularis externa, or in the sub mucosal ganglia, which lie between the circular muscle and the mucosa {Fig 3b (ii)}. The sub mucosal plexus is divisible into at least two networks: Meissner's plexus, which lies closer to the mucosa, and Schabadasch's plexus, which lies adjacent to the circular muscle. [83]

RELATIONSHIPS AMONG CELLULAR EVENTS, PRESSURE, AND FLOW

Smooth muscle activation often is divided into two components. The first component is the tonic, ongoing activation that gives smooth muscle its basal resistance to stretch, its tone. The second component comprises the dynamic, phasic contractions that mix and propel contents. Compliance is a term used to describe the extent to which the bowel wall can stretch to accommodate contents. During phasic contractions, a transient increase occurs in the resistance of the bowel wall to stretch, namely, a decrease in its compliance. If bowel contents are fluid and no downstream resistance is present to impede flow, the smooth muscle rapidly shortens. The contents are then propelled, with a minimal increase in intraluminal pressure. By contrast, if resistance to forward flow of contents is encountered, as by a lumen-occluding contraction occurring distally, the smooth muscle does not shorten significantly, although its tension increases. This increase in tension increases intraluminal pressure, but it does not cause propulsion. In most situations in vivo, smooth muscle contraction causes a mixture of shortening, increased tension, increased pressure, and propulsion. The process of propagation is controlled by pathways intrinsic to the enteric neural circuitry and by triggering sequences of polarized reflexes that cause peristaltic propulsion. [83]
Fig 3b(i) The extrinsic innervation of the human colon.

Fig 3b(ii) Diagram showing the layers and components of the intestinal wall.

RECTAL MOTOR COMPLEXES
Periodic contractile activity predominates in the sigmoid colon and rectum. This activity is commonly termed the *rectal motor complex* (RMC) or *periodic rectal motor activity* (PRMA). The mean RMC amplitude ranges from 15 to 60 mm Hg with duration of 3 to 30 minutes. [84] In contrast to all other colonic contractile patterns, the circadian trend for RMCs is reversed, i.e., the RMC is more prevalent during sleep, suggesting the relevance of the extrinsic neural control of this pattern. The relationship between the RMC and flow is still incompletely understood. RMCs can be triggered by propagating pressure waves from the proximal colon and by the arrival of stool or gas from the sigmoid colon, [85] suggesting the RMC provides a braking mechanism to keep the rectum empty.

**DEFAECATION**

Variations in propagating motor activity along the colon, namely non propagating and propagating complexes, would limit or might even prevent colonic contents from ever reaching the rectum and being expelled. Clearly, additional mechanisms must occur from time to time that lead to defaecation. Traditionally, defaecation was conceptualized as an exclusively anorectal function; however, evidence for the integration of colonic motor activity with defaecation has come from several sources. Radio-opaque markers and scintigraphic recordings confirm that the greater proportion of the entire colonic contents is evacuated in some cases.

Furthermore, pan colonic manometric studies have demonstrated that the preparatory phase of defecation not only involves the greater part of the colon but also commences up to one hour before stool expulsion. [86] In this predefaecatory phase, a characteristic progressive increase occurs in the frequency of propagating pressure wave sequences. These sequences start first in the proximal colon, with each successive sequence originating slightly more distal to the preceding one; these priming sequences do not evoke conscious sensation. By contrast, in the 15 minutes leading up to defaecation, a dramatic increase occurs in the frequency of these propagating sequences, which leads to a strong defaecatory urge. In the last 15 minutes of the predefaecatory phase, propagating pressure waves begin to originate in the distal colon; however, in this late phase, each successive propagating sequence originates from a site *proximal* to the preceding one. Each sequence also tends to run for a slightly longer distance and has higher amplitude compared with the preceding propagating sequence (Fig 3b (iii)). These final sequences provide potent forces to fill
and distend the rectum, activating specialized low-threshold sacral spinal afferent mechanoreceptors. These mechanoreceptors then give rise to the defaecatory urge, prompting the expulsive phase in which the anorectum comes into play.

**RECTAL FILLING, CAPACITANCE, AND ACCOMMODATION AND MOTILITY OF THE ANAL SPHINCTERS**

When stool or gas enters the rectum, the rectal wall is stretched, thereby simultaneously activating an enteric descending inhibitory reflex that causes transient relaxation of the internal anal sphincter and an extrinsic reflex pathway that leads to a brief contraction of the external anal sphincter. The anorectal inhibitory reflex can be demonstrated and tested by balloon distension of the rectum, and its presence reflects the integrity of enteric neural pathways. For example, the rectoanal inhibitory reflex is absent in Hirschsprung's disease, which is characterized by loss of enteric ganglia in the rectal myenteric plexus. In health, this reflex permits entry of a small amount of content into the upper anal canal, and continence is maintained by the reflexive contraction of the external anal sphincter. This sampling of content by sensory receptors in the proximal anal canal permits the distinction between solid or liquid stool and gas. Sampling reflexes of this kind occur many times each day in response to low-volume rectal distensions, are not registered consciously, and do not cause an urge to defaecate.

A large-volume rectal distension causes an internal sphincter relaxation of longer duration, which is registered consciously and which necessitates extra voluntary contraction of the external anal sphincter to maintain continence while the person decides how best to deal with the intraluminal content (stool or gas). Suppression of the defaecation urge at this time, together with receptive accommodation of the rectum (see later), results in temporary storage of stool or gas in the rectum or retrograde transport of the stool or gas back to the sigmoid colon. Although the rectum is usually empty, it has the capacity to temporarily store faeces until convenient evacuation can be arranged. More-prolonged rectal storage is made possible by the ability of the rectum to accommodate an increasing volume without a corresponding increase in intrarectal pressure, in a manner similar to gastric fundic relaxation. [87] This adaptive increase in rectal compliance, mediated by inhibitory nerves, is important for maintaining continence by permitting prolonged faecal storage without a
Fig 3b(iii) Intracolic pressures leading to spontaneous defecation by the healthy human colon. (From Bampton PA, Dinning PG, Kennedy ML, et al. Spatial and temporal organization of pressure patterns throughout the unprepared colon during spontaneous defecation. Am J Gastroenterol 2000;98:1027.)
constant urge to defaecate. Such rectal distension also has negative feedback effects on the proximal bowel and inhibits gastric emptying, slows small bowel transit, reduces the frequency of proximal colonic propagating pressure waves, and delays colonic transit. [88, 89] Typically, rectal tone is increased following a meal. A pathologic reduction of rectal compliance, such as after pelvic radiotherapy, causes rectal urgency. Conversely, excessive compliance, as in megarectum, attenuates the urge to defaecate.

**ANORECTAL MOTILITY DURING DEFECATION**

If the processes just described give rise to the urge to defaecate and the social circumstances are appropriate, the full defaecation process is activated. This process involves a combination of pelvic reflexes coordinated in the medulla and pons. Rectal distension by stool stimulates reflex-induced complete relaxation of the internal anal sphincter, and the stool moves into the upper anal canal, heightening the sense of urge. Postural changes and straining facilitate this process in several ways: Sitting or squatting causes descent of the anorectal junction, and straining produces further rectal descent. Both activities serve to increase the anorectal angle, thereby reducing resistance to outflow. At this point, if the person wishes to proceed to expel stool, the external anal sphincter is relaxed voluntarily. At the same time, the puborectalis muscle is relaxed (further increasing the anorectal angle); the levator ani muscles contract; the perineum descends further; and stool is funnelled into the anal canal and expelled by increasing strain-induced, intrarectal pressure {Fig 3b (iv)}. Once the expulsion phase has commenced, evacuation of stool can proceed in some cases without further straining, as a consequence of colonic contractions propagating toward the anus {Fig 3b (iii)}. [86] Expulsion of stool is possible in response to strain alone without rectosigmoid contractions, although a contribution from increased rectal wall tone cannot be excluded.
Fig 3b(iv) Some of the mechanical processes that facilitate stool expulsion, as illustrated by sequential films of a simulated defecation of thickened barium during defecation proctography.  

A, The rectum at rest with a normal resting angle of approximately 90 degrees; the anal canal is closed.  

B, On straining, as the anterior rectal wall begins to flatten, the proximal anal canal begins to funnel as barium contrast is forced into it.  

C, As more pressure is exerted, the anterior rectal wall flattens further, contrast fills the anal canal, and evacuation begins. At this time, the puborectalis muscle and external anal sphincter are relaxing, resulting in the onset of descent of the rectoanal junction. At the same time, the levator ani muscles are activated and help control the descent of the rectoanal junction (note the posterior indentation resulting from contraction of the pubococcygeus muscle).  

D, The puborectalis is fully relaxed; this, in combination with vigorous straining, has resulted in nearly complete descent of the rectoanal junction. Note the position of the rectoanal junction, which in this frame is well below the *horizontal pale artifact* (due to the water-filled toilet seat), compared with that in the previous frame, in which the junction is level with this artifact. This descent has now opened up the anorectal angle, thereby further reducing the resistance to outflow through the anal canal.  

E, Rectal emptying continues, and anterior rectal compression is more obvious.  

F, After evacuation, the anorectal junction has ascended to its original position, and the anorectal angle has returned to its more acute resting angle.  

(Courtesy of Prof. D. Z. Lubowski.)
Distension of the rectum with faeces initiates reflex contractions of its musculature and the desire to defaecate. In humans, the sympathetic nerve supply to the internal (involuntary) anal sphincter is excitatory, whereas the parasympathetic supply is inhibitory. This sphincter relaxes when the rectum is distended. The nerve supply to the external anal sphincter, a skeletal muscle, comes from the pudendal nerve. The sphincter is maintained in a state of tonic contraction, and moderate distension of the rectum increases the force of its contraction (Fig 3b (v)). The urge to defaecate first occurs when rectal pressure increases to about 18 mm Hg. When this pressure reaches 55 mm Hg, the external as well as the internal sphincter relaxes and there is reflex expulsion of the contents of the rectum. This is why reflex evacuation of the rectum can occur even in the setting of spinal injury. [90, 91]

Before the pressure that relaxes the external anal sphincter is reached, voluntary defaecation can be initiated by straining. Normally, the angle between the anus and the rectum is approximately 90 degrees (Fig 3b (vi)), and this plus contraction of the puborectalis muscle inhibits defecation. With straining, the abdominal muscles contract, the pelvic floor is lowered 1 to 3 cm, and the puborectalis muscle relaxes. The anorectal angle is reduced to 15 degrees or less. This is combined with relaxation of the external anal sphincter and defaecation occurs. Defaecation is therefore a spinal reflex that can be voluntarily inhibited by keeping the external sphincter contracted or facilitated by relaxing the sphincter and contracting the abdominal muscles. [92-94]

Distension of the stomach by food initiates contractions of the rectum and, frequently, a desire to defaecate. The response is called the gastrocolic reflex, and may be amplified by an action of gastrin on the colon. Because of the response, defaecation after meals is the rule in children. In adults, habit and cultural factors play a large role in determining when defaecation occurs. [90] Constipation refers to a pathological decrease in bowel movements. It was previously considered to reflect changes in motility, but the recent success of a drug designed to enhance chloride secretion for the treatment of chronic constipation suggests alterations in the balance between secretion and absorption in the colon could also contribute to symptom generation. Patients with persistent constipation, and particularly those with a recent change in bowel habits, should be examined carefully to rule out underlying organic disease. However, many normal humans defaecate only once every 2-3 d, even though others defaecate once a day and some as often as three times a day. Furthermore, the only
symptoms caused by constipation are slight anorexia and mild abdominal discomfort and distension. These symptoms are not due to absorption of “toxic substances,” because they are promptly relieved by evacuating the rectum and can be reproduced by distending the rectum with inert material. [95]

MODULATORS OF COLONIC MOTILITY

PHYSIOLOGIC

Twenty-four hour recordings of myoelectric activity or intraluminal pressure show that colonic phasic and tonic activity predictably are increased one to two hours after a meal (the gastrocolonic response) and are markedly suppressed at night. [96] The entire colon responds to the meal, with an increase in colonic wall tone, migratory long spike-bursts, and propagating and segmenting contractile patterns. A minimum caloric load of approximately 300 kcal is required to generate the colonic response to a meal, and a meal of only 200 kcal increases rectal muscle tone. [97] The meal response also is highly dependent on the fat content of the caloric load. For example, 600 kcal of fat induces the response, whereas an equicaloric load of protein or carbohydrate does not.

Colonic myoelectric and pressure activities are profoundly suppressed at night. [96] During stable sleep, colonic motility virtually ceases (except for the anti-propulsive rectal motor complexes, which increase), thereby reducing the challenges to continence at a time when anal sphincter tone and awareness of colorectal sensations are minimal. If the subject shifts to a lighter level of sleep, even without actually awakening, an immediate increase occurs in propagating and non-propagating pressure waves. Forced awakening at night and spontaneous early-morning awakening both stimulate an immediate increase in colonic propagating pressure waves. This phenomenon clearly is linked with the readily identifiable habit of defaecation soon after awakening in the morning and demonstrates the potential for profound modulation of colonic motor activity by the central nervous system.
Stress and emotional factors long have been believed to influence colonic motility, but experimental evidence for this is conflicting, possibly because of a reliance on measurements from the distal colon, which might not be representative. In light of the profound waking-response, it is likely, but unproved, that stress does induce propagating pressure waves.
**Fig 3b(v)** Responses to distension of the rectum by pressures less than 55 mm Hg. Distension produces passive tension due to stretching of the wall of the rectum, and additional active tension when the smooth muscle in the wall contracts. (Reproduced with permission from Davenport HW: *A Digest of Digestion*, 2nd ed. Year Book, 1978.)

**Fig 3b(vi)** Sagittal view of the anorectal area at rest (above) and during straining (below). Note the reduction of the anorectal angle and lowering of the pelvic floor during straining. (Modified and reproduced with permission from Lembo A, Camilleri, M: Chronic constipation. N Engl J Med 2003;349:1360.)
Due to technical difficulties associated with trying to record physical activity and colonic motility simultaneously, data on the colonic response to physical activity are sparse; however, physical exercise, perhaps through increased sympathetic tone, decreases colonic motility. [98] The colonic response to stress and exercise highlight the importance of the autonomic nervous system in modulating colonic function. Similarly, autonomic dysfunction, resulting from pelvic surgery, childbirth, or neural degradation, has been implicated in several colonic disorders including slow-transit constipation and irritable bowel syndrome (IBS). [99]

**PHARMACOLOGIC**

Laxatives exert their diarrheal actions by increasing mucosal secretion or by stimulating colonic propulsive activity. Bisacodyl exerts its motor effect through mucosal afferent nerve fibres, because the response can be blocked by topical mucosal application of lignocaine. In addition to the local response, these agents, when administered rectally, can stimulate motor activity in the proximal colon, thereby indicating the existence of long reflex pathways between the rectum and proximal colon.

Colchicine, a natural alkaloid, is well known to cause diarrhoea. Colchicine increases the frequency of spontaneous bowel movements and accelerates colonic transit in patients with chronic constipation. Lubiprostone, a type 2 chloride channel (CIC2) activator, is a member of a new class of compounds known as prostones. Activation of CIC2 increases intestinal chloride secretion resulting in increased intraluminal fluid accumulation, which accelerates intestinal transit, softens stools, and increases spontaneous stool frequency in patients with constipation. [100]

Serotonin (5-HT) is an important mediator of bowel physiology, and both 5-HT₃ and 5-HT₄ receptors play a role in colonic peristalsis and transit. For example, the 5-HT₃ receptor antagonists granisetron and ondansetron blunt the gastrocolic response and delay colonic transit, respectively. [101] Alosetron, another antagonist of the 5-HT₃ receptor, exerts a significant constipating affect by slowing colonic transit. [102] In contrast, 5-HT₄ agonists (e.g., tegaserod, prucalopride, renzapride), act on presynaptic receptors and facilitate release of acetylcholine and CGRP (calcitonin gene-related peptide), thereby inducing colonic propagating contractions and accelerating colonic transit. Although this class of drug shows promise for the treatment of constipation, tegaserod, a 5-HT₄ agonist, was withdrawn from the market because of concern about associated adverse cardiovascular events. Other highly selective 5-HT₄ agonists,
such as prucalopride, might be attractive options because they do not interact with 5-HT₃ or 5-HT₁B receptors, and prucalopride does improve stool frequency and symptoms in severe constipation. [104] Further trials with these agents are awaited.

Opiates are well known to have an anti-diarrhoeal effect, but their mechanism of action is less clear. In the human colon, morphine increases phasic segmenting activity, reduces colonic tone, and attenuates the bowel's response to a meal. [105] Opiates are known to inhibit presynaptic and postsynaptic enteric neural circuitry. The reduction in neurally dependent propagating contractions and the enhancement of myogenic mixing movements and fluid absorption contribute to the constipating effect of the drug. Specific constipation syndromes, such as opiate-induced constipation or postsurgical ileus, might respond to opiate antagonists such as methylnaltrexone and alvimopan [106]

Nitric oxide is a potent endogenous inhibitor of colonic propulsive activity and the human colon appears to be under a state of tonic nitrergic inhibition. For example, infusion of the nitric oxide synthase inhibitor, l-NMMA (N⁵-monomethyl l-arginine), is a potent stimulator of colonic propagating contractions. [88] Alternatively, segmental lengthening of the colon induced by the entry of content triggers nitric oxide release from descending pathways, which in turn inhibits colonic propulsive activity. [107]

NONPHARMACOLOGIC

Probiotics are living organisms that, when ingested in adequate amounts, are claimed to exert a health benefit to the host. Relatively few rigorously designed studies have been conducted with probiotics but some strains have been shown to have a beneficial effect in IBS, ulcerative colitis and diarrhoea. [108] In the colon, probiotics are likely to modulate the inflammatory response through activation of signals with the epithelium and immune system. [108] Probiotics may well influence colonic motility, but this has not been systematically evaluated.

Sacral nerve stimulation modulates the extrinsic nerves innervating the pelvic floor and colon. Electrical stimulation of the S3 sacral root induces a modest increase in external anal sphincter tone and has been used successfully in the management of faecal incontinence. Stimulation of the S3 root also induces propulsive activity throughout the entire colon and has been shown to increase stool frequency in patients with slow-transit constipation. [109] Randomized trials of this promising technique for treating
slow-transit constipation are in progress; the precise mode of this action remains unknown. The substantial latency between stimulus and pelvic floor or colonic contractile responses is longer than would be expected via a polysynaptic efferent pathway, which suggests possible involvement of extrinsic neural pathways. [110] Magnetic stimulation of the sacral nerve S3 also shows promise in modulating colonic and anorectal function. [111] Because this approach is less invasive than electrical stimulation of sacral nerves, it may be a reasonable treatment option in children with colonic or anorectal dysfunction.

Acupuncture has been shown to have significant effects upon upper gastrointestinal tract disorders such as nausea and vomiting. Only two studies have evaluated its potential in constipation, one in children and one in adults. [112] Acupuncture improved stool frequency in children, but these results weren't replicated in adults; this warrants further study. Acupuncture is known to activate neural, opioid, humoral, and serotoninergic pathways and potentially has a clinical role in treating disorders such as constipation and IBS. [112]

Biofeedback has been shown to improve stool frequency and rectal evacuation in patients with pelvic floor dyssynergia, and the technique has been shown to accelerate colonic transit in this subset of patients with constipation. [113] The mode of action of biofeedback is not fully understood, but evidence suggests that extrinsic autonomic efferent pathways mediate the response. [114]
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Chapter 2  Hypothesis, study parameters and justifications

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Chapter 9  General Discussion
CHAPTER 4

EPIDEMIOLOGY OF INCONTINENCE
INTRODUCTION

In geographical terms, Australia is the driest continent on earth; regrettably the same cannot be said of its inhabitants. Studies show that 5–6% of adult Australians have regular or severe urinary incontinence, a prevalence remarkably similar to that reported from other basically Caucasian populations. [115, 116] Data regarding prevalence in Australia have been available since a study performed in Sydney in 1983. [117, 118] No systematic study of general prevalence has been conducted since that time. However, the longitudinal Women’s Health Australia study, involving over 40,000 women [119] has provided new data on prevalence in women [120] and may yield further data on the incidence of incontinence over the next 10–20 years as the cohorts age.

The Sydney study attempted to ascertain the prevalence of all past and present urinary incontinence and to stratify the type, severity, and frequency of occurrence of the incontinence problems discovered in the study population. The study was designed to ascertain the prevalence of urinary incontinence in Australia. Prevalence was correlated with age, gender, and socioeconomic stratification. An attempt was made to define at-risk groups, types and severity of incontinence, and use of protective appliances. A detailed, 38-question, self-report questionnaire was devised and tested for comprehensibility in small focus groups before distribution. A multistage cluster sampling technique was used to target 3000 adults in 1000 homes, randomly selected from 100 postal districts. All 3000 were telephoned to increase compliance and to check data received, and a total of 1256 completed questionnaires were analysed.

Three hospitals (1666 beds) and 15 nursing homes (1631 beds) were also surveyed by questionnaires sent to staff, and the data from these establishments were analysed separately. A total of 293 individuals admitted to some degree of present urinary incontinence or leakage by day, and 51 also had some loss of urine at night. In all, 301 persons (24%) – 13% of the male and 34% of the female respondents – had some degree of urinary loss. Eight people were incontinent only at night. The male-to-female ratio among those with urinary leakage was 1:2.7, with females accounting for 73% of sufferers. The frequency of urinary loss is shown in Table 4a. Leakage was more common in members of blue-collar families (27%) than in members of white-collar families (25%). Students and those in full-time employment tended to have half the prevalence of incontinence (13% and 16%, respectively) reported by the other groups (30–34%). Housewives had the highest prevalence of incontinence overall (40%). The
mean duration of all leakage problems was 8.8 years; 18% reported leakage for less than a year, whereas 23% had had problems for 15 or more years; 17% could not specify the duration of their problem. The 293 positive respondents were asked to specify circumstances under which they experienced leakage (more than one answer was allowed) (Table 4b). All 293 individuals who reported some current degree of leakage were asked to quantify the severity of the urine loss (Table 4c). Severe incontinence was twice as common in blue-collar as in white-collar families, but minor degrees of leakage were equally prevalent. The type of incontinence was correlated with severity and frequency of leakage episodes as shown in Table 4d. In most cases, incontinence occurred infrequently and was of minor severity. What stands out is the relatively more frequent nature of the leakage of the quiet dribbling incontinence type, which occurs without warning or provocation.
### Table 4a  Frequency of incontinence episodes

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>Often wet</td>
<td>2</td>
</tr>
<tr>
<td>Once a day</td>
<td>2</td>
</tr>
<tr>
<td>Once a week</td>
<td>1</td>
</tr>
<tr>
<td>Once or twice a month</td>
<td>0</td>
</tr>
<tr>
<td>Rarely</td>
<td>8</td>
</tr>
<tr>
<td>Never wet</td>
<td>87</td>
</tr>
</tbody>
</table>

### Table 4b  Circumstances in which respondents experienced leakage

<table>
<thead>
<tr>
<th>Circumstances</th>
<th>Percentage of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males (n=79)</td>
</tr>
<tr>
<td>Coughing or sneezing</td>
<td>5</td>
</tr>
<tr>
<td>Straining or lifting</td>
<td>5</td>
</tr>
<tr>
<td>Urge</td>
<td>27</td>
</tr>
<tr>
<td>Giggle</td>
<td>9</td>
</tr>
<tr>
<td>No warning or provocation</td>
<td>1</td>
</tr>
<tr>
<td>Postmicturition dribble</td>
<td>59</td>
</tr>
<tr>
<td>With urinary infections</td>
<td>8</td>
</tr>
<tr>
<td>Other</td>
<td>8</td>
</tr>
<tr>
<td>Total*</td>
<td>122</td>
</tr>
</tbody>
</table>
Table 4c  Quantification of severity of urinary loss in 293 respondents

<table>
<thead>
<tr>
<th>Urinary loss</th>
<th>Male (n=79)</th>
<th>Female (n= 214)</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always wet</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Flooding</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Moderate loss</td>
<td>8</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Slight loss</td>
<td>25</td>
<td>41</td>
<td>37</td>
</tr>
<tr>
<td>Just a spot</td>
<td>66</td>
<td>49</td>
<td>54</td>
</tr>
</tbody>
</table>

Table 4d  Percentage frequency and severity of leakage in 293 respondents wet by day

<table>
<thead>
<tr>
<th>Type of incontinence</th>
<th>Frequency</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Often</td>
<td>1/day</td>
</tr>
<tr>
<td>Coughing</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Strain</td>
<td>31</td>
<td>7</td>
</tr>
<tr>
<td>Urge</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>Giggle</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>No warning</td>
<td>38</td>
<td>19</td>
</tr>
<tr>
<td>Postmicturition</td>
<td>22</td>
<td>15</td>
</tr>
<tr>
<td>Other</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Always</td>
<td>Flood</td>
</tr>
<tr>
<td>Coughing</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Strain</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Urge</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>No warning</td>
<td>19</td>
<td>6</td>
</tr>
<tr>
<td>Postmicturition</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>With UTI</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
NOCTURNAL INCONTINENCE

Incontinence at night was reported by 51 (26 female and 25 male) individuals, a prevalence of 4% of the population over the age of 10 years. The frequency of nocturnal incontinence is shown in Table 4e, correlated with sex and age group.

TREATMENT EXPERIENCE

Perhaps reflecting the minor nature of the problem for the majority of the positive respondents, 70% of the 301 with leakage had never sought any treatment. However, 31% of the women and 26% of the men had sought help from general practitioners (24%), from specialists (14%) or from other health professionals (1%). (Respondents may have sought help from more than one healthcare professional.) Those most likely to seek help were over 60 years of age, and either blue-collar or unemployed persons. This may be explained by the fact that it is the elderly and those from blue-collar families who have the highest prevalence of urinary leakage and also the more severe degrees of incontinence. At the time of the study, 93 people were having treatment for incontinence, representing 31% of the 301 with current leakage. This is similar to the treatment rate reported by Thomas et al. [120] The types of treatment being received were pharmaceutical agents in 33%, appliances in 8%, bladder/muscle training in 13%, and surgery in 24% of patients.

RELATIONSHIP BETWEEN INCONTINENCE AND AGE GROUP

The prevalence of incontinence and its relationship to age group and gender is shown in Figure 2d.1 and in Table 4f. The increased prevalence seen with increasing age is particularly prominent in men over 60 years of age. The normal female preponderance is lost in old age, with a consequent rise in overall prevalence. The high (40%+) prevalence rate in the over-60 age groups is similar to that found in other studies [120] and to the prevalence of incontinence found in nursing homes. [121] Those over 60 years of age reported more severe and more frequent episodes of incontinence than did younger people. Even young women have a higher prevalence of incontinence than young men, and this trend is accentuated after 30 years of age, possibly as a result of pregnancy and childbirth. This was particularly apparent in the rates of stress urinary incontinence, which increased from 7% in the 10–29 year-old group to 26% in 30- to 44-year-old women and to 36% in the 45- to 60-year-old group. These data are similar to those obtained from the Women’s Health Australia study. [120] The relationship
between incontinence type and age group is shown in Table 4g, which emphasizes the rising prevalence of urge incontinence in the elderly and the high rate of simple stress incontinence in middle age.

**PRECIPITATING FACTORS**

The 301 individuals who were ‘wet day or night’ were requested to identify the ‘cause’ of their leakage problem (Table 4h). Hysterectomy was blamed for incontinence in 7% of the women, mostly by women from blue-collar families or those off the workforce, compared with only 1% of the women from white-collar families. Incontinence associated with urinary tract infection was also twice as common in women from blue-collar families. The association between incontinence and hysterectomy and other pelvic surgery has been observed in other studies by Foldspang et al. [122] and Parys et al. [123] The relationship between incontinence and number of children is shown in Figure 2d.2. The first child and pregnancy virtually doubled the prevalence of incontinence in women from 20% to about 40%. There was no change then until the fourth child, when the prevalence rose to 56%.

The effect of parity has been noted from other studies. [115, 116, 120, 124] Women from blue-collar families were more likely than others to blame childbirth for their incontinence. A recent study of incontinence during pregnancy was reported by Chiarelli and Campbell. [125] In a cross-sectional descriptive study using a five-item structured interview, 336 women were approached and 304 participated (90%): overall, 64% reported stress urinary incontinence during pregnancy; in the last month of pregnancy 57% reported stress incontinence (with or without urge incontinence) while 42% had urge incontinence (with or without stress incontinence). Among the 195 women experiencing incontinence, 25% lost only a few drops, 57% lost sufficient to dampen the underwear or pad, and 18% reported severe loss. The leakage had started during the first trimester in 8%, in 18% in the second trimester, and in 47% in the last trimester of the most recent pregnancy, whereas, for 20%, leakage had begun in a previous pregnancy, in 6% it began after the birth of a previous child, and only 3% indicated that they had been incontinent before any of their pregnancies. For 49%, leakage was not at all bothersome, 31% found it a little bothersome, 16% quite bothersome and 4% extremely bothersome.
Table 4e  Frequency of nocturnal incontinence, correlated to sex and age group

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Overall percentage</th>
<th>M</th>
<th>F</th>
<th>10-29</th>
<th>30-44</th>
<th>45-59</th>
<th>60-74</th>
<th>75+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most nights</td>
<td>8</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Once a month</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Occasionally</td>
<td>16</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rarely</td>
<td>73</td>
<td>16</td>
<td>21</td>
<td>19</td>
<td>7</td>
<td>8</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>28</td>
<td>8</td>
<td>11</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
<td>5.6</td>
<td>2.3</td>
<td>4.4</td>
<td>1</td>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig 4(i)  Prevalence of Incontinence and its relationship to age and gender
### Table 4f Prevalence of incontinence and its relationship to age group and gender

<table>
<thead>
<tr>
<th>No. of individuals</th>
<th>Age group (years)</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10-29</td>
<td>30-44</td>
</tr>
<tr>
<td>Sample total</td>
<td>498</td>
<td>354</td>
</tr>
<tr>
<td>Female</td>
<td>243</td>
<td>194</td>
</tr>
<tr>
<td>Wet*</td>
<td>47</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>(19)</td>
<td>(39)</td>
</tr>
<tr>
<td>Male</td>
<td>255</td>
<td>160</td>
</tr>
<tr>
<td>Wet*</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>(10)</td>
<td>(13)</td>
</tr>
</tbody>
</table>

* Percentages in parentheses.

### Table 4g Relationship between incontinence type and age group

<table>
<thead>
<tr>
<th>Incontinence</th>
<th>Percentage in age group (years)</th>
<th>Overall percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10-29</td>
<td>30-44</td>
</tr>
<tr>
<td>Cough/sneeze</td>
<td>97</td>
<td>25</td>
</tr>
<tr>
<td>Strain/lift</td>
<td>86</td>
<td>7</td>
</tr>
<tr>
<td>Urge</td>
<td>78</td>
<td>31</td>
</tr>
<tr>
<td>Giggle</td>
<td>90</td>
<td>29</td>
</tr>
<tr>
<td>No warning</td>
<td>94</td>
<td>6</td>
</tr>
<tr>
<td>Postmicturition</td>
<td>37</td>
<td>26</td>
</tr>
<tr>
<td>With UTI</td>
<td>78</td>
<td>11</td>
</tr>
<tr>
<td>Other</td>
<td>77</td>
<td>14</td>
</tr>
<tr>
<td>No./group size</td>
<td>72/498</td>
<td>97/354</td>
</tr>
<tr>
<td>Prevalence (%)</td>
<td>14</td>
<td>27</td>
</tr>
<tr>
<td>Percentage of responses/sufferers*</td>
<td>150</td>
<td>171</td>
</tr>
</tbody>
</table>

* A patient may have more than one type of incontinence. UTI, urinary tract infection.
Table 4h  Cause of leakage identified by 301 individuals who were ‘wet by day or night’

<table>
<thead>
<tr>
<th>Cause</th>
<th>Percentage of individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>Urinary tract infection</td>
<td>5</td>
</tr>
<tr>
<td>Hysterectomy</td>
<td>–</td>
</tr>
<tr>
<td>Childbirth/pregnancy</td>
<td>–</td>
</tr>
<tr>
<td>Menopause</td>
<td>–</td>
</tr>
<tr>
<td>Prostatectomy</td>
<td>5</td>
</tr>
<tr>
<td>Other operation</td>
<td>4</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>13</td>
</tr>
<tr>
<td>No cause identified</td>
<td>69</td>
</tr>
</tbody>
</table>

Fig 4(ii)  Relationship between incontinence and the number of children
Chi-square analysis showed four factors to be significantly associated with continence status: previous delivery mode, parity, chronic cough, and bouts of sneezing. Women who had previous vaginal deliveries were 2.5 times more likely to be incontinent than those who had no previous delivery or had only caesarean section. Those who reported previous forceps delivery were 10 times more likely to be incontinent than those with no prior delivery. Only 8% of the women had had their pelvic floor muscles tested during their pregnancy. [125]

RISK FACTORS INFLUENCING INCONTINENCE

An analysis of potential risk factors was undertaken. The groups found to be associated with higher rates of incontinence are shown in Table 4i. The association between incontinence and cystitis has been noted by Mommsen et al., [124] who found a six-fold increase in experience of incontinence. A more detailed analysis of risk factors in women has emerged from the Women’s Health Australia project6 (Table 4j). This longitudinal study involved three cohorts of women: young (age 18–23 years), middle aged (age 45–50 years) and older (70–75 years) at the time of the baseline survey. The women were selected randomly from the Australian Medicare database covering all women resident in Australia. During 1996, 14,761 young women, 14,070 middle-aged women, and 12,893 older women completed baseline surveys (respectively, 48, 54 and 41% of those of each group invited to take part). The baseline questionnaire consisted of 252, 285 and 260 items, respectively, for each of the age cohorts. Participants were asked whether they had leaked urine in the last month ‘never’, ‘rarely’, ‘sometimes’ or ‘often’: responses other than ‘never’ were taken as indicating incontinence. The advantages of this study were its large sample size and the representative nature of the sample. The limitation was the use of a single non-validated question about leaking urine which fails to differentiate between different types of incontinence. The prevalence of leaking urine in young women was 12.8% (95% confidence interval [CI] 12.2–13.3); in middle-aged women it was 36.15% (CI 35.2–37.0), and in older women 35.0% (CI 34.1–35.9). [120] These figures are similar to those reported by the earlier Australian prevalence study.

Parity was significantly associated with the prevalence of incontinence in young women but was less strongly correlated in the other age groups. There was a strong association between any degree of constipation and urinary leakage. In middle-aged women, those with high body mass index (BMI >25) and constipation were those most likely to experience leakage of urine. Hysterectomy alone had a lower odds ratio (OR)
### Table 4i  Groups found to be associated with higher rates of incontinence

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Percentage incontinence in group</th>
<th>Percentage incontinence in remainder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes</td>
<td>36</td>
<td>24</td>
</tr>
<tr>
<td>Cerebrovascular accident</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>Neurologic disorder</td>
<td>29</td>
<td>24</td>
</tr>
<tr>
<td>Locomotor difficulty</td>
<td>45</td>
<td>24</td>
</tr>
<tr>
<td>Over 75 years of age</td>
<td>43</td>
<td>24</td>
</tr>
<tr>
<td>Recurrent urinary tract infection</td>
<td>55</td>
<td>24</td>
</tr>
<tr>
<td>Pregnancy</td>
<td>45</td>
<td>34</td>
</tr>
<tr>
<td>Four (or more) children</td>
<td>56</td>
<td>34</td>
</tr>
</tbody>
</table>

### Table 4j  Adjusted odd ratios for variables associated with leakage of urine

<table>
<thead>
<tr>
<th>Variable</th>
<th>Young (18–23 years)</th>
<th>Middle-aged (45–50 years)</th>
<th>Older (70–75 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parity</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>2.82 (2.37–3.35)</td>
<td>1.58 (1.29–1.93)</td>
<td>0.88 (0.71–1.0)</td>
</tr>
<tr>
<td>1</td>
<td>2.59 (1.86–3.61)</td>
<td>1.66 (1.41–1.95)</td>
<td>1.14 (0.96–1.36)</td>
</tr>
<tr>
<td>2 or more</td>
<td>4.84 (2.54–9.20)</td>
<td>1.81 (1.54–2.12)</td>
<td>1.16 (0.98–1.36)</td>
</tr>
<tr>
<td>Constipation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rarely</td>
<td>2.13 (1.86–2.42)</td>
<td>2.46 (2.24–2.71)</td>
<td>2.67 (2.38–2.99)</td>
</tr>
<tr>
<td>Sometimes</td>
<td>2.86 (2.43–3.36)</td>
<td>2.16 (1.94–2.40)</td>
<td>2.05 (1.82–2.31)</td>
</tr>
<tr>
<td>Often</td>
<td>2.66 (2.07–3.40)</td>
<td>2.31 (1.84–3.35)</td>
<td>2.21 (1.87–2.61)</td>
</tr>
<tr>
<td>Body mass index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight</td>
<td>&lt;19.9</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Ideal</td>
<td>20–24.99</td>
<td>1.08 (0.94–1.23)</td>
<td>1.31 (1.10–1.55)</td>
</tr>
<tr>
<td>Overweight</td>
<td>25–29.99</td>
<td>1.34 (1.13–1.60)</td>
<td>1.47 (1.23–1.75)</td>
</tr>
<tr>
<td>Obese</td>
<td>30–40</td>
<td>2.09 (1.67–2.61)</td>
<td>2.05 (1.70–2.46)</td>
</tr>
<tr>
<td>Very obese</td>
<td>&gt;40</td>
<td>1.82 (1.07–3.09)</td>
<td>2.49 (1.84–3.35)</td>
</tr>
<tr>
<td>Burning and stinging*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rare</td>
<td>2.94 (2.59–3.33)</td>
<td>2.17 (1.96–2.42)</td>
<td>2.45 (2.18–2.76)</td>
</tr>
<tr>
<td>Sometimes</td>
<td>4.19 (3.56–4.93)</td>
<td>2.71 (2.35–3.14)</td>
<td>2.99 (2.62–3.41)</td>
</tr>
<tr>
<td>Often</td>
<td>4.93 (3.60–6.74)</td>
<td>4.29 (2.85–6.45)</td>
<td>7.97 (5.71–11.12)</td>
</tr>
</tbody>
</table>

* Indicative of a history of urinary tract infection.
for leakage, whereas women who reported a prolapse repair, either alone or with a hysterectomy, were more likely to leak. Neither current use of hormone replacement therapy nor duration of use was associated with leaking urine. In the older cohort, the effect of parity was obscured. Pelvic surgery of any kind had a positive association with incontinence. Those with high BMI and those with a history suggestive of urinary tract infection (burning and stinging) were more likely to report incontinence. At all ages, women who reported leaking urine had lower scores on the physical and mental component of the Swedish Short Form 36 (SF36) inventory, suggesting a lower quality of life for these women compared with continent women. In a follow-up study reported in 2003, [126] the cohorts had aged by 5 years. The majority of all age groups reported mixed incontinence, most commonly mixtures of stress and urge leakage, almost 80% of wet women over 50 years of age having mixed urinary incontinence (Table 4k). The severity of incontinence was as high as or worse than that in older women. Incontinence severity was associated with BMI and this effect involved women with stress urinary incontinence or urge urinary incontinence. Other risk factors identified for severity included number of deliveries but there were insufficient numbers of women with large babies for a significant difference to be attributed to the size of the baby. Smoking >20 cigarettes per day was a risk factor (OR 3.34, 95% CI 1.6, 6.98) in even young women in contrast to other studies that have only shown this association in older cohorts. Urine that burns or stings was often associated with higher adjusted odds ratios in all age cohorts. Adolescents with chronic lung disease and cystic fibrosis aged 12–19 years have been reported to have a high incidence of incontinence. [127] Of 55 adolescents, 47% had ever experienced urinary incontinence (UI) and 22% had UI at least twice a month. Median age of onset was 13 (range 7–16 years) and most had leakage associated with coughing (84%) or laughing (64%). Importantly, 42% reported that it sometimes prevented them from doing effective physiotherapy and 33% said their social life had been affected. Only 58% had told anyone about their problem and only 2 of 26 girls had talked to their doctor.

PAST EXPERIENCE OF INCONTINENCE IF NO PROBLEM AT PRESENT

The 955 respondents who denied any degree of urinary leakage at the present time were asked to report if they had ever experienced urinary leakage since they were 17 years of age. Replies showed that 16% of men and 30% of women had had previous experience of leakage: in 6% leakage had occurred occasionally and in 17% it had
been experienced only rarely. The pattern of previous incontinence was similar to that found among those who admitted to present leakage.

**CHILDHOOD INCONTINENCE AND RELATIVE RISK**

Of the whole group of 1256 respondents, 21% (269) recalled having problems as a child with bedwetting. The occurrence of this problem was equal in males and females. In addition, 9% (114 respondents, 67% female) recalled having had urinary leakage at school. Bedwetting was apparently more common in white collar families (25% of whom were affected) than in blue-collar families (where only 20% recalled problems). Childhood nocturnal enuresis was recalled by 269 individuals. As adults, 11% of these individuals still wet the bed while 32% had diurnal incontinence. Childhood bed wetters accounted for 57% of all those currently wet at night and 30% of all those wet by day (Table 4l). Childhood bed wetters appeared to carry a five-fold increased risk of nocturnal incontinence in adult life compared with non-bed wetters. They were also at higher risk of developing some degree of urinary incontinence by day, with 1.7 times the prevalence rate of non-bed wetters. Of 114 respondents (9%) wet at school, 39% were wet by day at the time of the survey, accounting for 15% of all those now wet; 7% of the group now suffer from incontinence at night and account for 16% of all those now wet at night (Table 4m). Individuals with incontinence in childhood at school carry a three-fold risk of night-time incontinence as an adult and twice the risk of diurnal incontinence than their fellows who had been dry at school. The epidemiology of childhood enuresis in Australia has been independently studied by Hawkins [128] in 1962 and by Bower et al. [129] in 1996. The former took a sample of 1000 children in one general practice only and found a prevalence of nocturnal enuresis (of one or more nights per week at school age) of 18%; daytime incontinence was not evaluated. The 1996 study by Bower and colleagues [129] used a self-administered questionnaire distributed to parents with children 5–12 years of age at the eight largest polling stations of three electorates. Voting is compulsory in Australia and these electorates were selected to represent voters of high (9000), middle (7600), and lower (9000) socioeconomic classification. Of the 3111 parents approached, 2292 (74%) responded. The prevalence rate was 15% for nocturnal enuresis, 2% for isolated day wetting and 4% for combined day and night wetting; overall, 79% of children were dry, 18.9% had nocturnal enuresis, and 5.5% had daytime incontinence. Whereas daytime wetting did not show a gender bias, 60% of children with enuresis were male, regardless of whether the enuresis was primary or secondary (Table 4n). The families of only 33.8% of enuretic children had sought professional help for the problem. Family strategies
used were reward charts (16%), waking the child to void (30%), fluid restriction (43%), and waiting for maturity (51%). Non-enuretic children woke spontaneously to void at night in 80% of cases; by contrast, enuretic children woke only 49% of the time. There was a significant difference in the incidence of a positive family history between enuretic and dry children: among dry children, 55.5% had no family history, whereas only 30.6% of enuretics had no known family history. These figures corroborate the findings of the earlier general population study, [117, 118] suggesting that 100,000 children wet the bed each night in Australia.

PREVALENCE OF SIGNIFICANT INCONTINENCE IN THE POPULATION

The results detailed above indicate that some urinary incontinence is experienced by many people. The problem has been identification of the rate of troublesome and significant leakage from most of the infrequently wet individuals. Using computer analysis, the entire sample was filtered to exclude all those with rare episodes of leakage and those who had ‘just a spot’ or slight loss of urine only, on infrequent occasions; patients who had leakage only with urinary infections were also excluded. The remainder were considered as having ‘significant’ urinary incontinence: of these 85 people, 10 were men and 75 were women. The frequency with which they experienced incontinence is shown in Table 4o. Infrequent urinary incontinence was rare in those women over 65 years of age, whereas frequent leakage was unusual in patients under 35 years of age. The degree of wetness experienced is detailed in Table 4p. Minor leakage volumes were rare over 65 years of age. Whereas those ‘always wet’ tended to be younger (<64 years old), the elderly tended to have ‘moderate loss’ or ‘flooding’. Of this group, only 40% of both sexes had ever sought treatment: 30% of each sex had seen their general practitioner, and specialists had seen 30% of the men but only 17% of the women. This low percentage of people seeking treatment reflects the fact that about 40% of each sex needed to wear protective underwear; the remainder managed by hygienic measures alone. The pattern of incontinence reported by those who were deemed to have significant incontinence is shown in Table 4q. Among the men with frequent incontinence, small volume post micturition loss was most commonly a complaint of younger men; older men suffered from urge incontinence (especially in the 75+ age group, in which this occurred in 20%). By contrast, females tended to have more than one cause of leakage, with stress incontinence predominant (particularly in middle-aged women). Urge incontinence in women appeared to be equally prevalent at all ages, but its severity grew with advancing years; flooding urinary loss was reported only by those over 50 years of age.
### Table 4k  Proportion of incontinent women in age cohorts who reported stress, urge or ‘other’ incontinence

<table>
<thead>
<tr>
<th>Type of incontinence</th>
<th>Young (21–26 years) (n=187)</th>
<th>Middle-aged (48–53 years) (n=389)</th>
<th>Older (73–79 years) (n=358)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress only (%)</td>
<td>10.7</td>
<td>6.4</td>
<td>2.0</td>
</tr>
<tr>
<td>Urge only (%)</td>
<td>2.7</td>
<td>1.3</td>
<td>6.1</td>
</tr>
<tr>
<td>Other only (%)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.8</td>
</tr>
<tr>
<td>Mixed (%)</td>
<td>86.6</td>
<td>92.3</td>
<td>91.1</td>
</tr>
<tr>
<td>Stress, urge and ‘other’</td>
<td>63.6</td>
<td>65.3</td>
<td>60.9</td>
</tr>
<tr>
<td>Stress and urge</td>
<td>18.2</td>
<td>26.0</td>
<td>26.8</td>
</tr>
<tr>
<td>Stress and ‘other’</td>
<td>3.2</td>
<td>0.8</td>
<td>2.5</td>
</tr>
<tr>
<td>Urge and ‘other’</td>
<td>1.6</td>
<td>0.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Any stress symptoms</td>
<td>95.7</td>
<td>98.5</td>
<td>92.2</td>
</tr>
<tr>
<td>Any urge symptoms</td>
<td>86.1</td>
<td>92.8</td>
<td>94.7</td>
</tr>
<tr>
<td>Any ‘other’ symptoms</td>
<td>68.4</td>
<td>66.3</td>
<td>65.1</td>
</tr>
</tbody>
</table>

### Table 4l  Present incontinence among those recalling nocturnal enuresis as a child

<table>
<thead>
<tr>
<th>Current</th>
<th>Childhood bedwetter</th>
<th>Childhood non-bedwetter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage wet at night now</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Percentage wet by day now</td>
<td>32</td>
<td>19</td>
</tr>
</tbody>
</table>
### Table 4m  Incontinence among those wet at school

<table>
<thead>
<tr>
<th>Current</th>
<th>Wet at school</th>
<th>Dry at school</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage wet at night now</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Percentage wet by day now</td>
<td>39</td>
<td>19</td>
</tr>
</tbody>
</table>

### Table 4n  Prevalence (%) of enuresis

<table>
<thead>
<tr>
<th>Type</th>
<th>Male (n=277)</th>
<th>Female (n=181)</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nocturnal enuresis</td>
<td>11.3</td>
<td>7.6</td>
<td>18.9</td>
</tr>
<tr>
<td>Daytime wetting</td>
<td>2.7</td>
<td>2.8</td>
<td>5.5</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>10.4</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Night</th>
<th>Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every day</td>
<td>2.4</td>
<td>0.6</td>
</tr>
<tr>
<td>2+/week</td>
<td>2.7</td>
<td>0.8</td>
</tr>
<tr>
<td>1/2 weeks</td>
<td>0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>1/month</td>
<td>1.8</td>
<td>0.4</td>
</tr>
<tr>
<td>&lt;1/month</td>
<td>11.1</td>
<td>3.4</td>
</tr>
</tbody>
</table>

### Table 4o  Frequency of significant urinary incontinence in 10 men and 75 women

<table>
<thead>
<tr>
<th>Frequency of incontinence</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>Often wet</td>
<td>50</td>
</tr>
<tr>
<td>Once a day</td>
<td>30</td>
</tr>
<tr>
<td>Once a week</td>
<td>20</td>
</tr>
<tr>
<td>Once or twice a month</td>
<td>–</td>
</tr>
</tbody>
</table>
URINARY INCONTINENCE IN PEOPLE IN INSTITUTIONS

A parallel study was conducted to determine the prevalence of incontinence among those in institutional care: 15 nursing homes in the Sydney area were surveyed; one public hospital (824 beds) and two private hospitals (842 beds) were also investigated.

INCONTINENCE IN NURSING HOMES

The staff of 15 of the larger nursing homes across the city were asked to fill out profiles of their patients’ continence status (Table 4r). Among the 1631 residents of these nursing homes, 596 were incontinent, a prevalence rate of 37%. Most of those who were incontinent were over 70 years of age. The ratio of males to females was close to 1:1, but females outnumbered males in the homes by 2.6:1; as a result there were more wet women than men. Wet men tended to be slightly younger than wet women. The degree of incontinence reported in this group is shown in Table 4s, correlated with mobility status. There was no significant difference between the degree of incontinence found in men and women in nursing homes. Residents who were chair-bound tended to have the highest rates of incontinence. Another Sydney study of 1659 residents of nursing homes found UI affected 77%, and that 25% of nursing staff time was spent dealing with urinary leakage. [130] The long-term care of looking after such residents was estimated at AUS$45,000 per patient per annum or $450 million a year. If the prevalence found in this survey (37%) is applied to the population of all nursing homes in Australia, an estimated 22,000 incontinent individuals might be expected to be found in these establishments. [117,118]

INCONTINENCE IN HOSPITALS

In order to assess the prevalence of incontinence, the staff of one large public hospital and two small private hospitals were asked to make a count of incontinence among their patients. In the public hospital, 3.4% of the 824 patients had incontinence known to the nursing staff and 71% of these were over 71 years of age. This may be an underestimate in that many patients who were able to manage their own incontinence may not have been known to the ward nursing staff. In the two small private hospitals, the prevalence of incontinence was 13 and 22%, respectively. There was a high proportion of psychiatric patients, of whom 15% were incontinent; 40% of the geriatric patients in these hospitals were incontinent.
### Table 4p  Degree of wetness in respondents with significant urinary incontinence

<table>
<thead>
<tr>
<th>Degree of wetness</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>Always wet</td>
<td>0</td>
</tr>
<tr>
<td>Flooding</td>
<td>0</td>
</tr>
<tr>
<td>Moderate loss</td>
<td>30</td>
</tr>
<tr>
<td>Slight loss</td>
<td>70</td>
</tr>
<tr>
<td>Just a spot</td>
<td>0</td>
</tr>
</tbody>
</table>

### Table 4q  Continence status in patients in 15 of the larger nursing homes in Sydney

<table>
<thead>
<tr>
<th>Degree of wetness</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>Always wet</td>
<td>39</td>
</tr>
<tr>
<td>Flooding</td>
<td>15</td>
</tr>
<tr>
<td>Moderate loss</td>
<td>31</td>
</tr>
<tr>
<td>Slight loss</td>
<td>13</td>
</tr>
<tr>
<td>(n)</td>
<td>194</td>
</tr>
</tbody>
</table>
PREVALENCE OF INCONTINENCE IN AUSTRALIA [115-118]

Among adult Australians, 24% of individuals admit to having some urinary loss and 6% of the population have significant or frequent urinary leakage. Of those who currently have no incontinence (76%), 23% have experienced some urinary leakage in their past adult life. Of those who currently suffer some form of leakage, 73% are female, but women account for 88% of those with severe incontinence (M:F ratio = 1:7.5). The female predominance disappears over the age of 60. A summary of the prevalence of incontinence is shown in Table 4t. If the figures for significant present incontinence are applied to the census figures, it can be estimated that as many as 960,000 adults in Australia may experience regular or severe incontinence; however, fewer than half of these ever seek professional help. Conversely, if prevalence figures of 24% of all women over 18 years are used and applied to current census data, a figure closer to 2 million incontinent individuals would be more appropriate. What then is prevalence? Should we only be interested in severe incontinence, or should we screen individuals in the community for lesser degrees of UI which might be amenable to interventions by the family practitioner, thereby perhaps avoiding more major problems later in life? A simple Incontinence Screening Questionnaire (ISQ) was evaluated and correlated with 48-hour pad test data, resulting in only five discriminating questions. [131] With an aging population we can anticipate an increase in the probability of UI and in its severity. In addition, with aging comes a change from stress incontinence to urge incontinence and co-morbidity. UI has a considerable financial impact on individuals and the healthcare system. In Australia the total annual cost of UI was estimated at AUS$710 million in 1998 for the 1,835,628 community-dwelling incontinent women over 18 years of age. This represents $387 per incontinent woman, comprising $338.47 million in treatment costs and $371.97 million in personal costs. These costs will escalate to AUS$1.27 billion per annum by 2018-2020. These figures do not include indirect or intangible costs, neither do they include the costs of nursing home care mentioned above.

We cannot afford to ignore the prevalence of incontinence; it is going to cost us or our children dearly. There is a need to emphasize to primary care physicians the importance of identifying at-risk women or those with minor degrees of UI, for which conservative options (pelvic floor exercise programs for stress urinary incontinence, or bladder training/drug therapy) may be restorative or may prevent deterioration. Clearly, the cost–benefit of early intervention needs to be evaluated in anticipation of the flood of incontinence with which the profession will be inundated as our population ages.
### Table 4r  
**Degree of incontinence analysed by patient mobility**

<table>
<thead>
<tr>
<th>Mobility</th>
<th>Percentage of patients incontinent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Always wet</td>
</tr>
<tr>
<td>Ambulant</td>
<td>10</td>
</tr>
<tr>
<td>Chair-bound</td>
<td>76</td>
</tr>
<tr>
<td>Bedridden</td>
<td>8</td>
</tr>
<tr>
<td>Mobile aided</td>
<td>6</td>
</tr>
<tr>
<td><strong>n</strong></td>
<td>234</td>
</tr>
</tbody>
</table>

### Table 4s  
**Summary of prevalence of incontinence in Australia**

<table>
<thead>
<tr>
<th>Incontinence</th>
<th>Percentage of individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>Childhood enuresis</td>
<td>21</td>
</tr>
<tr>
<td>Past incontinence (in adult life)</td>
<td>16</td>
</tr>
<tr>
<td>All present incontinence</td>
<td>13</td>
</tr>
<tr>
<td>Ever incontinent as an adult</td>
<td>28</td>
</tr>
<tr>
<td>Significant incontinence now</td>
<td>2</td>
</tr>
</tbody>
</table>

### Table 4p  
**Predictive validity of Incontinence screening questionnaire**

<table>
<thead>
<tr>
<th>Have you leaked urine when:</th>
<th>PPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• coughing/laughing/sneezing</td>
<td>64</td>
</tr>
<tr>
<td>• on the way to the toilet</td>
<td>68</td>
</tr>
<tr>
<td>• waiting to use the toilet</td>
<td>67</td>
</tr>
<tr>
<td>• going to the toilet urgently when first feeling the need</td>
<td>67</td>
</tr>
<tr>
<td>• going to the toilet ‘just in case’</td>
<td>68</td>
</tr>
</tbody>
</table>
PREVALENCE OF VOIDING DYSFUNCTION

Dysfunctional voiding is an abnormality of bladder emptying in neurologically normal individuals in whom there is increased external sphincter activity during voluntary voiding. It is learned behavior and, hence, differentiated from true external-detrusor sphincter dyssynergia, which occurs as a result of neurological disease or injury. Thus, the terms pseudodyssynergia and learned voiding dysfunction have also been used to describe the condition. Dysfunctional voiding may result in various lower urinary tract symptoms, including storage symptoms (frequency, urgency and urge incontinence) and emptying symptoms (decreased force of stream, hesitancy, need to strain and a feeling of incomplete bladder emptying). It may also be responsible for recurrent urinary tract infections, acute or chronic urinary retention, and in severe cases upper and lower urinary tract decompensation. In 1973 Hinman and Bauman popularized the concept of dyscoordination between the detrusor and activity of the pelvic floor-external sphincter complex in neurologically normal individuals. Many reports describe this phenomenon, also known as the nonneurogenic neurogenic bladder or the Hinman syndrome, as occurring in children and adolescents who typically present with enuresis, recurrent urinary tract infections and sometimes hydronephrosis. In 1978 Allen and Bright used the term dysfunctional voiding to describe the failure to coordinate detrusor and sphincter activity in children. The literature is replete with reports of this condition in children. However, in adults much less has been written, although it has been reported to cause various lower urinary tract symptoms, incomplete emptying, incontinence and recurrent urinary tract infections. [132]

The condition of voiding difficulty is defined as abnormally slow and/or incomplete micturition. Voiding difficulty has been relatively overlooked as a diagnosis in comparison with urodynamic stress incontinence (USI), overactive bladder (OAB) and uterine and/or vaginal prolapse. The presence of voiding difficulty may impact on the management of the first two of the other three conditions. Women presenting for urogynecological assessment have a 39% prevalence of voiding difficulty. This is much more frequent than previously determined. It is the third most common diagnosis, after USI (72%) and prolapse (61%) and ahead of OAB (13%). Failure to allow for voiding difficulty in the management of USI and/or OAB may lead to the risk of exacerbating the voiding difficulty with the possibility of acute or chronic retention. There is a significant increase in voiding difficulty with age and prolapse appears to be a most important factor. Voiding difficulty as a diagnosis can be easily made with a non-invasive voiding study, involving free uroflowmetry and RUV measurement by
ultrasound, all lasting only a few minutes. There is a significant inverse relationship between voiding difficulty and USI which implies any surgical treatment of USI is less likely to be compromised by the presence of pre-existing voiding difficulty. This finding was also seen in Costantini’s series. [133]
Chapter 1  General introduction

Chapter 2  Hypothesis, study parameters and justifications

Chapter 3  Physiology of Pelvic structures during toileting
   3a.  Physiology of Micturition
   3b.  Physiology of Defaecation

Chapter 4  Epidemiology of Incontinence

Chapter 5  The Perfect Pee Study

Chapter 6  The Near Squat Study

Chapter 7  The Squat Study
   7a.  The Squatability study amongst adults and children
   7b.  Abdominal pressures in the sitting and squatting positions
   7c.  Levator hiatus in the supine and squatting position

Chapter 8  Inventions to aid squatting

Chapter 9  General Discussion
CHAPTER 5

THE PERFECT PEE STUDY
AIM

The aim of this study was to find out whether posture does affect micturition when tested in two separate positions - the anteverted (Lean Forward) position and the Upright position.

INTRODUCTION

Research into posture and voiding are sparse. The only available data is based on a case report by S.A. Vincent in 1966, a British outpatient study done in 1991 by K.H. Moore et. al. and a Paediatric Neurourology study done by H. Wennergren in 1995 all of which have been elaborated in the discussion part of this chapter. In the yogic scriptures of Patanjali, 7000 years ago, there is a description on the use of a Hatha Yoga technique called ‘Mahabandha’ for control of anal and urethral canals through perineal pressure by the heel of the left foot. [14] The lotus position and heel pressure on the perineum to defer micturition are also well enshrined in the teachings of Tai-Chi. [14] It was therefore possible that change of posture during micturition could affect Uroflowmetric parameters.

EQUIPMENT

Our studies had no internal or external funding. The bladder scanner for residual urine was loaned from the Townsville Hospital. The uroflowmeter was already present in our urodynamics laboratory. The uroflowmeter is a device that measures voiding parameters that include volume, peak flow, average flow, peak time, average time, time to peak flow and displays a graphical voiding pattern. It is a highly accurate non-invasive measuring device that requires very little maintenance [2, 4, 134-137]

METHODS:

The first part was to look at the prevalence of crouching habits in a volunteer female population on the western toilet. This was done via a questionnaire. This population was recruited by posting fliers in the gynaecology outpatients after institutional ethics approval (no. 84/00). All our volunteers were either nursing staff or medical students; our target population was selected because of their prior knowledge of medicine and their ready availability to perform voids at different intervals. The sample size was selected as a convenience since no prior data was available. Our exclusion criteria
included only those with significant voiding problems, volunteers that were unable to hold a comfortably full bladder (at 300mls) and those who had on going urinary tract infections. All volunteers signed an informed consent from and were not given any incentives to participate in the studies. They had to visit numerous times to complete the parameters of the study.

Following the questionnaire, the volunteers were asked to perform two acts of micturition in two different positions on the conventional western toilet- the sitting upright position and the leaning forward position. The LFP was assumed with forearms resting on the thighs, elbows 20 centimetres(cms) behind the knees, with feet flat and knees at least 30 cms apart. In the upright position the volunteers were asked to imagine as if they were reading a newspaper with their back straight. The elbows were not in contact with the knees and the feet were either flat or on tip toes.

Bladder scanning and uroflowmetry were used to ensure uniformity in reporting of data. The volunteers were allowed to choose which position they wanted to go in first. This ensured that we had instructed our volunteers well enough on both positions. The volunteers had to report with a comfortably full bladder, have a pre void scan and then void in their privacy after one of the researchers had checked that the chosen position adopted was correct. The uroflowmeter started as soon as fluid started running through it thus avoiding any verbal instructions just before, during or after voiding. The volunteers then has a post void residual check with a bladder scan which was duly recorded.

The statistician was blinded to the types of position for data analysis. The data was normally distributed as evidenced by age, parity, incidence of stress incontinence and urge incontinence. When comparing the two positions to stress incontinence, urge incontinence, parity and age – the data on numerical variables was quite skewed hence non parametric tests were used for bivariate analysis for this data. The Mann – Whitney U test was used specifically. SPSS 13 was used as a tool for analysis to reduce further bias. A ‘p’ value of <0.05 was considered significant. A total of 50 volunteers were recruited of which one could not complete the study and hence data sets of 49 were included in the analysis.
RESULTS

Our results are reported in three parts

Table 5a shows the demographics and symptoms of stress and/or urge incontinence
Table 5b shows the effect of two different positions on micturition
Table 5c shows the crouching habits of volunteers

The leaning forward position showed a statistically significant improvement in flow rates and reduction in residual urine rates.
### Table 5a Demographic data

<table>
<thead>
<tr>
<th></th>
<th>17-70 years</th>
<th>Mean 42 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parity</td>
<td>0-4</td>
<td>Mean 2.4</td>
</tr>
<tr>
<td>Stress leak&gt; 1/month</td>
<td>19/49</td>
<td>38%</td>
</tr>
<tr>
<td>Urge Leak &gt; 1/month</td>
<td>8/49</td>
<td>16%</td>
</tr>
<tr>
<td>Post. Mic. Dribble</td>
<td>6/49</td>
<td>12%</td>
</tr>
</tbody>
</table>

### Table 5b Peak and average flows on micturition on upright and lean forward positions

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Range</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Peak flow</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=49</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upright</td>
<td>32.95</td>
<td>32.00</td>
<td>10.32</td>
<td>12-50 ml/sec</td>
<td>P&lt;0.0054</td>
</tr>
<tr>
<td>Forward</td>
<td>35.49</td>
<td>33.00</td>
<td>9.624</td>
<td>17-50 ml/sec</td>
<td></td>
</tr>
<tr>
<td>Improved flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in 29/49 (59%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Average Flow</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N = 49</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upright</td>
<td>18.14</td>
<td>16.00</td>
<td>6.583</td>
<td>6-35 ml/sec</td>
<td>P&lt;0.0097</td>
</tr>
<tr>
<td>Forward</td>
<td>20.00</td>
<td>20.00</td>
<td>6.624</td>
<td>8-35 ml/sec</td>
<td></td>
</tr>
<tr>
<td>Improved flow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in 29/49 (59%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Post void residual (&gt;50ml)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upright 9/49 (18%)</td>
<td>84.40</td>
<td>80</td>
<td>6.32</td>
<td>68-124 ml</td>
<td>P&lt;0.013</td>
</tr>
<tr>
<td>Forward 3/49 (6%)</td>
<td>81.33</td>
<td>84</td>
<td>4.21</td>
<td>76-84 ml</td>
<td></td>
</tr>
<tr>
<td><strong>Voided volumes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaning forward</td>
<td>478</td>
<td>164</td>
<td>Mean diff = 13.1 with 95% CI of -32.2 to +58.3</td>
<td>P=0.56</td>
<td></td>
</tr>
<tr>
<td>Upright position</td>
<td>465</td>
<td>157</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean diff = 13.1 with 95% CI of -32.2 to +58.3
### Table 5c Crouching habits of volunteers

**Do you ‘hover’ over the toilet seat?**

<table>
<thead>
<tr>
<th>Option</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always</td>
<td>0/49</td>
<td></td>
</tr>
<tr>
<td>Only on a public toilet</td>
<td>20/49</td>
<td>40.81%</td>
</tr>
<tr>
<td>Never</td>
<td>29/49</td>
<td>59.18%</td>
</tr>
</tbody>
</table>

**Do you lean forward when sitting on the toilet?**

<table>
<thead>
<tr>
<th>Option</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always</td>
<td>23/49</td>
<td>46.93%</td>
</tr>
<tr>
<td>Sometimes</td>
<td>10/49</td>
<td>20.40%</td>
</tr>
<tr>
<td>Never</td>
<td>16/49</td>
<td>32.65%</td>
</tr>
</tbody>
</table>
DISCUSSION:

This study clearly showed that leaning forward during micturition with good foot support ensures more efficacious flow of urine with less residual urine. It also showed that nearly half of our volunteer population lent forwards during micturition and more than half the population never hovered over a toilet seat.

The interest in local and national and international press on this phase 1 study resulted in a private media company putting together a book or it.

Ancient Indian ‘Hatha Yoga’ describes a technique called the *Maha Bandha* or ‘Great Binding’ for the control of the anal and urethral canals through perineal pressure by the heel of the left foot. [14] Posture is supposed to contribute to anal continence as described in a recent study by Altomare et.al. [138] S.A. Vincent described the ‘curtsy sign’ in an eight-year-old girl with nocturnal enuresis and gross diurnal urinary frequency and urgency that assumed a position akin to the squatting position whenever she had the urge to micturate. When asked to demonstrate the posture she was seen to be sitting firmly on her left heel which was pressing firmly upwards into her perineal and anal regions- almost as if she were ‘curtsying elegantly’. [139] Therefore the pressure is applied on the highest part of the bladder outlet rather than by an uncomfortable squeezing of the urethra at a lower level achieving a stoppage of the flow of urine immediately at any stage of micturition. In fact Faradic stimuli to the perineum contract the anus and pull it upward and forward by the action of the levator-ani muscle achieving the same results as the ‘curtsy position’ {Fig 5(i)}. 
Fig 5(i) The Curtsy Sign
THE SCANDINAVIAN STUDY 1991, 1995

The ability of the relaxation of the pelvic floor muscles (PF) is a necessary component of the function of the PF especially during normal voiding. However for some people especially children, even neurologically normal one this relaxation can be difficult to achieve resulting in disco-ordinated micturition with or without residual urine. [138] Pelvic-floor therapy and biofeedback can also help with dysfunctional voiding associated with recurrent urinary tract infections and obstipation.[141-144] Wennergren and colleagues noted that it was possible to train children (or for that matter adults) to assume postures that would result in optimal pelvic floor relaxation and by extension help with more efficient voiding. [1] EMG recordings were taken in three different postures, namely in the supine posture, sitting on the toilet seat and sitting with flexed knees with the back leaning against the wall. In each posture the legs were either supported or not supported. Relaxation of PF and adjacent muscles took place to a very large extent when the subjects had some kind of leg support. Unsupported legs resulted in higher EMG amplitudes and this indicates that choice of such postures particularly with adequate leg support is an important condition in achieving optimal pelvic relaxation {Fig 5(ii)}.

We used findings from this study to ensure proper foot support was afforded with feet flat during micturition in our study.
Sitting comfortably with child seat and foot support

Sitting down in the "hole"

Sitting on the brim

Fig 5(ii)

EMG recordings in sitting on a toilet seat. Electrode sites: A=Anal, U=Urethral, ADD=Adductor Femoris, RA=Rectus abdominis, GM=Gluteus Maximus
THE BRITISH STUDY BY KATE MOORE 1991

In 1991 Kate Moore and colleagues studied the prevalence in British gynaecological outpatient of the effects of crouching [hovering] over the toilet seat. They specifically looked at effect of this voiding position on urine flow rate and residual urine volume. Of the 528 consecutive women studied 85% usually crouched when using a public convenience, 12% applied paper to the seat and 2% sat directly over the toilet seats. This pattern repeated itself when women used the bathroom when visiting friends or even when they attended urodynamics. [2]

The 155 women attending urodynamic clinic were invited to undergo uroflowmetry and transvaginal ultrasound measurement of residual volume. Average and maximum (peak) urine flow rates were measured. Because urine flow rate is known to be volume dependent, centile flow rates based on the volume of urine voided were derived from the Liverpool normograms. [39] There was a 21% reduction in average urine flow rate and a 149% increase in residual urine volume in the crouching position. The results of this study suggest that when low urinary flow rates or a high urine residual are encountered during urodynamic testing it would be worthwhile to ask if the micturition took place in the sitting or crouching position. If the latter position was assumed then repeat studies with the patient sitting comfortably should be considered before ruling on the results of the uroflowmetry. Equally patients with a reduced functional bladder capacity may benefit from being encouraged to sit comfortably on the toilet whenever possible. [2]

In our study the experience was completely different with more than 59% of volunteers not crouching or ‘hovering at all’ whilst the rest did so only on a public toilet. This could be explained by the education program we have had in place since 1997 about proper posture on the toilet.
THE BELGIAN STUDY 2000

In 2000 researchers from the University of Gasthiusberg studied the effect of posture and straining and their effect on urinary-flow parameters in normal women. [4] Their research model based on the assumption that pelvic inclinations can bias the results of uroflowmetry because the pelvic floor which is a muscular hammock with three ‘holes’ fixed to the pelvic bone and its position varies with pelvic inclination. Retroversion of the pelvis brings the hammock forward almost horizontally whereas anteversion inclines the hammock to a forward position. Also the impact of abdominal forces (pressure and gravity) on the pelvic floor is determined by inclination of the pelvis. For example the abdominal pressure can be directed to the anterior part of the pelvis during micturition or to the posterior part during defecation. The peripelvic musculature that inclines the pelvis also influences the tone and power of the PFM. The study that was performed on 21 healthy female volunteers required the subjects to void on a uroflowmetry device in five different test situations viz. anteversion, anteversion with straining, retroversion, retroversion with straining and forward bending with straining [Fig 5(iii)]. The parameters of interest that were analysed were volume, peak flow, time to peak, peak-to-end time, total time and mean flow. Surprisingly no statistical differences in urinary flow parameters were noted between the three different positions. Interestingly however the peak flow rate was significantly higher in anteversion with straining against anteversion, retroversion, and forward bending and in retroversion with straining versus retroversion and anteversion. The quickest time to peak was in anteversion with straining. The peak-to-end flow time was lower in all voiding with straining and in the forward-bending position. The total flow time was shorter and mean flow volume greater when straining was applied in ante- or retroversion. The voided volumes were greatest when strain was applied during micturition, smallest in anteversion and approximately equal in the other two postures. So the researchers were unable to prove their null hypothesis that posture and more specifically pelvic inclination influences urinary flow and incontinence. So this means that pelvis inclination at normal complete relaxation of the urethra in normal women has no effect on voiding apart from the fact that staccatos (irregularities in the uroflow curve) were least frequent in the forward-bending position. The study group was too small to detect differences and the main factor explaining the absence of any difference in voiding amongst the various groups was the complete relaxation of the PFM occurring in normal female micturition. Apparently the detrusor contraction is the most important muscle in force production.
The literature shows that reflexes from the peripelvic musculature inserted to the pelvis can, however, impede the inhibition of the PFM. In the supine position with the lower extremities in a flexed adducted and externally rotated position, PFM are easily facilitated [145], whereas the lithotomy position with flexed legs and abducted hips allows more rotational descent of the bladder base and neck. [146] On the contrary during defecation pelvic floor mobility during squeezing is greater in the sitting position than in the supine and greater in females than in males. [147] In the proprioceptive neuromuscular facilitation concept of Kabat [148], urination is associated with the flexion patterns of the lower trunk and lower extremities. Actively changing from the supine to upright position induced a reflex pelvic floor relaxation in 45% of patients [149] and passively tipping the bed of elderly people to the erect position also caused incontinence. [150] Versprille-Fischer in 1993 [151] demonstrated that some toilet positions impede normal bladder emptying by creating an angle between the urethra and the bladder. Norton and Baker [152] found that bending forward from the hips did not diminish incontinence, whereas crossing the legs did. The latter posture is characteristic of unstable bladder in children. [153] Straining during voiding, which involves an abdominal muscle contraction, is a frequent phenomenon especially in women. This study shows that in normal women straining strongly increases the flow parameters, the peak flow being most increased in anteversion and the mean flow in retroversion. This reinforcement of flow occurs only if the urethra is completely relaxed and if the flow controlling zone of the urethra is not under the influence of abdominal pressure. Hasegawa et al. [154] stated that straining increases flow rate in stress incontinent patients but does not ameliorate flow in cases of obstruction of the prostatic urethra in men or of the proximal urethra in women. However, Versprille-Fischer [145] warned against straining during voiding because of increased compression of especially high compliant urethras. Indeed Bo et al. [155] demonstrated that during abdominal contraction the PFM but not the striated urethral wall muscle contract synergistic with hip adduction and gluteus muscle contraction. Flow impeding straining is often seen in the urethral syndrome in women with chronic suprapubic pain, hesitation, and frequency, the so-called perineal spastic syndrome prostatodynia, the spastic external sphincter in girls with recurrent infection, and other aspects of the dysfunctional elimination syndrome (DES). Herbaut et al. showed that paradoxical contraction of PFM during defecation straining may be asymptomatic, although a cause of emptying difficulty. [156]
This study was published 8 months after our study was published reinforcing the fact that there are researchers who believe that posture on the toilet can affect Uroflowmetric parameters. Position C in this study coincides with our lean forward position and the results are comparable to our study.
This study was published 8 months after our study was published reinforcing the fact that there are researchers who believe that posture on the toilet can affect uroflowmetric parameters. Position C in this study coincides with our lean forward position (LFP) and the results are comparable to our study.

Fig 5(iii) Positions on the toilet seat: A, anteversion; B, retroversion; C, bending forward.
A recent study from Taiwan [3] looked at the effect of female voiding postures and their effects on micturition. In Taiwan, as well as in many other Asian countries, both sitting- and squatting-type toilets are provided in public lavatories. As noted above, many women adopt a non-sitting posture for micturition when using a public sitting-type toilet [157,158]. They might partly squat (semi squatting) by bending the knees with the hips over the toilet without contacting the seat, or crouch over the toilet (squatting on the brim of the toilet seat) (Fig 5(iv)). However, the extent to which the two postures are used and their effects on micturition have not been investigated. The aim of the above study was to compare the effects of non-sitting and sitting postures for micturition on urinary flow and PVR and to investigate women's preferred voiding posture when using a public sitting-type toilet. Uroflowmetry indices measured were standardized as follows: Maximum flow rate (Qmax) is the maximum measured flow rate. Qave is the voided volume divided by flow time. Voided volume (VV) is the total volume expelled via the urethra. Time to peak flow (TQmax) is the elapsed time from onset of flow to maximum flow. Voiding time (VT) is total duration of micturition. PVR is defined as the volume of urine left in the bladder at the end of micturition. For this study, they added delay time to void (DT), the elapsed time from hearing "begin to void" to actual voiding.

In the above study data on uroflowmetric parameters were collected from participants in three different postures, i.e., sitting, semi squatting, and crouching over (Fig 5(v)). Data on uroflowmetric parameters were collected from participants in three different postures, i.e., sitting, semi squatting, and crouching over (Fig 5(v)). All women were instructed to void without increasing abdominal pressure to avoid physiological artefacts caused by straining, which reduces voiding time and increases Qmax and Qave. After each voiding, the same researcher (KNY) estimated the PVR. After finishing one posture test, participants were asked to drink water to produce urine until they felt a desire to void. They were then asked to void on the toilet in the next posture. The procedure was repeated for the third posture. The sitting, semi-squatting, and crouching over postures were labelled A, B, and C, respectively. These three postures had six possible sequence sets: ABC, ACB, BCA, BAC, CAB, and CBA. Thus, each woman used a different sequence of postures.

When voiding in the semi-squatting posture, women had a longer delay time to void than in both the sitting and crouching over postures. No statistically significant differences were found among the three voiding postures for TQmax, Qave, Qmax,
cQmax, voiding volume, voiding time, and PVR. Since the shape of the flow curve is considered a more reliable indicator of obstructed urinary flow than peak flow [159, 160], the researchers examined the urinary flow curve pattern of each void. Using the definitions of urinary flow curve patterns [160], three patterns were identified: normal flow (also called bell-shaped), fluctuating flow, and plateau flow. The study shows that the bell-shaped pattern was produced by more women voiding in the sitting posture (51.1%) than in the semi-squatting (22.2%) and crouching over (17.8%) postures.

The women’s reasons for adopting a non-sitting voiding posture were toilet seat not clean (97.8%), space limited (82.2%), and toilet height (66.7%). Of the 45 women, 40 (88.9%) preferred to adopt a non-sitting posture to void when they used a public sitting-type toilet. While 80% of women using the sitting posture felt comfortable while voiding, only one third of those adopting the semi squatting posture felt comfortable, and none reported feeling comfortable when using the crouching over posture. Among the 40 women who preferred to adopt a non-sitting posture when using a public toilet, 39.5% reported that they had adopted their voiding posture since junior high school age, while only 16.3% indicated they had adopted this posture before school. The results show that urine flow of women adopting the three voiding postures did not differ significantly in terms of TQmax, Qmax, Qave, mean voided volume, mean voiding time, and PVR.

The authors of the above study found that semi-squatting posture for micturition was associated with a significantly higher delay time to void than the sitting posture and crouching over posture. Urine flow in the sitting position also showed a more normal flow curve pattern. This result could be explained by the pelvic floor (PF) not being fully relaxed in semi-squatting posture. Incomplete PF relaxation might have deterred the onset of micturition (delay time to void). This explanation is supported by evidence that the optimal voiding posture involves relaxing the PF [1, 4]. For example, a study of posture and straining effects on urinary flow parameters [4] concluded that the forward-bending position is the most preferable urinating position to relax the pelvic floor. Moreover, in a study of postures that provided optimal relaxation of the pelvic floor [159, 160], postures with the legs supported resulted in 94% relaxation of the pelvic floor and 97% of adjacent muscles. Thus, sitting with the legs well supported, the thighs spread apart to obtain good relaxation of the pelvic floor, and the back held straight and tilted slightly forward will help voiding. To void in a semi-squatting posture on a sitting-type toilet, women have to contract their gluteus maximus and adductus femoris to hold the posture for tens of seconds. Contraction of the adductor muscles has been associated with failure of pelvic floor relaxation, thus impeding micturition.
The results in the Taiwanese study with women in a crouching over posture differ from a previous report that the squatting posture was associated with a significantly higher Qmax and lower PVR in normal young Indian women (mean age, 32 years). The squatting posture is helpful for PF relaxation. Although crouching over in this study looks like squatting, participants were unsteadily squatting on the narrow curved platform next to the toilet seat rather than on solid ground. Fear of falling and unsteadily supported feet made it difficult to relax the PF. This effect might have been underestimated due to our modifications of the study toilet because the regular toilet brim is more slippery to step on, which would hinder PF relaxation. In clinical practice, patients with detrusor instability were shown to be more likely to crouch over the toilet at their friend's house (51%) than patients with genuine stress incontinence (33%). Taken together, these results suggest that unhealthy bladder behaviours (e.g., using uncomfortable voiding postures) may be linked to the occurrence of Lower Urinary Tract Symptoms (LUTS) in older women.

Therefore, sitting on a toilet seat is suggested when using a sitting-type toilet seat. Non-sitting posture, either semi-squatting or crouching over, hinders PF relaxation and in the long run may affect bladder function. The Taiwanese study had several limitations. Firstly, the study toilet was modified for participants' safety by a small platform around the seat. This modification might have underestimated the effect of the crouching-over posture on micturition because a regular toilet brim is more slippery to step on. Hence, our findings might not be generalizable to a regular public sitting-type toilet. Secondly, since the study participants were limited to healthy female students, caution should be used in generalizing the findings to all female populations. Thirdly, the test–retest reliability of the exam was not estimated, thus threatening the study's internal validity. Lastly, the small sample might have compromised the detection of a difference in PVR between sitting and non-sitting postures. The large standard deviation in PVR suggests that some women using non-sitting postures did have higher PVR. Thus, this phenomenon warrants further study with a bigger sample.

In summary, the semi-squatting voiding posture in the study from Taiwan increased women's delay time to void, and non-sitting voiding postures decreased normal flow curve (bell-shaped) patterns. Women preferred to adopt a non-sitting posture to void when using a public sitting-type toilet, but they did not feel comfortable with these awkward postures. This dilemma needs to be resolved. Most participants learned this behaviour after entering school, so that elementary, middle, and high school education might have a role in teaching girls not to adopt non-sitting postures when voiding on a
sitting-type toilet. Women using the semi-squatting positions to void on a sitting-type toilet had higher delay time to void. Non-sitting positions, both semi-squatting and crouching over, had less bell-shaped urinary flow curve patterns than in the sitting position. Women should be encouraged to relax fully on the toilet seat by adopting a sitting position whenever possible.

CONCLUSION

The Perfect Pee study is the first study in adults that researched the effects of posture on micturition. In our methodology we employed the principles that H. Wennergren used in her study with children, namely ‘lean forward position’ and ‘foot support’. The results of the study were encouraging in that it managed to show a significant difference in uroflow rates in the ‘lean forward position’ as compared to the ‘sit upright position. At this point it became evident that some of the findings of our study could be translated into practical advice to the lay public on posture on the western toilet seat. This fact generated intense publicity in the press and also encouraged us to expand our research parameters to include the ‘near squat’ and ‘full squat’ position in further studies on voiding.
This study was performed two years after our study comparing squatting versus lean forward (chapter 7). Of note is position A which coincides with our lean forward position (LFP) which is the position that confers optimal voiding parameters.

Fig 5(iv) Modified sitting-type toilet. The wooden frame with a 7.5-cm platform by each side of the toilet seat guaranteed participant's safe footing while crouching.

Fig 5(v) Voiding positions on public toilet seats. a Sitting b Semi-squatting c Crouching over

This study was performed two years after our study comparing squatting versus lean forward (chapter 7). Of note is position A which coincides with our lean forward position (LFP) which is the position that confers optimal voiding parameters.
Chapter 1 General introduction

Chapter 2 Hypothesis, study parameters and justifications

Chapter 3 Physiology of Pelvic structures during toileting
   3a. Physiology of Micturition
   3b. Physiology of Defaecation

Chapter 4 Epidemiology of Incontinence

Chapter 5 The Perfect Pee Study

Chapter 6 The Near Squat Study

Chapter 7 The Squat Study
   7a. The Squatability study amongst adults and children
   7b. Abdominal pressures in the sitting and squatting positions
   7c. Levator hiatus in the supine and squatting position

Chapter 8 Inventions to aid squatting

Chapter 9 General Discussion
CHAPTER 6

THE NEAR SQUAT STUDY
Fig 6(i) CFA poster demonstrating correct sitting position on the toilet

Fig 6(ii) “The Perfect Pee”  “Near Squat”
POSTURE AND MICTURITION – A TRIAL COMPARING THE NEAR SQUAT POSITION (NSP) TO THE LEANING FORWARD POSITION (LFP)

INTRODUCTION

Posture on the toilet has been a research question in many studies. Corstiaans and Devreese in two separate studies performed in the same year showed that uroflowmetric parameters improved in the position of anteversion or LFP. [4, 161] It has been anecdotally suggested that a near squat position using a ‘foot stool’ with raising knees above the pelvic brim promotes better bowel and bladder evacuation – CFA 2001. [162] On television in a famous program ‘Two and a Half men’ a footstool is shown to improve one of the characters bowel evacuation! [163]

There were no previous studies on this issue at all. The aim of our study was to look at the effect of the NSP and LFP on Uroflowmetric parameters.

AIM

The aim of this study was to find out whether posture does affect micturition when tested in two separate positions - the Near Squat Position to the anteverted (Lean Forward) position.

METHODS

After obtaining local ethics approval (H3489), 20 female volunteers were recruited to pass urine in the two different positions after proper instructions. This population was recruited by posting fliers in the gynaecology outpatients. All our volunteers were drawn from either the nursing staff or medical students. All volunteers signed an informed consent from and were not given any incentives to participate in the studies. They had to visit numerous times to complete the parameters of the study. Most of the volunteers in this study had participated in our previous study (Chapter 5).

The volunteers were randomly allocated their first and second positions and voids were done at least 48 hours apart when volunteers had a comfortably full bladder and would have gone to pass urine normally. All volunteers sat on the commode and tested the height to ensure proper LFP. The foot stool was 120 millimeters (mm) in height and all volunteers used it to ensure that they were comfortable and that their knees were above the level of the Anterior superior iliac spine (ASIS) before they voided. The LFP
was assumed with forearms resting on the thighs, elbows 20 centimeters (cms) behind the knees, with feet flat and knees at least 30 cms apart. The NSP was assumed with knees above the ASIS and feet flat with knees at least 30 cms apart. A pre void bladder scan was performed and volumes of more than 300 mls were considered adequate to void in this study. After proper pre void instructions volunteers were given their allocated position as per the list that was generated via a computerised randomisation program. They were then allowed to void in complete privacy.

Parameters studied during uroflowmetry were voided volume, maximum and average uroflow, time to peak flow, total time and post void bladder residual volume (PVRBV). The morphology of the uroflow curves was also studied to check the presence of staccato voiding and straining. Sample size was calculated from our previous study since there were no other studies to compare with. The data was normally distributed. Paired Wilcoxon tests were used for all uroflowmetric parameters. Mann Whitney U tests were not used due to low incidence of stress incontinence. A ‘p’ value of < 0.5 was considered significant.

RESULTS:

The data was normally distributed. The mean age of the volunteers was 36.75 years (SD 6.742). There were 7 nulliparous (35%) and 13 multiparous (65%) volunteers with a mean parity of two and maximum parity of four. Two (10%) volunteers gave a history of both stress incontinence and urgency. They were both multiparous patients.

The values for uroflowmetric parameters are presented in Table 6(a).
Statistically significant differences were found in both maximum and average flows between the two positions with the NSP showing higher values implying more efficient voiding. Of interest however was a trend (not statistically significant) to a higher PVRBV in the NSP. Residual volumes over 50 ml were 150 and 74 mls in two volunteers in the LFP and there were 4 volunteers who had PVRBV > 50 ml 61, 224, 260, 262 mls respectively.

The mean PVRBV in the LFP group was 16.95 ml
The mean PVRBV in the NSQ group was 48.1 ml.
The mean difference in PVRBV was -31.5 and at 95% CI (-68 to +5) p = 0.086 which is not significant.
### TABLE 6a Uroflowmetric parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>LFP</th>
<th>NSQ</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>Mean</td>
<td>466.05</td>
<td>515.40</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>142.03</td>
<td>153.39</td>
</tr>
<tr>
<td>Peak Flow</td>
<td>Mean</td>
<td>32.40</td>
<td>36.05</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>10.81</td>
<td>9.95</td>
</tr>
<tr>
<td>Average Fl.</td>
<td>Mean</td>
<td>18.95</td>
<td>20.65</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>6.393</td>
<td>5.56</td>
</tr>
</tbody>
</table>

s=significant  
ns= not significant
DISCUSSION:

Our study is the first study looking at the NSP scientifically for urination. There are no studies looking at the effect of knee raising published before. Using a foot stool to help bowel motions has been advised widely by health authorities (CFA, bowel and bladder association, many state health authorities) [162-164] and commercial TV (Two and a Half Men show Alan needing a foot stool ‘if the coffee didn’t generate enough pressure!’). These recommendations have been made with no evidence whatsoever. It however stands to reason that a population that only gave up squatting a hundred years ago was now seeking methods to relax the pelvic floor with good foot support and possibly generate increased abdominal pressure to facilitate more effective bowel and bladder control. One also has to question whether knee raising relaxes the levator muscles and further help bladder and bowel movements.

When ‘foot stool for toilet’ is ‘Googled’ a whole myriad of health authorities, books, kinesiologists etc. seem to have an opinion on use of a foot stool for toileting. Stephanie Relfe, a kinesiologist from the US writes on her website (perfect health with kinesiology) that squatting is the best way to improve bowel and bladder function. However she concedes that not a lot of Westerners can squat (no figures or evidence) and the she quotes ‘it is especially important for children to squat. [165] Place a raised area that is as high as the potty or toilet in front of the potty or toilet. I believe the shorter the person the more likely they will have bowel problems. She finally quotes ‘if you can’t manage (to squat ) it can work quite well to place a foot stool in front of your toilet. Try to get one as tall as your toilet, You may be amazed at the results! This is especially important for children because of their shorter legs.’

This further supports the theory of having feet in contact with the ground in children as shown by Wennergren et al and our previous study (Chapter 5). Newer studies have studied the full squat position (Chapter 7) and compared it to the LFP but these studies have NOT studied the NSQ a probably more ‘practical’ position rather than the full squat position.

Chet Day on his website ‘Try the Footstool home remedy for constipation relief’ says ‘using a footstool with an American toilet helps to more closely get the body in the natural position’. [166] Independent Living Centre (ILC) Australia describes in great detail with dimensions a wooden footstool they recommend (ILC 2002). [167] They describe it as ‘a stool designed to encourage the natural squatting position for effective
bowel evacuation’. The dimensions include a height of 210 mm (Fig 6(iii)). There is no scientific evidence that this works. Also a ‘zero’ height of 210 mm could be quite high for normal adults and may result in an uncomfortable crouch. Without a stool that can have a ‘mobile’ height it is difficult to see how a ‘universal’ application can be achieved. Our study had a ‘zero’ height of 120 mm for adults and it has shown a difference when compared to the LFP. We suggest that a ‘mobile’ height stool would be ideal if this position (NSQ) were to be used by people of all ages and heights.

Western Australia Health (2007) in their booklet ‘Toilet Training ’extensively’ recommend the use of footstools for ‘potty training’. There is no scientific evidence to these anecdotal therapeutic advises but there must be some innate feeling that these things must work during toileting! [164]

The main postural factor that seems to affect micturition include feet position and lumbar spine position. The effect of knee raising along with feet support and lumbar anteversion adds another ‘dimension’ to position during micturition and bowel evacuation. Does it increase resting abdominal pressure to aid evacuation? Does it further help pelvic floor relaxation? These are further questions generated by this study.

Our study did have small numbers but there have been no previous studies looking at the NSQ and we impart our conclusions with caution. Bo (1994) demonstrated that during abdominal muscle contraction, the pelvic muscles contract synergistically with hip adduction and gluteus muscle contraction. Herbaut (1994) showed that paradoxical contraction of pelvic muscles during defecation straining may be asymptomatic but causes emptying difficulty. This means that both abdominal muscles and pelvic muscles should be completely relaxed during micturition and bowel movements.

**CONCLUSION:**

Uroflowmetric parameters are significantly affected by changing posture from LFP to NSQ during micturition. Due to the small numbers in this study this conclusion needs to be interpreted with caution. Our study does show that the NSQ position can be adopted and a ‘mobile zero height’ would be desirable for a universal application.
Fig 6 (iii) ILC Australia-Toiletting Footstool
Chapter 1  General introduction

Chapter 2  Hypothesis, study parameters and justifications

Chapter 3  Physiology of Pelvic structures during toileting
  3a.  Physiology of Micturition
  3b.  Physiology of Defaecation

Chapter 4  Epidemiology of Incontinence

Chapter 5  The Perfect Pee Study

Chapter 6  The Near Squat Study

Chapter 7  The Squat Study
  7a.  The Squatability study amongst adults and children
  7b.  Abdominal pressures in the sitting and squatting positions
  7c.  Levator hiatus in the supine and squatting position

Chapter 8  Inventions to aid squatting

Chapter 9  General Discussion
CHAPTER 7

THE SQUAT STUDY
Fig 7(i) “The DUNI with my son Ben”
DOES MICTURITION IMPROVE IN THE SQUATTING POSITION?

After completing the Near Squat versus Lean forward study it was time to move on to the next part of our study design.

INTRODUCTION:

Squatting has been the subject of numerous papers pertaining mainly to bowel movement. A study by Rad et al. look at defecography in the western position and the squat position. [35] Long discourses by Jonathan Nesbit and Wallace Bowles on the Internet (Natures Platform.com ) show real enthusiasm but there are only few and sporadic studies with small numbers like those done by Sikirov et al. [15, 29, 30, 32, 168-170] available in the scientific literature.

Brieger in his questionnaire study postulated a resurgence in incontinence and prolapse in urban Hong Chinese women due to lack of squatting on the toilet when compared to their rural counterparts. [20]

Numerous challenges arose during this study in adopting its methodology. These included,

a. The construction of an experimental squat toilet that would be able to accommodate a uroflowmeter under it, and be robust enough to withstand a body weight of 150 kilograms. It had to be clean, washable, and robust.

b. The study of a ‘squatting index’ due to poor ‘squatability’ amongst volunteers, running a real risk of abandonment of this study. The study of squatability will be discussed in the next chapter.

c. The interpretation of data due to the ‘newness’ of the full squat position.

AIM

The aim of this study was to prove that intra-abdominal pressures increase during micturition and are lower in the squatting position.
METHODS

Ethical approval (56/04) was obtained for the study from the local ethics committee. The recruitment technique was the same as described in Chapters 5 and 6.

54 volunteers women out of 125 were recruited in the study since they were the cohort able to do a full squat for more than 30 seconds with their feet flat and without discomfort. This study is further described in Chapter 8. Volunteers were recruited to pass urine in the two different positions after proper instructions. The volunteers were allocated their first and second positions and voids were done at least 48 hours apart when volunteers had a comfortably full bladder and would have gone to pass urine normally. All of them have a pre void bladder scan to ensure a bladder volume of at least 300 ml.

All volunteers sat on the commode and tested the height to ensure proper LFP. The LFP was assumed with forearms resting on the thighs, elbows 20 cms behind the knees, with feet flat and knees at least 30 cms apart. The squat position (SP) was the full squat position on a custom built squat toilet. Handles were provided on the side of the toilet to aid lowering and rising of the volunteers in their own privacy.

A pre void bladder scan was performed and volumes of more than 300 mls were considered adequate to void in this study. After proper pre void instructions volunteers were given their allocated position as per the list that was generated via a computerised randomisation program.

Statistical analysis was done using SPSS 13.

RESULTS:

Numerical variables proved to be in a skewed distribution especially when comparing variables like mode of delivery, symptoms of stress and urge incontinence and crouching habits to the two positions. That is why medians were used as measures for central tendency and inter quartile ranges as a measure of dispersion. Consequently non – parametric test procedures were used for bivariate analysis especially for the above mentioned data.
Paired Wilcoxon tests were used for all uroflowmetric parameters and Mann-Whitney U test was used to compare dichotomous categorical risk factors like stress leakage, urge etc to the uroflowmetric parameters. Correlation with age and uroflowmetric parameters was assessed using non-parametric Spearman rank correlation coefficients.

The Mean age was 39 with a range of 18 to 62 years. The Mean parity was 2 with a range of 0 to 4. There were 24 nulliparous women, 5 women had caesareans as mode of delivery and 23 had vaginal births.

FLOWMETRIC DATA:

Of all the parameters that we looked at only ‘time to peak flow’ was statistically significant (p = 0.003).

The ‘unpaired test data was quite skewed and revealed the following

**Symptoms of stress and urge incontinence:**

Stress incontinence did not affect any voiding parameters

Urge incontinence seemed to only influence peak flow when leaning forward p=0.051 , more a trend than significance. Average flow when squatting is higher in women without urge incontinence ( p=0.049 ), again more a trend than significance.

**Crouching habits:**

40 (74.1%) women never ‘hovered’ over the toilet

14 (25.9%) women sometimes hovered over the toilet

Women who never hovered on the toilet as a habit had a higher average flow rate in the squatting position (p=0.013). Women who sometimes tended to hover made no difference to voiding parameters.

**Mode of Delivery:**

Caesarean section: this influenced average flow in the LFP though ONLY via age (p = 0.053). Average flow in general is better in women without caesarean section. When squatting the residual urine was significantly higher in the vaginal delivery group ( p=0.043 )
<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>LEAN FORWARD POSITION</th>
<th>SQUATTING</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume</td>
<td>515.00</td>
<td>456.00</td>
<td>0.94</td>
</tr>
<tr>
<td>Max Flow</td>
<td>31.50</td>
<td>34.50</td>
<td>0.26</td>
</tr>
<tr>
<td>Average Flow</td>
<td>19.00</td>
<td>17.00</td>
<td>0.25</td>
</tr>
<tr>
<td>Time to Max Flow</td>
<td>7.00</td>
<td>8.50</td>
<td>0.003</td>
</tr>
<tr>
<td>Residual urine</td>
<td>42.50</td>
<td>24.75</td>
<td>0.66</td>
</tr>
</tbody>
</table>
DISCUSSION:

Squatting and micturition

Numerous issues arose out of this study. The first being construction of our study toilet. The study toilet needed to be on a platform so that the uroflowmeter could be housed underneath the “hole” for accurate data measurement. It needed to be robust and hold at least 150 kilograms (kgs) in weight. Wall handles needed to be attached to help people get in and out of the squatting position. It needed to be portable and finally we decided to paint it white to convey cleanliness. The platform was made of wood (see photo) and continues to be used for further studies. All our volunteers could complete the study using our ‘duni’.

During the instruction part of the study a third of our volunteers were worried that the stream of urine would flow forwards and make a mess of the flooring of the raised toilet. We made a funnel with a plastic lip in the front to allay anxiety of women who made this assumption. It was also quite apparent that although our volunteers were screened for ‘squatability’ from a safety point of view, they had very seldom actually passed urine in such positions except at camping or trekking. This ‘newness’ of the squatting position could have contributed to a subtle hesitance on the part of our volunteers although this was not apparent in our results. We do however believe that compared to the study done by Gupta et al., [5] the newness of the position probably did fail to bring out the perceived efficacy of squatting over a toilet in our Volunteers.

The statistically significant value of time to maximum follow is difficult to interpret and may be due to complete relaxation of the pelvic floor and/or due to increased passive intraabdominal pressure (see chapter 8 b). Similarly it is difficult to explain why there was a trend that was not significant to higher PVRBV in the squat group. We attribute this to the ‘newness’ of the position. The other non-paired data analysis was quite difficult to interpret and to draw any significant conclusions. Of note again was the 74% of women who never hovered over a toilet as compared to the British study showing a 85% hovering rate. [2] We attribute this to continuing education and research in our community on posture and toileting.

In 2008, Gupta et al., [5] published their study on squatting versus sitting in Indian women. They had 67 healthy volunteers participate in this study out of 217 asymptomatic female attendants of patients attending a urology clinic. This low rate of acceptance could be because of inherent shyness in Indian women. None of these
women underwent a squatability test (unlike our women) since squatting is quite ubiquitous in India. 92.6% of women in their study preferred to adopt squatting position for micturition whilst a minority were equally comfortable with both positions. In Gupta’s study they modified their urodynamics chair to promote squatting (how they did this is not mentioned, nor does the figure in their paper depict this). Our assumption is that this would be adding foot print pedestal attachments on a standard urodynamics chair. This position could be quite precarious as shown in a recent study from Taiwan. [3] On analysing their results critically statistically significant results were Q max (maximum flow) and PVRBV (post void residual bladder volume). Even though significant Q max in the sitting cohort was still within the normal range – 18.4 +/- 3.2 mls/sec, whilst PVR in each group was around 50 mls – 51.8 mls vs 21.6 mls. The voided volumes in each group were also relatively smaller than our study 264.9 mls sitting versus 259 mls squatting against our cohort 515 mls sitting versus 456 mls squatting – a more realistic bladder capacity volume. We would speculate here that the modified urodynamics chair would have had an effect on these results due to the insecurity of ‘perching’ on a chair as shown by the Taiwanese study even in a population used to squatting since childhood.

We would only like to discuss salient issues pertaining to squatting only in this chapter. Their main conclusion was that 88.9% of women prefer a ‘non – sitting posture when using a public toilet. This figure is similar to the British study and dis similar to our studies. [2] 51 fit healthy students were recruited in this study. Again for the purpose of squatting a modified toilet chair was used as compared to our purpose built squat toilet. None of the volunteers felt comfortable in this position during the study despite 39.5 % of volunteers being used the traditional squat position. This further goes to prove that a ‘modified perch ‘ for full squatting may affect micturition adversely.

In 2010 Choudhury et al. published their data on uroflowmetric parameters in 61 men. [6] They used the sitting, standing and squatting positions for men. In their study 45 men preferred standing, 15 preferred squatting whilst only 1 man preferred sitting. Usually men from rural areas preferred squatting whilst city dwellers preferred standing or sitting. This study highlights the importance of squatting in men and also the distinction between rural and urban dwellings. Their conclusions were that uroflows were significantly better in the standing and squatting positions. This study however does not elaborate on how the males squatted on a uroflowmeter – i.e. whether they had a purpose built squat toilet or a perch.
Unsal and Cimentepe (2004) studied 36 male and 36 female volunteers in the standing (for men), sitting and crouching positions (for male and female) and analysed their uroflowmetric data. Their found no difference in any uroflowmetric parameters in any position. [171] Again this study fails to elaborate on what ‘crouching’ actually meant. Our assumption is that crouching means perching on a western pedestal to squat.

Brieger in 1997 reported from Hong Kong on the incidence of pelvic floor disorders in the form of genital prolapsed and stress incontinence. In a postal survey of 819 responses, he showed a prevalence of 22% for stress incontinence which is pretty similar to Western figures. He postulated that change in diet and toileting from squat to sit with rapid urbanisation as the main causes for this parity in incontinence between the western and the eastern worlds. [20]

SQUATTING AND BOWEL

Although scientific studies on squatting and bowel function are rare there are numerous hypothesis and benefits promulgated in available literature.

Rad in 2002, performed defecography in 30 Iranian patients who were referred for barium enema. Patients were instructed to perform two bowel motions and X rays taken on the western commode and the squat toilet. The age range was from 11 to 70 years. In his results Rad showed a much wider anorectal angle in the squat position with the angle disappearing in some patients completely. He also reported that the distance between the perineum and the horizontal plane of the pelvic floor was 8.4 cms in the squat toilet and 6.6 cms in the western toilet. [35]

No statistical analysis was done on any data. He concludes that there is a ‘remarkable’ straightening of the anorectum in the squatting position whilst in the western position there is ‘remarkable’ folding in the terminal rectum predisposing to rectocele formation and incomplete puborectalis relaxation. However in this study the numbers are small, there is a wide variation in age groups and no statistical analysis has been undertaken.
Fig 7(ii) Defecograph showing the anorectal angle as measured in two different positions of bowel evacuation
Taggart (1966) also studied the angle of the anorectum on 10 volunteers with known normal anal function.\[172\] X rays of the rectum containing radio opaque fluid in a flexible tube were taken with the hips erect, 90 degree flexed and fully flexed (squat) position. They concluded that flexion of the hips pulls the anal canal forward and changes the anorectal angle.

Sikirov (1987) advised 20 patients diagnosed with haemorrhoids on proctoscopic examination to change their toilet habits in two ways – to wait until urge to defecate was strong and to defecate in the squatting position. [168] Of the 20 patients, 18 reported significant reduction or absence of symptoms within 3 months whilst two patients required surgery. He followed up these patients at 12 and 30 months with no recurrence of haemorrhoids. In another study he enlisted 30 volunteers and made them measure the time taken to complete defecation in the western position and the squatting position. His results showed that the average time spent on the squat toilet was 1 minute as compared to 4 to 15 minutes on the western toilet. Also the number of episodes of straining was 1-2 on the squat toilet as compared to 4-7 on the western toilet. [29]

Although Taggart (1966) suggested that a footstool would help flex the hips enough Sikirov does not agree with that sentiment. [29, 170, 171] Lam et al (1993) studied 52 patients referred to a colorectal unit to compare descent of pelvic floor during straining in the sitting and squatting positions. [174] A perineometer was used to assess this descent. There is no data on how they assessed squatability but they has no patients that could not squat. In their study there was no significant difference between the measurements of perineal descent for the sitting and squatting positions. Perineometry is notoriously difficult to assess pelvic muscle squeeze, we feel it would be even harder to assess perineal descent with a perineometer.

**CONCLUSIONS:**
Our study is one of the first study looking at the full squat toilet position and its impact on micturition. Care was taken in our study to pre assess our volunteers’ ability to do a full squat. Further care was taken to provide a proper squat toilet rather than a perching urodynamics chair which has been found to be unsafe and uncomfortable in a Taiwanese study.
THE SQUAT TOILET

Advantages of a squat toilet [175] (as quoted in Wikipedia)

- It is less expensive and easier to clean and maintain
- It does not involve any contact between the buttocks and thighs with a potentially unsanitary surface
- The absence of water in the bowl avoids the problems of water splashing upwards
- Squatting might help to reach the required expulsion pressure more comfortably and quickly
- Squatting makes elimination faster, easier and more complete
- Elimination in squatting posture protects the nerves that control the prostate, bladder and uterus from becoming stretched and damaged
- Squatting relaxes the puborectalis muscle which normally chokes the rectum in order to maintain continence
- Squatting securely seals the ileocaecal valve, between the colon and small intestine. In the conventional position. This valve is unsupported and often leaks during evacuation
- For pregnant women, squatting avoids pressure on the uterus when using the toilet. Daily squatting helps prepare the mother-to-be for a more natural delivery.
- Squatting may reduce the occurrence or severity of haemorrhoids and possibly other colorectal disorders such as diverticulosis and appendicitis [173]

ALL THESE ARE PERCEIVED ADVANTAGES WITH NO LARGE BODY OF SCIENTIFIC EVIDENCE

The case against the sitting toilet (as quoted in Wikipedia)

- Without pressure from the right and left thighs, no intra-abdominal pressure is created to facilitate expulsion of waste.
- Without the action of the right thigh there is no squeezing action to direct waste upwards and away from the appendix.
- Without the action of the left thigh, the natural bend between the sigmoid colon and rectum is not released.
- The angle of the anorectum is not straightened whilst sitting.
- Young children have a more serious impact due to lack of feet support.
- In a study in India squatting induced rise in blood pressure was thought to be a triggering factor for stroke.[176]

AGAIN SOME OF THESE ARE PERCEIVED DISADVANTAGES.
So what is a squat toilet?

A squat toilet known as Arabic, Japanese, Korean, Iranian, Indian, Turkish or natural position toilet, is a toilet used by squatting not sitting. Essentially there is a hole in the ground with or without a flush facility. The ones with a flush are called *alafranga* as compared to non-flush which are called *Alaturka*. In Alafranga the user puts their feet on foot rests, faces the entrance of the cubicle and eliminates waste towards the hole. [175]

In oriental countries like Japan, China, Korea and Taiwan the user squats facing the flush apparatus with stools being deposited on the dry section of the toilet to avoid splashing but allowing some odour. When flushed, the dry section is washed towards a pool of water at the flushing end.

In Asia, squatter toilets are merely a communal trough at times shared by many users. Plumbing may be non-existent in such cases. When water is not available in arid areas a hole dug in the ground is covered up after ablution.

**Numerous pictures with examples of squat toilets are depicted alongside.**

From our point of view very few Westerners can actually perform a full squat, therefore to get the perceived advantages of a full squat a different design needs to be invented. A **squat toilet** (also known as Arabic, Japanese, Korean, Iranian, Indian, Pakistani, Turkish or Natural-Position toilet) is a toilet used by squatting, rather than sitting. There are several types of squat toilets, but they all consist essentially of a hole in the ground. The only exception is a "pedestal" squat toilet, which is the same height as a standard flush toilet. It is also possible to squat over standard Western pedestal toilets, but this requires extra care as they are not specifically designed for squatting.
Squat toilet

From Wikipedia, the free encyclopaedia

Fig 7(iii) American squat toilet with tank (Saline, Michigan)

Fig 7(iv) Toilet retrofit installation
STUDY OF SQUATABILITY IN ADULTS AND CHILDREN

STUDY OF SQUATABILITY IN ADULTS

INTRODUCTION:

Kidd showed that there is a ‘squatting facet’ on the Talus bone of humans at birth and that this facet disappears in adult if they do not squat as a habit. [177, 178] Brieger in his paper suggested a change from squatting to sitting toilets in urban Hong Kong has resulted in a significant increase in incontinence and prolapsed in urban Hong Kong when compared with their rural counterparts. [20] Numerous publications from India (Gupta, Choudhury), Taiwan (Yang), Israel (Sikirov) have studied patients in the squatting position but none of these studies have actually studied the ability of their patients to squat before commencing their studies.

There are no studies looking at squatability published to date.

METHODS:

To get some idea about squatting, we took advice from our physiotherapist. All potential volunteers were advised about squatting. The three characteristics we studied were ‘cannot squat at even with support’, ‘can squat on tip toes with support for more than 30 seconds’, ‘can do a full squat unsupported for more than 30 seconds’. Only the last group was chosen for the squatting study.

125 women volunteered for the squat study. Volunteers were asked to take support of the back of the chair and try and squat. There were completely supervised at all times and their attempt to squat was abandoned if any pain or discomfort was perceived.

RESULTS:

The mean age was 39 years with a range of 18 to 62 years. 48 women were nulliparous, 9 had caesarean births and 68 had vaginal births.
Table 7aa shows the distribution data against mode of delivery

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Nulliparous (nos/%)</th>
<th>Caesarean (nos/%)</th>
<th>Multiparous (nos/%)</th>
<th>Total (nos/%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not able to squat</td>
<td>6(12.5)</td>
<td>2(22.2)</td>
<td>11(16.2)</td>
<td>19(15.2)</td>
</tr>
<tr>
<td>Squat on toes</td>
<td>19(39.6)</td>
<td>2(22.2)</td>
<td>31(45.6)</td>
<td>52(41.6)</td>
</tr>
<tr>
<td>Full squat</td>
<td>23(47.9)</td>
<td>5(55.6)</td>
<td>26(38.2)</td>
<td>54(43.2)</td>
</tr>
<tr>
<td>Total</td>
<td>48(38.4)</td>
<td>9(7.2)</td>
<td>68(54.4)</td>
<td>125(100)</td>
</tr>
</tbody>
</table>

Table 7ab Squat by parity

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Nulliparous (nos/%)</th>
<th>Multiparous (nos/%)</th>
<th>Total (nos/%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not able to squat</td>
<td>6(12.5)</td>
<td>11(16.2)</td>
<td>17(14.7)</td>
</tr>
<tr>
<td>Squat on toes</td>
<td>19(39.6)</td>
<td>31(45.6)</td>
<td>50(43.1)</td>
</tr>
<tr>
<td>Full squat</td>
<td>23(47.9)</td>
<td>26(38.2)</td>
<td>49(42.2)</td>
</tr>
<tr>
<td>Total</td>
<td>48(41.4)</td>
<td>68(58.6)</td>
<td>116(100.0)</td>
</tr>
</tbody>
</table>

Table 7ac shows the distribution data against age

<table>
<thead>
<tr>
<th>Age in years</th>
<th>Not able to squat</th>
<th>Squat on toes</th>
<th>Full squat</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 20</td>
<td>4</td>
<td>9</td>
<td>14(48.14%)</td>
</tr>
<tr>
<td>20-29</td>
<td>0</td>
<td>17</td>
<td>12(58.62%)</td>
</tr>
<tr>
<td>30-39</td>
<td>3</td>
<td>8</td>
<td>12(47.8)</td>
</tr>
<tr>
<td>40-49</td>
<td>3</td>
<td>8</td>
<td>10(52.38)</td>
</tr>
<tr>
<td>50-59</td>
<td>4</td>
<td>7</td>
<td>6(64.70)</td>
</tr>
<tr>
<td>60-69</td>
<td>5</td>
<td>2</td>
<td>1(87.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19</td>
<td>51(43.2%)</td>
</tr>
</tbody>
</table>

Table 7ad Squat by age category

<table>
<thead>
<tr>
<th>Parameters</th>
<th>&lt;30 years (nos/%)</th>
<th>30-49 years (nos/%)</th>
<th>&gt;50 years (nos/%)</th>
<th>Total (nos/%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not able to squat</td>
<td>4(7.1)</td>
<td>6(13.6)</td>
<td>9(36)</td>
<td>19(15.2)</td>
</tr>
<tr>
<td>Squat on toes</td>
<td>26(46.4)</td>
<td>16(36.4)</td>
<td>9(36)</td>
<td>51(40.8)</td>
</tr>
<tr>
<td>Full squat</td>
<td>26(46.4)</td>
<td>22(50)</td>
<td>7(28.0)</td>
<td>55(44)</td>
</tr>
<tr>
<td>Total</td>
<td>56(100)</td>
<td>44(100)</td>
<td>25(100)</td>
<td>125(100)</td>
</tr>
</tbody>
</table>
Of the nulliparous ladies 12.5% were unable to squat, 39.6% could squat on their toes and 47.9% could fully squat. This compares to 16.2% unable to squat, 45.6% able to squat on toes and 38.2% able to fully squat in multiparous women. On chi square testing the ability to squat was not statistically significantly associated with parity.

In women below the age of 30 7.1% were unable to squat, 46.4% could only squat on toes and 46.4% could fully squat. Women between the ages of 30 and 49 years 13.6% were unable to squat, 36.4% could squat on their toes and 50% could fully squat. Women over the age of 50 36% were unable to squat, 36% could squat on toes and 28% were able to fully squat. On chi square testing this is statistically significant (p=0.014) showing a deterioration in the ability to squat as one ages.

43.2% women in total could not squat when tested.

CONCLUSIONS

In this study it was readily evident that nearly half of study population could not perform a full squat and this ability was reduced significantly with advancing age. Further discussion and conclusions are written at the end of the next chapter.
STUDY OF SQUATABILITY IN CHILDREN

INTRODUCTION

Ability to squat is not just a toileting issue. For centuries people have squatted to ablute and to sit and work and chat. The recent development of chairs and western toilets has drastically reduced the need for squatting. Kidd showed in autopsies of children over thirteen that the ‘squatting facet’ on the talus bone disappears in skeletons in ‘non squatters’. [177] Our previous study had shown that ability to squat deteriorates with age. We also showed that about half of our volunteer population could not perform a full squat. The aim of this study was to look at squatability in school going children from the age of 5 upwards. There have been no such studies reported before.

METHODS:

After getting approval from the local school administration our aim was to recruit children of all age groups and see if they could squat. The squatting index was applied to them as well. They were instructed by their teacher and also by us about squatting and a chair was provided for support. Each Child was asked to stop squatting if there was any pain, discomfort or loss of balance. The children were fully and appropriately clothed to avoid embarrassment and they were not expected to micturate.

A total of 243 children were tested. The age range was 5 to 17. Both sexes were tested.
RESULTS:

Table 7ae Age, sex and duration of squat in children

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>Tip&lt;30s</th>
<th>Tip&gt;30s</th>
<th>Squat &gt; 30s</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>M</td>
<td>-</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
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<td>3</td>
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<tr>
<td>6</td>
<td>M</td>
<td>1</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>2</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
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<td>10</td>
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<td>M</td>
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<td>9</td>
<td>M</td>
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<td>4(6n)</td>
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<td>F</td>
<td>0</td>
<td>10</td>
<td>7(3n)</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>0</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>0</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>0</td>
<td>9</td>
<td>9</td>
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<td>11</td>
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<td>2</td>
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<td>9(4n)</td>
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<td>12</td>
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<td>9(1n)</td>
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<td>7(3n)</td>
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<td>13</td>
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<td>5(5n)</td>
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<td>13</td>
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<td>4(6n)</td>
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<td>10</td>
<td>4(6n)</td>
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<td>7(3n)</td>
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<td>2(8n)</td>
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<td>F</td>
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<td>2(8n)</td>
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<td>16</td>
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<td>F</td>
<td>0</td>
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<td>8(2n)</td>
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<td>M</td>
<td>0</td>
<td>10</td>
<td>7(3n)</td>
</tr>
<tr>
<td>17</td>
<td>F</td>
<td>0</td>
<td>10</td>
<td>3(7n)</td>
</tr>
</tbody>
</table>
EFFECT OF AGE ON SQUATTING

To analyse this data we categorised more than > 30 seconds on toes and full squat as ability to squat. We further categorised age groups as 5-7/8-12/13-17. (Table 7 af)

This table very clearly shows that age is significantly associated with ability to squat. Using exact binomial test for linear trend p < 0.0001. 100% children form the age group of 5-7 were able to squat, this percentage went down to 84.3% in children between 8 and 11 years and went down dramatically to 45.2% for children between the ages of 13 and 17. (Table 7 ag)

Data analysis here shows that the ability to squat is independent of gender. On exact binomial test for trend p = 0.97.

71.7% of males could fully squat as compared to 72.3% females
25.7% of males could only squat on their toes as compared to 23.8% females
2.7% males were unable to squat when compared to 3.8% females.

DISCUSSION:

These two studies were performed due to our startling finding during recruitment of the squat study that nearly half of our adult volunteers could not do a full squat. Studies done in the Indian subcontinent [5, 6] showed all volunteers were able to squat in their studies although there is no mention of a specific testing done. The same applied to the subsection of our Malaysian study. [179] A study recently done in Taiwan on young fit volunteers revealed that all girls felt unsteady when asked to crouch on a makeshift squat toilet on a western commode. [3]

Our studies have numerous impacts for the future of toilet designs. Firstly as the numbers of western toilets proliferate, the ability to squat down even in Oriental and Asian communities is going to reduce. Secondly, one has to speculate whether the inability of children to squat have a larger impact on their flexibility and health? And finally, future toilet designs are going to need better innovation than just a ‘hole in the ground’.
### Table 7af Squatting by age

<table>
<thead>
<tr>
<th>Parameters/ Age in years</th>
<th>5-7 (nos/%)</th>
<th>8-11 (nos/%)</th>
<th>13-17 (nos/%)</th>
<th>Total (nos/%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unable to squat</td>
<td>-</td>
<td>-</td>
<td>8(8.6)</td>
<td>8(3.3)</td>
</tr>
<tr>
<td>Squat on toes</td>
<td></td>
<td>17(15.7)</td>
<td>43(46.2)</td>
<td>60(24.7)</td>
</tr>
<tr>
<td>Full Squat</td>
<td>42(100)</td>
<td>91(84.3)</td>
<td>42(45.2)</td>
<td>175(72)</td>
</tr>
<tr>
<td>Total (nos)</td>
<td>42</td>
<td>108</td>
<td>93</td>
<td>243</td>
</tr>
</tbody>
</table>

### Table 7ag Squatting by gender

<table>
<thead>
<tr>
<th>Parameters/ Age in years</th>
<th>Male (nos/%)</th>
<th>Female (nos/%)</th>
<th>Total (nos/%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unable to squat</td>
<td>3(2.7)</td>
<td>5(3.8)</td>
<td>8(3.3)</td>
</tr>
<tr>
<td>Squat on toes</td>
<td>29(25.7)</td>
<td>31(23.8)</td>
<td>60(24.7)</td>
</tr>
<tr>
<td>Full Squat</td>
<td>81(71.7)</td>
<td>94(72.3)</td>
<td>175(72)</td>
</tr>
<tr>
<td>Total (nos)</td>
<td>113</td>
<td>130</td>
<td>243</td>
</tr>
</tbody>
</table>
One of our keen followers produced data from an anatomist that we indeed are born with a squatting facet on our Talus bone of the foot. [178] This facet seems to disappear in cadavers over the age of 13 years in their experience [175, 179] in children who do not squat. Pandey (1990) studied the squatting facet of adults showed that there are definite extensions to the trochlear surfaces of the talus bone in men and women who squat. [178, 182, 183] We assume this is a 'supportive' development to the bone in 'squatters'. In our adult study we showed that overall 43.2% of women could not squat. This ability further regressed with age. Our study of school children over the age of 13 showed the ability to squat at 45.2% irrespective of gender. This is very similar to the percentage of adult women from the adult squatting study.

This means that even if there were significant health gains from squatting on the toilet about half the western population and the rapidly urbanising eastern population would not benefit from adopting an Asian toilet. There is a further worrying 'trend' to get labouring women to squat during childbirth. This is particularly dangerous because less than half the female population can squat. Labouring women have significant lordosis, which can further compromise squatting. They are often in pain and writhing around, so perching them precariously on a stool would be dangerous and letting them squat on the floor would prevent the accoucheur from monitoring and later intervening to help the birth process.

In our opinion a way forward would be to have a mobile toileting device that can be used with existing western commodes and afford either a NSQ or a full squat position or a LFP to all members of a family, young and old; male and female.
ABDOMINAL PRESSURES IN THE SITTING AND SQUATTING POSITIONS

STUDY OF INTRAABDOMINAL PRESSURES IN THE SITTING AND SQUATTING POSITIONS

INTRODUCTION

The effect of posture on the toilet has been well researched in the western toilet setting but not adequately researched on a squatting toilet. There is a hypothesis that micturition syncope is rare in Indian women due to the nature of the toilet that requires squatting. A recent study by Gupta et al showed that flow rates are better in the squatting position in Indian women when compared to the western toilet. [5]

AIM

The aim of this study was to compare intraabdominal and intravesical pressures during urodynamics in the sitting and squatting positions in women who were conversant with the squatting position.

METHODS

This study had to be done in Malaysia where the facilities for urodynamics were available and that the women chosen were habituated to squatting. There have been no such studies reported before that looked at pressures in these two positions. After getting local hospital approval in Malaysia and ethics approval in Townsville a study of 89 patients was undertaken. Patients from the Urogynaecology clinic who were having urodynamic investigation were asked to participate in the study. Squatability was initially determined by asking patients to squat with flat feet for more than 30 seconds. If they could successfully squat, they were offered enrolment. No patients declined enrolment in Malaysia. Since the facilities were all available in Malaysia and the patients were very conversant with the squatting position we decided to conduct the whole study in Malaysia under the supervision of Dr Siva Balakrishnan who was a visiting fellow in our unit the year prior to this study.

In the Malaysian unit multichannel urodynamic testing was performed using a Laborie device (Laborie Medical Technologies) and MediPlus 5400 urethral and abdominal catheters. All procedures were done in a supine dorsal position with normal saline
infusion at room temperature. The filling rate was 50 cm³/min unless this provoked urinary urgency. A transducer placed vaginally measured the abdominal pressure. Prolapse to or beyond the hymen was reduced manually. Provocative manoeuvres, including water stimulation and cough, were used in an effort to provoke detrusor overactivity or demonstrate stress incontinence. Urethral pressure profilometry was performed manually at a rate of approximately 1 mm/s. Both static and dynamic profiles were performed at cystometric capacity. Recorded urodynamic parameters in addition to the urodynamic tracings were from the uroflowmetry (voided volume, post void residual, maximal and average flow rate, voiding time), cystometrogram (first sensation, first desire to void, strong desire, urgency, capacity, fill rate, detrusor overactivity, detrusor overactivity incontinence, urodynamic stress incontinence) and urethral pressure profilometry. Any pertinent documentation regarding sensory urgency or leakage during testing was included. Our unit also performs flexible cystoscopy at the end of urodynamics thus providing an anatomic assessment of the bladder that complements its functional assessment by urodynamics and uroflowmetry.

When cystometric capacity was reached on urodynamics the intraabdominal and intravesical pressures were noted at rest. With the catheters still in situ and securely taped, patients were asked to squat for 30 seconds and resting intraabdominal and intravesical pressures were noted and then the patients continued with further urodynamic evaluation including cough provocation in supine position followed by urethral pressure profilometry.
RESULTS

A total of 89 patients were studied

Demographics:
The mean age of the population was 45.83 (range 30 to 82 years)
65.5% of patients were in the age group of 51 to 70 years
13.4% of patients were in the 41 to 50 and 71 to 80 age group.
The mean parity was 3 (range 1 to 5)

In 2 patients the catheters from the vagina fell out in the squat position. These were 'zeroed' and resited successfully. A total of 89 patients were studied. The results are as shown in Table 7b

P Ves (Pressure Vesical) {which is P Abd (Pressure Abdominal) + PDet (Pressure Detrusor)} was significantly higher in the squat position when compared to the sitting position - p < 0.003
P Abd (which measures only intra-abdominal pressure) was also significantly higher in the squat position when compared to the sitting position - p < 0.003
P Det – There was no statistically significant difference between the two groups although there was a trend to higher detrusor pressure in the squat position.
### Table 7b  Urodynamic parameters

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Sitting</th>
<th>Squatting</th>
<th>P value (S/NS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P abd</td>
<td>18.7 (15.4 – 19.8)</td>
<td>26.15 (22.9 – 30.3)</td>
<td>&lt;0.003 (S)</td>
</tr>
<tr>
<td>P ves</td>
<td>19.1 (15.2 – 21.6)</td>
<td>25.4 (21.7 – 29.8)</td>
<td>&lt;0.003 (S)</td>
</tr>
<tr>
<td>P det</td>
<td>0.67 (-1.3 – 3.5)</td>
<td>1.95 (-0.7 – 4.2)</td>
<td>NS</td>
</tr>
</tbody>
</table>

P abd (abdominal pressure); P ves (vesical pressure); P det (detrusor pressure)

S- Significant  NS-Not significant
DISCUSSION

Our study is the first of its kind that studied passive intra-abdominal pressure in the squatting position.

The benefits of squatting quoted were – the generation of enough expulsive pressure, pressure from the right – pushing matter up the ascending colon and closing the ileocaecal valve, pressure from the left unkinking the sigmoid from the rectum and opening the anorectal angle. [184] These features would be impossible to study even with a colonoscope and pressure transducers.

Patients having urodynamics have one pressure transducer in their bladder and other in the vagina. Our study therefore did not increase any intervention except asking the patients to squat on the ground with the transducers and then sit up on the commode.

It appears that there is an increase in intra-abdominal pressure with no increase in detrusor pressure in the squatting position when compared to the sitting position. The question is what increase is significant enough to improve bladder and bowel function. Obviously a passive increase is better than increase by straining and performing a Valsalva manoeuvre since that splints the pelvic floor and may lead to further anorectal kinking and also dysfunctional voiding.

Limitations of our study, include the use of patients in Malaysia and its inherent language barriers – but the ability to squat was very easy to assess. Could we have used trans rectal balloon catheters for measurement of abdominal pressures in women? Would it have given more information about bowel status in the squatting position? The remit of our study was looking at bladder issues and we also felt that women were more comfortable with intravaginal catheters rather than intra rectal catheters. Our urodynamics units, routinely use intravaginal catheters and we did not want to change the routine functioning of the unit. If passive intraabdominal pressure is higher in the squatting, which is the case in this study, then it may prevent people from repeatedly ‘straining’ to achieve the same intra-abdominal pressure in the sitting position during toileting. In our opinion this study and the next study have been attempts to further look at precisely how squatting may help better toileting.
If passive intraabdominal pressure is higher in the squatting which is the case in this study then it may prevent people from repeatedly ‘straining’ to achieve the same intra-abdominal pressure in the sitting position during toileting.

**CONCLUSION**

Passive intra-abdominal and intra-vesical pressure is higher in the squatting position when compared to the sitting position. There is no effect on detrusor pressure. Interpretation of this data needs caution due to small numbers.
7c LEVATOR HIATUS IN THE SUPINE AND SQUATTING POSITION – THE SCAN STUDIES.

STUDY OF LEVATOR HIATUS IN THE SUPINE AND SQUATTING POSITIONS

INTRODUCTION

The study of the dimensions of the levator hiatus is an emerging technique with unproven benefits. Levator hiatus is studied using 3D/4D Ultrasound mainly in the field of Urogynaecology for incontinence and prolapse. Peter Dietz has developed a technique to measure the levator hiatus using 3D/4D ultrasound.

PELVIC FLOOR 3D/4D ULTRASOUND SCANNING

Recent advances in imaging technology have facilitated assessment of pelvic floor structures including the levator muscle and paravaginal and paraurethral tissues. While assessment of paravaginal defects via transabdominal ultrasound has been claimed to be possible, this appears questionable due to the absence of clear reference points and the confounding effect of bladder and rectal filling as well as uterine position and size. Translabial ultrasound has been used extensively for pelvic floor assessment, but generally only the midsagittal plane is imaged in clinical practice and research applications, since this plane provides a convenient point of reference, the symphysis pubis. Parasagittal planes have not been described. The advent of three-dimensional (3D) ultrasound made it possible to image paravaginal support structures by giving access to transverse planes similar to those employed in MRI (Fig 7c (ii)). [48, 49]

The main advantage of 3D or ‘volume’ ultrasound is the fact that it allows access to the axial or transverse plane, i.e., the plane in which both levator hiatus and paravaginal support structures can be visualized. Fortuitously, transducer characteristics on currently available systems for use in obstetrics and gynaecology have been almost perfect for pelvic floor imaging. They are well suited to translabial or perineal scanning, with the transducer placed on the introital area in a midsagittal orientation. A single volume obtained at rest with an acquisition angle of 70° or higher will include the entire levator hiatus with symphysis pubis, urethra, paravaginal tissues, the vagina, anorectum and puborectalis loop from the pelvic sidewall in the area of the arcus tendineus of the levator ani (ATLA) to the posterior aspect of the anorectal junction (Fig 7c (i)). Depending on the anteroposterior dimensions of the puborectalis loop, it may also include the anal canal and even the external sphincter [48, 49].
4D IMAGING

Four-dimensional (4D) imaging implies the real-time acquisition of volume ultrasound data, which can then be represented in orthogonal planes or rendered volumes. Most recently, it has become possible to save cineloops of volumes, which is of major importance in pelvic floor imaging. Even on 2D single-plane imaging, a static assessment at rest gives little information compared with the evaluation of manoeuvres such as a levator contraction and Valsalva. The observation of such manoeuvres will allow an assessment of levator function and delineate levator or fascial trauma more clearly. [48, 49, 185]
Fig 7c (i) The usual acquisition/evaluation screen on Voluson-type systems shows the three orthogonal planes: (a) sagittal, (b) coronal and (c) axial, as well as (d) a rendered volume, which is a semitransparent representation of all gray-scale data in the rendered volume (box delineated in (a), (b) and (c)).

Fig 7c (ii) The axial plane on (a) magnetic resonance imaging and (b) ultrasound (freehand three-dimensional). While these images were obtained in different patients, all significant structures can be identified by both methods. Image (a) courtesy of Dr Ben Adekamni, Plymouth, UK.
3D imaging of the levator ani complex

With translabial acquisition the whole levator hiatus and surrounding muscle (pubococcygeus and puborectalis) can be visualized as a highly echogenic structure. We used 3D translabial ultrasound (probe RAB 4-8 MHz 3D/4D, Voluson 730 Expert GE Healthcare) to image the dimensions of the levator hiatus at rest, on squatting and on a Valsalva manoeuvre on squatting {Fig 7c(iii & iv)}. The currently offered abdominal 8–4 MHz volume transducer for Voluson 730 expert systems allows acquisition angles of up to 85°, ensuring that the levator hiatus can be imaged in its entirety even in women with significant enlargement (“ballooning”) of the hiatus on Valsalva. Imaging planes on 3D ultrasound can be varied in a completely arbitrary manner to enhance the visibility of a given anatomic structure, either at the time of acquisition or off line at a later time. The levator ani for example usually requires an axial plane that is tilted in a ventrocaudal to dorsocranial direction – by about 20° for a volume acquired at rest, more for volumes on pelvic floor muscle contraction, and less for volumes on Valsalva.

After a standardized interview, paper-towel test and bladder emptying with uroflowmetry, routine translabial two dimensional (2D) imaging was performed. Amongst other parameters, the descent of the internal urethral meatus or bladder neck on maximal Valsalva manoeuvre was defined relative to the infero-posterior margin of the symphysis pubis. The degree of urethral rotation on Valsalva manoeuvre was defined as the increase in angle between the central transducer axis and the axis of the proximal urethra. The best of at least three maximal Valsalva manoeuvres was used for evaluation. Three-dimensional volume datasets were then acquired in both the anteroposterior and transverse directions. All imaging was performed by author. In total between three and 16 volumes per patient were stored. Both symmetry of the sweep (i.e. geometrical accuracy) and lateral reach were confirmed immediately after data acquisition and the process repeated as often as necessary to ensure inclusion of paravaginal areas and both levator muscles between the symphysis pubis and the anal canal. This makes the measurement of levator hiaatal dimensions much simpler in the rendered volumes {Fig 7c(v)}. [185]
Fig 7c (iii) The levator hiatus (a) at rest and (b) on Valsalva in a young, nulliparous woman without significant pelvic organ descent. The dimensions of the levator hiatus are measured in the sagittal (1) and coronal (2) planes.

Fig 7c (iv) The levator hiatus (a) at rest and (b) on Valsalva in a young, nulliparous woman with significant pelvic organ descent. On Valsalva the levator is situated partly outside the acquisition volume.
Fig 7c (v) The three orthogonal planes: midsagittal (A, top left), coronal (B, top right), and axial (C, bottom left) as well as a semitransparent rendering of all voxels in the region of interest (the boxed area evident in the orthogonal B planes) at the bottom right.
AIM

The aim of this study was to look at the dimensions of the levator hiatus in the supine and squatting positions. Supine levator hiatus measurements are routinely measured in our patients who have prolapse or incontinence. This pilot was done to study the change (if any) in the levator hiatal dimensions in the squatting position.

METHODS

Fifty patients from the Urogynaecology clinic who were having levator scan assessment were approached for the study. Only 20 patients could perform a full squat. They consented to having an additional scan in the squatting position for both visualisation of prolapse and levator hiatus. In one patient we were unable to measure the levator hiatus in the squatting position so only 19 paired measurements were studied.

Transperineal 3D/4D ultrasound was carried out using RAB 4-8 MHz probe 3D/4D with a Voluson Expert 730 machine (GE Healthcare). Levator hiatus was identified in the axial plane in the plane of minimal dimension and levator area was measured. With translabial acquisition, the whole levator hiatus and surrounding muscle (pubococcygeus and puborectalis) can be visualized, provided acquisition angles are at or above 70°.[48, 49, 185] The currently offered abdominal 8–4 MHz volume transducer for Voluson 730 expert systems allows acquisition angles of up to 85°, ensuring that the levator hiatus can be imaged in its entirety even in women with significant enlargement (“ballooning”) of the hiatus on Valsalva. The patients were then transferred to a custom built squatting device, which allowed easy access to scan transperineally. None of the scans took more than 5 minutes in total. The comparison were made between measurements obtained in the supine and squatting position purely for practical reasons, since it was impossible to position our probe with a woman sitting on a western commode.
RESULTS:

Table 7c Levator Hiatus measurements on sitting and squatting

<table>
<thead>
<tr>
<th>Patient</th>
<th>Levator Hiatus supine cm$^2$</th>
<th>Levator Hiatus squatting cm$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient A</td>
<td>23</td>
<td>36</td>
</tr>
<tr>
<td>Patient B</td>
<td>22.8</td>
<td>38.6</td>
</tr>
<tr>
<td>Patient C</td>
<td>26.3</td>
<td>Could not be measured</td>
</tr>
<tr>
<td>Patient D</td>
<td>24.2</td>
<td>34.6</td>
</tr>
<tr>
<td>Patient E</td>
<td>25.6</td>
<td>32.3</td>
</tr>
<tr>
<td>Patient F</td>
<td>32.0</td>
<td>44.2</td>
</tr>
<tr>
<td>Patient G</td>
<td>21.6</td>
<td>30.8</td>
</tr>
<tr>
<td>Patient H</td>
<td>31.4</td>
<td>41.0</td>
</tr>
<tr>
<td>Patient I</td>
<td>24.4</td>
<td>32.6</td>
</tr>
<tr>
<td>Patient J</td>
<td>33.4</td>
<td>45.6</td>
</tr>
<tr>
<td>Patient K</td>
<td>26.8</td>
<td>34.8</td>
</tr>
<tr>
<td>Patient L</td>
<td>23.8</td>
<td>31.6</td>
</tr>
<tr>
<td>Patient M</td>
<td>36.4</td>
<td>48.8</td>
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<td>27.8</td>
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<td>Patient P</td>
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<td>48.6</td>
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<td>Patient Q</td>
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<td>30.4</td>
</tr>
<tr>
<td>Patient R</td>
<td>20.6</td>
<td>28.8</td>
</tr>
<tr>
<td>Patient S</td>
<td>24.4</td>
<td>28.6</td>
</tr>
<tr>
<td>Patient T</td>
<td>29.2</td>
<td>36.6</td>
</tr>
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</table>
We used the currently recommended classification for levator hiatus measurements (for ballooning) as reference viz. an area of 30–34.9 cm² as mild, 35–39.9 cm² as moderate, and 40+ cm² as severe ballooning, with extreme cases reaching 50 cm² and above. [48,49,185]

On paired T test, the levator hiatus in the squatting position is on average 9.5 cm² larger (95% CI -10.0 to -8.0) than the levator hiatus supine. This difference is statistically significant (p <0.001)
DISCUSSION:

This was a pilot study. Our experience with such scanning is less than 12 months. The clinical significance of levator hiatal measurements are yet to be determined but from our pilot study it was abundantly clear that the puborectalis muscle relaxes enormously in the full squat position making it difficult to measure accurately on scan in one patient in this study. Our numbers are small but since each patient is their own control it can be speculated that these results actually mean something. In the previous chapter we suggested that the study of pressure measurements in the squatting position and the use of 4D ultrasound as in this chapter could shed some light on how squatting can help better toileting. So far it appears that there is a passive increase in intra-abdominal pressure and a significant relaxation in the levator hiatus on squatting. This means that there is loss of resistance from the pelvis by means of hiatal relaxation and passive increase in intra-abdominal pressure which may facilitate quicker and smoother expulsion of waste matters. Further studies are obviously needed to look at which specific parameters of the levator and pressure measurements affect the mechanism of squatting and defecation.
Chapter 1  General introduction

Chapter 2  Hypothesis, study parameters and justifications

Chapter 3  Physiology of Pelvic structures during toileting
    3a. Physiology of Micturition
    3b. Physiology of Defecation

Chapter 4  Epidemiology of Incontinence

Chapter 5  The Perfect Pee Study

Chapter 6  The Near Squat Study

Chapter 7  The Squat Study
    7a. The Squatability study amongst adults and children
    7b. Abdominal pressures in the sitting and squatting positions
    7c. Levator hiatus in the supine and squatting position

Chapter 8  Inventions to aid squatting

Chapter 9  General Discussion
CHAPTER 8

INVENTIONS TO AID SQUATTING
There are a few inventions in the market aiding squatting over a toilet.

**DUNEZE** [186]

This patented device is showing promise because it encompasses a MOBILE height adjustable device attached to the western toilet. Duneze utilises the concepts of the Feet Flat position (Chapter 4), the Near squat position (Chapter 5) and the full squat position (Chapter 6). Due to its versatile height adjustment all ages and genders can use this device if marketed. The zero height is at 110 mm suitable for children and the maximum height is 400 mm. The full squat can only take 120 kgs in weight.
Fig 8 (i)  Duneze
NATURE’S PLATFORM

This device by Jonathan Isbit is a device that utilises the full squat position over the conventional western toilet. One of the first devices to be marketed, Jonathan has written extensively on the benefits of squatting without necessarily providing robust scientific proof. Natures’ Platform (Fig 8(ii)) has the following disadvantages:

1. Fixed platform means everyone big and small has to conform to the same design
2. Has the potential for falling off the toilet
3. Expensive – at over 150 US dollars per piece.

The device also assumes that each person using it can do the full squat – this is certainly not the case in adults or children from the western world as shown in our studies (Chapter 7a, 7b).
Fig 8 (ii) NATURES PLATFORM [15]
LILLY PAD (Lillipad squatting platform) [187]

The LILLYPAD squatting platform is another fixed platform device attached to the western toilet – it also has a fixed height but also has a little platform to put ones feet on. This device also assumes that people of all ages can do a full squat – which in our studies shows possible only in 40% of the population. It is also not suitable for children. The price of the Lillypad is around 100 US dollars.
The squat position — the healthy way we evolved to go! Infants instinctively squat to relieve themselves, as do the majority of the world's population.
SQUAT SUPPORT [188] (*Statements provided by manufacturer*)

‘The Squat Support medical device supports the user in optimal squat position on any toilet. Proper squat position during defecation can prevent straining, haemorrhoids, diverticulosis, constipation and colorectal cancer. In a sitting position, the anal canal is bent at a right angle to the rectum (Figure 8 (iv)). The bend is nature-intended to resist the passage of bowel contents, thereby maintaining anal continence. Sitting to defecate, therefore, often results in excessive straining, constipation, irregularity and increased stool transit time. Effects can be cumulative and may pose serious health risks.’

In a squat position, the anal canal is vertically aligned with the rectum (Figure 8 (v)) for easy passage of bowel contents. Defecation in a squat position is more complete, efficient and timely, thereby reducing stool transit time and absorption of stool toxins. Risk of haemorrhoids, colorectal cancer and other lower bowel disease is abated.

The optimum angle between the torso and femurs is 30 degrees for aligning the anal canal with the rectum (Figure 8 (vi)). The Squat Support includes a frontal upper body support that cooperates with a movable footrest to comfortably position and support a user at the optimum squat angle. A calibrated scale ensures fast, accurate adjustments of the footrest according to the user’s height.

There is no scientific evidence to support this.

Squat Support Features:

- **Upper body support**: Supports upper body of user
- **Angled and vertically adjustable footrest**: Supports user’s legs in an elevated bent position
- **Upstanding footrest height-adjuster**: Positioned above the footrest so the user can conveniently adjust the footrest without stooping
- **Height scale**: Calibrated cooperatively with the height-adjuster for adjusting according to the user’s height to support the user in an optimal 30 degree squat posture
- **Compact and light**: Takes up very little space and is portable
Fig 8 (iv) Sitting position

Fig 8 (v) Squatting position
Fig 8 (vi) The optimum angle between the torso and femurs is 30 degrees for aligning the anal canal with the rectum

Fig 8 (vii) Squat Support features

- Foam-cushioned upper body support
- Graduated height scale for making adjustments according to user's height
- Footrest height-adjuster for adjusting footrest without stooping
- Angled & vertically adjustable footrest
IN LEIU [32]

This solid state plastic device is an Australian invention. It assumes more a ‘side on’ squat arrangement. This is a fixed device that does not have any height adjustment either to suit the pedestal or the user. This device also assumes that the user can do a full squat without any problems. The device is available on the internet for 130 dollars.
Fig 8 (viii) IN LEIU [32]
CHAPTER 9

GENERAL DISCUSSION
The main objective of this thesis was to study the effect of posture on toileting. Research in this area was found to be largely anecdotal and of questionable scientific merit. This body of work was started to introduce an element of ‘science’ and physiological basis to the much discussed but little understood art of ‘toileting’.

In the first instance we observed the act of micturition in the leaning forward position, which chiefly focussed on two main parameters – appropriate foot support and elbows on knees during voiding. During this study we also administered a questionnaire aimed at studying the crouching habits in female volunteers from North Queensland. This study revealed that 41% of women crouched over a public toilet whereas the remainder 59% did not. These findings were markedly different from a UK study in 1991 which showed 86% of women crouched over a public toilet. [2] Our study further showed that the uroflowmetric parameters were better in the lean forward position when compared to the upright sitting position.

A number of Australian health authorities have ‘flogged’ the apparent benefits of a foot rest to raise the legs during the act of defecation and micturition. These recommendations were based on anecdotal evidence and had no scientific merit. Our next study used ‘leg raising’ using a foot stool as a study parameter and again addressed the issue of the effect of this posture on uroflowmetric values. This study required the subject’s feet to be 120 cms above the ground with knees above the level of the anterior superior iliac spines. This study showed a statistically significant improvement in uroflowmetric parameters in the ‘leg raised’ or ‘near squat position’ when compared with the ‘lean forward position’. Numbers in this study were small but there was no data available as a precedent to calculate an ‘appropriate’ sample size.

The study that posed the greatest challenge was the squatting study and very early on it became apparent that squatting was a ‘dying art’! Not surprisingly only 43.2% of women could perform a full squat when tested. This was unrelated to the woman’s parity although older volunteers did find it harder to squat. This study also administered a questionnaire about crouching habits and in this cohort 74% of women said they would never crouch on a toilet.

We then embarked on a similar study, this time targeting school children between the ages of 5 and 17 years, testing their ability to squat. The results were very interesting indeed; below the age of 13 almost all children could squat, whereas above that age the percentage was only 45.2% irrespective of gender. Once again these findings were
unprecedented as similar studies had never been reported before. The squat study failed to show any statistically significant difference in uroflowmetric parameters when compared to the lean forward position i.e. a failure to disprove the Null Hypothesis. We believe this could be attributed to the 'newness' of the position.

Our next study parameters were to research the changes that occur in the body in the squatting position. At our disposal were our urodynamics laboratory and a newly acquired 4D ultrasound machine. We also recruited a fully equipped urodynamics laboratory in Malaysia that was run by an ex-Fellow and co-researcher. We studied the effect of squatting on the resting abdominal pressure and also the effect of squatting on the dimensions of levator hiatus. Again the limitation was the absence of any antecedents in medical literature. The pressure study quite clearly showed that the resting abdominal pressure is higher in the squat position when compared with the sitting posture. We concluded that it would be interesting to research the potential of raised intra-abdominal pressure on squatting in reducing 'repetitive stress injury' to the pelvic floor.

The 4D ultrasound measurement of the levator hiatus is a unique way of looking at the levator muscle function. A contraction of the levator muscle should reduce the hiatus and an enlargement of the hiatus should suggest relaxation. Our study clearly showed a significant difference in hiatal dimensions on squatting compared to the lying down position. This means that there is visible relaxation of the levator muscle in the squatting position which could further aid expulsion of bowel and bladder contents. Whether there is a difference between sitting on a western commode and squatting on an Asian toilet could be a matter for future research.

We wish to justify our conclusions about the effect of posture on normal bladder function mainly via the Perfect Pee and Near Squat study. The subjects were a fairly homogeneous group of people who were ‘local’ and used to the western toilet. This homogeneity gets skewed in the Squatting Study when a squat toilet was used both in the local setting as well as when studying subjects in Malaysia. However that part of the study was done to further our attempts to answer one basic question - why does a change in posture cause change in voiding parameters?

In summary, therefore, it is possible to say that posture (differing positions on the toilet seat) does affect micturition parameters. The squat position is something that less than half of the western population can manage, in which case, even if the squat position
showed tangible health benefits, these will not be readily available to a majority of the world’s populace. Further scientific research is called for if health benefits are to apply to one half of the world’s non-squatting population. One obvious direction in which the research could proceed would be to employ a device that fits or retrofits on to the existing toileting infrastructure rather than taking the hammer to the western commode!

AREAS FOR FURTHER RESEARCH

- The study of intra-abdominal pressures in sitting and squatting on Valsalva manoeuvre and during micturition
- The study of levator anatomy in the sitting and squatting positions at rest and on Valsalva.
- The study of defecography in the squatting position and comparing it to the sitting position
- A longitudinal study of health benefits in people who routinely squat during toileting
- The study of squatting in children and adults with dysfunctional voiding
- The study of squatting in the pathogenesis and management of constipation, irritable bowel syndrome and haemorrhoids.
REFERENCES


151. Versprille-Fischer ES. *Liggingsafwijkingen van de organen in het kleine bekken.* Fysiopraxis. 1993; **5:** p. 4-7.


158. Hong YJ, Chen YR, Huang SH. *A questionnaire survey of users and managers of public toilets.* Gend Space Team Commun. 1996; **3:** p. 46-66.


APPENDIX A

SQUATTING INDEX QUESTIONNAIRE

**SQUATTING INDEX ADULTS**

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### SQUATTING INDEX CHILDREN

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APPENDIX B

PUBLICITY MATERIAL

THESE ARTICLES HAVE BEEN REMOVED DUE TO COPYRIGHT RESTRICTIONS