Original Article

Physiological association of the breakpoint with the duration of hyperventilation

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ABSTRACT

الأهداف: تحديد العلاقة بين مؤشر كتلة الجسم (BMI) وزمن حبس النفس (BHT)، وكذلك BHT مع مدة فرط التنفس (DOH) لدى الشباب الأصحاء.

المنهجية: تم إجراء دراسة رصدية في كلية شالامار للطب وطب الأسنان، لاهور، باكستان، في الفترة ما بين مايو 2021 ويونيو 2022. وتم تضمين طلاب بكالوريوس الطب في السنة الأولى الأصحاء، وبكالوريوس الجراحة الذين تتراوح أعمارهم بين 22–18 عامًا، مع مؤشر كتلة جسم طبيعية. تم أخذ قياسات التنفس من خلال حجرة مقياس التنفس المتصلة بمقياس ضغط الهواء (النموذج: Power Lab 26T). تم حساب مؤشر كتلة الجسم كنسبة الوزن (كجم) إلى الطول (m^2). وتم تطبيق اختبارات ارتباط بيرسون والانحدار الخطي واختبارات t باستخدام برنامج SPSS.

النتائج: شارك في الدراسة 101 شخصًا، منهم 44 رجلاً و57 امرأة. تم العثور على ارتباط سلبي ضعيف بين BMI وBHT في جميع المشاركين (p=0.34، r= −0.08)، عند الرجال (p=0.11، r= −0.24)، وفي النساء (p=0.497، r= −0.092). علاوة على ذلك، لوحظ وجود ارتباط قوي بين BHT وDOH في جميع المشاركين (p=0.000، r=0.64)، في الرجال (p=0.000، r=0.604)، وفي النساء (p=0.000، r=0.518). بالإضافة الى ذلك، تم العثور على انحدار خطي معكوس ضعيف غير مهم بين BMI و BHT لجميع المشاركين (p=0.38، β= −0.087)، للرجال (β= −0.241، p=0.11)، والنساء (p=0.49، β= −0.092). أخيرًا، لوحظ انحدار إيجابي قوي بشكل ملحوظ بين BHT وDOH لجميع المشاركين (β=0.637، p=0.000)، للرجال (p=0.000، β=0.604)، والنساء (β=0.518، p=0.000).

الخلاصة: لم يتم العثور على ارتباط بين BMI وBHT. كما لوحظ وجود علاقة إيجابية قوية بين BHT وDOH في جميع الشباب الأصحاء.

Objectives: To determine the relationship of body mass index (BMI) with breath-holding time (BHT) as well as that of BHT with the duration of hyperventilation (DOH) in young healthy adults.

Methods: An observational study was performed at Shalamar Medical and Dental College, Lahore, Pakistan, between May 2021 and June 2022. Healthy first-year Bachelor of Medicine, Bachelor of Surgery students aged 18-22 years, with a normal BMI were included. Spirometric measurements were taken through a spirometer pod connected to a pneumotachometer (model: Power Lab 26T). Body mass index was calculated as the weight (kg) to height (m^2) ratio. Pearson correlation, linear regression, and t tests were applied using SPSS.

Results: A total of 101 subjects participated, comprising of 44 men and 57 women. A weak negative association was found between BMI and BHT in all subjects (r= −0.08, p=0.34), in men (r= −0.24, p=0.11), and in women (r= −0.092, p=0.497). Furthermore, a strong association was observed between BHT and DOH in all subjects (r=0.64, p=0.000), in men (r=0.604, p=0.000), and in women (r=0.518, p=0.000). Moreover, a nonsignificant weak inverse linear regression was found between the BMI and BHT of all subjects (β= −0.087, p=0.38), of men (β= −0.241, p=0.11), and of women (β= −0.092, p=0.49). Lastly, a significantly strong positive regression was observed between the BHT and DOH of all subjects (β=0.637, p=0.000), of men (β=0.604, p=0.000), and of women (β=0.518, p=0.000).

Conclusion: No association was found between BMI and BHT. A strong positive association was observed between BHT and DOH in all healthy young people.

Keywords: breath-holding, body mass index, hyperventilation, maximal voluntary ventilation, breathing capacity, young adults

Saudi Med J 2023; Vol. 44 (10): 995-999
doi: 10.15537/smj.2023.44.10.20230358

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Received 13th May 2023. Accepted 24th August 2023.

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In bio-physiological sciences, a composite relationship exists between familial facts and socioecological dynamics. This association has a great impact on the understanding of the correlation of body mass index (BMI) with respiratory health in humans.[1] Under resting conditions, a minimum O_2-diffusion breathing pattern is maintained to meet the maximal physiological demands.[2]

Respiratory physiology is a multifaceted area that includes essential spontaneous reflex actions. In the same connection, breath-holding is a sort of easy natural process that can be used to unfold various respiratory controls maximal breath-holding time (BHT), or the breakpoint, is undoubtedly an interplay of chemical, mechanical, motivational, and perceptive drives in humans.[3,4] The act of breathing can be terminated voluntarily, after which a reflex control mechanism kicks in to manage reduced oxygen While hyperventilation is attained with an increased metabolic rate to expel that extra CO_2, one can down-regulate CO_2 without a considerable change in O_2 through hyperventilation.[5-7]

While obesity-related respiratory pathology has been significantly covered in the literature, the effect of BMI on healthy young adults' respiratory limits has been ignored by global researchers.[8] The literature does indicate that factors such as the threshold of the peripheral chemo-reflex, gender, and age are determinants of the duration of hyperventilation (DOH), although there remains a paucity of research regarding the physiological range of BMI in the healthy population.[9]

Therefore, the present study aimed to observe the relationship between BMI and BHT as well as that between BHT and DOH in young healthy adults.

Methods. A prospective observational cross-sectional study was conducted at Shalamar Medical and Dental College (SMDC), Lahore, Pakistan, from May 2021 to June 2022. First-year Bachelor of Medicine, Bachelor of Surgery students aged 18-22 years were included as participants. Physically healthy students (such as, normal lung function tests, normal range of BMI, and no medical illness) of both genders were included. Students who were involved in any physical endurance training programme, were on any medication, or had any systemic disease were excluded from the study.

Disclosure. Authors have no conflict of interests, and the work was not supported or funded by any drug company.

All ethical concerns were dealt with according to the principles of the Helsinki Declaration, and the study was ethically approved by the college's Institutional Review Board. Informed consent was obtained from all participants. All spirometric measurements were taken from each participant by a professional medical physiologist using a spirometer pod connected to a pneumotachometer (Power Lab 26T; ADInstruments Inc. – North America, USA). Initially, each participant was guided in taking 3 normal breaths into the spirometric pod to record their tidal breathing pattern. Then, they were instructed to hold their breath after inhaling deeply and the time in seconds was recorded. To record the DOH, the time was noted from the start of the participant's exhalation until the breathing reached the normal tidal volume that was initially taken from that participant. Each participant performed 3 acceptable breath holds to measure the DOH, and the best one was recorded.

A height and weight scale (ZT-160; everich Nanjing, China) was used to measure each participant's body height (to the nearest 0.5 cm) and body weight (to the nearest 0.1 kg), including their shoes.

Statistical analysis. Minitab version 17 was used to obtain descriptive statistics. Descriptive statistics and correlational analysis (such as Pearson correlation) of the study variables were performed through IBM SPSS for Windows version 20.0 (IBM Corp., Armonk, NY, USA). The effect of the independent variable on the dependent variable was determined through a linear regression plot using Microsoft Excel. For statistical comparison between the 2 study groups, a Student's t test was applied. For all statistical tests, the alpha value was taken as 0.05 at a 95% confidence interval; therefore, a p-value of <0.05 was considered statistically significant.

Results. This study recruited a total of 110 healthy subjects, of whom 9 were excluded because of technically incorrect spirometric manoeuvres. Therefore, for the data analysis, there were 101 healthy participants (44 men and 57 women). The mean age (year) of the studied population was 19.34±0.075, with almost the same mean age for both genders.

The average BMI of all participants was 22.58±0.46 (kg/m^2), with men exhibiting a greater mean BMI than women. A non-significant difference was found between the BMIs of both genders (p=0.08). The mean BHT value for all participants was 25.49±1.14 seconds (sec). Men had a 44.2% increased BHT compared with their female counterparts, and the difference was statistically significant (p=0.0001). The mean DOH value of all participants was 25.75±1.15 sec, where again men had a 39.8% increased DOH compared with their female counterparts, and this difference was again significant (*p*=0.0001; Table 1).

The correlation of the BMI of all healthy subjects with their BHT was found to be statistically nonsignificant. A weak negative correlation was observed between BMI and BHT in all studied individuals (r= −0.08, *p*=0.34). Specifically, the correlation between the BMI of men and their BHT was statistically nonsignificant, with a moderately negative relationship between the 2 variables (r= −0.24, *p*=0.11). Similarly, the correlation between the same 2 variables for women was nonsignificant, again with a weak negative correlation between the BMI of the studied women and their BHT (r= −0.092, *p*=0.497; Table 2).

The correlation of BHT with the DOH was highly significant in all groups. When this correlation was applied to all studied populations, a significantly strong positive correlation was observed (r=0.64, *p*=0.000). The same correlation of BHT with the DOH was also found to be significant in men, again with a strong positive relation (r=0.604, *p*=0.000). The same significantly strong positive correlation was found for women (r=0.518, *p*=0.000; Table 2).

Furthermore, the regression pattern between BMI as the independent variable and BHT as the dependent variable was nonsignificant in all groups. When the regression analysis was observed with all studied populations, a one-unit increase in BMI appeared to be accompanied by a nonsignificant decrease in BHT of 0.087 units (*p*=0.38). Specifically, for men, the regression pattern between BMI and BHT was clear: a one-unit increase in BMI was accompanied by a decrease in BHT of 0.241 units (*p*=0.11). Similarly, for women, a one-unit increase in BMI was accompanied by a nonsignificant decrease in BHT of 0.092 units (*p*=0.49; Table 2).

By contrast, a regression analysis between BHT as the independent variable and DOH as the dependent variable revealed a highly significantly positive relationship in each group. When this regression was plotted for the whole sample, a one-unit increase in BHT was observed to be accompanied by a significant increase in DOH of 0.637 units (*p*=0.000). When the regression was plotted for men, a one-unit increase in BHT was found to be accompanied by a significant increase in DOH of 0.604 units (*p*=0.000). Lastly, the same regression plotted for women revealed that a one-unit rise in BHT was accompanied by a significant increase in DOH of 0.518 units (*p*=0.000; Table 2).

Table 1 - Baseline characteristics of the study population (N=101).

Demographics	Mean±SEM*	*P*-value
Men : Women	44 : 57	
Age* of all subjects	19.34±0.075	
Age of men: Age of women	19.33±0.13 : 19.34±0.09	1.0
BMI* of all subjects	22.58±0.46	
BMI of men: BMI of women	23.52±0.74 : 21.91±0.57	0.08
BHT* of all subjects	25.49±1.14	
BHT of men : BHT of women	30.82±1.88 : 21.38±1.14	0.0001*
DOH* of all subjects	25.75±1.15	
DOH of men : DOH of women	30.68±1.94 : 21.95±1.17	0.0001*

*Age (in years), *BMI: body mass index (kg/m^2), *BHT: breath-holding time (sec.), *DOH: duration of hyperventilation (sec.), *SEM: standard error of the mean, *p<0.05 is statistically significant

Table 2 - Association of BMI with BHT and of BHT with DOH in the study population.

Pearson correlation *(Along the x-axis)*	*(Along the y-axis)*	R^2 Linear	Pearson r	*P*-value
BMI* of all subjects	BHT* of all subjects	0.008	−0.08	0.34
BMI* of men	BHT* of men	0.06	−0.24	0.11
BMI* of women	BHT* of women	0.008	−0.092	0.497
BHT of all subjects	DOH* of all subjects	0.41	0.64	0.000*
BHT of men	DOH* of men	0.37	0.604	0.000*
BHT of women	DOH* of women	0.268	0.518	0.000*
Regression analysis *Independent variable*	*Dependent variable*	**β coefficient**	**Odds ratio***	**P-value**
BMI* of all subjects	BHT* of all subjects	−0.087	−0.76 to 0.29	0.38
BMI* of men	BHT* of men	−0.241	−1.53 to 0.17	0.11
BMI* of women	BHT* of women	−0.092	−0.76 to 0.37	0.497
BHT of all subjects	DOH* of all subjects	0.637	0.48 to 0.80	0.000*
BHT of men	DOH* of men	0.604	0.37 to 0.88	0.000*
BHT of women	DOH* of women	0.518	0.29 to 0.77	0.000*

*BMI: body mass index (kg/m^2), *BHT: breath holding time (sec.), *DOH: duration of hyperventilation (sec.), *p<0.05 is significant, odds ratio* = 95% confidence interval

Discussion. While a physiological impact of BMI on respiratory health has been proven, its specific association with the breakpoint, as well as the connection of the breakpoint with the DOH in healthy young adults, require elucidation.[1] Another study elaborated that a decreased duration of voluntary apnoea in healthy individuals with a raised BMI was mainly due to the enhanced sensitivity of their peripheral chemoreflex to carbon dioxide.[3] In the same vein, studies have reported 22.5±1.4 as the average BMI (kg/m^2) of their participants, with an average age of 39.4±4.4 years and an average BHT of 47.2±8.7 (sec).[3,10] Comparatively, the present study found that healthy men with an average age of 19.33±0.13 years had a slightly raised mean BMI of 23.52±0.74 with a decreased BHT of 30.82±1.88.

Messineo et al[11] revealed a 108% increased BHT and a 600% increased recovery breath in their study population compared with the present study. However, the mean age of their healthy volunteers was 45.4±10.6 years with a mean BMI of 25.2±4.7. Amatya et al[12] carried out a similar study in Nepal on medical undergraduates with an average age of 19.6±1.2, reporting a BMI of 21.9±3.1 in men and of 21.5±3.3 in women. Moreover, compared with the present study, the BHT was found to be increased in their male participants by 76% and in their female participants by 38.5%. Furthermore, they reported a 38% higher BHT in men compared with women, whereas the present study found a 44% higher BHT in men.

In India, Mohammad et al[13] carried out similar research and reported an average BMI in men of 23.11±4.6 and women of 22.59±4.4. The average BHT in men was 42.17±39.64 and women was 26.96±9.435; thus, it was much lower in women than in men. Similar to the present study, in which the mean BMI in men was 23.52±0.74 and women was 21.91±0.57, the average BHT in men was 30.82±1.88 and women was 21.38±1.14, in Mohammad et al's study, again revealing a lower BHT in women.

Furthermore, an Italian study reported a raised BHT value (45–55 sec) in healthy male participants compared with their female participants.[14] Parallel to our findings, the study claimed that the BHT was longer in healthy men than in healthy women of the same age.[14] The same study reported a mean BHT of 48.27±16.02 (±SD) with a mean DOH of 62.20±21.68 sec in healthy men aged 17-25 years.[14] By contrast, the present study found somewhat higher BHT and DOH values.

Parallel to our results, Trembach et al[15] studied healthy medical undergraduates aged 18 years and found a nonsignificant association between the breakpoint and BMI in both genders. Another similar study found an inverse relationship between estimated body fat and BHT in healthy subjects aged 20-60 years.[15] Similarly, the present study found a weak negative correlation between BMI and BHT in all of the studied groups.

Regarding the association between age and BHT, a study with a population aged 25-85 years declared no association between age and BHT in individuals with a normal BMI.[16] Another study remained inconclusive regarding a "physiologically safe" breakpoint limit without the risk of cerebral hypoxia.[17]

Similar to our findings, Vagedes et al[18] confirmed a significant linear correlation between BHT and hyperventilation in healthy volunteers. Parallel to our results, a study conducted in Los Angeles, California, proved that voluntary BHT control is positively correlated with the depth and rate of breathing.[19] Similar to our findings regarding the BHT in young adults of both genders, an Indian study reported a BHT in elderly healthy men of 28.20±8.51 and women of 26.11±6.63.[20]

In addition, the current study found a significantly longer BHT by 44.2% in men than in women, while another study showed found no significant difference in BHT between healthy men and women aged 18-30 years.[21] Another study suggested that it is the size of the chest, not gender, that makes a difference in respiratory values, including BHT and the associated DOH.[22]

Noteworthily, one study not only supported the physiological influence of female hormones on lung function but also verified the relationship between anthropometric variances in both genders.[23] Another study reported similar results – namely that female participants had a decreased BHT along with relatively more sensitive respiratory centres because of the direct hormonal influence.[24]

Study limitations and recommendations. The present study definitely adds knowledge to the literature, especially for physiologists with respiratory interests; however, some limitations of the study must be acknowledged. The significance of anthropometric measurements, such as the chest size of the study population, could have added vital value to the BHT and DOH results, yet these measurements were ignored and not included. Moreover, a larger sample size could have enhanced the results' generalizability. Future research should include chest size, an increased unit of analysis, and a more varied age range. Doing so could add significant value to the results in the same physiological connection of lung functions.

In conclusion, both the breakpoint and DOH variables were significantly higher in young healthy men than in women with a normal average BMI. Furthermore, a significantly strong and positive correlation was also found between BHT and DOH in each study group. Lastly, a significantly strong positive regression link was observed between BHT and DOH in each study group.

Acknowledgment. *The authors gratefully acknowledge Scribbr (https://www.scribbr.com/) for the English language editing.*

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