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The effect of two body positions on tidal breathing

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Abstract
The effect of two different body positions on tidal breathing.
Key words: *Tidal volume, body positions, administration, inhalation therapy, inspiration volume*

Background
Inhalation therapy is becoming a more habitual way of distributing different types of drugs. Several factors are important to consider for optimising inhalation therapy.

Physiotherapists play a key role in inhalation therapy. Earlier studies have shown some benefit from a seated, slightly forward leaning position during inhalation. In light of this, physiotherapists have often recommended this position during inhalation therapy, as opposed to a supine or semi-recumbent position in a hospital bed.

Aim
The aim of this study was to explore if the quality of breath and inspiration pattern is affected in different body positions. A second aim was also to simulate and analyze how different inhalation patterns could influence drug deposition in a device for aerodynamic size fractionation of aerosol clouds

Study design
Clinical study.

Method and measuring instruments
11 participants were included in the study. Their spontaneous tidal breathing was registered in 2 body positions using a mass flow measurer. Inspiration volume, max flow and breaths per minute was calculated for a total of 66 registrations; each registration lasted 10 seconds, 3 registrations were recorded per participant and position. Drug deposition would have been analyzed in vitro through aerodynamic size fractionation of aerosol clouds. Results were analyzed using descriptive statistics.

Ethical considerations
This study was approved by the advisory committee for research ethics in health education at Lund University. The participants were given verbal and written information about the study and signed a consent form before participating. Participation was voluntary.

Result
Considerable variation of inspiration volume, max flow of inspiration and breaths per minute was seen on an individual level. The second aim was not analyzed due to no significant difference on a group level between the semi-recumbent and the seated position.

Conclusion
In spite of variation of inspiration values on an individual level, the differences on a group level were clinically insignificant when comparing the two body positions. With a different population, such as patients with respiratory disorders, results might have differed. For specific patient groups further studies are required. From the results of this study, we can conclude that the healthy adults' tidal breathing was not affected in a seated position or a semi-recumbent position.

Sammanfattning
Två olika kroppspositioners effekt på tidalandning.
Nyckelord: *Tidalvolym, kroppspositioner, administration, inhalationsterapi, inspirationsvolym*

Bakgrund
Inhalationsterapi blir allt vanligare som distributionssätt för olika typer av läkemedel. Flera faktorer är viktiga att ta hänsyn till vid optimering av inhalationsterapi.

Fysioterapeuter spelar en nyckelroll när det kommer till inhalationsterapi. Tidigare studier har visat på vissa fördelar med en sittande, något framåtlutad position vid inhalation. Med bakgrund i detta har fysioterapeuter ofta rekommenderat denna position vid inhalationsterapi, till skillnad från en ryggliggande eller halvliggande position i en sjukhussäng.

Syfte
Studiens syfte var att undersöka huruvida andetagskvalitén vid tidalandning och inspirationsmönstret påverkas i olika kroppspositioner. Det andra syftet var att simulera samt analysera hur olika inhalationsmönster kunde påverka distributionen av läkemedelspartiklar i en apparat för aerodynamisk storleksfraktionering av aerosolmoln.

Studiedesign
Klinisk studie.

Metod och mätinstrument
11 deltagare medverkade i studien. Deltagarnas spontana tidalandning registrerades i 2 olika kroppspositioner med en massflödesmätare. Tidalandningens inspirationsvolym, maxflöde och andetag per minut beräknades för totalt 66 registreringar; 3 registreringar á 10 sekunder per deltagare och position. Läkemedelsdistribution skulle ha analyserats in vitro genom aerodynamisk storleksfraktionering av aerosolmoln. Resultaten analyserades med hjälp av deskriptiv statistik.

Etiska ställningstaganden
Studien godkändes av Vårdvetenskapliga Etiknämnden vid Lunds Universitet. Deltagarna fick muntlig och skriftlig information om studien och skrev under en medgivandeblankett innan deltagande. Medverkande i studien var frivilligt.

Resultat
Avsevärd variation gällande inspirationsvolym, inspirationsmaxflöde och andetag per minut kunde ses på individnivå. På gruppnivå kunde ingen signifikant skillnad ses mellan den halv-liggande och den sittande positionen. På grund av detta analyserades inte det andra syftet.

Slutsats
Trots variation gällande inspirationsvärden på individnivå var skillnaden på gruppnivå inte signifikant när de två positionerna jämfördes. Med en annan population, till exempel patienter med respirationssjukdomar, hade resultatet kunnat se annorlunda ut. För specifika patientgrupper behövs vidare studier. Från denna studies resultat kan vi dra slutsatsen att friska vuxnas tidalandning inte påverkades av en sittande eller halvliggande position.

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Background

Inhalation therapy is a common way of distributing drugs and various drugs are being developed in aerosol form. Distributing drugs in aerosol form leads to reduced unwanted systemic impact and ensures that medication intended for the lungs and airways end up there. Lack of clinical efficacy of inhalation therapy is often blamed on the drug rather than inhalation technique and use of inhalation device, leading to larger drug doses being prescribed rather than evaluating the technique and patient device interaction. Larger drug doses increase the risk of toxicity and detrimental side effects. (1-3)

Common drugs that have been used in inhalation therapy for some time involve antibiotics, mucolytics, short- and long-acting β2-adrenergic agonists, anticholinergics as well as steroidal and non-steroidal anti-inflammatory drugs. Other types of drugs are now starting to be used in inhalation therapy: some distribute nucleic acid to restore or subdue a gene construct, protein coding sequence or abnormal gene product (ie gene therapy); others distribute peptides to target diseases either directly in the lungs or in the systemic circulation. (4)

Several factors can influence inhalation therapy, which can prove problematic. The type of inhalation device used is one of those factors. Dry powder inhalers, DPIs, pressurised metered dose inhalers, pMDIs, and nebulisers are the three main devices used for inhalation therapy, and vary in terms of particle size and doses per unit of time (5, 6). In DPIs the medication lies in the bottom of the device in powder form as the name suggests. By drawing a quick, sharp breath from the device the patient mobilises the medication from the device. pMDIs use a liquified gas propellant to deliver a metered dose through the mouthpiece of the device after actuation by the patient. Problems with coordination regarding actuation and inhalation can be helped by the use of a spacer between the device and the patient’s mouth. The nebuliser is a device that produces the medication in mist form, either by mechanical or electrical nebulisation (7).

Another factor affecting inhalation therapy is the flow rate of the breath. Slow, deep breaths are often recommended for inhalation therapy, but differs depending on the inhalation device used (8, 9). Fast, rapid breaths create turbulent flow in the airways, affecting inertial impaction and causing aerosol particles to err from the main direction of airflow. This causes the particles to collide with airway walls and deposit there, which is not desired in inhalation therapies where peripheral deposition is intended. When a pressurised metered dose inhaler, pMDI, or nebuliser is used, slower breaths, ie tidal breathing, are preferable, while dry powder inhalers, DPIs require a stronger and faster inspiratory flow in order to mobilise the drug from the device in sufficiently small particles. In some DPIs, this means a necessary inspiratory flow rate of 60 L/min, while for example the pMDI *Autohaler* requires a minimum of 27 L/min (10, 5, 11).

An important factor to consider is the size of the particles of the medicine distributed, as larger particles (>5µm) tend to get stuck in the upper airways, largely due to their increased momentum compared to smaller particles, and as a result of this their susceptibility to inertial impaction. (12, 10)

Using the device in a correct manner is of considerable importance, which is why patient information is of great relevance. Studies have shown that despite information on correct utilisation, a large number of patients tend to not use their inhalation device correctly (13). In light of this, Kamps et al (13) believes that monitoring and follow-ups may be of significance.

It is previously known that different postures affect lung volumes (14). Brandão et al (15) observed that a seated, slightly forward leaning posture with elbows resting on the thighs was more favorable in acute asthma attacks than other sitting postures. Sá et al (12) noted how aerosol particles were more likely to be transported to the alveoli in a seated position (compared to a supine position), which in some inhalation therapies is favorable, ie inhalation of antibiotics through nebulisation (4, 7).

Physiotherapists play a key role in inhalation therapy. They are involved in choosing the appropriate device and equipment as well as instructing the patient and practicing correct use. Furthermore, physiotherapists instruct other health care professionals in inhalation therapy (16). Optimising as many of the impacting factors as possible takes us closer to optimal inhalation therapy. Comprehensive knowledge on how to enhance inhalation is vital to patients in order for them to fully benefit from treatment. It is also of great importance that physiotherapists have the right tools to guide patients and other healthcare professionals in optimal usage.

Different ways of distributing drugs through inhalation occur in hospitals. During clinical training, we have observed that in some instances patients are not mobilised to a seated position out of the bed during inhalation therapy. Instead, the head end of the bed is raised, leading to a slouching, semi-recumbent position of the patient. This is something we as physiotherapists are taught to be a non-optimal position for lung function as it decreases functional residual capacity, FRC, which predisposes patients for atelectasis (16).

Earlier studies (12,14,15) have shown some benefit from a seated, slightly forward leaning position during inhalation. In light of this, physiotherapists have often recommended this position during inhalation therapy, as opposed to a supine or semi-recumbent position in a hospital bed.

Our present study wishes to build on previous knowledge on body positions' effect on breathing patterns and inhalation in healthy subjects.

2. Aim

The aim of this study was to explore if the quality of breath and inspiration pattern is affected in different body positions. The aim was also to analyze how drug particle deposition could be influenced by the presumably different inhalation patterns shown sitting or semi-recumbent.

3. Questions

1. What does spontaneous tidal breathing look like regarding volume of inspiration, max flow of inspiration and breaths per minute when sitting upright?
2. What does spontaneous tidal breathing look like regarding volume of inspiration, max flow of inspiration and breaths per minute in a semi-recumbent position?
3. Is there any difference in breathing quality regarding volume of inspiration, max flow and breaths per minute between the two body positions?
4. If a clinically significant difference in breathing patterns on a group level is identified, how is the drug deposited in a device for aerodynamic size fractionation of aerosol clouds (see *Measuring instruments*)?

4. Method

The study included eleven participants, hereafter termed participant 1-11, all over 18 years of age. The participants were in good general health at the time of the test and did not have any ongoing infection that could compromise their breathing.

The participants were recruited through personal e-mail among physiotherapy students at Lund University, and through our supervisor among the staff at VO Barnmedicin SUS, Lund. Four males and seven females participated, making the percentage 36% and 64% respectively. The participants were aged 23-55, median age being 40. Median weight was 65 kg and median height 175.5 cm, the median BMI was 20.74.

The participants' height and weight were measured at the time of the breath-registration. They were asked about their age and sex, as well as asked if they had any ongoing infections. If any participant had answered yes to having an ongoing infection, they would have been excluded from the study.

4.1 Measuring instrument

The device used for breath recording is based on the mass flow measurer from *TSI Corp, model 4040*, linked to the software *Amazing Flow, version 1.0*. The analysis was performed with assistance and equipment from Emmace Consulting AB, under the direction of CEO Mårten Svensson and follows their standard protocol. A disposable mouthpiece from *Vitalograph* was used in conjunction with the mass flow measurer, and measures 6 cm in length and 3 cm in diameter.

TSI Corp 4040 includes a certificate of National Institute of Standards and Technology (NIST) calibration (17) which means that all test and calibration data supplied by TSI has been obtained using standards whose accuracies are traceable to NIST.

Every second year the mass flow measurer is calibrated in certified laboratories, in accordance to national standard. The controls keep the same level of control as the pharmaceutical industry to ensure proper measurement values.

If the analysis had proceeded to comparing inhalation deposition, analysing the particle deposition would have meant using a device for aerodynamic size fractionation of aerosol clouds, with a saline solution in vitro. We would have used *Next Generation Impactor, NGI, model 170* from *MSP Corp, US*.

4.2 Positions

The participants' tidal breathing was registered in two different body positions.

4.2a Position 1

The first position was an upright, seated position on a 44 cm high chair with feet resting flat on the ground. The participants were slightly forward inclined with their elbows placed on a table, height of the table being 69 cm. Breathing normally, their breaths were registered using the TSI Corp, model 4040 which was connected to a mouthpiece. The participants held the mouthpiece between their teeth with their lips tightly sealed around it, supporting the device with their hands. A nose clip was placed on their nose to make sure no air escaped through the nose (see fig. 1).

FIG 1. Position 1, the upright position.

4.2b Position 2

The second position was a semi-recumbent position in a hospital bed, with the head end raised 50° and one pillow behind their head. The participants held the mouthpiece between their teeth, with their lips tightly sealed around the mouthpiece, supporting the TSI Corp, model 4040 with their hands. A nose clip was placed on their nose to ensure no air escaped through the nose (see fig. 2).

FIG 2. Position 2, the semi-recumbent position.

4.3 Registrations and data analysis

Due to the design of the software used, each registration lasted 10 seconds. For each body position, three consecutive registrations were conducted. The participants were instructed to breathe normally without any additional effort for approximately 40 seconds while three consecutive registrations were conducted. Participants were not made aware of when the three individual recordings started and ended. The three registrations per person and position resulted in 33 registrations per position and 66 registrations in total.

Registrations from software *Amazing Flow* were transferred to *Microsoft Excel*. The data was converted into line charts where each curve represented an in- or expiration. After inspecting the curves, we extracted data from the first full in-/expiration and the following in-/expiration in each registration (see fig. 3). This data was inserted into a formulae provided by Emmace Consulting AB. This formulae converted the data into information regarding tidal volume of inspiration/expiration, time to max flow, max flow, time for inspiration/expiration, time for total breath and number of breaths per minute. Of these parameters, tidal volume of inspiration (L), max flow of inspiration during tidal breathing (L/min) and breaths per minute were used for further analysis.

A database was established using *Microsoft Excel* to include information on each participant (age, sex, height, weight) and values for the breath chosen from each registration and position. Values for each tidal breath (inspiration and expiration) included volume (L), time to max flow (ms), max flow (L/min), time for inspiration/expiration (ms), time for total breath (ms) and number of breaths per minute.

From the database, values from each registration were extracted. The values extracted were volume of inspiration (L), max flow of inspiration (L/min) and breaths per minute (see fig 5 and 6, table 3).

If a complete inspiration or expiration was not registered during the 10 second registration in question (see fig. 4), the missing in-/expiration was supplemented by the values in the previous registration of the participant. If a previous registration to the registration in question did not exist, the registration that followed supplemented the missing in-/expiration. The supplementing breaths were matched by type (in-/expiration, upright/semi-recumbent position, participant).

Registration 14 (see fig. 5, 6 and table 1-3), the second registration in the upright position in participant four, lacked a complete expiration, and registration 16, the first registration in the semi-recumbent position in the same participant, lacked a complete inspiration. Registration 32 lacked a complete expiration in the second registration in the upright position in participant six. These three values were supplemented as stated above.

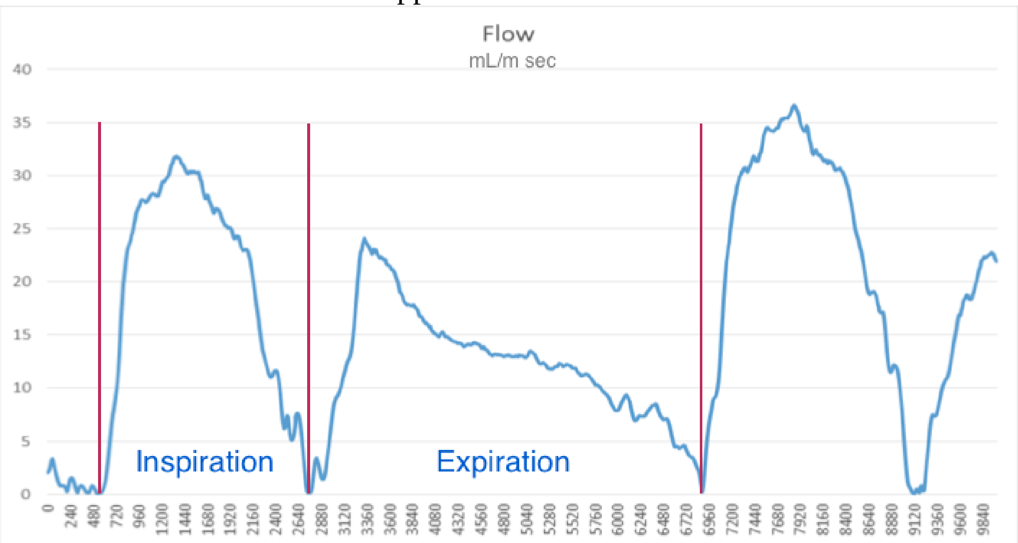

FIG 3. Complete inspiration and expiration curve. The blue line, representing flow, descends low enough to be considered the start of the inspiration (by the first red line), the end/start of the inspiration/expiration (by the second red line) and the end of the expiration (by the third red line). Y-axis = millilitre, x-axis = millisecond.

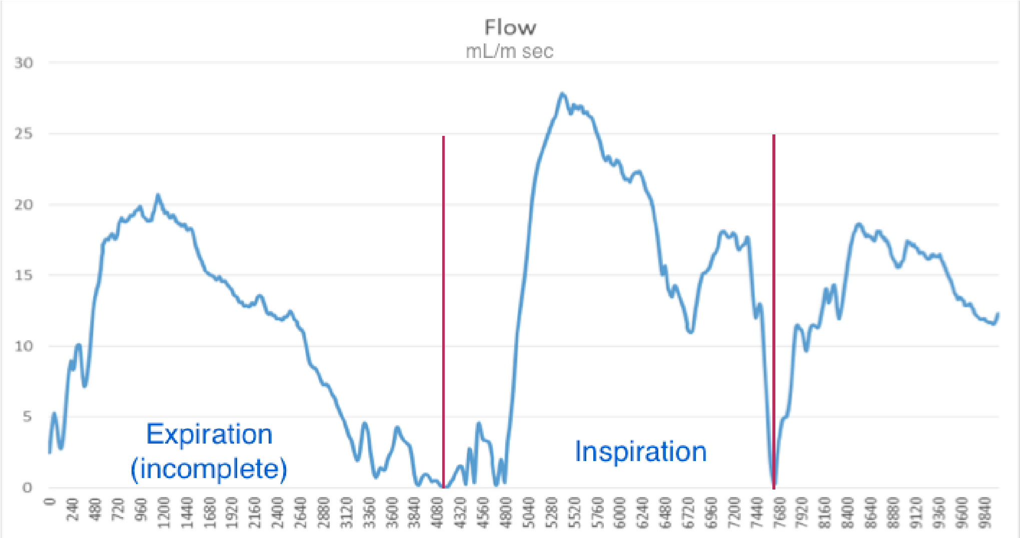

FIG 4. Incomplete expiration curve and complete inspiration curve. To the far left of the figure, the blue line does not descend low enough to be considered to start of the expiration, which occurred just before the registration started. After the expiration curve, the line dips down sufficiently enough to signal the start of the inspiration (by the first red line), the end of which is also clearly marked by the sharp descent of the blue line (by the second red line). Y-axis = millilitre, x-axis = millisecond.

4.4 Statistical analysis

To see if and how the tidal breath inspiration volume, max flow of inspiration and breaths per minute changed from the upright to the semi-recumbent position the values for the semi-recumbent position were divided with the values for the upright position and presented as an increase or decrease in percentage. This was done for each registration as well as on a group level. On a group level, a median inspiration volume, max flow of inspiration and breaths per minute were calculated using all registrations in the different body positions (see table 4-6).

In accordance with Emmace Consulting AB and CEO Mårten Svensson, a clinically significant difference in volume of inspiration and max flow of inspiration was set to 10% on a group level.

Data was analysed using descriptive statistics.

4.5 Ethical considerations

The participants were informed that participation in the study was completely voluntary and that they could withdraw from the study at any point without any explanation required. They received verbal and written information about the study (appendix 1) by the authors through personal invitation one week prior to the conduction of the test. At the time of the test, they were given the opportunity to ask questions before giving written consent. Written consent was also given to document the test using photography and video recordings (appendix 2), and to use the material in relevant publications.

The participants were recruited from physiotherapy students at Lund University as well as staff at the university hospital in Lund, and were therefore not in any situation of dependence to the researchers, in contrast to patients. The participants did not inhale any drugs and thus our assessment was that there was no risk of physical impact.

In order to not involve an unnecessary amount of participants we let each participant do six consecutive breath registrations.

An application form for ethical advisory opinion was submitted to the advisory committee for research ethics in health education at Lund University, who had no ethical objections to this study being carried out as described in the method.

5. Result

Results are presented as follows: Individual values for each registration’s inspiration volume (fig 5, table 1), max flow inspiration value (fig 6, table 2) and breaths per minute (table 3) are presented in both positions, as well as a comparison of the values. Lastly values for the entire population as a group are presented, and compared (table 4-6). In table 1-6, the shaded areas represent numbers where the volume of inspiration, inspiration max flow value and breaths per minute increase in the semi-recumbent position. The green area in table 3 represents numbers where no difference between the two positions was found.

There were 11 participants and three recordings per participant and position. The first three registrations pertains to participant one, registration 4-6 pertains to participant two and so forth.

5.1 Tidal volume and max tidal flow - per registration

Each registration’s inspiration volume is presented in figure 5 where the registrations in the upright position are matched with the registrations in the semi-recumbent position. The first registration in the upright position is compared to the first registration in the semi-recumbent position, et cetera. The inspiration volume for the upright position ranged between 0.36-1.29 litres and the inspiration volume for the semi-recumbent position ranged between 0.30-1.08 litres.

The max flow inspiration values are presented in figure 6. As with the inspiration volume, the max flow inspiration value for the first registration in the upright position is matched with the max flow inspiration value for the first registration in the semi-recumbent position, and so forth. In the upright position the max flow inspiration values ranged between 17.2 - 44.97 L/min, and in the semi-recumbent position the values ranged between 21.56 - 49.71 L/min.

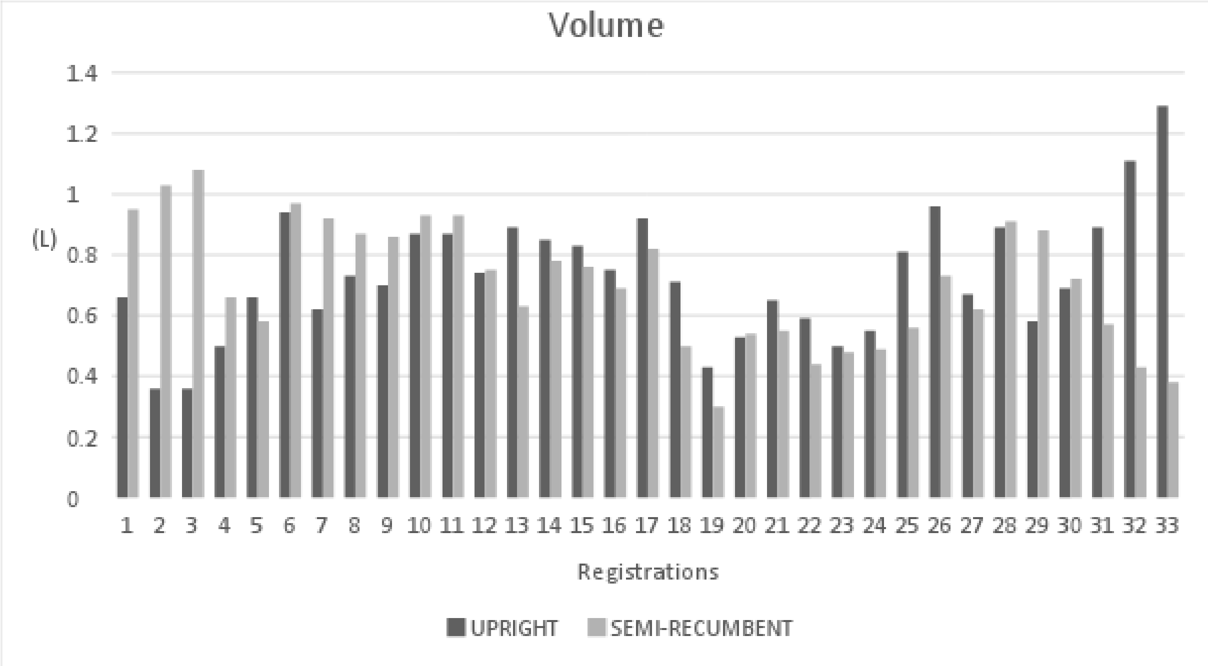

FIG 5. Tidal volume of inspiration in upright and semi-recumbent position for each registration. The first registration in the upright and semi-recumbent position are compared, the second registration in the upright and semi-recumbent position are compared, and so forth.

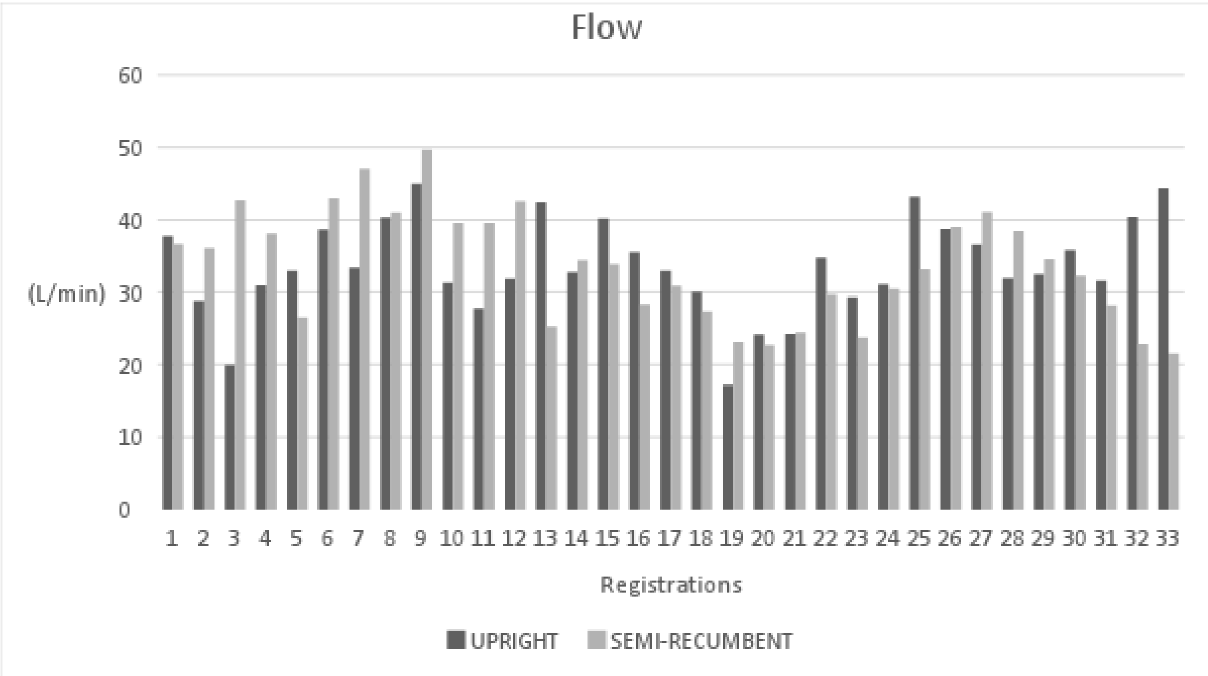

FIG 6. Tidal max flow value of inspiration in upright and semi-recumbent position for each registration. The first registration in the upright and semi-recumbent position are compared, the second registration in the upright and semi-recumbent position are compared, and so forth.

The values of inspiratory volume between the positions varied from an increase in volume of 200% in the semi-recumbent position, to a decrease in volume of 71% in the semi-recumbent position (table 1). Regarding max flow of inspiration, the greatest increase in the semi-recumbent position was 114%, whereas the greatest decrease in the semi-recumbent position was 51% (table 2).

Inspiration volume and max flow value corresponds in the majority of the registrations (26 of the 33 registrations), in how an increase of inspiration volume in one position has an increase of max flow value in the corresponding registration and position, and vice versa (table 1 and 2).

Table 1. Comparing the upright and semi-recumbent tidal inspiration volume for each registration. The difference is expressed in percentage; n = 15 increased, n = 18 decreased. Numbers showing percentage indicates a change compared to the upright position.

Registrations	Upright Inspiration volume (L)	Semi-recumbent Inspiration volume (L)	Diff
1	0,66	0,95	↑ 44 %
2	0,36	1,03	↑ 186 %
3	0,36	1,08	↑ 200 %
4	0,5	0,66	↑ 32 %
5	0,66	0,58	↓ 12 %
6	0,94	0,97	↑ 3 %
7	0,62	0,92	↑ 48 %
8	0,73	0,87	↑ 19 %
9	0,70	0,86	↑ 23 %
10	0,87	0,93	↑ 7 %
11	0,87	0,93	↑ 7 %
12	0,74	0,75	↑ 1 %
13	0,89	0,63	↓ 29 %
14	0,85	0,78	↓ 8 %
15	0,83	0,76	↓ 8 %
16	0,75	0,69	↓ 8 %
17	0,92	0,82	↓ 11 %
18	0,71	0,50	↓ 30 %
19	0,43	0,30	↓ 30 %
20	0,53	0,54	↑ 2 %
21	0,65	0,55	↓ 15 %
22	0,59	0,44	↓ 25 %
23	0,50	0,48	↓ 4 %
24	0,55	0,49	↓ 11 %
25	0,81	0,56	↓ 31 %
26	0,96	0,73	↓ 24 %
27	0,67	0,62	↓ 7 %
28	0,89	0,91	↑ 2 %
29	0,58	0,88	↑ 52 %
30	0,69	0,72	↑ 4 %
31	0,89	0,57	↓ 36 %
32	1,11	0,43	↓ 61 %
33	1,29	0,38	↓ 71 %

Table 2. Comparing the upright and semi-recumbent tidal max flow inspiration value for each registration. The difference is expressed in percentage; n = 17 increased, n = 16 decreased. Numbers showing percentage indicates a change compared to the upright position.

Registrations	Upright Inspiration max flow (L/min)	Semi-recumbent Inspiration max flow (L/min)	Diff
1	37,76	36,68	↓ 3 %
2	28,83	36,11	↑ 25 %
3	19,95	42,67	↑ 114 %
4	30,96	38,14	↑ 23 %
5	33,00	26,57	↓ 19 %
6	38,71	42,97	↑ 11 %
7	33,39	47,03	↑ 41 %
8	40,37	41,05	↑ 2 %
9	44,97	49,71	↑ 11 %
10	31,28	39,58	↑ 27 %
11	27,81	39,58	↑ 42 %
12	31,83	42,53	↑ 34 %
13	42,38	25,29	↓ 40 %
14	32,75	34,41	↑ 5 %
15	40,25	33,85	↓ 16 %
16	35,53	28,35	↓ 20 %
17	32,94	30,87	↓ 6 %
18	30,04	27,36	↓ 9 %
19	17,20	23,17	↑ 35 %
20	24,17	22,75	↓ 6 %
21	24,28	24,48	↑ 1 %
22	34,79	29,71	↓ 15 %
23	29,34	23,78	↓ 19 %
24	31,06	30,43	↓ 2 %
25	43,17	33,16	↓ 23 %
26	38,79	39,04	↑ 1 %
27	36,56	41,11	↑ 12 %
28	31,91	38,50	↑ 21 %
29	32,45	34,54	↑ 6 %
30	35,81	32,26	↓ 10 %
31	31,59	28,26	↓ 11 %
32	40,46	22,88	↓ 43 %
33	44,36	21,56	↓ 51 %

5.2 Breaths per minute - per registration

Breaths per minute are presented in table 3 below. In the upright position the number of breaths per minute differs between 7.86 - 18.99. In the semi-recumbent position the number of breaths per minute differs between 7.76 - 18.24.

In the majority of the registrations where the inspiration volume decreased, the number of breaths per minute increased (13 out 18 registrations).

Table 3. Comparing number of breaths per minute in the upright and semi-recumbent position for each registration. The difference is expressed in percentage; n = 18 increased, n = 14 decreased, n = 1 no difference. Numbers showing percentage indicates a change compared to the upright position.

Registrations	Upright Breaths per minute	Semi-recumbent Breaths per minute	Diff
1	13,13	10,17	↓ 23 %
2	11,17	10,17	↓ 9 %
3	11,61	7,76	↓ 33 %
4	14,85	16,04	↑ 8 %
5	13,89	12,82	↓ 8 %
6	9,85	10,79	↑ 10 %
7	15,35	15,75	↑ 3 %
8	15,23	14,29	↓ 6 %
9	18,99	17,75	↓ 7 %
10	9,92	7,78	↓ 22 %
11	9,39	10,51	↑ 12 %
12	9,42	9,46	0 %
13	14,08	13,25	↓ 6 %
14	12,85	14,39	↑ 12 %
15	13,82	12,53	↓9 %
16	11,86	14,15	↑ 19 %
17	10,95	13,02	↑ 19 %
18	11,45	8,24	↓ 28 %
19	12,40	15,19	↑ 23 %
20	14,60	12,47	↓ 15 %
21	11,34	11,72	↑ 3 %
22	13,99	14,12	↑ 1 %
23	12,20	13,10	↑ 7 %
24	17,86	15,04	↓ 16 %
25	16,57	17,96	↑ 8 %
26	12,68	14,16	↑ 14 %
27	16,62	18,18	↑ 9 %
28	7,86	13,33	↑ 70 %
29	13,48	9,52	↓ 29 %
30	13,70	10,60	↓ 23 %
31	10,99	13,92	↑ 27 %
32	11,32	16,22	↑ 43 %
33	11,34	18,24	↑ 61 %

5.3 Tidal volume - group

A comparison of the upright and semi-recumbent inspiration volume for all registrations as a group is presented in table 4. A minor increase of inspiration volume in the semi-recumbent position can be seen in the median value. The semi-recumbent position convey a smaller minimal and maximal inspiration volume than the upright position.

Table 4. Comparison of tidal volume of inspiration in the two body positions. The median values for all 33 registrations in their respective positions, as well as minimal and maximal values, and values for the 1st and 3rd quartile. Numbers showing percentage indicates a change compared to the upright position.

	Upright inspiration volume (L)	Semi-recumbent inspiration volume (L)	Diff
Min	0.36	0.30	↓ 17 %
1st	0.59	0.55	↓ 7 %
Median	0.71	0.72	↑ 1 %
3rd	0.87	0.88	↑ 1 %
Max	1.29	1.08	↓ 16 %

5.4 Tidal max flow inspiration value - group

In table 5 the max flow inspiration values for all registrations as a group are compared in the two different body positions. A small increase can be seen in the median value from the upright to the semi-recumbent position. The semi-recumbent positions convey a greater minimal and maximal max flow value than the upright position.

Table 5. Comparison of tidal max flow values in the two body positions. The median values for all 33 registrations in their respective positions, as well as minimal and maximal values, and values for the 1st and 3rd quartile. Numbers showing percentage indicates a change compared to the upright position.

	Upright inspiration max flow (L/min)	Semi-recumbent inspiration max flow (L/min)	Diff
Min	17.20	21.56	↑ 25 %
1st	30.96	27.36	↓ 12 %
Median	32.94	33.85	↑ 3 %
3rd	38.71	39.58	↑ 2 %
Max	44.97	49.71	↑ 11 %

5.5 Breaths per minute - group

Number of breaths per minute based on all registrations are seen in table 6. A small increase in number of breaths per minute based on the median value can be seen from the upright position to the semi-recumbent position. The minimal and maximal value of the breaths per minute in the two positions are exceedingly similar.

Table 6. Difference in number of breaths per minute in the two body positions. The median values for all 33 registrations in their respective positions, as well as minimal and maximal values, and values for the 1st and 3rd quartile. Numbers showing percentage indicates a change compared to the upright position.

	Upright breaths per minute	Semi-recumbent breaths per minute	Diff
Min	7.86	7.76	↓ 1 %
1st	11.32	10.60	↓ 6 %
Median	12.68	13.25	↑ 4 %
3rd	14.08	15.04	↑ 7 %
Max	18.99	18.24	↓ 4 %

6. Discussion

In the discussion section we highlight advantages and disadvantages of the methodology and discuss the results of the present study, as well as discuss our expectations and how they were or were not met.

6.1 Method

To the extent of our knowledge no previous study has measured tidal breathing in different body positions, which makes the study design of the present study one of its' greatest advantages. Due to the fact that fast, rapid breaths cause unwanted turbulent airflow and slow, deep breaths are recommended for inhalation therapy (8, 9), one can argue that tidal volume is a more clinically relevant measure than maximal forced inspiratory volume and maximal forced expiratory volume such as utilized by Lumb et al. (14) when inhalation therapy using a nebuliser or a pMDI is concerned.

The participants in the present study differed in age, sex and body size making them a heterogeneous group, which could make the result more representative of the general population. However, all participants were of good health at the time of the study, something possibly unlikely to cohere with an individual in need of inhalation therapy. The majority of the participants were physiotherapists or physiotherapy students and as such has knowledge of breathing physiology and mechanics, as well as a possible greater than average body awareness, which could contribute to them being more mindful of how they breathe.

The participants in the present study were unable to breathe through their nose due to the use of a mouthpiece in conjunction with the mass flow measurer and a nose clip being placed on their nose, much like in the study conducted by Sá et al (12). This could be seen as unnatural, as many adults tend to breathe through their nose. Using a face mask could possibly encourage more natural breathing in the participants, at the same time however adding an increased risk of air leakage, along with the fact that a face mask is another unnatural element. Evidence suggests that breathing through the mouth increases the particle deposition in the lungs compared to nasal breathing (9), thus supporting our decision to use a mouthpiece.

In the present study, the starting position of the participant was always the same; the upright, seated position. Not randomising in this instance means we had control over a possible learning curve; we know that all participants had the same starting point. However, this also means that each participant did have a learning curve where once they were placed in the semi-recumbent position, they knew the procedure which could affect the outcome. The reasoning behind our choice also came from concern for the participant; starting in a seated position could be perceived as more comfortable and with more control compared to a semi-recumbent position, therefore a more agreeable starting position. We saw no indication that a learning curve affected registrations in each position, seeing as values varied greatly between registrations.

The seated, slightly forward leaning and supported position chosen as the starting position, was a position we as students of physiotherapy are taught to be a more favorable position, where the elbow support allows for more relaxed accessory muscles of respiration, especially in patients with respiratory disorders (16). A seated, slightly forward leaning position has also been proven to be a more favorable position in patients with acute asthma attacks (15). A supine position, as well as a slumped position, increases the pressure of abdominal contents on the lungs, leading to decreased FRC (16). However, in our study in did not affect our healthy subjects tidal breathing on a group level.

The software used in the present study allowed for a maximum registration time of 10 seconds where each registration session lasted approximately 40 seconds. This could arguably be a too short amount of time to normalise one's breathing in an unnatural situation. To get around this, a different approach could have been to let the participant breathe in the mouthpiece for a longer period of time, with the registrations starting after a set amount of time had passed, again without the participant knowing when the registrations started. The 10 second registrations also proved to be sub-optimal in three registrations, where the participant did not complete a full inspiration and/or expiration. Future studies could consider recording the same number of breaths a set amount of solution, ie saline, in nebulised form needs in order to be fully inhaled.

The process of extracting the in/expiration data was time consuming, as the mass flow measurer used did not automatically differ inspiration from expiration. The curves seen in figure 3 and 4 had to be created by manually extracting the relevant data from Microsoft Excel. In a future study, we strongly suggest using a different device, one sensitive to airflow direction.

It is previously known that knowledge of your breathing being monitored will affect your breathing. This would however be difficult to completely avoid in a clinical study. Modifying your behaviour or performance when you are aware of that you are being studied, in accordance to the perceived expectations or attention of the investigators, is known as the Hawthorne effect (18). As the participants in the present study were not made aware of our theory of decreasing volumes and flows in the semi-recumbent position, the perceived expectations they wanted to meet were perhaps different than the result we actually expected.

To be able to generalise to a greater population we would have used a randomised sample, calculated power and possibly have had a greater amount of registrations. A greater number of registrations was not possible given the resources available to us. In spite of this, we do have a reasonable generous amount of registrations, which we compare individually and on a group level. It is previously known (19) that there is considerable variation around numbers pertaining to normal breathing; due to these variations, studies where breathing and tidal breathing is looked at should aim to involve a great number of registrations. When calculating the median the data does not have to follow the normal distribution (20). In light of this, we chose to calculate the median when looking the values on a group level, as the values at first glance appears skewed due to a few registrations being quite different from the rest. However, when calculating the mean we found that the mean and median were very similar in value and either one had been representative of the group.

6.2 Result

Many factors could contribute to the wide range of results derived from the study. As previously stated, there is a considerable variation in what is considered normal volume and flow (19), which could explain the differences between registrations. The present study contributes to an increased understanding of inspiration patterns in different body positions, as it showed a result perhaps not expected.

Based on previous studies (12,14,15) we would have expected a greater number of registrations to have a similar ratio *volume in upright* to *volume in semi-recumbent* to that in registrations 32 and 33 (see fig 5), albeit with a smaller overall volume. The previous studies did however look at maximal inspiration volume, which is a very different value than the values garnered from tidal volume.

Typical tidal volume is often said to be 500 ml (19) whereas the majority of the volume registrations in both body positions in the present study is significantly greater. The median of breaths per minute (see table 6) is slightly lower than the average, which West (19) quotes as 15 breaths per minute. An increase in volume of inspiration could explain a decrease in breaths per minute. In 18 registrations the inspiration volume decreased from the upright to the semi-recumbent position. Of these 18 registrations, a total of 13 registrations showed an increase in breaths per minute. Had the majority of the inspiration volumes been closer to 500 ml in the upright position and shown a decrease in volume in the semi-recumbent position, it is possible to assume that a greater number of registrations had shown an increase in breaths per minute in the semi-recumbent position in order to compensate for the diminished inspiration volume.

On a group level, the present study produced no significant difference in inspiration volume, max flow value or breaths per minute in the two positions. This lead to us not continuing with the fourth question, "*If a significant difference in breathing patterns on a group level is identified, how is the drug deposited in a device for aerodynamic size fractionation of aerosol clouds?*". As mentioned above, previous studies (12,14,15) have seen a difference between positions, however, these studies looked at maximal inspiratory and expiratory volume, something perhaps not relevant when discussing how breathing impacts inhalation forms where tidal volume is advised. By looking at tidal breathing, the present study looked at the specific values relevant to inhalation therapy, which we argue increases the clinical relevance.

7. Conclusion and clinical relevance

Individual results in the present study differs and there is considerable variation of tidal inspiration volume, max flow of tidal inspiration and breaths per minute. In spite of this, when analyzing group values the differences in inspiration pattern between positions are insignificant. With a different population, such as patients with respiratory disorders, results might have been different and perhaps shown a greater clinical difference in tidal inspiration volume, max flow of tidal inspiration and breaths per minute.

For a specific patient group, ie COPD, asthma or cystic fibrosis patients, this study is not automatically relevant and further studies with patient groups are required before we could change recommendations. However, from the results of this study, we can conclude that the healthy adults' tidal breathing was not dependent on them being in a seated, upright position or a semi-recumbent position. As a result of this, without measuring, we deduct that the deposition of inhalation medication would not have differed much either.

8. References

1. Pai VB, Nahata MC. Efficacy and safety of aerosolized tobramycin in cystic fibrosis. Pediatr Pulmonol. Pediatr Pulmonol. 2001;32(4):314-27.
2. Zarogoulidis P, Darwiche K, Hohenforst-Schmidt W, Huang H, Li Q, Freitag L, et al. Inhaled gene therapy in lung cancer: proof-of-concept for nano-oncology and nanobiotechnology in the management of lung cancer. Future Oncol. 2013;9(8):1171-94. Doi:10.2217.
3. Bonini M, Usmani OS. The importance of inhaler devices in the treatment of COPD. COPD Res. Pract. 2015 Sept.
4. Laube BL. Aerosolized Medications for Gene and Peptide Therapy. Respir Care. 2015;60(6):806-21.
5. Dunbar CA, Hickey AJ, Holzner P. Dispersion and characterization of pharmaceutical dry powder aerosols. KONA Powder Part J. 1998;16:7–45.
6. Goralski JL, Davis SD. Breathing easier: addressing the challenges of aerosolizing medications to infants and preschoolers. Respir Med. 2014;108(8):1069-74.
7. Colombo P, Traini D, Buttini F, editor(s). Inhalation drug delivery: Techniques and products [Internet]. John Wiley & Sons, Ltd; 2013. [cited 2017 Apr 04]. Available from: http://onlinelibrary.wiley.com/book/10.1002/9781118397145.
8. Everard ML. Inhaler devices in infants and children: Challenges and solutions. J Aerosol Med. 2004;17(2):186-195.
9. Schuepp KG, Straub D, Möller A, Wildhaber JH. Deposition of aerosols in infants and children. J Aerosol Med. 2004;17(2):153-156.
10. Darquenne C. Aerosol deposition in health and disease. J Aerosol Med Pulm Drug Deliv. 2012;25(3):140–147.
11. Hess DR. Aerosol delivery devices in the treatment of asthma. Respir Care. 2008 Jun;53(6):699-723; discussion 723-5.
12. Sá RC, Zeman KL, Bennett WD, Prisk GK, Darquenne C. Effect of posture on regional deposition of coarse particles in the healthy human lung. J Aerosol Med Pul Drug Deliv. 2015;28(6):423-31. Doi:10.1089.
13. Kamps AW, Van Ewijk B, Roorda RJ, Brand PL. Poor inhalation technique, even after inhalation instructions, in children with asthma. Pediatr Pulmonol. 2000;29(1):39-42.
14. Lumb AB, Nunn JF. Respiratory function and ribcage contribution to ventilation in body position commonly used during anesthesia. Anesth Analg. 1991;73:422-6.
15. Brandão DC, Britto MC, Pessoa MF, de Sá RB, Alcoforado L, Matos LO, et al. Heliox and forward-leaning posture improve the efficacy of nebulized bronchodilator in acute asthma: a randomized trial. Respir Care. 2011;56(7):947-52.
16. Olséni L, Wollmer P. Sjukgymnastik vid nedsatt lungfunktion. 2nd edition. Lund: Studentlitteratur; 2003.
17. TSI 4040 mass flowmeter for gases with LCD [Internet]. [date unknown; cited 2017-29-03]. Available from: http://www.valuetesters.com/tsi-4040-mass-flowmeter-for-gases-with-lcd-1.html
18. McCambridge J, Witton J, Elbourne DR. Systematic review of the Hawthorne effect: new concepts are needed to study research participation effects. J Clin Epidemiol. 2014 Mar;67(3):267-77. doi: 10.1016/j.jclinepi.2013.08.015.
19. West JB. Respiratory physiology - the essentials. 5th edition. Baltimore: Williams & Wilkins; 1995.
20. Ejlertsson G. Statistik för hälsovetenskaperna. Lund: Studentlitteratur; 2003.

Appendix 1

LUNDS UNIVERSITET
Medicinska fakulteten
Institutionen för hälsovetenskaper

Jämförelse av olika kroppspositioners påverkan på andning och inhalationsmönster

Du tillfrågas om deltagande i ovanstående studie.

Deltagandet innebär att Du kommer till SUS Lund där dina andetag kommer att registreras i två olika kroppspositioner; sittandes på en stol och halvliggandes i en sjukhussäng. Andetagen registreras genom att Du andas med ett munstycke som är kopplat till en inspelningsapparat. Du kommer att andas vanligt, utan någon extra ansträngning i två minuter per registrering. För de olika kroppspositionerna kommer tre registreringar att göras vilket innebär en tidsåtgång på 12 minuter. Räkna med en total tidsåtgång på ca 30 minuter. Du kommer inte andas in någon form av läkemedel under andningsregistreringen, utan enbart andas vanligt.

Syftet med studien är att undersöka om andetagskvalité och inhalationsmönster påverkas vid olika kroppspositioner.

Vår bedömning är att deltagandet i studien inte är förenat med några risker eller obehag.

Den insamlade datan kommer att förvaras så att ingen obehörig kan ta del av den. Informationen kommer att avidentifieras när den matas in i analyssystemet. Resultaten kommer att redovisas på gruppnivå och kommer ej kunna härledas till någon enskild person.

Deltagandet är helt frivilligt och Du kan avbryta när som helst utan att du behöver ange varför.

Om Du vill delta ber vi Dig underteckna samtyckesblanketten.
Studien ingår som ett examensarbete i fysioterapeutprogrammet.
Om Du har några frågor eller vill veta mer, kontakta gärna oss eller vår handledare.

Med vänlig hälsning

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Appendix 2

Skånes universitetssjukhus
En del av Region Skåne

Medgivande användning av bilder

Undertecknad har frivilligt deltagit i fotografering vid Skånes universitetssjukhus.

Jag lämnar härmed mitt medgivande till att bilden/bilderna används publikt som tillhör Skånes universitetssjukhus.

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