ORIGINAL ARTICLE

Correlation between blood pressure and lung function in Malaysian adult population

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ABSTRACT

Introduction: The correlation between pulmonary function and hypertension remains ambiguous. This study therefore determined the relationship between pulmonary function and hypertension among adult subgroup in Malaysia.

Materials and Methods: Data for this study were obtained from an ongoing Prospective Urban Rural Epidemiology-Rural Urban Study (PURE RUS) , which is a prospective cohort study done by MARA University of Technology (UiTM) Medical Faculty research team to track risk factors, changing lifestyles, and chronic diseases in rural and urban population. The inclusion criteria included: Malaysian citizen, age 18–80 years, not on any anti-hypertensive agents, and able to perform lung function test. 1640 participants satisfied the criteria and were recruited in this study.

Results: From the studied population, males comprised 43.5% of them and female comprised 56.5%. A significant inverse relationship was found between pulmonary function and systolic blood pressure in both sexes measured by forced vital capacity (FVC) and Forced Expiratory Volume in 1 second (FEV1). A substantial inverse relationship was also found between pulmonary function and age, and there was a profound positive association between blood pressure and age. No major disparities were significant in pulmonary function between hypertensive and age-matched normotensive participants.

Conclusion: Even though a substantial inverse relationship was evident between systolic blood pressure and pulmonary function, its precise clinical importance needs to be further explored particularly when age can influence both pulmonary function and blood pressure. Clearly, the impact of age has to be removed before FVC can be used as a prognosticator of hypertension.

KEYWORDS:
Pulmonary function, blood pressure, hypertension

INTRODUCTION

Hypertension is one of the main risk factors for cardiovascular, cerebro-vascular, and renal diseases.[1] About 4.5% of the global disease burden has been estimated to be caused by hypertension and it is prevalent in many developing and developed countries around the world.[2] Based on the national prevalence of hypertension in Malaysia is 32.7% for residents aged 18 years and older.[3] This is higher than that reported in the United States (28% in 2010).[4]

An inverse correlation between pulmonary function and blood pressure has been found in few research. Baseline forced vital capacity (FVC) was noted to be inversely correlated to probability of developing hypertension, and this correlation was not affected by weight, blood pressure, age, and cigarette smoking.[5] A strong inverted correlation between FVC and the probability of developing high blood pressure has also been described in another study.[6] These two studies established that FVC is a valuable prognosticator of further development of high blood pressure. An earlier study in China reported a reverse correlation between pulmonary function and blood pressure in the Chinese population but the relationship was very weak.[7] A study in Germany, on the other hand reported that hypertension and the consumption of beta blockers, are strongly linked with reduced pulmonary function in the German population of adult.[8] In contrast, another research, also in Germany, found that hypertension in blend with antihypertensive medications and not high blood pressure itself may possibly be linked with reduced pulmonary function in the overall mature population.[9] A more recent paper from Korea concluded that hypertension might be linked with an augmented deterioration in FVC, and high blood pressure medications might reduce the rate of deterioration in healthy subjects who have no symptom.[10] The precise reason/s for the differences in the findings and in the strength of the link between pulmonary function and hypertension in these researches is unclear. It is possible the differences might be due to the differences in race, regions, or study methodologies used. Association between hypertension and pulmonary function in a community-based setting has also not been well investigated in Malaysian population. Hence, the objective of this analysis is to explore if there is any significant association between hypertension and pulmonary function in the Malaysian adult population. Given that Malaysia is a multi-racial society, the findings in this study might alter the perception on the association between hypertension and pulmonary function. This study also attempts to look at age and sex as the confounding

This article was accepted: 10 August 2022
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factors that may or may not affect the inverse relationship between hypertension and pulmonary function.

MATERIALS AND METHODS

Study Design

Data for the analysis of correlation between pulmonary function and blood pressure were derived from an ongoing PURE RUS study. This study is a prospective cohort study done by UITM Medical Faculty research team to trace changing risk factors, lifestyles, and chronic disease in rural and urban settings. It is a continuing 15-year longitudinal and cross-sectional study, commenced in 2008. Baseline lung function data of adult men and women, rural and urban, from east and west Malaysia were collected. The inclusion criteria consisted of: Malaysian citizen, aged 18–80 years, not on any anti-hypertensive (anti-HPT) medications and able to perform lung function test. An overall of 1640 subjects matched the standard criteria and were enrolled in this study.

Ethical Consideration

Consent had been received from all subjects during the recruitment for the PURE RUS to the usage of their data for other related studies. The usage of the data for this study analysis was endorsed by Universiti Teknologi MARA (UiTM) Ethics Committee, which governs all studies involving humans by staff and students of the centre. Research Ethics Code (Rec): REC/UITM/2007(10).

Pulmonary Function

Pulmonary function tests were performed by qualified personnel involved in the research team. Pulmonary function was assessed via a portable Spirometer (Micro Medical Ltd.). Before the test, the correct procedure was demonstrated to all the participants by the assessor and the subjects were supervised throughout the tests. Spirometric measurements were recorded while the subject was standing, with at least one minute rest in between the repetitive measurements, and were done according to the American Thoracic Society (ATS) requirements.[11] The subjects completed at least three forced expiratory pulmonary function tests in order to acquire a minimum of two satisfactory and reproducible readings. The average of two best recordings was recorded. The parameters measured were FVC and forced expiratory volume in 1 sec (FEV_1). The most excellent results for FEV_1 and FVC were obtained and percent predicted values were determined based on Crapo et al.[12]. However, the predicted values were not used in the correlation, as the predicted value is consistently higher than the actual value.

Hypertension, Medical Treatments, and Other Factors

Blood pressure measurement was obtained from the right arm in a sitting position using an automated blood pressure recorder (Omron HEM-757).[9] Apart from that, anthropometric values, computer-assisted standardized feedback form and self-administered surveys on lifestyle and health-related aspects, medical history, and pulmonary symptoms were completed. Lung diseases such as asthma were established from self-reported physician's analysis. The smoking status (current, former, or never-smokers) was evaluated from patient's own self-assessment.

Statistical Analysis

Statistical analysis was conducted using statistical assessments contained in Statistical Package for Social Sciences (SPSS) Version 20.0 software. Measure of central tendencies, the frequency distribution, and measure of distribution were calculated. The normality of continuous data was confirmed by Kolmogorov-Smirnov testing. α=0.05 was set as the significant level. The normally distributed continuous data are shown as mean and standard deviation. The categorical data is presented in the form of absolute numbers and their corresponding percentage values. Pearson's correlation coefficient was applied to ascertain the relationship between systolic blood pressure (SBP), FEV_1, and FVC. Simple linear regression was used for univariate analysis for the association between independent variables and the outcome (FEV_1 and FVC). All significant variables in simple linear regression were adjusted for the confounding factor using multiple linear regressions.

RESULTS

Characteristics of the 1640 participants involved in this study are presented in Table I. Male participants were significantly older, had lower BMI, higher FEV_1, higher FVC, and higher SBP compared to female participants.

SBP had a significant negative correlation with FEV1 (r= -0.111, p<0.001) and FVC (r= -0.104, p<0.001) from the overall population, also in male and female subjects when correlated separately. However, no significant correlation was noted between diastolic blood pressure (DBP) and lung function (FEV_1 and FVC) in male and female subjects and the overall population (Table II).

The correlation between age and SBP is also noted to be statistically significant in which r=0.322, p<0.001. However, age and DBP are not statistically significant with r=0.023, p =0.347.

In the overall population, FEV_1 was significantly correlated with age (negative correlation), sex and BMI in simple and multiple linear regressions. However, it only correlated significantly with SBP (negative correlation) in simple linear regression (Beta[a] = -0.003). FVC was significantly correlated with age, sex, BMI, and SBP (negative correlation) in simple and multiple linear regression and it is only significantly correlated with DBP in multiple linear regression (Table III).

Following simple and multiple regression analysis, in males, FEV_1 had a significant negative correlation with age, and FVC had a weak negative correlation with age. In females, FEV_1 correlated significantly with age (negative correlation) and BMI in simple and multiple linear regressions, and only significantly correlated with SBP (negative correlation) and DBP in multiple linear regression (Table IV).

To minimize the influence of age, pulmonary function, and blood pressure were correlated in subjects aged 30–35 years. No significant correlation was evident between BP and lung function in this group (Table V).

Table I: Overall parameters comparing male and female participants of the study population

Parameter	Gender	N	Mean (SD)	Mean difference (95%CI)	*p* value
Age	Male	713	53.88 (9.79)	4.50 (3.55, 5.44)	<0.001*
(years)	Female	927	49.38 (9.50)		
BMI	Male	709	25.35 (4.64)	-0.89 (-1.37, -0.41)	<0.001*
(kg/m^2)	Female	922	26.34 (5.12)		
FEV_1	Male	713	2.41 (0.55)	0.58 (0.02, 0.53)	<0.001*
	Female	927	1.84 (0.43)		
FVC	Male	713	2.84 (0.68)	0.72 (0.66, 0.77)	<0.001*
	Female	927	2.12 (0.53)		
SBP	Male	712	136.52 (19.76)	3.92 (1.92, 5.92)	<0.001*
(mmHg)	Female	918	132.60 (20.9)		
DBP	Male	712	79.94 (11.54)	0.72 (-0.41, 1.84)	0.213
(mmHg)	Female	918	79.22 (11.46)		

* denotes statistically significant at α=0.05

Table II: Correlation between Blood Pressure (Systolic and Diastolic) and Lung Function in subject 18–80 years of age

		Correlation between SBP and:		Correlation between DBP and:	
		r	*p* value	*r*	*p* value
FEV	General	-0.111	<0.001*	0.015	0.550
	Male	-0.179	<0.001*	0.013	0.719
	Female	-0.197	<0.001*	0.016	0.637
FVC	General	-0.104	<0.001*	0.014	0.584
	Male	-0.187	<0.001*	0.100	0.785
	Female	-0.173	<0.001*	0.005	0.878

*Denotes statistically significant at α=0.05.

Table III: Factors associated with lung function (FEV1 and FVC) in 18–80 years old

Model for:	Variables	Simple linear regression (SLR)		Multiple linear regression (MLR)		
		Betaa(95%CI)	*p* value	Adjusted Betab (95%CI)	*p* value	R^2
FEV_1	SBP	-0.003 (-0.004, -0.002)	<0.001*	-0.001 (-0.002, 0.001)	0.088	0.483
	DBP	0.001 (-0.002, 0.003)	ns	-	ns	
	Age	-0.020 (-0.022, -0.017)	<0.001*	-0.026 (-0.028, -0.024)	<0.001*	
	Sex	0.576 (0.528, 1.868)	<0.001*	0.705 (0.664, 0.746)	<0.001*	
	BMI	0.010 (0.004, 0.015)	0.001*	0.008 (0.003, 0.012)	<0.001*	
FVC	SBP	-0.004 (-0.005, -0.002)	<0.001*	-0.003 (-0.005, -0.001)	0.046*	0.416
	DBP	0.001 (-0.002, 0.004)	0.584	0.003 (0.001, 0.007)	0.001*	
	Age	-0.019 (-0.022, -0.015)	<0.001*	-0.026 (-0.029, -0.023)	<0.001*	
	Sex	0.718 (0.659, 0.777)	<0.001*	0.847 (0.793, 0.901)	<0.001*	
	BMI	0.008 (0.001, 0.015)	0.029*	0.006 (0.001, 0.012)	0.030*	

[a] Crude regression coefficient;
[b] Adjusted regression coefficient; (Multiple linear regression with backward method. The model reasonably fits well. Model assumptions are met. There is no interaction between independent variables and muti-collinearity problem)
* denotes statistically significant at α=0.05

Table IV: Factors associated with lung function (FEV_1 and FVC) in Male and Female participants among 18–80 years old

Model for:	Variables	Simple linear regression (SLR)		Multiple linear regression (MLR)		
		Beta[a] (95%CI)	*p* value	Adjusted Beta[b] (95%CI)	*p* value	R^2
FEV_1	SBP	-0.003 (-0.007, 0.001)	0.159	-	ns	0.044
(Male)	DBP	-0.002 (-0.009, 0.004)	0.479	-	ns	
	BMI	0.008 (-0.009, 0.025)	0.345	-	ns	
FEV_1	SBP	-0.001 (-0.003, 0.001)	0.176	-0.005 (-0.007, -0.002)	0.001*	0.114
(Female)	DBP	0.003 (-.001, 0.007)	0.187	0.008 (0.002, 0.013)	0.005*	
	BMI	0.012 (0.002, 0.021)	0.028*	0.009 (0.001, 0.019)	0.049*	
FVC	SBP	-0.003 (-0.008, 0.002)	0.218	-	ns	0.012
(Male)	DBP	-0.006 (-0.014, 0.002)	0.148	-	ns	
	BMI	0.001 (-0.020, 0.020)	0.985	-	ns	
FVC	SBP	-0.001 (-0.004, 0.001)	0.356	-0.005 (-0.009, -0.001)	0.010*	0.115
(Female)	DBP	0.004 (-0.002, 0.009)	0.174	0.009 (0.002, 0.017)	0.015*	
	BMI	0.016 (0.003, 0.029)	0.017*	0.013 (0.001, 0.026)	0.047*	

[a] Crude regression coefficient;
[b] Adjusted regression coefficient; (Multiple linear regression with backward method. The model reasonably fits well. Model assumptions are met. There is no interaction between independent variables and muti-collinearity problem)
* denotes statistically significant at α=0.05

Table V: Correlation between Blood Pressure and lung function in 30–35 years old participants

	Systolic Blood Pressure (SBP)		Diastolic blood Pressure (DBP)	
	r	*p* value	*r*	*p* value
FEV	-0.239	0.098	-0.111	0.449
FVC	-0.274	0.057	-0.094	0.519

DISCUSSION

The evaluation of this population-based analysis confirms that raised systolic blood pressure is correlated with reduced lung function or *vice versa* (Table II). Predicted lung functions (FEV_1 % Pred, FVC % Pred) were not included in the results because the formulae available for prediction were not derived from the population under study and might therefore be inappropriate. Earlier studies on lung function in the Malaysian population found the actual FVC and FEV_1 values to be consistently lower in the Malaysian population when compared to the predicted values, with differences ranging from 5 to 49% depending on the formula used.[13,16] The main reason for this difference appears to be related to the population from which the data for the formulae were derived. In any case, the objective of this analysis is to assess and look for correlations between actual pulmonary function and blood pressure, hence predicted values were deemed not critical or necessary.

As a general comment on the data, as expected lung function values were significantly higher in the males than females (Table I). This is primarily due to the bigger build of males than that of females. Males have significantly higher mean systolic blood pressure than females (Table I). With regard to the findings on pulmonary function and blood pressure, they seem to be consistent with previous studies showing that blood pressure and lung function are in reverse association.[7,17,18] Whilst the precise reason for this link might not be evident, the interpretation of any link between blood pressure and lung function has to take into account the influence of age. Age has a positive and negative correlation with blood pressure and pulmonary function, respectively.[19-22] The data in Table III clearly demonstrated the influence of age on pulmonary function which shows a significant negative correlation between FEV_1, FVC, and age. Age and SBP are also significantly correlated with r=0.322. Age also revealed a very strong negative correlation with FEV_1 and FVC in males and females even when analysed individually (Table IV). The correlation is stronger in males than females, and the reason for this is unclear but it might be due to differences in the body frame between the two. There were no other factors that correlated significantly with lung function in males other than age. Significant age-related decline in FVC has been reported in Malaysian males where the average decline in FVC was found to be about 295 ml per decade between the age of 13 and 78 years. It was also interesting to note that although a substantial negative association was evident between blood pressure and pulmonary function and in the whole population, this association was not so evident when examined for just within a group aged 30–35 years (Table V). The objective of this brief analysis was to observe if the correlation between lung function and blood pressure was evident when the impact of age was minimised. The absence of any significant difference in this group could imply that the evident relationship between pulmonary function and blood pressure in normal individuals are more likely contributed by the age factor rather than the effect of pulmonary function on blood pressure or *vice versa*. The assumption might appear in contrast to previous reports, which postulated that lung function itself is one of the main factors that increase the risk of developing hypertension, independent of age.[5,6] Clearly the findings of this study do not confidently support the above postulation. The impact of age has to be removed completely to ascertain the relationship between blood pressure and pulmonary function. Substantial positive correlation is reported between small artery elasticity and forced vital capacity and with forced expiratory volume in 1 second in middle-aged to older free-living adult.[23] This has been proposed to be due to corresponding physiological paths for elastic changes in the vasculature and in pulmonary parenchyma, which happens with aging. Age related decrease in small artery elasticity would increase resistance and consequently pressure and decreased elasticity in the lung parenchymal tissue which would increase its resistance and consequently its expansion. It is therefore not surprising that a negative correlation exists between blood pressure and lung function when examined over a wide age range. The increment in blood pressure and reduction in lung function is not because they are interacting with each other, but mainly because they occur independently, in the same human body due to ageing process. The positive correlation between blood pressure and age have been shown in previous studies as well.[24-26]

There are varieties of other confounders which might also influence the correlation between hypertension and pulmonary function, such as gender and BMI. It is clear that gender and BMI is significantly correlated with lung function (Tables I and III), and BMI has significant effects especially to the female subjects (Table IV).

LIMITATION

Some limitation to our study would be procedural bias, which might lead to inadequate pulmonary function measurements. However, we believe that this possible bias is unlikely to greatly alter our findings. It is difficult to make a clear statement about the temporal sequence and causality between high blood pressure and lung function due to the cross-sectional study design of this analysis. Few prospective analysis pointed out that hypertension is a risk factor for declined pulmonary function, and yet others indicate diminished pulmonary function raise the probability of developing hypertension.[5-7,27] Thus, it is paramount to assess the temporal order, acute and chronic effects and the interconnection between pulmonary function and hypertension in prospective longitudinal analysis, while taking into consideration other confounding factors, such as cardio and respiratory co-morbids, smoking, occupation, and lifestyle.

CONCLUSION

Our observations are in line with previous findings demonstrating a reverse relationship between pulmonary function and blood pressure. However, this association is more age dependant and likely caused by the effect of age rather than the effect of pulmonary function on SBP or *vice versa*. However, these findings do not exclude the possibility of correlation between lung function and hypertension in lung disease but clearly the hypothesis needs more study.

COMPETING INTERESTS

The authors declare that they have no competing interests.

ACKNOWLEDGEMENTS

We thank all the participants in the study. We are indebted to the PURE RUS study group and to all co-workers who are responsible for the design and conduct of the PURE RUS study.

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