

Urinary bladder function and acquisition of bladder control in healthy children

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ABSTRACT

The overall aim was to advance the knowledge of urinary bladder function and the acquisition of bladder control in healthy children.

The participants in papers I, II and III were from the same population (n=59). In paper I the participants (n=22) were parents of children who had been dry for at least 6 months. The voiding pattern was observed through the 4-hour voiding observation method and thereafter through uroflow measurements and post-void residual urine (Papers I, II). Using a questionnaire, the parents' perceptions of the occurrence of life events, how upsetting they had been for the child and the degree of adaptation needed was studied (Paper III). In order to share parents' experiences of how their children became dry, parents were interviewed (Paper IV).

The children voided 5 times/4hours at 3 months of age and 2 times/4hours at 3 years. Signs of arousal during sleep at voiding were noted in the infants (76% and 90%) at ages 3 and 6 months respectively. The storing ability increased from 67 ml at 3 months to 123 ml at 3 years. Interrupted voidings were seen in decreasing numbers: 33% at 3 months and 3% at 2 years of age. The post-void residual urine decreased from 5 ml at 3 months to 0 ml at 3 years of age. Awareness of the voiding process was reported from age 1.5 years. Signs of bladder dysfunction were occasionally reported in 30-50% of the children from age 3 to 6 years. The children achieved day dryness at a median age of 3.5 years and night dryness at 4 years.

The children experienced an average of 5 life events. Half these life events were related to childcare, 24% to illness/accident/death, 16% to family composition and 9% to living conditions. The children had experienced these life events as negatively in 30% of the cases. Adaptation had been difficult in 15%. Many life events and difficulties in adapting to a life event were associated with a later age of dryness.

The parents experiences of how their children became dry was divided into four categories: "The time had come" including making a decision and having time, "New daily routines" including creating a positive atmosphere and testing different activities, "The child's willingness" including cognitive skills and personality traits, "Being like others" including unspoken rules and comparing the child with others to fit in and not to deviate.

Healthy children do not void at constant volumes and they do not empty their bladders completely at each voiding but at least once every 4 hours. The decreasing number of interrupted voidings and the fact that most voidings were performed while awake may indicate that the voiding process is part of a maturation process. Children become dry at later ages today. The more life events and the more difficult adaptation, the later the child will become dry. The parents experienced that they were responsible for initiating the process for their children to become dry and that the process is time consuming. The parents compared their children with others and tried to fit within the unspoken norms and limits about when it is not longer acceptable to wear diapers. The parents missed having support and guidance about how to help their children become dry. The findings from this thesis can be used as reference values in both healthy children and in children with bladder dysfunction.

Keywords: Urinary bladder, urination, reference values, life events, healthy children development bladder control, experiences, content analysis, potty training.

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DEFINITIONS AND ABBREVIATIONS

Healthy child	No history of urinary tract infection, no malformation of the urinary tract that could affect bladder function.
Life events	An event from the life event list of Coddington implying a change in everyday life from the parents' point of view, regardless of whether or not the event was desirable.
Bladder Capacity, BC	Functional bladder capacity – maximal sum of the voided volume plus post-void residual urine volume.
Post Void Residual, PVU	Post-void residual urine volume measured by ultrasound.
Interrupted voiding	2 or 3 voiding episodes at an interval of less than 10 minutes and with the lowest amount of post-void residual urine after the final episode. This phenomenon was considered 1 voiding episode and the volume of urine remaining in the bladder after the final voiding episode was considered post-void residual urine.
Dryness	Always dry = every day/night
Toilet training	Any efforts from parents or caregivers with purpose to get the child dry
Toilet trained	Complete dryness day- and night
CHC	Child Health Care centre

INTRODUCTION

Achieving urinary bladder control seems to be a significant developmental accomplishment for a child and his or her family (1, 2) and of great importance for the individual regardless of age, sex or ethnicity (3). Bladder control is a complex learning process, and the consequences for health and well-being of not controlling the urinary bladder function may be troublesome for children. These include shame, guilt and problems with peers (2, 4, 5). Incontinence is also known to affect the relationship between the child and the parent, which may lead to negative perceptions of well-being and poor self-esteem in the child (6-8) as well as to parental frustration. There are a large number of studies about the prevalence of incontinence in children, its treatment and impacts on health and well-being. However, comprehensive studies about normal urinary bladder function and bladder control achievement, including not only being continent, but also to controlling urine storage as well as urine emptying, over time are rare. This knowledge is needed to help children with urinary bladder disturbances, to achieve “normalcy” in their micturition pattern and to improve or maintain the functioning of the urinary tract and perceived health and well-being.

BACKGROUND

The general view of children has changed greatly over the last century and today every child is regarded as a human with his or her own worth and needs. Earlier, children were viewed as small miniatures of adults, already complete and without their own characteristics (9). The competence of infants has become successively emphasized, and the concept adolescent introduced.

The rapid and continuous development of children, especially during infancy, is the main difference between children and adults, making it to an adventure and advantage but also a challenge, for health professionals, to work with children and their families.

Health, growth and general development in children

Health is one of the four nursing concepts first introduced by Jackelin Fawcett in 1970. There is not yet complete agreement about the concept of health, but commonly accepted definitions include not only the absence of disease or symptoms of illness but also the ability to perform one's role satisfactorily. The ability to carry out self-care activities and to adapt to changes and health problems and to attain well-being are also

usually included (10). This is also applicable to children. The organisation American Board of Children, Youth and Families has stressed the importance of development and has defined health as “the extent to which individual children are able or enabled to develop and realize their potential, satisfy their needs, and develop their capacities that will allow them to interact successfully with their biological, physical and social environments” (11, p. 4). Well-being, often mentioned together with health, is the subjective experience of health and can be viewed as synonymous with health (12).

In health promotion, the ambitions are to facilitate, encourage and support children and their families to move towards optimal health (9, 12). Having control of one’s bladder function and being continent at an age when it is expected is commonly viewed as important for the individual and also for the family, in order to perceive oneself as healthy (4).

Children’s development is related to their health and well-being and knowledge about developmental changes are the standpoint for all work with children. Growth represents the quantitative changes which are measurable and easily observed and studied, while development represents the qualitative changes that result from mastery of a series of small steps, and is more complex and less easily measured and studied (12). Development and growth in children describe the process of maturation from childhood to adulthood. Development is considered to be a process of maturation, learning, conflict resolution, cognitive change, and cultural adaptation. Development and growth are influenced by the family and lifestyle, socio-economic status, climate, schools and mass media. Certain physical aspects such as genetics and the intrauterine environment are also of importance (9, 12).

The child can be seen as a physical, intellectual and emotional-social being within the context of the family and the community (9). The family may be regarded as a system, in which each family member affects the others, and the family’s experiences are assumed to have great and lasting impact on the child’s development; physical, socially and culturally. However, each child is seen as an unique person who shares a core of commonalities with other children (12). Commonalities are defined here as what is shared by most children of the same age. Knowledge about children’s growth and development describes typical behaviours at different ages, explains the significance of these behaviours, and predicts behaviours that might occur in a given situation. This knowledge is also used as a tool for recognizing

potential and actual deviations from growth and development, or possible signs of illness or the absence of well-being. Development is also predictable in that there is a general chronology that allows for individual differences, since each child has his or her own genetic potential for growth and development (9, 12). Knowledge about urinary bladder function and its development is important to explore and for the same reasons.

Theory of developmental psychology

According to Erikson (13) the personality develops stepwise after a predetermined pattern but also under influence of important adults. He described the psychosocial development in eight stages during the human lifespan. Three of the stages may be connected to the development of urinary bladder function. The first stage, the most fundamental in life, takes place between the birth and 1.5 years of age. During this stage the infant is completely dependent on its caregiver and consequently on the quality of care given. If the caregiver acts consistently and is emotionally available and able to include the child, the child will feel safe and secure and develop basic trust. The second stage of Erikson's theory of psychosocial development takes place during the period 1 to 3 years of age and focuses on developing a sense of personal control. Erikson believed that toilet training was an important part of this progression. To learn to control one's body functions leads to a feeling of control and a sense of independence. If the child successfully completes this stage she or he will feel secure and confident. The third stage takes place between 3 and 5 years of age and is when the child achieves a sense of initiative. During this stage children learn intensively. If the child is not able to accomplish what the parents expect, the child will experience a sense of guilt and feelings of anxiety and fear. It is easy to see how important the parents are in Erikson's theory and that they must be confident enough to support their child during the achievement of bladder control. It is also important for health professionals to support parents in their efforts to help their children become dry (13).

Knowledge of urinary bladder function

The normal urinary bladder has two major functions, storage and emptying of the urine. The bladder is supposed to fill to an adequate level and to empty completely, periodically and voluntarily (14). During the filling phase the bladder should remain relaxed. During the voiding phase the detrusor-muscle of the urinary bladder contracts in order to increase the pressure and thereby make it possible to empty the bladder. At the same time the urethral sphincters relax and the urine can be evacuated (14). Thus perfect co-ordination of bladder and urethra muscles, including the pelvic

floor, in which the neural system also plays an important role, is the basis for continence and normal voiding.

Many quantitative studies have been conducted contributing to knowledge about single parts of the bladder function including numbers of voiding (15-20), voided volumes, bladder capacity (17, 20, 21), residual urine (17, 20, 22-25) and arousal state (16, 26). The study by Muellner published in 1960, (15) for decades constituted the foundation of how to consider the development of the bladder function and a large number of articles have been written based on assumptions from this research. The voiding was believed to be initiated at the same bladder volume during the first year of life (15, 27). This means that before 1990, during the first year of life, voiding was considered to be induced by a reflex independent of the brain and leading to urination even during sleep. Voiding was also supposed always to be complete.

Interest in infant bladder function was more or less absent before the 1990s. Although there were occasional studies dealing with the subject, they did not receive any attention. The new interest in the 90s was mainly due to the fact that children with congenital anomalies such as posterior urethral valve (28) and high grade infant vesico-urethral reflux (29) were shown to have bladder dysfunction already during infancy. It then became evident that very little was known about bladder function in healthy infants.

Looking back, however, there are studies before the 90s that support some of the new findings during the last decade, including those of the present study. Duche (30) for example reported in the 70s that most infants showed signs of arousal before voiding, results that were confirmed by Yeung (26) in the 1990s, and which were an indication that the micturition reflex has connections with the cerebral cortex as early as in the neonatal period. There were also early studies suggesting that almost half of infants do not empty their bladders completely (22, 25, 31).

In children, bladder capacity was believed to increase linearly with height and weight growth (31). In 1976, Hjälmås (31) described functional bladder capacity as the voided volume plus possible residual urine. He also constructed a rule of thumb from investigations in children 3 months to 6 years; $30 + (\text{age in years} \times 30 \text{ ml})$, which has been useful for clinical purpose to evaluating the bladder capacity of infants and children. Since then several formulas have been constructed for bladder capacity in children, with some variations in expected capacity for age (19, 21, 32, 33).

The difference between the formulas can be attributed to many aspects such as differences in investigation procedures; free voiding versus catheter-based investigations, age of the child, and the environment for the investigation. However, the formulas can be regarded as determining the maximum volume. Muellner (15) also stated that bladder capacity more than doubled between 2 and 4.5 years, and that when the bladder can hold 300 – 360 ml of urine the child will not wet at night. Later study results from Denmark reported that during the night urine production decreases to around the half of the daytime production and this ability increases the possibility for the bladder to hold urine when the child is sleeping (34).

When children begin school, in Sweden around 6 years of age, most children are dry both during the day and at night. At these ages the voided volumes still vary, which may be due to fact that the need to visit the toilet is influenced by social behaviour, in that healthy children seem to void when it is convenient, not necessarily when the bladder is full (35).

Urinary bladder dysfunction

In order to discover, and to help children with bladder dysfunction regardless of its origin, knowledge about normalcy is valuable. Disturbances in normal bladder function can be a sign of neurogenic or anatomical malformation. However, the most common problems have a functional origin and the reasons some children get these problems are not known.

Prevalence of urinary bladder dysfunction and urinary incontinence in children

Studies about the occurrence of bladder dysfunction symptoms such as urgency or emptying difficulties are still sparse, but such symptoms have been reported in 26% of seven-year-old children in a Swedish population (36). The prevalence of daytime functional incontinence varies in 7-year-old children from 3 to 7% (36-39). The prevalence seems to decrease by approximately 2 % per year (40) with age but is still 1 – 13% at around 12 years and 1 - 3% at around 16 years of age (41). Daytime problems are found to be more common in girls than in boys in all age groups.

The prevalence of nocturnal enuresis, NE, in 7-year-old children varies in different studies between 5-10% (41). In these studies mono-symptomatic nocturnal enuresis, MNE (without any other symptoms than wetting), and poly-symptomatic nocturnal enuresis, PNE (nocturnal enuresis combined with daytime wetting), were combined. The spontaneous cure rate seems to

be around 15% annually from the ages of 7 to 16, which indicates that it is a part of maturation process. At the age around 12 years the prevalence of both MNE and PNE is around 3%. Almost all the epidemiological studies of NE report a higher prevalence in boys than in girls (ratio 2:1) in Western countries. In adolescents the prevalence is still around 2% according to the study of Yeung et al. (42).

Symptoms of urinary bladder dysfunction

When a child does not use diapers any more or in children of school age, symptoms of functional bladder disturbance can be expressed by imperative urgency together with small voided volumes, frequency, and urinary leakage or bedwetting. These symptoms can be signs of an overactive bladder. Other symptoms can be voiding postponement manoeuvres and infrequent voiding with large voided volumes. Furthermore, a urinary tract infection can indicate a bladder disturbance, often due to incomplete emptying, leaving residual urine in the bladder, which can be a sign of a dyscoordinated bladder and sphincter, referred to as dysfunctional voiding. The underactive bladder, with a weak detrusor contraction, is rarely seen. The symptoms are large bladder volumes, infrequent voiding, straining, incomplete emptying and incontinence (43).

Treatment of urinary bladder dysfunction

The treatment of first choice is usually urotherapy (44-47). The aim of urotherapy treatment is to normalise the voiding pattern and prevent further disturbance of the bladder function. To be able to do this the current function of the bladder, and also habits of daily life, must be evaluated using history and voiding diaries. There are many validated instruments for this purpose, such as micturition charts, continence test and 4 hour-voiding observation (48). The standard urotherapy treatment includes encouragement of the child to cooperate actively in the treatment process; learning and practicing how the bladder works and recognising its signals. The treatment is based on behavioural therapy, and the child is taught to modify his or her habits. This requires cognitive components: the child and the parents have to understand, obtain a comprehensive picture of the situation including the function of the bladder, frequency of voiding and fluid intake, and realize how these factors affect bladder function in daily life. The child will also practise going to the toilet voluntarily and not waiting for an urge, according to a pre-determined schedule which is individually constructed for each child. Children with emptying problem should also practise relaxation of the pelvic floor muscles (49) at voiding, using a relaxed sitting position.

Treatment in infants is mainly directed towards incomplete emptying. However, the diagnosis is often not evident until the first urinary tract infection occurs. Four-hour voiding observation is an excellent method to diagnose such disturbances in this age group (19). The treatment to improve emptying is early potty-training or even clean intermittent catheterisation, if symptoms are severe (50).

Achievement of urinary bladder control

The importance of being dry has been a matter of concern for parents and trends in society have historically also influenced trends in toilet training. During 1920 – 1930, firm habit-training was started in order to get children become dry. This remained the prevailing norm until the 1950s. However, in the beginning of the 1930s, a child-oriented approach was recommended, but there was no recommendation about how to toilet train children. Not until the early 1960s was the child oriented approach of toilet training highlighted (51-53). After these studies the trend shifted and the recommendation became to wait until the child is mature enough, when the achievement will come naturally.

The existing norm prior to 1990 was that an infant was not able to control his or her bladder function. Between 1 and 2 years of age the child was able to give obvious signs of need to void, but the latency between signals and voiding was very short. The latency period was assumed to increase until the child was completely dry, and depended on maturation of perception and training. The child was also believed to begin to control the external sphincter consciously. Between 2 and 4 years of age, it was suggested that voluntary control developed by the pathways from the cerebral cortex being activated to inhibit the wish to void through activation of the external sphincter and inhibition of the bladder. No studies were performed to confirm this theory.

There is a great variation in the age at which a child is reported to have achieved dryness, from 5 months to 6 years in different studies (38, 53-57). The main reasons for these variations in age when achieving urinary continence are probably the definition used and the support given to the child. However, an increasing number of studies now report a clear postponement of toilet training today (55, 56, 58-61). The concept of toilet trained is commonly used synonymously with the concept of achieved bladder control in the literature, without consideration for whether or not the child was actively trained. In the Swedish language the terms achieved bladder control or becoming dry are used instead of becoming toilet

trained. Toilet training is used to describe a process in which the child is actively trained with the aim of achieving dryness.

A child can be considered as having achieved bladder control if the child indicates the need to void, after which the parents or caretakers put the child on the potty. Under normal circumstances the child can stay dry when such training is supported. To be responsible for the whole process the child needs to be mature enough to cope with every aspect of his or her own toileting, including timing, dressing and undressing, closing the door and flushing the toilet. Such independent bladder control is probably not possible until age 4 years.

Factors influencing the time for achieving urinary bladder control

Most young children spend their weekdays outside the family. In Sweden most children, from the age of 1 year, usually spend their days at daycare centres. These daycare centres have a pedagogical approach and of stimulating the development of the child in all respects. However, potty-training does not seem to be included in the daycare centres' activities, with few exceptions.

Many studies have been conducted about different impacting factors on achieving bladder control, or in order to explain the variation in ages when children become dry. Intensive and structured training have been proved by Foxx and Azrin to make the child dry earlier (62). This is contradictory to the findings of Largo, who showed that the age when toilet training starts does not affect the age of becoming dry (53). In developing countries where no diapers are available, it is known that infants can learn to be dry very early. The impact of socio-cultural factors is evident in reports from East Africa, where infants are taught from birth and to be reliable dry 5-6 months of age (54). Horn stated in 2006 that the toilet training age is associated with culture, showing that American-African mothers train their children earlier than Caucasian mothers (63). This is in agreement with the findings of Oppel (64). Since the child-oriented approach to toilet training was recommended by Brazelton in 1962, the child's readiness has been focused on in order to know when to start toilet training a child (2, 54, 57, 65-69).

Muellner's (15) research conclusion was, that bladder control is a maturation process, i.e. a self-learned skill in using different skeletal muscle groups including the diaphragm, the lower abdominal and the pubococcygus muscles to contract and relax the intra-abdominal pressure.

He regarded the ability to be continent as depending on both physical and psychological skills (15). The abdominal muscles need to be strong enough, and a sign of this is that the child is able to stand, sit and walk (2). The psychological skills include the child being motivated and able to recognize the need to go and willingness to learn. The child needs to be able to listen and be receptive to parental encouragement to sit on the potty and have a feeling of having accomplished something good when delivering some results on the potty (2). The child must also be able to stay dry for at least 2 hours, appear uncomfortable when wet, and indicate a need to void (57).

Factors that might also contribute to the postponement of toilet training today include lifestyle and welfare. Today there is intensive disposable diaper marketing and most parents have access to super-absorbents diapers (59). The economic situation of parents is of importance with regard to what age parents start toilet training their children, and also the effort on the part of the parents. Schum (2001) showed that single parents trained their children earlier than two parent families (70). Two parent families where there are conflicting interests between parent and day care may contribute to later ages for dryness (59). In a study by Takahashi no difference was found between the age of achieving dryness in children using disposable diapers and children only using cloth diapers (71). Wearing underwear without diapers was found by Simon and Thompson to increase success at becoming dry (72).

Low birth weight has been reported to be another factor postponing the age for achieving bladder control (64). Breastfeeding for 3 months or longer may protect against bed-wetting during childhood according to Barone et al. (73). Children who were breast fed for a period of 3 months or longer developed fewer enuresis problems than children breast fed for a period of less than 3 months. Barone et al. stressed the importance of breastfeeding and its beneficial effects in terms of developmental and psychological advantages (73).

In the late 1960s there were several reports about the association between a higher number of life events and the time of illness onset in adults (74). The same findings were made about childhood morbidity (75), child-rearing problems (76), and enuresis (77) and the number of experienced life events. The higher number of experienced life events in childhood, the higher the risk of developing illnesses.

The achievement of bladder control may be influenced by the living conditions of the child and his or her family. During first years of life there are a lot of skills to be developed and learned. According to Erikson (13) young children enjoy learning control of the body. This period is intensive and if a life event occurs that occupies the child's mind and thoughts, there might be a risk of delay in some aspects of development (13).

Irrespective of whether a life event becomes a positive or a negative experience for a child, it demands a certain amount of energy and therefore may affect daily life (12). The instrument developed by Holmes and Rahe (74), published in 1967, described a number of possible life events and their magnitude, called the social readjustment rating scale, SRRS. Many further studies were conducted to measure the impact of life events on health through correlations between the numbers and the magnitude of life events and the occurrence of diseases. In the mid-1970s Lundberg and Theorell (78) further developed the instrument, according to the stress theory (12, 79), by adding measurements of how upsetting a life event had been as well as how the individual had adapted to each event. When an individual fails to cope with changes, ill health may occur. The impact of daily life events on the time for achieving bladder control has not yet been studied.

Toilet training

Parents have probably always tried to affect the age of their children's dryness for different reasons. Brazelton's (51) child oriented approach in the late 1950s emphasized a gradual learning process, gently introduced from the age 1.5 years, to sit on a potty with clothes on in the beginning, with the parent reading a book or the child having a snack. Thereafter the diaper was taken off prior to sitting on the potty. When the child became interested the parent encouraged the child to go to the potty twice a day and finally to go on his or her own when needed (51).

A more structured behavioural method was designed by Azrin and Foxx as a single one day training program in 1974 (62) for children from age 20 months. In order to have any success using this method, it was clear that before starting the child needed readiness in three areas including: being able to void a good deal at one time, being able to stay dry for at least 2 hours and also showing an awareness of her or his need to eliminate. The child also needed physical readiness including enough fine motor co-ordination to pick up small objects and walking easily. The child needed to show an instructional readiness such as touching his or her nose when

asked, imitating the parent and being capable of carrying out requests correctly. The training was intensive in an environment free from distractions included increased fluid intake, practice dressing skills and approaching the toilet, gradual elimination of reminders. The training also included frequent diaper checking, negative reinforcement if wet and continuous positive reinforcement for staying dry (66).

According to Klackenberg (52) and Largo (53) bladder- and bowel control are maturational processes which can not be accelerated by early onset or high intensity of training. They recommended that parents focus on the child's readiness rather than age (52, 53). There were also reports on risks if parent started too early, and that expectations might create frustration between the child and the parents. According to Stebhens and Silber (80) this might interfere negatively with the normal process of bladder development.

The trend during the last 50 years has thus been towards later dryness ages in children (56, 59-61, 70). Median age for dryness in the 1950s was 2 years, whereas in the 1990s it was 3 years (57). During the last decade, however, there have been some reports about a more positive attitude towards toilet training. Schmitt declared that toilet training can start before 18 months of age since most learning is done by repeating (2). It has been emphasized that if potty training starts early it takes longer to achieve dryness, and accidents are common (2). Younger children are easily distracted and they need a lot of support in order to manage the toilet training procedure (2, 81). Blum et al. stated, however, that the earlier toilet training starts, the earlier the child will be dry (61, 65).

Consequences of not achieving urinary bladder control

Wearing diapers or wetting at an age when children are expected to be dry is embarrassing for the child, the parents and siblings. Children with enuresis have been reported to have less self-confidence than children without enuresis (7), especially if the enuresis is combined with day wetting (82). Self-esteem has been investigated before and after the treatment of urinary incontinence in children and was significantly lower before the treatment than after (7). Successful treatment of bedwetting has shown happier and more confident children (6).

Children with nocturnal enuresis may feel different from other and may be teased by their peers. Children have described feeling angry, moody and ashamed (83). They may have problem in participating in normal childhood

activities like camping and sleep-overs and they are worried that their bedroom smells of urine (84).

Enuresis influences the child and the entire family, and there is an increasing intolerance as the child grows older (85). The parents of enuretic children can be confused and concerned for the child's well-being as well as frustrated, which may lead to increasing intolerance (85). The frequent changing and washing of bed linens is an extra workload and also a financial burden on parents (86).

The trend towards achieving dryness at later ages means increased costs for diapers for the family (86). There are also health risks shown in childcare settings owing to spreading of infections when changing the diapers of a large number of children (87). It has also been discussed whether the prolonged time for achieving bladder control increases the risk of urinary tract infections, but there is no evidence of this in healthy children. There is also a lack of knowledge about the correlation between the age for bladder control and the incidence of bladder dysfunction (56).

Studies have been conducted with the aim of understanding bladder disturbances in childhood and of treating children with different urinary bladder disturbances. These latter have been performed in unhealthy children. We have tried to reverse the perspective by studying healthy children and expanding the knowledge about their acquisition of bladder control.

PURPOSE

The overall aim of the thesis was to advance the knowledge of urinary bladder function in healthy children and the acquisition of bladder control by describing the voiding pattern over time, ages for day and night dryness, the impact of life events on bladder control and parents' experiences of their children achieving bladder control.

Specific aims

- To observe, follow and describe the voiding patterns in healthy children during their first three 3 years of life.
- To observe, follow and describe the voiding patterns and the acquisition of bladder control in healthy children up to 6 years of age.

- To investigate the relationship between the incidence and nature of life events and age of bladder control acquisition of healthy children.
- To describe parents' experiences of how their children became dry.

PARTICIPANTS AND METHODS

Participants

In papers I, II and III the participants were from the same population of children (n = 59) and parents. One child health care centre (CHC) for children was the venue of the study. The CHC was located in an urban area of Göteborg, Sweden, serving between 1300 (1994) and 1500 (2006) children and their families. In paper IV, the parents (n=22) were of children who had been dry for a period of at least 6 months. The parents in paper IV were not the same as in papers I, II and III (Table 1).

Table 1. An overview of subjects, variables, instruments, methods and analysis.

	SUBJECTS	CLINICAL VARIABLES	INSTRUMENTS	METHOD	ANALYSIS
Study I	57 (59) children	n voidings / 4h Voided volume Post-void residual urine Uroflow	4-h voiding observation Ultrasound (7.5 MHz. Linear scaprobe) Uro-flow-potty	Correlation Comparison	Descriptive analysis Pearson's correlation coefficient Spearman's correlation coefficient
Study II	40 (59) children from study I	Sleep Bladder sensation Urgency Postponement Leakage Potty/toilet use Dryness – day/night Use of potty/toilet Starting/emptying problems Soiling Bedwetting	4-h voiding observation Uro-flow potty Ultrasound		Descriptive analysis Spearman's rank correlation Wilcoxon's signed rank test Mann-Whitney U-test
Study III	35 parents of 36 (59) children from study I and II	Life events Reaction grade Adaptation grade Life Change Unit, LCU	Coddington life event questionnaire	Structured interviews	Descriptive analysis Spearman' rank correlation Mann-Whitney U-test Wilcoxon' s signed rank test
Study IV	22 parents of 21 children			Interviews	Qualitative content analysis

Methods

- 4-hour voiding observation

The 4-hour voiding observation was used to gather data about number of voiding episodes, voided volumes and post-void residual urine every third month in healthy children until 3 years of age (Paper I). The child was observed by his or her parent under the supervision of a trained urotherapist. The normal daily routine was followed as far as possible, including diaper use. Initially bladder volume was estimated by ultrasonography. A dry, weighed diaper was applied, including a gossip text with letters that became inky when wet by urine which immediately indicated when the child was voiding. The parents checked the diaper every 5 minutes. Times of sleeping or eating were also registered. The wet diaper was then removed and weighed. The residual volume was estimated at the same time by ultrasound. The diaper was not opened until 1 minute after the inky text indicated wetness to avoid disturbing the voiding process (Papers I and II). To determine post-void residual urine volume the bladder was considered a rectangular box with all 3 dimensions variable. Bladder width, height and depth were determined and the 3 measurements were multiplied to obtain actual bladder volume previously described (19).

- Uroflow measurement and residual urine observation, FRO / 4 hours

Uroflow measurement and Residual urine Observation (FRO) was used to determine voided volumes (uroflowmetry) and post-void residual urine (ultrasonography) during 4 hours. The child voided on a uroflow potty on at least one occasion every 6 months up to the age of 6 years (Paper II).

- Study protocol questionnaire

The parents were also asked questions at every observation, about the child's weight and height, eating, diaper and potty use, age of day and night dryness, signs of bladder sensation, voiding postponement and leakage, signs of urgency, voiding habits, and also about health/illness and whether there had been other changes in daily life (Papers I, II, III).

- Life event measurement (according to the life event questionnaire of Coddington and Höök (88, 89))

The parents of healthy children, from the same population as in studies I and II, were interviewed when their children were 6 years old. The Coddington life event list (88), modified according to Höök et al. (89) was used. It includes 36 events about family composition (10 items), child care and parental occupation (9 items), living conditions (3 items) and

illness/injury/death (14 items). Data was collected about the occurrence of life events, how upsetting they had been for the child and the degree of adaptation needed (Paper III).

- Interviews

Parents of healthy children were interviewed about their experiences of how their children became dry. One open question was asked and supportive questions were added during the interview (90, 91). The interviews were analyzed stepwise by the qualitative content analysis method according to Krippendorff (92) (Paper IV).

Methodological considerations

In this thesis both quantitative and qualitative methods have been used. The research question was determined to be primarily quantitative since the questions guiding the three first studies were: How do children void? What is the function of the urinary bladder in early childhood? How do children achieve bladder control? What factors influence the development? A quantitative approach thereby directed the study in Papers I, II, III, and was supplemented by the use of a qualitative method in Paper IV. According to Creswell (91) looking at the world with a pragmatic view, the problem is more important than the method. This means that the researcher may use many possible approaches to understand the problem (91).

The methods chosen were all non-invasive and used in natural settings familiar to the families. This was important in order to capture the development of bladder function and acquisition of bladder control in normal daily life, under as normal circumstances as possible. In order to follow the individual variations and changes over time a longitudinal design was selected for Papers I and II.

In order to gain a deeper understanding about bladder control acquisition a qualitative approach was chosen for Paper IV, and analysed using the content analysis method regarding manifest and latent content. The starting points for a qualitative interview is that it should take place in a natural setting, look for involvement of their participants, let the interviewee talk freely, and be emergent rather than prefigured. During the interviews the researcher strove to be open and sensitive to what the parents were telling her but also respectful, by being attentive, listening and letting the parents' expressions guide the interview forward (93).

Statistical analysis

For descriptive purposes mean, median, standard deviation and range were given for continuous variables and n (%) for categorical variables. The 5th, 50th and 95th percentiles were used to illustrate variations in bladder capacity and post-void residual urine among the children (Paper I). For comparisons between two groups, Mann-Whitney U-test was used (Papers II and III). Changes over time in Paper II and comparison of parents' answers with previously registered data in Paper III were analysed using the Wilcoxon signed rank test.

Pearson's correlation coefficients of the log values in Paper I, table 2 and table 4, were not totally correctly calculated and have been replaced with Spearman's rank correlation coefficients in table 2 in the framework of the thesis. Spearman's rank correlation was also used for all correlations analyses in Papers II and III.

All the tests were two-tailed and conducted at the 5% significance level.

Mean, median and tolerance intervals for bladder capacity as a function of age for children was calculated in the following way: The distribution of bladder capacity as a function of age was not normally distributed. The bladder capacity values were transformed to a normal distribution using the inverse of the normal cumulative density function as a function of the empirical cumulative density function for bladder capacity.

A piecewise linear regression with transformed bladder capacity values as dependent variable and age, and with breakpoint at 18 months, as independent variable was estimated using the maximum likelihood principle. The standard deviation of the residuals was estimated as a piecewise linear function of time, breakpoint at 9 months. Given the estimated means and standard deviations the 1SD and 2SD tolerance intervals could be calculated for the transformed bladder capacity values. Median, 1SD and 2SD tolerance intervals could be given directly for the actual bladder capacity values by using the inverse function for normal transformation as described above.

The mean for actual bladder capacity values at each age was calculated by taking the integral of 1- cumulative density function (F(x)).

Content analysis

Content analysis is defined as "a research technique" for making replicable and valid inferences from texts to the context of their use" (92). In paper IV a qualitative content analysis method was used to analyze the interviews with the parents. The text was analyzed in various steps with regard to the content. The interviews with the parents were transferred to one text. This

text was read and reread. The analysis was performed in an inductive way, i.e. the content was structured into meaning units according to the aim of the study. These were lifted out and coded. From the codes and preliminary categories eight subcategories emerged. Four categories were created by going back and forth between the preliminary categories, the codes, and the meaning units. The text was independently analyzed regarding agreement among all the authors to increase the credibility of the analysis. If agreement was not possible to achieve a further analysis was performed until consensus among the authors was reached.

ETHICS

All parents received oral and written information and gave oral and written consent. They were also informed about their right to withdraw at any time and without given any reason. Ethical considerations concerning autonomy and risking emotional harm by bringing up issues of sensitive matter were considered. A potential risk for the parents participating in the study was that they might find it distressing to talk about and remember past events in their lives and that they might experience painful memories of different life events. The researcher tried to be open-minded, sensitive and respectful of the parents' statements during the interviews. All data was treated confidentially. The Ethic Committee of Göteborg University approved the studies (Dnr 515-93 and Ö 584-02).

RESULTS

The results of the four original papers are presented in chronological order. The results of Papers I and II are reported together, owing to their longitudinal design, with a summary of the most important results in each paper. Papers III and IV are presented separately. Readers are referred to the original papers.

Summary Papers I and II

The participation rate varied during the study (Figure 1). A total of 57 children (34 girls and 23 boys) participated in 3 to 17 observations, on 18 possible occasions, with an average of 11 observations per child (md 11). A total of 618 observations were performed between 1993 and 2002.

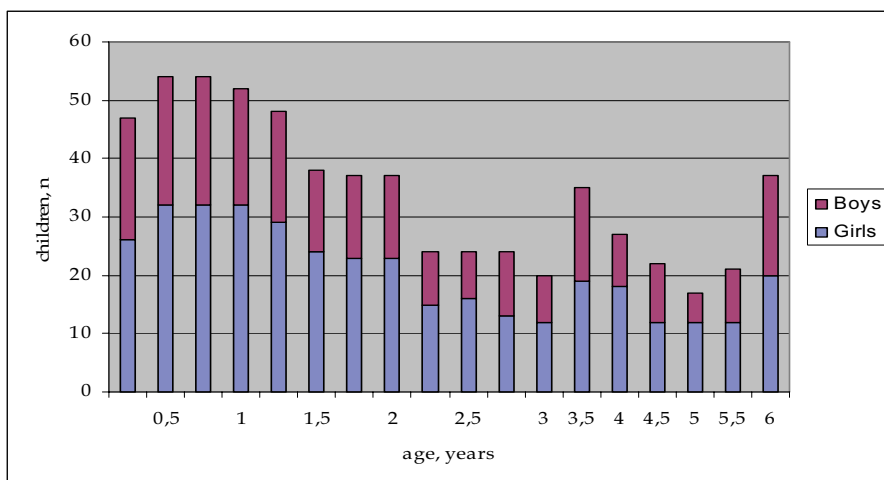


Figure 1. Participation rate for the children from 3 months to 6 years of age, Papers I and II.

Voiding patterns from 3 months to age 6 years, and age of achieving urinary bladder control

The children voided 1 to 8 times during the 4 hour observation period with a median frequency decreasing from 5 voiding episodes at 3 months to 2 voiding episodes at 3 years of age. From the age of 3.5 years, or when the child had achieved bladder control, one voiding was observed most often, and consequently the voiding frequency was not possible to measure.

Signs of arousal during sleep at voiding were a characteristic noted in the majority of the infants (76% and 90%) at ages 3 and 6 months respectively, and at all voidings after the children were 18 months old.

The lowest volumes initiating a voiding were found to vary from 3% to 100% of bladder capacity during the first 3 years of life. The ability to store the urine, measured in terms of bladder capacity, varied greatly among the children, as well as for each child, and increased from a median of 67 ml to 123 ml to 140 ml from ages 1 to 3 to 6 years. The increase was significant from 0.5 to 1 year of age and from 2 to 2.5 years (Table 2). Bladder capacity at 3 months did not correlate with the bladder capacity value at any age interval later and bladder capacity at 6 and 12 months were almost only correlated with the following observation (Table 3). However, bladder capacity at 15 months and thereafter was correlated with all subsequent values (Table 3). A large bladder capacity at age of day dryness was also found to be significantly correlated ($r=-0.33$, $p=0.03$) with an earlier age of day-dryness, as the smaller the bladder capacity the later the children were dry during the day. The median bladder capacity volume was 88 ml (m 108, range 20-329), when the children were day-dry and 96 ml (m 103, 20-211) when night dryness was achieved.

Table 2. Changes in bladder capacity and post-void residual urine for each six month period.

Change from-to years	Change in Bladder capacity			Change in Post-void residual urine		
	n	Mean (SD)	Median (range)	n	Mean (SD)	Median (range)
0.5-1	49	16.2 (35.8)	21.0 (-62-122)	49	1.2 (7.8)	1.0 (-20-21)
1-1.5	36	-1.2 (40.6)	-4.5 (-90-112)	36	-0.1 (9.1)	0.5 (-26-23)
1.5-2	26	12.0 (34.6)	13.5 (-65-84)	27	1.1 (9.4)	0.0 (-26-20)
2-2.5	20	25.8 (55.8)	14.5 (-71-205)	20	-3.7 (8.8)	-1.0 (-24-8)
2.5-3	12	43.3 (83.2)	4.0 (-49-210)	13	0.9 (5.0)	0.0 (-8-9)
3-3.5	14	-22.9 (90.8)	-6.5 (-208-154)	15	1.3 (13.7)	0.0 (-17-42)
3.5-4	24	-11.4 (63.4)	-10.5 (-150-121)	24	-6.9 (16.8)	0.0 (-56-19)
4-4.5	16	10.1 (75.0)	1.5 (-119-180)	16	2.4 (6.5)	0.0 (-6-20)
4.5-5	14	-9.4 (84.7)	-2.0 (203-124)	14	-4.1 (6.7)	-0.8 (-20-2)
5-5.5	13	-5.9 (84.0)	12.0 (-140-148)	13	1.0 (3.1)	0.0 (-6-8)
5.5-6	19	61.6 (122.5)	36.0 (-140-322)	19	2.1 (7.3)	1.0 (-12-21)

Table 3. The correlation (r_s) between bladder capacity at different ages in healthy children 3-33 months of age is presented in the upper right area. The correlation (r_s) between post-void residual urine at different ages in healthy children 3-33 months of age is presented in the lower left area.

r_s/n	Bladder capacity										
	3 mo	6 mo	9 mo	12 mo	15 mo	18 mo	21 mo	24 mo	27 mo	30 mo	33 mo
3 months	1	0.01 44	0.12 44	0.23 42	-0.01 41	-0.02 31	-0.08 29	-0.19 27	-0.13 21	-0.35 18	-0.15 22
6 months	0.05 44	1	0.36 52	-0.04 49	-0.03 45	0.09 35	-0.09 34	-0.11 33	-0.13 22	-0.35 22	-0.45 22
9 months	0.03 44	0.30 52	1	0.32 49	0.16 45	0.16 35	0.18 34	0.15 32	0.63 21	-0.02 22	0.44 23
12 months	-0.15 42	-0.04 49	0.17 49	1	0.51 44	0.24 36	0.27 35	0.06 35	0.37 22	0.16 23	0.21 23
15 months	-0.08 41	0.23 45	0.25 45	0.31 44	1	0.54 34	0.34 32	0.29 31	0.34 23	0.34 23	-0.05 23
18 months	-0.49 31	0.42 35	0.15 35	0.06 36	0.24 34	1	0.55 26	0.33 26	0.57 17	0.27 23	0.36 14
21 months	-0.13 29	-0.07 34	0.25 34	-0.18 35	0.35 32	0.31 26	1	0.32 26	0.70 17	0.35 19	0.54 17
24 months	0.11 29	-0.05 35	0.18 34	-0.15 36	0.00 33	0.23 27	0.41 27	1	0.56 15	0.50 20	0.59 15
27 months	0.08 21	0.38 23	0.64 22	0.04 23	0.11 24	0.07 18	0.14 18	0.32 17	1	0.89 11	0.78 14
30 months	-0.27 18	-0.00 22	0.10 22	-0.29 23	-0.07 23	-0.06 23	0.37 19	0.18 20	0.11 12	1	0.34 11
33 months	-0.16 22	-0.09 22	0.15 23	0.45 23	-0.09 23	-0.74 14	0.00 17	0.22 16	0.27 14	0.00 11	1

Post-void residual urine

Based on the results of data in Paper I tolerance intervals the bladder capacity were estimated with the mean, median and 1SD and 2SD (Figure 2). The estimation is based on values from 3 months to 37 months. Only values based on the outcome of the 4 hour voiding observation method were considered.

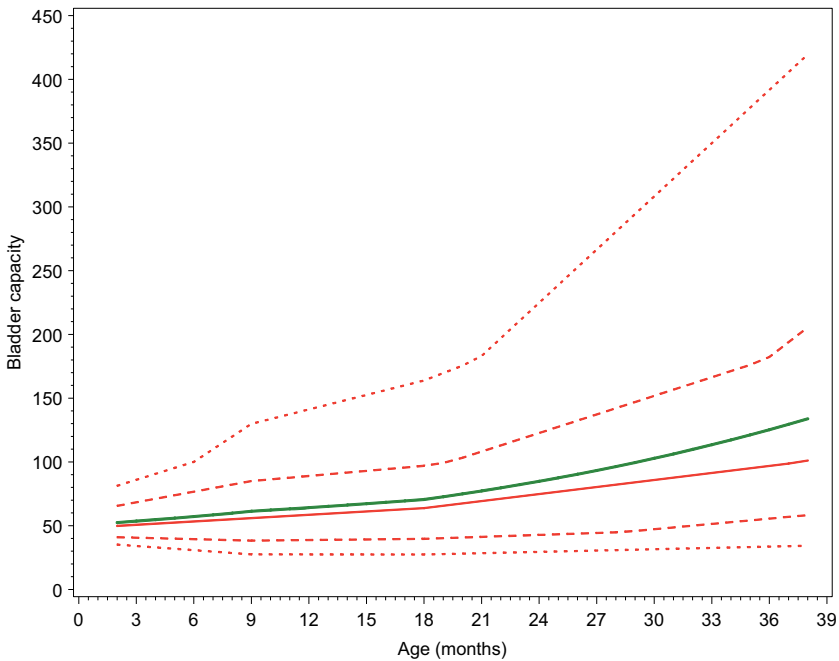


Figure 2. Mean (green line), median (red line) with 1SD and 2SD tolerance intervals for bladder capacity as function of age in healthy children.

Interrupted voidings (2-3 voiding episodes within 10 minutes and with the lowest residual urine after the final voiding) were seen in a decreasing number of children up to age 2 years; 33%, 21%, 3% at 3 months, 1 year, 2 years, respectively. The ability to empty the bladder measured by post-void residual urine increased slightly during the first year from a median of 4 ml to 5.5 ml, then decreased to 3.5 at 2 years and during the third year to median of 0 ml, and remained at 0 except for 2 ml at age 6 years. The variations of the changes were large in all age-intervals (Table 2). The decrease in post-void residual urine over time was not significant at any age interval (Table 2). The post-void residual urine at 3 months was not correlated with any values thereafter, except 18, and this was probably by chance. The post-void residuals at 6 months were almost only correlated with the next two observations (Table 3). The correlation coefficients were lower for post-void residual urine than for bladder capacity in general. No significant correlation between post-void residual and age of day or night dryness was found. However, a significant positive correlation was found between post-void residual at age 0.5 years and age at day dryness. A small

post-void residual at age 6 months was associated with an earlier age of dryness compared to the children with large post-void residual.

Urinary flow measurements were performed beginning at age 3.5 years when possible. Bell or tower shaped uroflow curves were most common at all ages. No bladder volume was less than 50% of the corresponding median value for age.

Awareness of a need to void was estimated by asking questions about the children's behaviour or expressions about the voiding process. Distinctions were made based on whether the children were aware of when they had voided ("I have voided/I am wet"), were aware of when they were actually voiding ("I am voiding") or had a sensation of needing to void ("I will void"). The children expressing "I have voided" reportedly did so up to age 2.5 years, those expressing "I am voiding" did so up to age 3.5 years and those expressing "I will void" did so up to age 4 years.

Signs of urgency and leakage were common among the children, and the first observation by the parents was in one child at age 1.75 years. Thereafter signs of urgency were reported in 43%, 53% and 50% of the children at 3, 3.5 and 6 years. Voiding postponement was only reported for one child at 2 years, but seemed to become more common after age 3 years with a peak (56%) at 3.5 years, and down to 44% at 6 years. The most common behaviours associated with voiding postponement were walking on the spot and hand pressing urethra. Another aspect of bladder control is the ability to store the urine without leakage. In 13 to 30% of the children, 2.75 to 6 years of age, involuntary small amounts (a few drops) of urine loss were reported, the first report being at age 1.75 years in one child.

The median age for becoming day and night-dry was 3.5 and 4 years respectively, reported by the children's parents. Girls were reported to be day-dry at a median age of 3 years (mean 3.25, range 1.75-5.5) and boys at a median age of 3.5 years (mean 4.0, range 2.5-4.5) but the difference was not significant. Night dryness was reported at a median age of 4 years (mean 4.0, range 2.25-6) for both girls and boys, with no significant difference between them. All but one child were day-dry for an average of 10 months (median 4, range 0-42), before becoming night dry. The process developed successively and the degree of having achieved bladder control at different ages according to parents' reports is illustrated in Figure 3. Daily potty use was not reported until the age of 2 years, with a median and mean of 34 months.

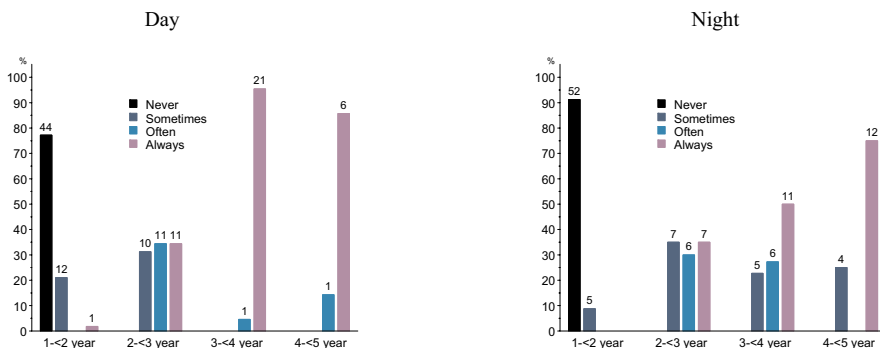


Figure 3. Day and night dryness of children in each age group.

Summary Paper III

Influence of life events on age for dryness

The children were reported by their parents, to have experienced a total of 185 life events with a median of 5 events (m 4.5, range 1-12) per child before becoming dry. The most common life events experienced were 51% about changes in child care or the parents' occupation, 24% related to illnesses, injuries or death, 16% about changes in the family composition and 9% to the living conditions of the family. The more events there had been the later the child was found to become day, night and completely dry. The correlation was significant to all changes except for changes related to living conditions and age of dryness. Most events had taken place after the children reached the age of 1 year. The average age at which the children experienced a life event was 2.5 years and the older the child was when an event was experienced, the later that child became dry. The children who had experienced the birth of a sibling became dry significantly later than those who had not ($p=0.0006$).

The children had reacted positively to the events in 39%, neutrally in 31%, and negatively in 30% of the cases. The five most common events negatively experienced were beginning nursery school/family day care, birth of a sibling, mother going back to work, serious illness/hospitalisation of a sibling or other significant illness/injury/death. We also found that the more positively a child had experienced an event the more easily the child adapted to it. Further, a correlation was found between a negatively experienced event related to the family composition and a later age of day dryness.

The children adapted easily to the life events in 85% of the cases, and had found it hard to adapt in 15%. These events were all related to separation from the mother. The children who did not find it difficult to adapt to any event were dry at a median age of 3 and 4 years during the day and night respectively, compared to 3.5 and 4 years, respectively, in the children who experienced at least one event to which they had difficulty adapting, but the difference was not significantly. Difficulties in adaptation to an event related to family composition or child care/parental occupation were associated with later ages of dryness during the days.

Summary Paper IV

Parents' experiences of how their children became dry

Subcategories and categories were identified from the content of the interview text, from parents' experiences of how their children became dry. Eight subcategories were identified: Making a decision and Having time, Creating a positive atmosphere and Doing activities, Cognitive skills and Personal traits, Unspoken rules and Comparing to fitting in. The subcategories created the 4 categories: The time had come, New daily routines, Child's willingness and Being like others. The analysis was performed using content analysis, and examples of the analysis process are given in Table 4.

The parents' experiences of how their children became dry were described as a process developing successively, which demanded having time. They also expressed the process as needing of a parental decision to get started when the right time had come. It was important for the parents to implement new daily routines and they tried to create a positive atmosphere as well as testing a lot of activities to support the process and encourage the child. The child's willingness was based on cognitive skills, maturation and personality traits and guided the parents' actions. The expression toilet training, spontaneously brought up by the parents, had negative connotations of forcing the child to sit on the potty and punishing the child if there were accidents. The parents did not experience that anyone in the surroundings brought up the subject and they felt there was no one to ask. The parents also experienced there was an unspoken age limit when a child should be dry, and when this limit was reached, group pressure arose. The parents compared their children to others in order to help and protect their own children, so they would be like others. They also expressed a strong desire, for their children to fit in, be good enough and be attractive to others, not to deviate.

Table 4. Example of the analysis process, from the condensed meaning units of the text, codes, subcategories and categories.

Condensed meaning unit	Code	Subcategory	Category
I took the diaper right away. When I had made up my mind – I had made up my mind, there was no way back.	made up my mind	making a decision	the time had come
We talked about it, when we go on vacation and she is not at the daycare centre we will try.	when on vacation	having time	the time had come
We started to put her on the potty with toys, mostly for fun, and after every meal in order for her to get used to it.	potty and fun	creating a positive atmosphere	new daily routines
If you praise them a lot when they are successful on the potty, they understand they've done something good.	praise a lot	“	“
Using cloth diapers will also help to become dry. When she was wet she felt wet and was probably uncomfortable.	using cloth diapers	doing activities	new daily routines
When she was 2 years old she got a potty, her first potty.	got a potty	doing activities	new daily routines
We tried several times but he did not understand at all, he was not interested. Then we stopped trying but when he was almost 4 he started to get interested in not wearing diapers.	did not understand get interested	cognitive skills “	child's willingness “
She did not like to be wet. She has always been very clean, never liked getting dirty.	been cleanly	personal traits	child's willingness
You want your child to be normal, so to speak. You would like your child to be normal in everything. Not to deviate at all.	not to deviate	comparing to fit in	to be like others
This is something you don't talk about, how to finish using diapers. It is a little taboo. If your child is late you don't tell anyone.	don't talk about taboo	unspoken rules	to be like others

DISCUSSION

In papers I and II the voiding habits of healthy children were studied longitudinally from 3 months to 6 years of age. During the first three years of life the "4-hour voiding observation" method was used. It has been elaborated with the purpose of studying the voiding patterns of children non-invasively and under as natural circumstances as possible (19). This method is very helpful when studying the voiding pattern in infants with bladder dysfunction since it makes it easy to recognize poor emptying. For the children in the present study who had achieved bladder control, a similar observation method, "uro-flow-measurement and residual urine observation," was used but without diapers. Instead, the child indicated when they needed to void, and then the flow meter was used.

Our findings indicate that during the early months of life there seems to be 1 voiding per hour, at least during the daytime, when the infant eats regularly. These results are in accordance with Goellner et al. (16), who described a voiding frequency of 20 per 24 hours in this age group. Gladh et al. also found a voiding frequency of 1-7 times per 4 hours in healthy newborns, aged 3 to 14 days of age (20).

In our study there were large variations in the bladder volume that triggered micturition, from 3% up to 100% of bladder capacity. This is also in agreement with a study of preterm neonates (94). This extreme variation in volumes initiating voiding indicates that the voiding reflex is influenced by the brain from birth. However, what triggers the micturition at different volumes is not known. One observation is that the bladder volume triggering voiding after a period of sleep is often higher than when the voiding takes place during a time when the child has been awake.

Another finding suggesting that the brain is involved in the regulation of bladder function from birth is that most young infants wake up before voiding. This was seen in the present study with an increasing number of infants who woke up before voiding during the first year of life. These findings are in line with those of Yeung (26) from the mid-1990s. He showed, using polysomnography and natural fill cystometry, that 85% of neonates had signs of arousal or woke up before voiding. This may indicate that the voiding reflex pathway connection to the cerebral cortex is developed anatomically, although function is immature in infants.

The increase in bladder capacity with age does not seem to be linear during the early years. According to the present studies the increase is most pronounced between 2 and 2.5 years, although there is also a significant increase between age 0.5 and 1 year. The steep increase at 2- 3 years can probably be related to the start of toilet training and the process of becoming dry. An increase in bladder capacity has previously been considered a prerequisite for becoming dry both day and night (15, 34).

The small increase in bladder volumes after age 3 years was probably attributed to the fact that bladder capacity was estimated from the uroflow study, which was often only measured on one occasion and can therefore be suspected of not being representative of the individual child's habits. Inter-individual variation over time was also noteworthy and increased with age. It is therefore difficult to establish normal values for functional bladder capacity after toilet training, as has been emphasized by Mattson et al. (95) in a study of Swedish schoolchildren.

Compared with other studies resulting in a formula for increase by age of bladder capacity (19, 21, 31-33), our values were in line with what has been suggested by Hjälmås, 1976 (31), despite the fact that his measurements have been from cystometric recordings. Since the 4-hour voiding observation method used in this longitudinally designed study is non-invasive and performed using a free voiding method a tolerance interval was estimated for children up to the age of 37 months (Figure 2). This interval includes the mean, median, 1SD and 2SD and can be used to follow an individual child's bladder capacity over time.

Our study, as well as a few others, (16, 20, 25, 31) have shown that healthy infants do not empty their bladders completely at each voiding. It has been postulated that infants empty their bladders automatically in response to a constant bladder volume (15, 27). An interesting finding in the present study was the interrupted voiding demonstrated in 33% of the children 3 months old. This phenomenon was suggested to be immature behaviour, because it was seen with decreasing frequency and then totally disappeared when the children became interested in voiding on the toilet. In other studies, interrupted voiding was demonstrated in as many as 60% of children born prematurely (94) and in 43% of healthy newborns (20), which also indicates that this phenomenon is part of the maturation process. Dyscoordination at voiding in healthy infants has also been demonstrated in urodynamic studies by Yeung (96), using natural fill cystometry, and by Bachelard (97) using standard cystometric investigations. This indicates that an observation of a single voiding, in children up to age 3 years, may

be misleading and that repeated voiding has to be observed to exclude abnormalities.

By the age of 3 the median value of residual volumes decreased, indicating a maturation of bladder function. The knowledge of improved emptying at this age can be used in the treatment of emptying problems by starting toilet training at an earlier age than is usually recommended. Toilet training can be started from age 1 year, with the aim of the child being able to voluntarily empty his or her bladder a few times during the day. However, it is important to remember that bladder control obtained in this way demands support from caregivers, who must try to observe and interpret the signals from the child and put the child on the potty whenever necessary. Sitting with relaxed pelvic floor muscles should facilitate the emptying process, as indicated by Wennergren (49).

In the present study, all the children used a potty/toilet from age 4.5 years when needed. The children started to report that they had voided or were just in the process of voiding from the age of 15 months. This means that they are observant about their voiding functions at the age of 18 months, and it therefore makes sense to introduce potty training from this age, which is in line with what Brazelton recommended as early as 1962 (51).

Bladder control was acquired later in the present study than in many previous studies (56, 59-61, 98). At the age of 2 years, these studies reported a percentage of children attaining complete daytime dryness that varied between 20% and 99%, with a weighted mean of 40%, and 39% (55), whereas in our study almost no child was dry at this age. With the introduction of disposable diapers and general acceptance of the view that the child should decide when she or he is ready to be dry, the age for starting training has risen. According to previous studies, acquiring bladder control was only regarded as a matter of maturation (15, 52, 99). However, the fact that training can accelerate this maturation process is quite clear from other studies (54, 56, 71, 100). It is interesting to note that although if the figures differed at ages 2 and 3 years between previous studies and the present one, the percentage of children with complete daytime control is very similar, with more than 90% at age 4 years both in the present and previous studies (55).

The same relationship applies to night time dryness, which occurs later than daytime control. In previous studies, between 8% and 41%, weighted mean 21%, are dry at night at the age of 2 (55), whereas none were dry in our study. At 4 years, the mean number of children attaining complete

night time dryness according to Berk et al. was 85% (69-99%), while the figure in our study was only 71%. At age six, 98% were dry according to the results of our study, i.e. 1 child was enuretic.

The present study suggests that bladder control is acquired today later than has been found in previous studies. Even in the relatively recent study by Bloom (38) the mean age for being toilet trained was 2.4 (SD \pm 0.6) years, as compared with the median of 3.5 years in the present study. The problem associated with studies of attaining dryness is that most are retrospective in the sense that the parents have to recall the age at which the transition took place, whereas in the present study the subjects were followed during this period of life. The study of Swiss children by Largo (99), which also used a longitudinal approach, revealed a frequency of complete dryness during the day more in line with our results, although a small number of the children were already completely dry at two years, 20%, compared with 1 child in the present study. This latter finding probably indicates an earlier start of toilet training, than in Swedish children today.

Signs of urgency, voiding postponement behaviour and urine leakage, symptoms frequently seen in functional bladder problems were frequently found in children in the process of attaining bladder control. They were most common at 3.5–4 years, but even at age 6 years the frequency was quite high, with 50% who had signs of urgency, as compared with the 20% reported by Hellström in an epidemiological study of 7-year-old school entrants (36). Signs of urine leakage were also seen in an average of 13% to 30% at each investigation after bladder control was acquired, which is similar to the findings of Bloom et al.(38).

The children in Paper III had experienced many life events, according to the Coddington list, as average of 5 events, before they achieved bladder control. There seems to be an association between the number of life events and the time of achieving bladder control. The more life events the later the children became dry, regardless of which type of life events there had been, except for life events related to living conditions, which were not associated with a later age of dryness. These findings can be compared with the results of Höök et al. (89), who found the risk of mental health disturbance doubled when a child had been exposed to a relatively large number of life events. Järvelin also found that enuretic children had experienced more life events than non-enuretic children (77). However, in the study by Höök et al., the children were older than in ours (9 years), while in the study of Järvelin they were 7 years old when the parent were asked about life events.

Järvelin et al. (77), who also used the Coddington life event list in a study of enuretic and non-enuretic children, found that the only single events associated with an increased risk of enuresis were the divorce or separation of parents. The children in our study were younger and only one child had experienced the separation of the parents before dryness was achieved. We found the birth of a sibling, another type of change in the family's composition, to be associated with a later age of dryness.

The children's experiences of the life events were mostly positive but in one third of the events the children had reacted negatively to them. We found that children who reacted negatively to a life event related to family composition were day-dry later than children who reacted positively to such an event.

Almost half of the children who experienced a life event in a negative way also had difficulties adapting to the event, of which some kind of separation was the most common. This is not unexpected since different kinds of separations from a parent are known as risk factors with negative effects on children, especially between the age of 1 to 5 (9, 12).

The ability to adapt to new situations or changes in the family was important and sometimes also delayed the time of achieving dryness. The achievement of bladder control was later for the children who had difficulties adapting to events compared with the children who adapted easily to an event.

Both positive and negative life events require considerable readjustment of one's mental state according to Betz (12). This needs to be considered when advising parents about toilet training their children. If a child has recently experienced a life event and reacted negatively, with difficulties in adapting, it seems not to be appropriate to initiate toilet training at that time. The family might need guidance about how to support their child. The present study suggests that the psychological stress that arises with the birth of a sibling might also delay the achievement of bladder control.

The findings regarding life events and bladder control in Paper III provide a rough picture of experienced life events before becoming dry, as described by the parents. The interviews were performed when the children were around six years of age and the results depend on what the parents remember from the age before their children were dry.

The transitional period for a child from being dependent on using diapers to becoming independent and dry, is governed by many factors. There are physiological characteristics that are important for the development of bladder control, and the results of the life events study indicate that life events may also affect the acquisition of bladder control. Life events may require a great deal of attention and, as a result, there may be no space left for practising bladder control. The effects of life events on children also suggests that life events like the birth of a sibling, could lead to a recommendation from professionals to wait with potty training until the child has adapted to the new situation even if the child is experiencing the life event in a positive way.

The new family lifestyle in Swedish society, where people become parents at the same time as both parties have careers has also been shown to be a stressor. It may be difficult for parents today to be responsible for the development of their children's bladder control since the training has to be done during the daytime, when the children are in daycare.

Becoming dry is a complex process which, like other developmental processes, takes time and is challenging even in a family where the child is developing normally. The parents' decision that it was time for the child to become dry was a starting point for the training process. All parents felt responsible and ready to take the command of the work that had to be done. They considered the training to have developed successively, in co-operation with the child and her or his skills. The process was time consuming and had taken place mainly on vacations or when the parents had longer periods of free time. The need for time is in agreement with the findings of de Vries (54) who, however, studied infants, describing the training process as watching out for and catching the child's need for eliminations.

The parents stated that they had a strong desire to help and support their children in achieving bladder control. In our study the mothers did not know who to ask for advice and had not been helped by reading parents' magazines or reports in the media, which Rundahl Hauck found in her study in the early 1990s (101). Another difference was that in our study toilet training was found to be a sensitive subject with unspoken rules about when a child is ought to be dry. The strong desire of the parents for their child should be like other children did not emerge in the study of Rundahl Hauck (101), but was very clear in our study.

The term potty or toilet training was negatively charged for the parents, equated with the older meaning of forcing the child to sit on the potty at fixed time intervals often combined with punishment if the child failed (84, 102). All the parents in our study denied having potty trained their children but emphasized that they had encouraged, reminded, praised and rewarded their children.

The parents expressed concerns about unspoken rules about when, or if to start any kind of potty training. The parents were frustrated that neither CHC nor daycare staff brought up the question or guided the parents in the process. There is a need for guidelines for now regarding how to advise parents as a service when parents ask. This confirms the findings from a questionnaire study of 266 parents about the potty training process they used. The parents in that study started potty train their children mostly by intuition (103).

The parents stated very clear they did not find the achievement of dryness a very important question. They were sure it would come to the child, and that sooner or later all children become dry. However, they also stated, contradictorily, that parents have to take the opportunity when the time had come to help the child become dry. That time was contingent on parents' opportunities and the child's willingness, and it was also important that the child not deviated from his or her peers.

There was a strong feeling of stress and fear that their child might not be perceived by others as good enough. The children reported on the Paper IV were dry at a median age of 2.5 years (mean 2.75 years), which is quite early as compared with the results of the longitudinal study (104) where healthy children became dry at a median age of 4 years (mean 3.5 years). Although the children in the present study became dry early, the parents still were concerned that their children would not be within the assumed time limit accepted for becoming dry.

CONCLUSIONS

Voiding patterns and acquisition of bladder control, 0-6 years

- Our findings indicate that infants do not void at constant volumes, nor do they empty their bladders completely at all voidings, but at least once every 4 hours.

- The voiding is associated with some state of arousal from birth. The decreasing frequency of voiding during sleep and the decrease of interrupted voiding may indicate that the voiding process is part of a maturation process.
- The ability of the child's bladder to store urine, measured in terms of bladder capacity, varies greatly in and among healthy children, and increases with age, most obviously between 2 and 3 years of age. Our results also indicate that children with a large bladder capacity at 15 months and up can predict a large bladder capacity up to 33 months.
- The emptying ability, measured as post-void residual urine, also varies greatly in and among children but decreases towards 0 ml at 3 years. Small amounts of post-void residual urine at 6 months of age indicate an earlier age of day dryness than large post-void residual urine at age 6 months.

Evaluating the storage and emptying abilities of the bladder in children is probably more correctly done during a 4-hour period than on a single occasion.

- Signs of bladder sensation appear from age 18 months and may indicate that potty-training could be started.
- Children seem to achieve bladder control later today than in the past, at 3.5 years during the days and at 4 years at nights. Day dryness is usually achieved before night dryness. We found no differences between girls and boys.
- Occasional signs of urgency, postponement and leakage even in children classified as healthy can be regarded as normal.

Life events 0-6 years

- Children experience many life events in everyday life, both positive and negative. Children mostly react positively to life events and mostly find it easy to adapt to them.
- The more negatively a child reacts to a life event the harder the adaptation.
- The more life events a child experiences the later the child will become day and night dry.
- The harder the adaptation to an event the later the child may become day dry.

Parents' experience of the toilet training process

- The parents feel responsible for initiating the toilet training process in their children. The parents have to make the decision and, have

time to actively take part in the process, and take the child's willingness into account. Creating a positive atmosphere in daily routines is important. Toilet training is a sensitive issue and there is an unspoken limit when it is thought that children should be dry. Parents strive to help their children become dry so they will fit in and be like others.

CLINICAL IMPLICATIONS

The results from our studies can be used as baseline knowledge by professionals working with children below 6 years of age and/or with children with urinary bladder dysfunctions. The voiding pattern parameters investigated in this thesis could be useful if implemented in paediatric urology clinics where urinary bladder function is estimated. The tolerance interval for bladder capacity could be helpful in following outcomes in individual children over time but also be used to identify children with bladder dysfunction.

Knowledge about urinary bladder function could be disseminated to CHCs and used by professionals in practice. It is appropriate to bring toilet training up at the CHC and to guide and support the parents about training could be introduced and carried out as with other skills. Parents should be guided, informed and encouraged about when it is possible to toilet train their child but not recommended to toilet train their children during a period when the family is experiencing, a life event especially not if the child has difficulties to adapting to the event.

FURTHER RESEARCH

There is a need to evaluate different toilet training methods. This could begin by creating new clinical guidelines about how to toilet train a child, to be implemented at a national level at all CHC's, and evaluated after 1 year. This would probably contribute to making the encounters with parents, children and professionals more open and encourage highlighting important questions for the family.

Since there are validated instruments regarding health-related quality of life outcomes even from the age of 5 (105) these could be used to investigate

children's own experience of being dry as well as their experience of wearing diapers.

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