

The Impact of Movement, Physical Activity and Position on Urine Production: A Pilot Study

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August 11, 2021

Abstract

Background: Many different internal factors have been proven to influence urine production such as age, weight, and quality of sleep. External factors such as consumption of caffeine and fluid consumption have been shown to have an impact on urine production. **Aim:** To investigate the impact of movement, physical activity, and position on urine production. **Methods:** This prospective observational study was executed at Ghent University Hospital, Belgium. Study participation was open for anyone visiting the hospital. Participants collected 1 basic and 2 extended 24-hour urine collections and filled in questionnaires concerning their general health and physical activity. Urinary levels of osmolality, sodium, and creatinine were determined. Data on movement, physical activity and position was described. **Results:** An increase in body movement leads to a significant increase in diuresis during daytime, night-time, and 24 hours ($p=0,002$, $p= <0,001$, and $p=<0,001$, respectively). An increase in body movement leads to a significant decrease in osmolality during night-time and 24 hours ($p=0,009$, and $p=0,004$, respectively). However, no significant influence of movement on osmolality was found during daytime ($p=0,12$). An increase in body movement leads to a significant decrease in creatinine during daytime, night-time, and 24 hours ($p=0,001$, $<0,001$, and $p=<0,001$, respectively). An increase in body movement leads to a significant increase in sodium during daytime ($p=0,046$) but this was statistically significant during night-time and 24 hours ($p=0,32$, and $p=0,84$ respectively). **Conclusion:** Our study demonstrates a statistically significant association of movement, physical activity, and position with urine production. It would therefore be interesting to explore this association further with the use of new technology to have more accurate data. Here lays a potential role for conservative measurements and lifestyle adaptations in the management of patients with bothersome LUTS and more precisely nocturia.

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levels of osmolality, sodium and creatinine were determined. Data on movement, physical activity and position was described.

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Conclusion: Our study demonstrates a statistically significant association of movement, physical activity, and position with urine production. It would therefore be interesting to explore this association further with the use of new technology to have more accurate data. Here lays a potential role for conservative measurements and lifestyle adaptations in the management of patients with bothersome LUTS and more precisely nocturia.

Keywords: movement, physical activity, position, urine.

What's already known about this topic?

In a healthy person, below normal hydration levels, the body produces an average of 1-2 liters of urine per day. Most of the urine production occurs during waking hours, and only 20-30% of urine is produced during sleep. Different factors have been hypothesized to affect urine production or voiding physiology. It may be due to internal and external factors such as age, antidiuretic hormone, fluid consumption, and caffeine intake, that affect urine production. In the literature, there is no study that investigates the impact of movement, physical activity and position on urine production.

What does this article add?

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Introduction

In a healthy person, below normal hydration levels, the body produces an average of 1-2 liters of urine per day¹. Most of the urine production occurs during waking hours, and only 20-30% of urine is produced during sleep¹. Different factors have been hypothesized to affect urine production or voiding physiology. It may be due to internal and external factors that affect urine production. One of the internal factors is age, as noted by Myron Miller, who studies changes in the kidney and hormonal systems that control water and sodium excretion². Hoshiyama et al. suggest that elderly patients show an increase in nocturnal urine production due to natriuresis resulting from increased B-type natriuretic peptide (BNP) secretion and decreased antidiuretic hormone (ADH) secretion³. Denys et al. state that circadian rhythms of the bladder and the kidney changes as patients grow older, the study found that 96% of patients >65 years, who consulted for complaints of UI, had nocturia⁴.

Different external factors have been known to give a significant impact on urine production. Fluid consumption is an example of such. Studies showed that decreasing fluid intake in patients with detrusor activity and/or urodynamic stress incontinence decreased voiding frequency, urgency and incontinence episodes^{5,6}. Studies have also shown an important impact of caffeine on urine production^{7,8}. Besides caffeine and fluid intake, there is increasing evidence to support the effect of carbonated drinks in the development of lower urinary tract symptoms (LUTS)⁸. Robinson et al. performed a large population-based study based on the Boston Area Community Health Survey which showed that an overall larger intake of energy resulted in more urinary incontinence as well as increased its severity. Furthermore, they demonstrated that an increase in saturated fat was associated with post micturition symptoms and nocturia⁷.

In the literature, there is no study that investigates the impact of movement, physical activity, and position on urine production. However, we the authors, have, based on the physiology, a strong inclination to believe that movement, physical activity, and position will have a significant impact on urine production. Therefore, in this pilot study, we aimed to investigate the effects of movement, physical activity, and position on urine production.

Subjects and methods

Study design and population

This prospective, observational study is based on a clinical study conducted at the between November 2013 and April 2016. The study participation was open for anyone visiting the hospital interested to participate in a clinical study.

There were no specific inclusion criteria. Exclusion criteria were night-work employment and intake of medication with a potential effect on urine output (such as diuretics, desmopressin, angiotensin-converting enzyme inhibitors, angiotensin II receptor antagonists and non-steroidal anti-inflammatory drugs).

Study protocol

A total of 65 persons signed an informed consent, 20 persons were excluded (never started ($n = 17$), night shift ($n = 1$), failed to follow the instructions for urine collections ($n = 2$)) and thus a total of 45 persons were eligible for analysis. Demographic data were collected.

Within a period of six weeks, two extended urine collections were obtained during two non-consecutive 24-hour periods to determine diuresis rate and renal functions. For this, participants were asked to collect 5 daytime 3 and nighttime urine samples at fixed time intervals over 24 hours. Voided volume at the time of sample collection, as well as volumes of any interim micturition, were recorded. During the first extended urine collection, participants also had to collect all daytime and nighttime urine in a daytime and nighttime container. Urinary concentration of osmolality, creatinine and sodium were determined for all urine samples and for both urine containers. Participants had to respect directives regarding the intake of fluids and food during both study days (drink 1.5-2 liters water and do not drink more than 2 units of alcohol per day; avoid salting their food and eating aperitif snacks, sauces, fast food and ready-made meals).

Furthermore, patients were asked to keep track of their movements and were requested to give an indication of what they had done the most during a period of time of one hour. Movement/position was divided into five categories. 0 was equivalent of having laid down the most that hour. 1 meant that the participant had been sat down for most of the hour. 2 stood for standing up. 3 was allocated to walking as the majority movement of the hour. 4 was given if the patient had performed more intense activity during that hour i.e. running, cycling etc.

The study was carried out in conformity with the Declaration of Helsinki. The Ghent University Hospital Review Board approved the study (EC/2013/802) and all participants gave written consent

Statistical Analysis

The statistical analysis that was done for this pilot study can be split up in four parts.

The first step was aligning the data pertaining to movement with the data regarding urine production. The first hurdle that had to be crossed was that of the discrepancy in data collection moments for both urine production as well as that of movement. As mentioned above, participants were asked to collect eight urine samples. Contrary to the urine sampling, participants were asked to fill in hourly updates regarding their majority movement of the past hour, resulting in 24 inputs of data for the same day regarding movement. The solution to this was clubbing three inputs of data of movement. Here the range of movements no longer went from 0-4, but now went from 0-12. Because of this, there was now a symmetry in the data input of urine samples as well as that of movement.

The second step was to change the database format in its entirety. The database was in a wide format. This had to be changed to a long format, as otherwise, the analysis that had to be done would have been statistically challenging. As such every participant in the study had 16 different data entries each pertaining to 1 of 8 timeslots of both days.

The third step was to test the hypothesis by conducting a basic statistical test such as the Kruskal Wallis and the Mann Whitney U test. To successfully conduct these tests, movement was divided into three categories, defined as 1,2 and 3. They respectively stood for less, moderate and more movement and physical activity. A p-value of <0,05 was considered as statistically significant.

The fourth and final step was the main statistical analysis. Mixed model statistics were used to analyze the impact of movement on urine production. Here diuresis, osmolality, creatinine and sodium were compared with movement to find any form of association. Parameters of fixed effects were estimated using maximum likelihood estimation and reported as standardized regression coefficients (β) with their respective standard error. A p-value <0.05 was considered as statistically significant. These tests were conducted for the entire day as well as day and night separately. Factors such as “BMI” and “age” were defined as confounders and included in the mixed model.

Statistical analysis was carried out using SPSS 24.

Results

Patient characteristics

A total of 45 people with a median age of 35 (26-54) were included in the study. Of these, 29 were female and 16 were male. 25% of the participants had one episode of nocturia and 18% had an average of two or more episodes of nocturia, the remaining had no nocturia. Demographic and patients characteristics are given in **Table 1** .

Basic statistical analysis

There were 448 data inputs in the first category (less movement), 160 in the second one (moderate movement) and 29 in the third one (more movement). This was the case for all four variables.

The mean of diuresis of less, moderate and more movement groups are 1.4 ± 1.0 ml/min, 1.8 ± 1.4 ml/min, and 2.0 ± 1.2 ml/min, respectively. Diuresis was significantly higher in the moderate and more movement group compared to the less movement group ($p=0,003$ and $p=0,014$). In terms of diuresis, there was no significant difference between the moderate and more movement groups ($p=0,701$) (**Figure 1A**).

The mean of creatinine of less, moderate and more movement groups are 108.1 ± 70.8 mg/dl, 89.5 ± 63.2 mg/, and 73.4 ± 47.8 md/dl respectively. Creatinine was significantly higher in the moderate and more movement group compared to the less movement group ($p=0,008$. and $p=0,026$). In terms of creatinine, there was no significant difference between the moderate and more movement groups ($p=0,787$) (**Figure 1B**).

The mean of osmolality of less, moderate and more movement groups are 550.4 ± 248.5 mosm/kg, 524.0 ± 256.4 mosm/kg, 477.7 ± 237.9 mosm/kg respectively. There was no significant difference in terms of osmolality between the three groups ($p=0.197$) (**Figure 1C**).

The mean of sodium of less, moderate and more movement groups are 101.6 ± 55.2 mmol/l, 96.1 ± 59.7 mmol/l, 80.6 ± 46.6 mmol/l respectively. There was no significant difference in terms of sodium between the three groups ($p=0.055$) (**Figure 1D**).

Complex statistical analysis

The different models generated for the evaluation of diuresis, osmolality and creatinine during daytime, nighttime and 24h had 3 variables as randomisation stratification variables: age, body mass index (BMI), and movements (Table 2-5). The Akaike information criterion (AIC) of the given set of data are summarized in the tables, and were superior to the other alternative models tested.

An increase in body movement leads to a significant increase in diuresis during daytime, night-time and 24 hours ($p=0,002$, $p= <0,001$, and $p=<0,001$, respectively) (Table 2).

An increase in body movement leads to a significant decrease in osmolality during night-time and 24 hours ($p=0,009$, and $p0,004$, respectively). However, no significant influence of movement on osmolality was found during daytime ($p=0,12$) (Table 3).

An increase in body movement leads to a significant decrease in creatinine during the daytime, night-time and 24 hours ($p=0,001$, $<0,001$, and $p=<0,001$, respectively) (Table 4).

An increase in body movement leads to a significant increase in sodium only during the daytime ($p=0,046$). However, this meaning does not exist in terms of during the night-time and 24 hours ($p=0,32$, and $p=0,84$ respectively) (Table 5).

Discussion

Movement, physical activity and position are known to influence a broad spectrum of mechanisms in the human body. Therefore, we set out to explore the impact movement may have on urine production. There is ample existing body of literature showcasing the effects of movement, physical activity and position, however, there is no existing data on the impact on urine production⁹⁻¹¹.

Our study was performed in a population of healthy patients with age varying from 26 years to 54 years with a mean of 35 years old. Due to multiple variables and the complex interaction between these, we opted for mixed model statistical analysis, A positive association was found between diuresis and physical activity, movement and position for all three timeframes i.e. 24 hours, daytime and night-time. Negative associations were found between osmolality and creatinine and physical activity, movement and position. The association between creatinine and physical activity, movement and position were significant for all three timeframes, however, this was not the case for osmolality where the association was only significant for 2 timeframes being 24-hours and night-time. Furthermore, there were no significant associations between sodium and physical activity, movement and position except a very slight statistically significant value for the model of daytime.

As this is a pilot study, there is a paucity of data exploring the topic of movement and urine production. There are, however, other studies exploring the association of physical activity and glomerular filtration rate (GFR) as well as kidney function. The general consensus states a positive association between physical activity and GFR as well as kidney function^{9,12-14}. Moreover, Wolin et al. state that physical activity may provide a strategy for the management of benign prostatic hyperplasia related outcomes, particularly nocturia¹¹.

Physical activity is known to increase blood pressure in the acute setting. An increase in blood pressure would theoretically increase the blood flow to the kidneys, without counting for any diversion of blood flow to skeletal muscle or cerebrum in cases of flight-and-fright responses. Nonetheless, an increase in renal blood flow, would increase the flow within the glomerulus. This would result in an increased glomerular filtration rate, which could be a potential hypothesis for increased urine production. Nonetheless, one must account for processes of reabsorption and filtration that occur within the renal tubules, which brings us to our second hypothesis^{15,16}.

The renin-angiotensin-aldosterone system (RAAS) is a hormone system that regulates fluid balance and blood pressure and works by increasing blood volume and hence blood pressure. With increased physical activity, blood pressure rises likely due to a combination of the baroreceptor reflex, increased cardiac output and increased systemic vascular resistance secondary to the effect of the sympathetic nervous system. As such, there is a possibility that RAAS activity may not be as required by the body's physiology since the blood pressure is already autoregulated and no increase in blood volume is required to increase blood pressure. Nonetheless, a simple increase in blood pressure causing an increased glomerular filtration rate with unchanged reabsorption dynamics, could very well be the principle cause of an increased diuresis associated with physical activity, movement and position. This would clarify the phenomenon of increased urinary excretion without impacting on urinary sodium, however, it is likely it is a combination of multiple systems that play a role^{10,15-17}.

The strengths of our study are that it has been performed in a well-designed sample that is representative of the general population. Furthermore, the study design is prospective, and the research topic is completely novel; hence the pilot study. However, some limitations must be noted such as the lack of data on serum. Due to this, we could not calculate the GFR and an estimate was made using BMI and age, however, we felt this would be too vague and not accurate enough. Furthermore, as the initial objective of the questionnaires was to compare the basic and extended urine sampling, targeted data for the movement was not specifically outlined. Urine samples were taken every 3 hours and were objectified; whereas, the data on movement was given a subjective score every hour by the patient. This data was then transformed to make the analysis more transparent. In addition, the sample of our study might be considered too small to note all the differences between certain confounders. As such it is difficult to amplify the results to larger patient groups. It is important to note that calculating the low level-1 variations of the different mixed models may have led to the loss of matching previous results within the same patient. As such all the data and its results could only be made with relation to intraindividual differences.

It remains clear that more research is necessary within this domain. As many studies have suggested physical activity is a very easy, non-invasive way to improve quality of life^{9-11,13}. Here it is vital to focus on a larger and more varied sample, as this could lead to more exact data. As there are many unanswered questions within this field of research, we must try and find a better understanding of the pathology and increase the methods and tools available to analyse the same. In an ideal situation, the researcher must gain information on the exact timing of movement, the exact intensity of movement, and finally how this impacts the renal system.

In the future, the use of automated monitoring devices for factors like voiding, urine production and residual volume, but also for diet, blood pressure, pulse and sleep will be necessary. In addition to this, fitting applications, such as bladder diaries and intake diaries, will be needed as well in support of these new monitoring devices. Technology is already available in the form of a smart flow, a smart diaper, but also a smart mattress that can supply the required information. Furthermore, the necessary applications are available or easy to make. The main problems to solve are validation of the applications and devices for the purpose of exploring nocturnal LUTS and the financial incentive for companies to this low-volume work. However, community-driven sponsoring might be a solution for this.

Conclusions

Our study demonstrates a statistically significant association of movement, physical activity and position with urine production. It would therefore be interesting to explore this association further with the use of new technology to have more accurate data. Here lays a potential role for conservative measurements and lifestyle adaptations in the management of patients with bothersome LUTS and more precisely nocturia.

Conflicts of Interest:

All authors disclose any potential conflict of interest.

Funding Sources:

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authorship

Study Design: Karel Everaert, Marie Astrid Denys, Data analysis: Mutlu Deger , Vansh Kapila, Manuscript writing: Mutlu Deger, Vansh Kapila, Manuscript editing: François Herve, Data colleciton: Marie Astrid Denys, Vansh Kapila, Supervision: Karel Everaert, Ibrahim Atilla Aridogan, François Herve.

All the authors have given the approval of the final version to be published and agreed to be accountable for all aspects of the work.

Data Availability Statement:

We can share our data with the journal for representing analysis and interpretation of the data. However, we do not want the readers to see or download our data.

Ethics:

The study was carried out in conformity with the Declaration of Helsinki. The Ghent University Hospital Review Board approved the study (EC/2013/802) and all participants gave written consent

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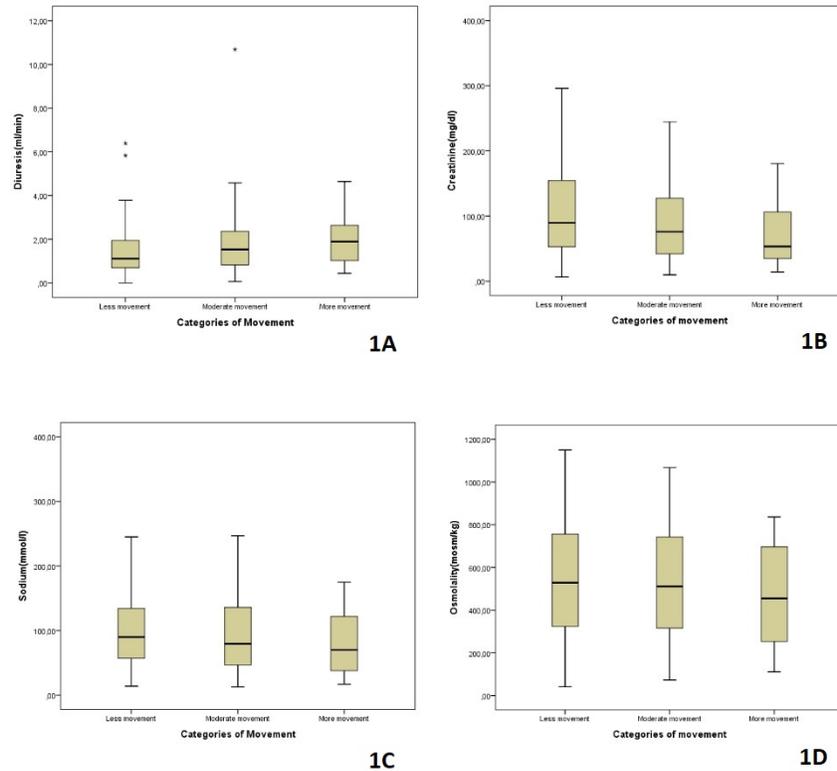
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Figure Legends:

Figure 1: Pairwise comparison of diuresis (1A), creatinine (1B), sodium (1C), and osmolality (1D) between different categories of movement



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