УДК 612.39/613.21-053.2:663.9 Original research

PECULIARITIES OF BREATH HOLDING TESTS IN SCHOOL AGE CHILDREN

Y.M.Nechytailo, Ben Othmen Mabrouk

Bukovinian State Medical University, Chernivtsi, Ukraine

Key words: *children, voluntary breath-holding test, Ruffier test, pulse oximetry, physical activity.*

Bukovinian Medical Herald. V.25, № 1 (97). P. 103-107.

DOI: *10.24061/2413-0737.XXV.1.97.2021.15*

E-mail: *nechitailo.yuri@bsmu.edu.ua*

Objective *of the study was to examine the performance of breath-holding and Ruffier tests, relationship between them and other factors in healthy school-age children.*

Material and methods. *The cross-sectional descriptive study with 45 healthy participants in age 7-13 years (22 boys and 23 girls) was performed. The study included assessment of nutrition, physical activity habits, family and socioeconomic data, resting anthropometric and blood pressure measurements, pulse oximetry, tests for the functional status of the cardiorespiratory system and readiness of child organism for physical loading (Ruffier and volitional breath-holding hypoxic tests).*

Results. *The Rufier index in most children was average and amounted to 8.75±0.32 units. Test with breath-holding on inspiration was at the level of 37.0±1.84 sec, on exhalation - 22.2±1.3 sec. In children with low tolerance to exercise during respiratory tests execution there were a decrease in blood saturation and changes in heart rate. The tests are based on different physiological processes in the human body that create physical load tolerance: heart tolerance and cardiorespiratory oxygen supply to tissues.*

Conclusions. *All selected tests could be executed anywhere and in a short period of time. They are easy to perform and do not cause emotional reactions in children and could be used for tolerance for physical loading assessment. The results obtained are complementary and can be recommended for use in the complex when examining the health and tolerance for physical loading in children during different screening types.*

ОСОБЛИВОСТІ ТЕСТІВ НА ЗАТРИМКУ ДИХАННЯ У ДІТЕЙ ШКІЛЬНОГО ВІКУ

Ю.М. Нечитайло, Бен Отмен Мабрук

Ключові слова: *діти, тест на затримку дихання, тест Руф'є, пульсоксиметрія, фізичні навантаження.*

Буковинський медичний вісник. Т.25, № 1 (97). С. 103-107.

Мета дослідження*. Вивчення результатів тестів на затримку дихання та тест Руф'є, взаємозв'язок між ними та іншими факторами у здорових дітей шкільного віку.*

Матеріал і методи. *Проведено дескриптивне дослідження з 45 здоровими учасниками віком 7-13 років (22 хлопчики та 23 дівчинки). Дослідження включало оцінку харчування, фізичної активності, сімейних та соціально-економічних даних, антропометричних вимірів та артеріального тиску, пульсоксиметрію, тести на функціональний стан серцево-дихальної системи та готовність дитячого організму до фізичного навантаження (Руф'є та гіпоксичні тести із затримкою дихання).*

Результати. *Індекс Руф'є у більшості дітей був середнім і становив 8,75±0,32 одиниці. Тест із затримкою дихання на вдиху був на рівні 37,0±1,84 с, на видиху - 22,2±1,3 с. У дітей із низькою толерантністю до фізичних вправ під час виконання дихальних тестів спостерігалося зниження рівня сатурації крові та зміни частоти серцевих скорочень. Тести базуються на різних фізіологічних процесах людського організму, які лежать в основі толерантності до фізичного навантаження: готовність серця та кардіореспіраторне забезпеченням тканин киснем.*

Висновки. *Усі обрані тести можна виконати де завгодно і за короткий*

проміжок часу. Вони прості у виконанні та не викликають емоційних реакцій у дітей і можуть бути використані для оцінки толерантності до фізичного навантаження. Отримані результати доповнюють один одного і можуть бути рекомендовані до використання в комплексі при вивченні стану здоров'я та толерантності до фізичного навантаження у дітей під час різних видів скринінгу.

ОСОБЕННОСТИ ТЕСТОВ НА ЗАДЕРЖКУ ДЫХАНИЯ У ДЕТЕЙ ШКОЛЬНОГО ВОЗРАСТА

Ю.Н. Нечитайло, Бен Отмен Мабрук

Ключевые слова: *дети, тест на задержку дыхания, тест Руфье, пульсоксиметрия, физические нагрузки.*

Буковинский медицинский вестник. Т.25, № 1 (97). С.103-107.

Цель исследования*. Изучение результатов тестов на задержку дыхания и Руфье теста, взаимосвязь между ними и другими факторами у здоровых детей школьного возраста.*

Материал и методы. *Проведено дескриптивное исследования с 45 здоровыми участниками в возрасте 7-13 лет (22 мальчика и 23 девочки). Исследование включало оценку питания, физической активности, семейных и социально-экономических данных, антропометрических измерений и артериального давления, пульсоксиметрии, тесты на функциональное состояние сердечно-дыхательной системы и готовность детского организма к физической нагрузке (Руфье и гипоксические тесты с задержкой дыхания).*

Результаты. *Индекс Руфье у большинства детей был средним и составил 8,75±0,32 единиц. Тест с задержкой дыхания на вдохе был на уровне 37,0±1,84 с, на выдохе - 22,2±1,3 с. У детей с низкой толерантностью к физическим упражнениям во время выполнения дыхательных тестов наблюдалось снижение уровня сатурации крови и изменения частоты сердечных сокращений. Тесты базируются на различных физиологических процессах человеческого организма, которые лежат в основе толерантности к физической нагрузке: готовность сердца и кардиореспираторное обеспечение тканей кислородом.*

Выводы. *Все выбранные тесты можно выполнить где угодно и за короткий промежуток времени. Они просты в исполнении, не вызывают эмоциональных реакций у детей и могут быть использованы для оценки толерантности к физической нагрузке. Полученные результаты дополняют друг друга и могут быть рекомендованы к использованию в комплексе при изучении состояния здоровья и толерантности к физической нагрузке у детей во время различных видов скрининга.*

The deterioration of the children health in Ukraine registered in recent years. It was not only due to different diseases but also to other factors such as low physical activity with insufficient tolerance for physical loading [3, 4]. Physical activity is a key to improving the health of the children population. Regular physical activity in children and adolescents promotes health and fitness. On the other side, the reduction in cardiorespiratory fitness is a strong predictor of cardiovascular events and respiratory diseases in future. Childhood is a critical period for developing movement skills, learning healthy habits and establishing a foundation for lifelong health and well-being. Recent researches indicate that moderate-to-vigorous physical activity improve not only general health but the cognitive functions of memory, executive function, processing speed, attention, and academic performance for these children [3, 4].

As an assessment measure of the school-age children adaptive capacity to physical loading, the Ruffier test was proposed and widely used in educational establishments as a selection index in a type of fitness for the child during school physical education lessons [3]. This test was based on muscle-strengthening activity and could not assess an aerobic physical activity profile. For this matter, more suitable are volitional breath-holding hypoxic tests (VBHT) [5, 8]. These simplest tests include the time of inspiration end breath-holding (BHTi) and expiration end (BHTe) probe. The first test was proposed more than hundred years by Russian surgeon V.A.Stange (1913), the other – by German

physician A.Genchi (1926). Functional breath-holding hypoxic Genchi's and Stange's tests were successfully used many years in experimental and in clinical practice, but many aspects of their effect on the body functions remain unclear. The mechanism of different duration VBHT and types of analyzed processes are also inconsistent. Hypoxia, hypercapnia and acidosis are usually considered to be the main causes of the tests termination [2]. But on investigating the VBHT termination mechanism, it is necessary to take into consideration that it is associated not only with changes in the blood parameters but also in the state of respiratory muscles, because at that period, their normal contraction–relaxation rhythm is changed by stopping in the state of static tension [1, 6, 9]. In any case, VBHT make it possible to evaluate a person's adaptation to hypoxia and hypoxemia, and give some idea of the body's ability to withstand oxygen deficiency and they are a good indicator for reserves of cardiorespiratory system and tolerance for physical loading [2]. They could be used rapid, painless, and easy to perform in all children's age groups for hypoxic event presence, especially with the pulse oximetry method which is an accurate and well-established test used to quantify hypoxemia [7]. Persons with high levels of Ruffier test and VBHT better tolerate physical activity and have a lower risk of cardiovascular and respiratory events.

Objective of the study was to examine the performance of breath-holding and Ruffier tests and relationship between them and other factors in healthy school-age children.

Materials and methods. The cross-sectional descriptive study with 45 healthy participants (22 boys and 23 girls) was performed. Children were subdivided into two age strata 7-9 years (29 persons) and 12-13 years (16 persons). The study includes an assessment of nutrition, physical activity habits, family and socioeconomic data, resting anthropometric and blood pressure (BP) measurements, pulse oximetry, tests for the functional status of the cardiorespiratory system, and readiness of child organism for physical loading (Ruffier and VBHT tests). VBHT were performed after the preliminary ventilation of the lungs (three deep inspirations and expirations). For BHTi the participants prompt to exhale as deeply as possible and then inhale once a full breath and hold their breath for as long as they can. The length of time the participants are able to hold their breath recorded via a stopwatch and was completed twice, with the longest of the two breath-holding trials used as the final index. The same was for BHTe test but with breath hold after exhaled air deeply. The tests carried out according to the following scheme: first – inspiration breath-holding test, then expiration breath-holding test (both with pulse oximetry) and at the end - the Ruffier test. For the execution of Ruffier test children were asked to sit and rest for 5 minutes, then resting heart rate (HR) for 15 seconds was collected (P1) and 20 squats in 60 seconds were performed. Next HR assessment (P2) was done at the end of physical loading and the last recovery post-test level (P3) - 30 seconds after previous. Based on the three HR measurements, the Ruffier Index (RI) was calculated, and by the assessment scale, children were belonged to four groups: persons with excellent endurance (RI from 0 to 5), with good endurance (RI from 5 to 10), with moderate endurance (RI from 10 to 15) and with poor endurance (RI from 15 and up). Statistical analysis conducted with program Statistica (version 5.11, StatSoft Inc.). Data were expressed as mean ± standard error for quantitative variables and nonparametric Spearmen correlation assessed. Statistical analysis was performed using the Student's t-test for numerical variables. All p-values were two-tailed and $p<0.05$ was considered statistically significant.

Results of the research. Anthropometric measurements of children established average age-related data of height and weight, but according to body mass index (BMI) some children were underweighted (6 persons) and other overweighted (7 persons). Systolic BP, in average, was 96.7±2.29 mm Hg (with range – 80 – 133 mm Hg), diastolic BP – 60.4±1.79 mm Hg (with range – 44 – 108 mm Hg). Children's HR was 85.0±1.50 beats per minute (bpm) (with range – 57 – 109 bpm).

During the execution of Ruffier test, resting HR P1 was collected at the end of 5 minutes sitting and, in average, was 80.6±1.28 bpm. Immediately after performing squats average HR P2 was 120.4±1.52 bpm and recovery post-test level HR P3 was 86.8±1.37 bpm. Based on the three HR measurements, the RI was calculated and average level was 8.75±0.32 units. By the RI scale, children with excellent endurance were absent, with good endurance were 30 persons (66.7%), with moderate endurance were 13 persons (28.9%) and with poor endurance were 2 persons (4.4%). By level of RI all children were divided into two groups according to median of RI (8.0). A better RI correlated with lower body mass index (15.9 kg/m2 against 17.3 kg/m2), higher level of physical activity and lower systolic BP (97.3 mm Hg against 102.0 mm Hg).

Volitional breath-holding tests were executed with following results: BHTi was 37.0±1.84 sec (with range from 13 no 76 sec). The summary statistic of BHTi presented on fig.1. There were no sufficient differences of BHTi depending on gender (boys - 36.2±2.32 sec and girls – 38.2±3.14 sec, $p>0.05$) and age of children. Test Stange's has negative correlation with RI ($R=-0.31$, $p<0.05$).

The summary statistic of BHTe presented on fig.2. The average level of BHTe was 22.2±1.3 sec (with range from 13 to 49 sec). In this test there were no sufficient differences depending on age and gender too (boys - 21.4±2.02 sec and girls – 22.9±1.82 sec, $p>0.05$). A slight skewness and kurtosis of data was registered but in the range of normality. Test Genchi's has no real correlation with RI ($R=-0.16$, $p>0.05$).

We could expect similarity of both VBHT tests, but according to the correlation level between them ($r=0.46$, $p<0.05$) (fig.3) there is sufficient difference in physiological processes in which they are mirrored.

The duration of voluntary apnea depends on many factors like decrease of blood oxygen saturation, velocities of blood flow, sensitivities of respiratory biomechanics changes, level of peripheral chemoreflex and other. Use of pulsoxymetry concomitant with VBHT show different

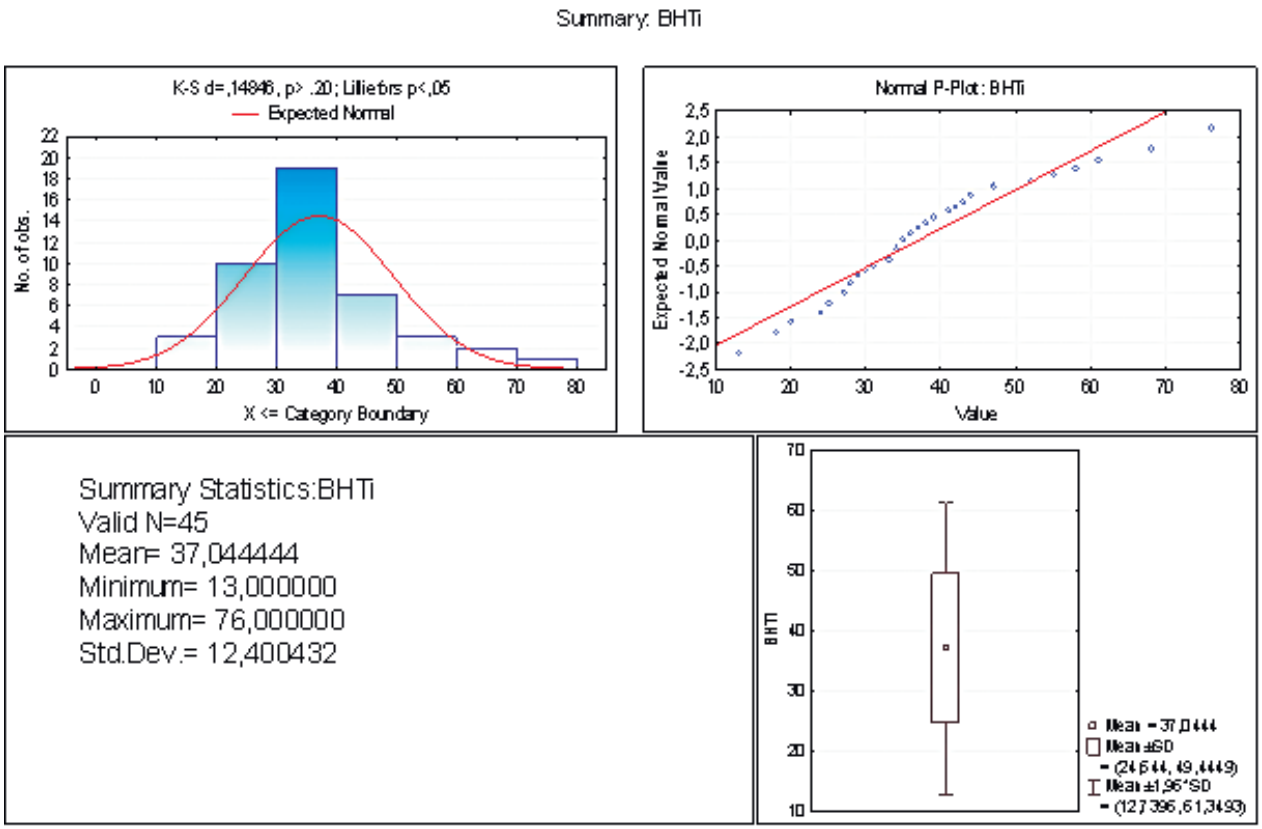

Fig.1. *The summary statistic of inspiration end breath-holding test (BHTi) time*

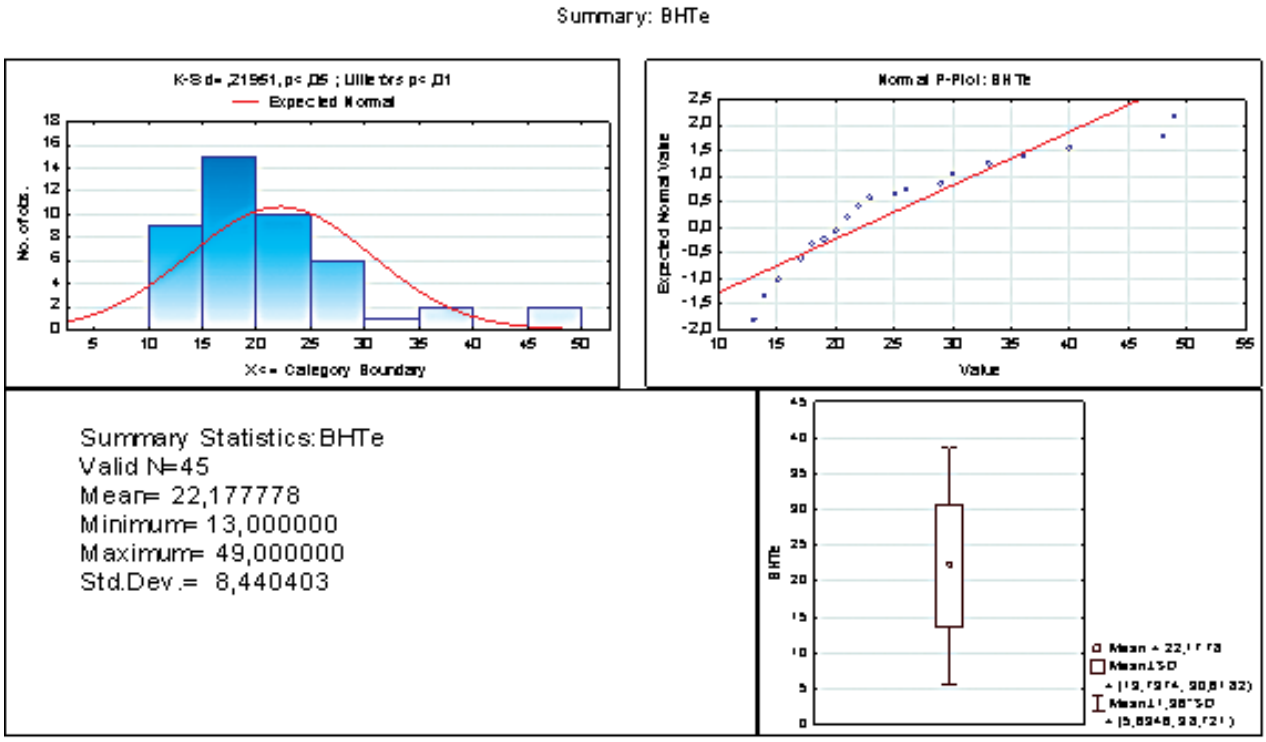

Fig.2. *The summary statistic of expiration end breath-holding test (BHTe) time*

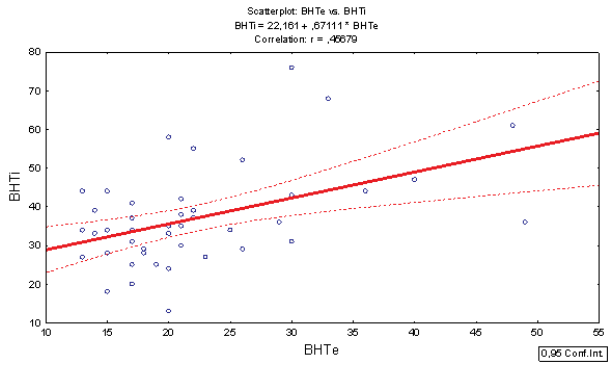

Fig.3. *Linear regression model for BHTe and BHTi*

type of saturation changes in groups of children according to RI level. In persons with better RI level of saturation did not changed during both BHTi and BTHe and HR was slightly slower. In other group oxygenation in the end of apnea dropped for 2-3% (more during BTHe) and HR slightly arise. Our data differ from characteristic of adult reaction [1]. A maximal VBHT time can be characterized by two phases: the initial period where an individual easily suppressed rebreathing and second - the onset of involuntary breathing movements where person couldn't longer suppressed breathing and diaphragmatic contractions unconsciously occur. During the second phase in adult reductions in oxygen saturation tension appear and provoke rebreathing while in children saturation is only a little lower and rebreathing starts as greater chemoreceptor afferent activity.

Conclusions

1. All tests could be executed anywhere and in a short period of time. They are easy to perform and do not cause emotional reactions in school-age children and could be used for tolerance for physical loading assessment.

2. The selected tests are based on different physiological processes of the human body, which create tolerance for physical loading: RI – heart tolerance, breath-holding tests – cardiorespiratory readiness with oxygen supplying.

3. The results obtained are complementary and can be recommended for use in the complex when examining the health and tolerance for physical loading in children during different screening types.

Conflict of interest. The authors declared no conflict of interest.

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Відомості про авторів

Нечитайло Ю.М. – д-р мед. наук, проф., зав. кафедри педіатрії, неонатології та перинатальної медицини Буковинського державного медичного університету, м. Чернівці, Україна.

Бен Отмен Мабрук – аспірант кафедри педіатрії, неонатології та перинатальної медицини Буковинського державного медичного університету, м. Чернівці, Україна.

Сведения об авторах

Нечитайло Ю.Н. – д-р мед. наук, проф., зав. кафедрой педиатрии, неонатологии и перинатальной медицины Буковинского государственного медицинского университета, г.Черновцы, Украина.

Бен Отмен Мабрук – аспирант кафедры педиатрии, неонатологии и перинатальной медицины Буковинского государственного медицинского университета, г.Черновцы, Украина.

Information about the authors

Nechytailo Y.M. – MD, PhD, DSci, Professor, Head of the Department of Pediatrics, Neonatology and Perinatal Medicine, Bukovinian State Medical University, Chernivtsi, Ukraine.

Ben Othmen Mabrouk – MD, PhD student of the Department of Pediatrics, Neonatology and Perinatal Medicine, Bukovinian State Medical University, Chernivtsi, Ukraine.

Надійшла до редакції 14.01.2021

Рецензент — проф. Сокольник С.В.