AUTOMATED DIASTOLIC BLOOD PRESSURE (ADBP) VARIATION ON RESPIRATORY PATTERN

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Abstract: *The two components of blood pressure are systolic pressure and diastolic pressure. Systolic pressure replicates the pressure inside arteries when the heart pumps while Diastolic Blood Pressure represents the pressure when the heart relaxes between beats. However, the two components of respiration are inhalation and exhalation. Blood Pressure is established to decrease during inhalation and increase during exhalation. To effectively use this approach to reduce BP more, study of different respiratory pattern could be of important. It has been showed deep breathing exercises could reduce automated diastolic blood pressure (ADBP).This study aimed to quantitatively investigate the effect of different breathing pattern on ADBP. It involved forty healthy subjects (15males and 25 females, aged from 18 to 60 years). ADBP were measured using a clinically validated automated blood pressure device. Two repeated measurement sessions were employed for each subject. Eight ADBP measurements were performed within each session. This includes four measurements during breathing using different patterns (Pattern 1: 4.5sec of inhalation and exhalation each; Pattern 2: 6sec inhalation and 2s exhalation; Pattern 3: 2sec inhalation and 6sec exhalation; Pattern 4: 1.5s inhalation and exhalation), and additional 4 measurements from 1 min after different breathing patterns. At the beginning and end of the two measurement sessions, there were two baseline ADBP measurements under resting condition. Lastly, the effect of breathing patterns on ADBP during and after deep breathing was analysed with the baseline ADBP. Experimental results showed that overall ADBP during deep breathing in Pattern 1, 2 and 4 were decreased by 3.7 ± 5.0 mmHg, 3.7 ± 4.9 mmHg and 4.6 ± 3.9 mmHg respectively (all $p < 0.001$, except in Pattern 3 with a decrease of 1.0 ± 4.3 mmHg, $p = 0.14$).To conclude, ADBP decrease with different breathing patterns has been quantitatively demonstrated.*

Keywords: *Automated, Diastolic, Blood pressure, Respiratory pattern*

1 INTRODUCTION

Deep breathing has been widely acknowledged as one of the significant features imposing a physiological change in blood pressure (Zheng et al., 2012). Breathing is the process by which air is inhaled into the lungs and is being exhaled via the nose or mouth. Two mechanisms involved in breathing are inspiration and expiration. Inspiration or inhalation involves taking oxygen into the body. During inspiration, inter costal muscles between the ribs contract, and get the ribs raised upward and outward, the ribcage is then expanded. Also, the diaphragm contracts, flattens, pulls down, and causes an increase in thorax volume. This lowers the pressure inside the thorax and gets air sucked into the lungs (Martini and Nath, 2009; Moini, 2012). Expiration or exhalation takes carbon dioxide out of the body. During exhalation, inter costal muscles relax and lower the ribs downward, causing the diaphragm to relax and move back upwards. This causes a decrease in thorax volume, which as a result, increases the pressure inside the thorax and forces air out of the lungs (Martini and Nath, 2009; Moini, 2012). Normal breathing also called apnea is involuntary and rhythmic (Moini, 2012; Martini and Bartholomew, 2007). Breathing pattern is characterized by the rate, depth, timing and consistency of breaths during inhalation and exhalation processes. It differs between individuals depending on their health condition (Thibodeau, 2010; Hubbard and Falco, 2015). Unfortunately, blood pressure measurement error could be generated from the measurements which do not follow the recommended guidelines (Fahey, Murphy and Hart, 2004). The importance of accurate and reliable BP measurement cannot be over emphasized (Mulrow, 2001; MacGregor and Kaplan, 2006). Firstly, it could systematically prevent BP overestimation, and reduce the number of patients who inappropriately receive unnecessary treatment. Secondly, it halts BP underestimation that denies access to essential treatment. Thirdly, it could reduce the incidence of alleviated cardiovascular situations in people with high BP. Fourthly, routine and accurate BP measurement helps in early prediction, prevention and treatment of high BP related diseases, including heart disease, kidney failure and stroke which have been shown to be global leading factors to death and disability. Accurate, reliable and routine BP measurement could ultimately reduce health cost for the society.To achieve accurate BP measurement, several international organisations including the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure (JNCDETHP) (1980), British

Hypertension Society (BHS) (1999), European Society of Hypertension (ESH) (2003), American Heart Association (AHA) (2005),American Heart Association, 2014; European Society of Cardiology (ESC) (2015), European Respiratory Society (ERS) (2015) and Canadian Hypertension Education Program Guidelines for Blood Pressure Measurement, Diagnosis, and Assessment (2016) have produced recommended guidelines (Shapiro, et al., 1996; ACOG Committee on Obstetric Practice, 2002; Lemogoum, et al., 2003; O'Brien, et al., 2005; Pickering, et al., 2005; Krause, et al., 2011; American Heart Association, 2014; Sharman, et al., 2016).

2 METHODS

2.1 Subjects

Forty healthy subjects, 15males and 25 females, aged 18 to 60, were employed and all gave their written informed consent to participate in the study. The inclusion conditions were, normal healthy individual with no known hypertension and antihypertensive medical treatment, or cardiovascular. Subject demographic data, including age, weight, height and arm circumference is shown in Table 1.

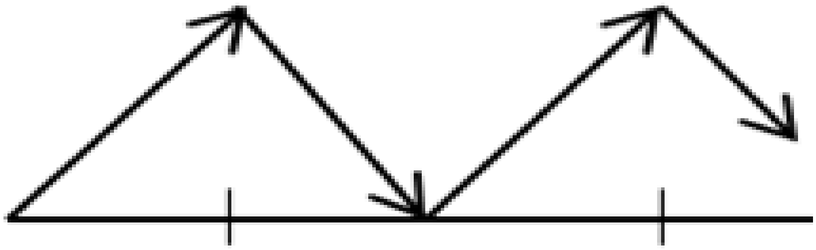
Table 1. Demographic data for the subjects studied

Data	Minimum	Maximum	Mean
Age	18	60	36
Height(cm)	150	180	169
Weight(kg)	51	108	74
Arm circumference (cm)	24	40	31

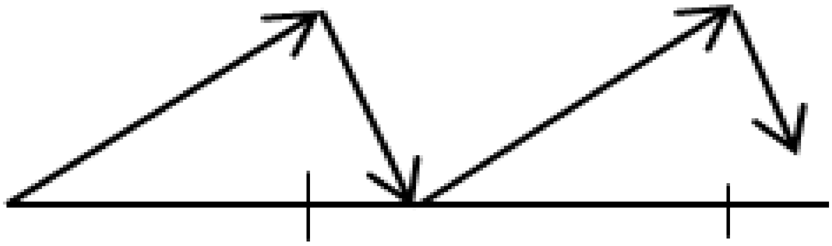
2.2. Measurement protocol and procedure

The study was conducted in a quiet, lighted, air conditioned measurement room to make subjects comfortable during the measurement process. At first, subjects were asked to rest in a seated position with no crossed hands and legs for 5 minutes before the proper ADBP measurement. ADBP were measured from the left arm using a suitable a clinically validated automated Omron, M6 Comfort, Blood Pressure that is clinically validated and approved by British Hypertension Society (2016).

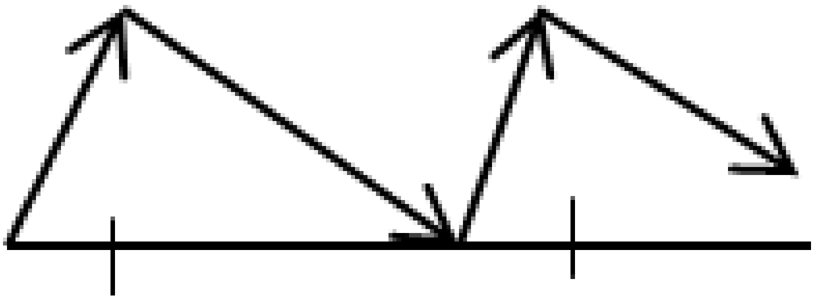
The measurement was taken for four different respiratory patterns as shown in figure 1a, b, c and d below with order of sequence randomised between subjects.



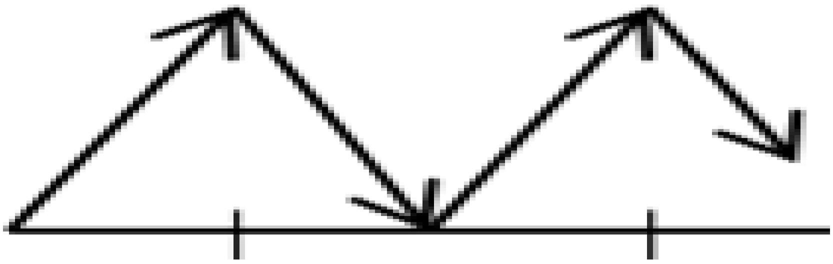
a) Pattern 1: 4.5 sec of inhalation and 4.5 sec exhalation



b) Pattern 2: 6 sec inhalation and 2 sec exhalation



c) Pattern 3: 2 sec inhalation and 6 sec exhalation



d) Pattern 4: 1.5 sec inhalation and 1.5 sec exhalation

Figure 1. a, b, c, d: Illustration of four different respiratory patterns "↗ "shows inhalation while " ↘ " shows exhalation)

A paced breathing android application on Google Play mobile phone designed to regulate time of inhalation and exhalation and to also show graphical breathing patterns was utilized. This is to enable subjects to synchronize their breathing with each chosen pattern in the course of ADBP measurement of the four breathing patterns. Each subject was asked to rehearse to be accustomed with the four respiratory patterns before the proper experimental measurement. Two repeated measurement sessions for each subject was involved. There were two baseline ADBP measurements under resting condition at the beginning and end of the two sessions. Eight ADBP measurements were performed within each session which includes four measurements during breathing using four different respiratory patterns and additional measurements after different patterns of deep breathing with one minute rest interval. Figure 2 shows the measurement procedure in this study.

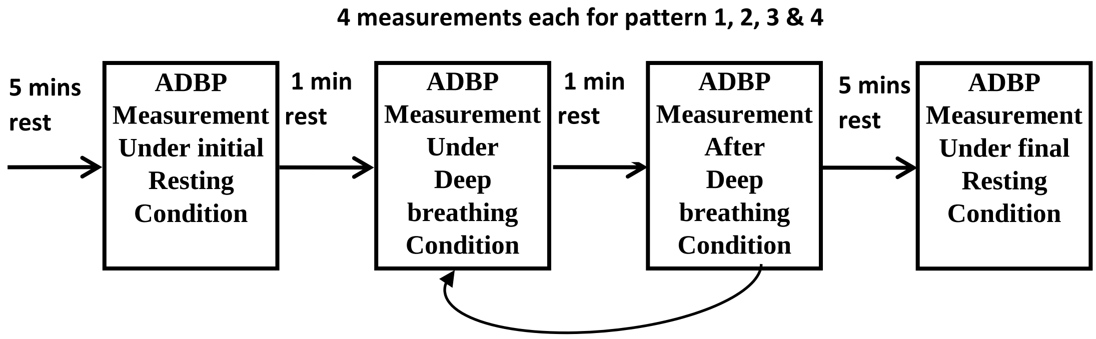


Figure 2: BP measurement procedure in this study

3 DATA AND STATISTICAL ANALYSIS

Excel Spread sheet was used to store all measured data. This was then transferred to and analysed in SPSS 20.0 statistical software The means of ADBP were calculated for baseline and for during and after different respiratory patterns for deep breathings. Analysis of variance was also performed to investigate ADBP measurement repeatability. The effect of respiratory pattern on ADBP and its differences during and after deep breathing were also analysed. P-value beneath 0.05 was considered statistically significant.

4 RESULTS

4.1 BP measurement repeatability

With ANOVA analysis the baseline ADBP measurements showed that the beginning and end of the main measurement sessions were repeatable with p value of 0.5 ($p = 0.5$) for ADBP. Likewise, ADBP measurements during and after deep breathing were repeatable between the repeat sessions with p value of 0.2 ($p = 0.2$) for ADBP. Hence, the Baseline mean value was used for further analysis.

4.2 ADBP changes during and after deep breathing in comparison with Baseline

In comparison with ADBP Baseline, ADBP in Patterns 1, 2 and 4 during deep breathing decreased significantly by 3.7 ± 5.0 mmHg, 3.7 ± 4.9 mmHg and 4.6 ± 3.9mmHg respectively (all p<0.001) ADBP in Pattern 3 did not decrease significantly in comparison with Baseline with the difference of 1.0 ± 4.3mmHg (p = 0.14).The results of ADBP after deep breathing show no significant changes in comparison with Baseline. ADBP in Patterns 1, 2, 3 and 4 decreased of -0.09 ± 4.15 mmHg, -0.14 ± 2.71 mmHg, 0.45 ± 2.71 mmHg and 0.46 ± 3.16 mmHg respectively (all p > 0.05).Figure 3 displays the ADBP baseline and ADBP measured during and after deep breathing while table 2 shows the means and standard deviation (Means± SDs) of ADBP measured during and after deep breathing, and their differences in comparison with ADBPs baseline. Figure 4 shows ADBP decrease in comparison with base line during and after deep breathings.

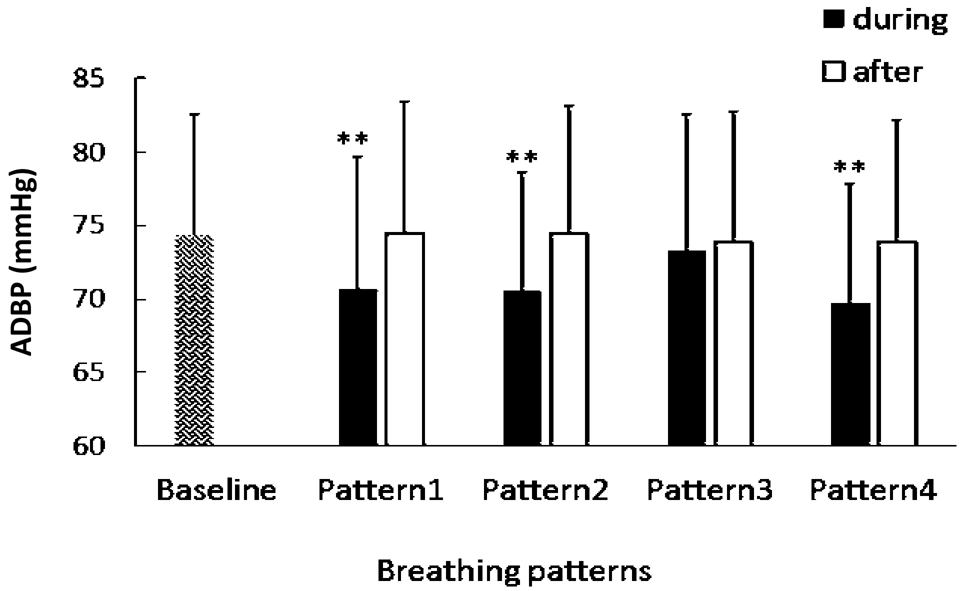


Figure 3: Means ± SDs of ADBP measured during and after deep breathing. ***p< 0.001; ***p**< 0.05in comparison with base line ADBP shows the results from different respiratory pattern**

Table 2: Means ± SDs of ADBP measured during and after deep breathing, and their differences in comparison with baseline ADBP. ***p< 0.001; ***p**< 0.05**

	Breathing Pattern	During breathing	BP decrease	After breathing	BP decrease
ADBP (mmHg)	Baseline	74.4 ± 8.2			
	Pattern 1	70.7 ± 9.0	3.7 ± 5.0 **	74.4 ± 9.0	-0.1 ± 4.1
	Pattern 2	70.7 ± 8.0	3.7 ± 4.9 **	74.5 ± 8.6	-0.1 ± 3.3
	Pattern 3	73.3 ± 9.2	1.0 ± 4.3	73.9 ± 8.8	0.5 ± 2.7
	Pattern 4	69.7 ± 8.2	4.6 ± 3.9 **	73.9 ± 8.3	0.5 ± 3.2

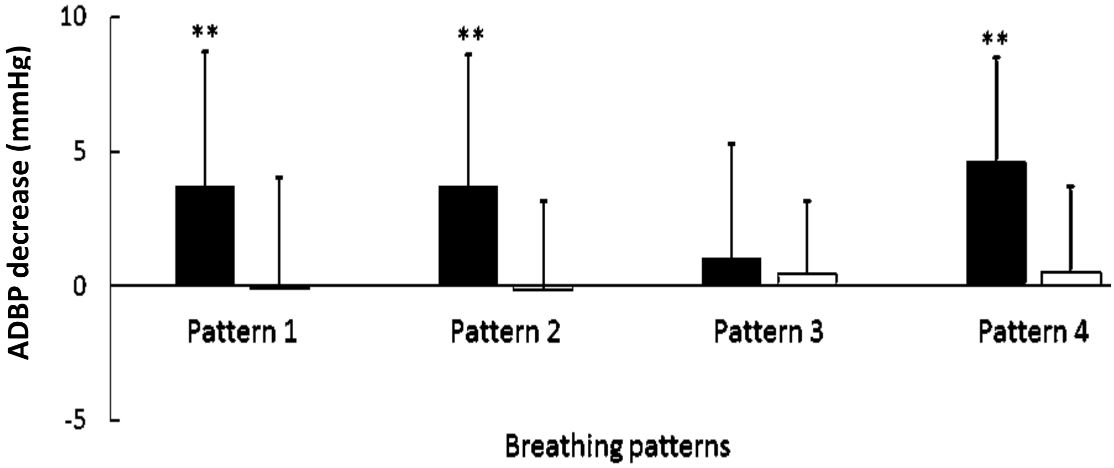


Figure 4: ADBP decrease in comparison with baseline during and after deep breathings.

5 DISCUSSION AND CONCLUSION

The effect of four different breathing patterns on ADBPs has been quantitatively demonstrated in this study. From the results Pattern 1achieved a significant decrease in ADBP by 3.7 ± 5.0 mmHg(p < 0.001).Pattern 2 showed a significant decrease in ADBP with 3.7 ± 4.9 mmHg. Pattern 3 did not show a significant ADBP decrease (1.0 ± 4.3 mmHg). Pattern 4 showed a significant ADBP decrease of 4.6 ± 3.9 mmHg.

These results agreed with the previous studies that blood pressure was reduced due to the autonomic imbalance, which reduced the arterial bar reflex sensitivity (Linsenbardt, Thomas, and Madsen, 1992; Maryon-Davis & Stewart., 2005; Meuret, Wilhelm, and Roth, 2001; Mourya,et al., 2009; Oneda, et al., 2010; NICE guidelines., 2011; Mohamed, Hanafy, and E-Naby., 2013). For Pattern 3, the physiology of exhalation relates to relaxation of diaphragm and an increase of intra thoracic pressure that refills the left ventricle with blood that resulted in the increase (Mourya,et al., 2009; Jacob, et al., 1992; Meuret, Wilhelm, and Roth, 2001; Anderson, McNeely, and Windham, 2010; Bhavanani, Madanmohan and Sanjay, 2012; Telles, Joshi, and Somvanshi., 2012; Prem, Sahoo, and Adhikari, 2012; Mohamed, Hanafy and E-Naby., 2013;Matthew, 2015).

However, the differences in the results of different breathing patterns ischaracterized by the rate, depth, timing and consistency of breaths during inhalation and exhalation processes (Thibodeau, 2010; Rickard, Reichand Dunn, 2014; Hubbard and Falco, 2015).

In conclusion, the effect of four different breathing patterns on ADBPs has been quantitatively demonstrated in this study

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