J Basic Clin Health Sci 2023; 7: 158-163
https://doi.org/10.30621/jbachs.1273896
RESEARCH ARTICLE

CHANGES IN RESPIRATORY MUSCLE PRESSURE OF HEALTHY INDIVIDUALS WITH DIFFERENT LEVELS OF IMMERSION IN WATER: OBSERVATIONAL STUDY

Baris Gurpinar[1], Seher Ozyurek[2], Ata Elvan[1], Sermin Tukel[1]

[1] Faculty of Health Sciences, Physiotherapy and Rehabilitation Department, Izmir University of Economics, Izmir, Turkey
[2] Faculty of Physical Therapy and Rehabilitation, Department of Prosthetics and Orthotics, Dokuz Eylül University, Izmir, Turkey

ORCID: B.G. 0000-0003-3886-4819; S.O. 0000-0002-8586-7214; A.E. 0000-0002-6478-433X; S.T. Tükel:0000-0002-6297-5271

Corresponding author: Baris Gurpinar, **E-mail:** baris.gurpinar@ieu.edu.tr
Received: 03.04.2023; **Accepted:** 10.07.2023; **Available Online Date:** 30.09.2023

Cite this article as: Gurpinar B, Ozyurek S, Elvan A, Tukel S. Changes in Respiratory Muscle Pressure of Healthy Individuals with Different Levels of Immersion in Water: Observational Study. J Basic Clin Health Sci 2023; 7: 158-163.

ABSTRACT

Purpose: Understanding the physiological effects of immersion, particularly on pulmonary dynamics in healthy individuals is important to predict and interpret the physiological responds in unhealthy group. The aim of our study is to evaluate the inspiratory and expiratory muscle strength and cough strength in healthy individuals during water immersion at different water depths.
Methods: A cross-sectional study was conducted in 24 healthy individuals with the mean age 20.0 years. Respiratory muscle strength test and cough force were tested on dry land and in pool at iliac crests, xiphoid appendix of the sternum and clavicles levels. Measurements were randomized at each level. The Friedman test was used for repeated measures with Wilcoxon signed ranks test with Bonferroni correction was applies to compare the variables.
Results: A significant difference between dry land and immersion in water of different levels for MEP ($p=0.001$) and PEF ($p= 0.015$). Multiple comparisons showed no difference between levels in PEF ($p<0.001$), whereas MEP values measured in clavicles level was significantly higher than both dry land and iliac crest level ($p<0.0125$).
Conclusion: Clavicle level immersion alters respiratory muscle strength when compared with the values measured out of the water and immersed at the iliac crest level in healthy individuals.

Keywords: Immersion, pulmonary function test, respiratory muscle

INTRODUCTION

The fludo-mechanic properties of water such as bouncy, hydrostatic pressure and viscosity alter the physiological responses of human body with water immersion. Central venous pressure, cardiac output and volume increase as a result of venous flow diverting from the periphery to the centre with the effect of decreasing gravity together with the hydrostatic pressure of the water (1). The elimination of gravity and hydrostatic pressure acting on the body during immersion directs the venous blood, especially in the lower extremities, to the lungs and heart. Increased central blood volume reduces diffusion capacity in the lungs, increases resistance in airways, which leads to decrease in pulmonary volume and vital capacity (VC), consequently breathing workload changes. Studies reported that inspiratory workload increases almost 60% as a result of central blood shifting, changes in lung volumes and respiratory mechanics (2-6).

The immersion level is one of the most important determinants in the pulmonary responses during water immersion. Limited studies have shown that different levels of immersion have effects on respiratory muscle strength. Andrade et al. showed that inspiratory muscle strength decreased as the immersion level increased, however they did not discuss the effects on expiratory muscle strength (7). It may be hypothesized that the increase in intra-abdominal pressure due to immersion reinforce the expiratory forces, there was no evidence found in related literature.

Coughing is the forceful expulsion of air with increased intra-abdominal and intrathoracic pressure against the closed epiglottis after deep inspiration. Thus, inspiratory and expiratory muscle strength have important role in effective cough (8). There was no study found investigating the effects of immersion on cough strength.

Decreased function is expected in the first stage of cough with increased inspiration workload and decreased VC, while increased intra-abdominal and intrathoracic pressure may be helpful in the second stage.

Recently, water-based exercises are being widely used for treatment purposes. Treatment techniques and applications became more advance and accessible. People with different diagnosis and age groups, especially more disadvantages individuals, are being referred to aquatic treatment centres as moving in water is easier and more comfortable. Water-based exercises or aquatherapy propose effective and safe environment for those with direct pulmonary involvement such as chronic obstructive pulmonary disease (9, 10), COVID-19 (11) and those with indirect involvement namely spinal cord injuries (12), neuromotor diseases (13, 14) and rheumatological diseases (15, 16). Number of people with variety diagnosis and problems are using aquatherapy for different purposes yet literature about pulmonary response to immersion is still scarce.

Understanding the physiological effects of immersion, particularly on pulmonary dynamics in healthy individuals is important to predict and interpret the physiological responds in unhealthy group. The aim of our study is to evaluate the inspiratory and expiratory muscle strength and cough strength in healthy individuals during water immersion at different water depths.

MATERIALS AND METHODS

Study design

This is an observational study. The study was approved by Non-interventional Clinical Ethics Committee of Izmir University of Economics ((Date: 19.07.2022, Number: B.30.2.İEÜSB.0.05.05-20-168).

Participants:

The sample size was calculated as 24 participants with a 95% confidence interval and a 5% deviation margin, using the data of a similar study in the literature (7). The participants were recruited via flyers and social media announcements. The participants, at the age of 18 to 25 years with no chronic disease were selected by convenience and sequentially.

Participants who had a history of respiratory or cardiovascular illness, regular aerobic exercise and hydrophobia were excluded. Participants who meet the inclusion criteria were informed about the study procedure and signed consent was obtained.

Materials and procedure

All evaluations and measurements were completed within 1 day for each participant. First, they were asked to rest for 5 minutes then demographic information was recorded by face-to-face interview method.

The measurement procedure was carried out in two stages, informative and experimental. At the informative stage participants were familiarized with the manoeuvres of inspiratory and expiratory pressure assessments following their anthropometric data was recorded. After the informative stage, measurements were conducted under four different conditions on land, immersion at the iliac crest level, immersion at the xiphoid level and immersion at the clavicle level. During the measurements, the participants were asked to perform the manoeuvres in a sitting position and with a nose clip attached. Maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) and cough force evaluations were randomization by using a random table.

The study was held in a treatment centre with a pool for aquatherapy purposes. The pool was 4X5 meter dimension and 1.40 m depth. The water temperature

Table 1. Descriptive data of participants (n=24).

Sex, n (%)	
Women	14 (58.3)
Men	10 (41.7)
Age, years	20.0 (19.0-20.0)
Height, cm	170.0 (165.0-181.75)
Body Weight, kg	67.5 (55.0-84.25)
BMI, kg/m^2	22.89 (20.70-25.46)

BMI, body mass index
Values expressed as median (interquartile range) or number of participants (%).

was 30-31^0 C. The participants were immersed with an electronic lift during the test procedure. Participants were asked to rest 2 minutes between measurements and 5 minutes rest after changing the conditions. Each participants measurement took almost an hour with 45 minutes water immersion.

Respiratory muscle strength test; is the measurement of intraoral pressures during maximal respiration against a valve that closes the airway during maximum inspiration and expiration. MIP and MEP were evaluated by digital manometer (RP Check, MD Diagnostic Ltd., Kent, UK) with a measurement range of 0-300 cmH$_2$O. MIP and MEP assessment were conducted according to the statement of European Respiratory Society (17).

Cough force or peak cough flow (L/min) was evaluated with a portable Pef-meter device (Mini Wright peak expiratory flow meter). Three attempts were undertaken, and the highest value was recorded for the analysis for each measurement condition (17).

Statistical Analysis

Statistical analyses were performed using the SPSS software version 25.0 (SPSS Inc., Chicago, IL, USA). According to Shapiro-Wilk test, most of the variables were not normally distributed. Therefore, non-parametric tests were deemed more adequate for this study. Medians and interquartile ranges (25th-75th percentile) were used for descriptive analyses. The Friedman test was used to examine the effect of dry land and different levels of immersion in water on respiratory muscle strength and cough strength. Significant results were then analysed by post-hoc tests (Wilcoxon signed ranks test with Bonferroni correction). The significance level was set at 0.05, except for post-hoc analysis, in which the significance level was set at 0.0125 (0.05/4) after Bonferroni correction.

RESULTS

Of 30 participants assessed for eligibility, 6 participants were excluded due to mild upper respiratory tract infection (n=3) and being elite athlete (n=3). Finally, a total of 24 healthy participants' data was analysed. The participants' characteristics are presented in Table 1.

Table 2 presents the results of changes in respiratory muscle strength and cough strength following dry land and different levels of water immersion. There were no significant changes in MIP values among four conditions ($p<0.05$).

The results revealed a significant difference between dry land and immersion in water of different levels for MEP and PEF ($p=0.001$ and $p= 0.015$, respectively). However, post hoc pairwise tests did not show any statistical difference in PEF. In contrast, multiple comparisons showed statistically significant differences in MEP between dry land and clavicles level ($p<0.001$), and between iliac crests level and clavicles level ($p= 0.003$). MEP values measured in clavicles level was significantly higher than both dry land and iliac crest level ($p<0.0125$).

DISCUSSION

Few studies examined the relation between pulmonary muscle strength and water immersion level (3, 7, 18, 19). In this paper we showed that especially expiratory forces increased with the level of immersion.

Aquatherapy is widely used especially for those who are more disadvantaged in moving on land (1, 13, 14, 16). Health problems involve mobility disorders mainly coincide with or eventually cause pulmonary disorders. Moreover, aquatic therapy for pulmonary diseases has additional effect in improving the endurance exercise capacity (20) therefore aquatherapy for this population could become more suggestible. Hence it is important to understand effects of water immersion on pulmonary system.

The initial studies have shown that head out immersion can lead to changes in pulmonary volumes, forced expiratory volume during the first second, and functional residual capacity decrease regarding to the level of immersion (4, 21) This reduction in lung volumes are due to central blood shifting and hydrostatic pressure around abdomen and chest. Therefore, volumetric reduction increases with immersion level (5, 6). Decreased gravity force and increased hydro pressure result in improved

Table 2. Effect of dry land and different levels of water immersion on respiratory muscle strength and cough strength

	Dry land	Iliac crests level	Xiphoid level	Clavicles level	*p* value
Respiratory Muscle Strength					
MIP, cmH_2O	96.0 (73.7-114.0)	92.5 (72.0-108.0)	86.5 (74.0-114.5)	85.5 (67.7-102.7)	0.168
MEP, cmH_2O	106.5 (86.5-119.5)	106.5 (93.7-123.7)	112.5 (92.2-139.5)	126.0 (93.0-156.0)	**0.001*** [a, b]
Cough Strength					
PEF, L/min	600.0 (485.0-787.5)	600.0 (500.0-800.0)	620.0 (502.5-800.0)	645.0 (472.5-800.0)	**0.015***

MIP, maximum inspiratory pressure; MEP, maximum expiratory pressure; PEF, peak expiratory flow
Values expressed as median (interquartile range)
*Statistically significant at p<0.05 (Friedman test: p-value indicates the comparisons among dry land and different levels of water immersion)
[a]Difference between dry land and clavicles level p<0.001 for MEP
[b]Difference between iliac crests level and clavicles level p= 0.003 for MEP
[a-b](post-hoc Wilcoxon signed ranks test with Bonferroni correction resulting in a significance level of p<0.0125)

blood flow to the lungs which leads increased work of breath up to 60% at neck level immersion (1). Hoshi et al. also reported that water immersion above xiphoid appendix level increase airway resistance (22). All these findings point out that pulmonary muscles are working in an altered condition during head immersion.

Andrade et al. found that MIP decreases significantly with the level of immersion at the xiphoid process and even more at clavicle level (7). In our study even though, MIP tended to decline there was no significant decrease occurred with immersion level. Both studies involved similar subject groups; young healthy individuals with around 40% male participants. They mentioned that they randomized measurement levels however in our study we randomized the measurement sequences rather than levels. This might be the reason of differences in results as our subjects may have developed adaptation to immersion. If the subjects were selected from a group of individuals with weaker adaptation mechanism the results would be expected differently. On the other hand, studies with healthy elderlies (3) and stroke (23) patients showed no difference in MIP on land and in water. Further studies are needed to understand the changes in inspiratory muscle strength during head out immersion.

Our study showed that immersion level had significant effect on MEP. MEP measured at iliac crest immersion was found greater than dry land. This result is conflicting with Andrade's (7) and Yamashina's (3) finding which they found no statistically significant difference at iliac crest level. They randomized their immersion level during their study whereas we immersed gradually and randomised oral cavity pressure measurements instead. Immersion at crest iliac level leads lower limb venous circulation shift to abdomen and thorax. Increased filling of abdominal and thoracic vessels may trigger some neuromuscular changes that generates more powerful contraction. However, this chance did not continue at xiphoid level where abdominal pressure increases.

At clavicle level immersion, the mechanical loads of water are higher than the previous conditions, MEP statistically increased. Our findings conflict with results where they reported no changes in in MEP values at any immersion level. On the other hand, Kim et al. investigated pulmonary changes in stroke patients on land and in clavicle level immersion in standing position. Their MEP results were similar to our findings, there was a significant increase with immersion (23).

Cough strength was evaluated in this study to investigate the power in the initial part of forced expiratory which may show correlation to forced expiratory flow between (FEF). Our findings showed that cough strength tend to increase with the level of immersion however post-hoc pairwise tests did not show any statistical difference between immersion levels. Other studies evaluated reported decrease in FEF with immersion comparing to the dry land values (18, 19).

In this paper we only discuss the passive effects of immersion on pulmonary muscle strength. It is known that pulmonary volumes reduce with the immersion. There are few studies investigated the changes the force generated by pulmonary muscles with altered conditions. Our findings showed that MIP did not change with the immersion level where as MEP increased in deeper levels. Cough strength had tendency to increase however there were significant difference was found between immersion levels. These findings showed similarities and conflictions with the existing scarce literature.

CONCLUSION

In conclusion pulmonary system undergoes physiological changes with immersion and response of inspiratory muscles are not entirely understood. These changes may vary depending on the depth and duration of the immersion, as well as the individual's fitness level and overall health. Further studies are needed to understand the effects of immersion responses of pulmonary muscles.

Acknowledgement: None.

Author contribution: All authors contributed equally at following precesses: Conceiving and designing the analysis; Collecting the data; Contributing data or analysis tools; Performing the analysis; Writing the paper.

Conflict of interests: None.

Ethical approval: Non-interventional Clinical Ethics Committee of Izmir University of Economics (Date: 19.07.2022, Number: B.30.2.İEÜSB.0.05.05-20-168).

Funding: None.

Peer-review: Externally peer-reviewed.

REFERENCES

1. Becker BEJP. Aquatic therapy: scientific foundations and clinical rehabilitation applications. Pm&r. 2009;1(9):859-72.
2. Yamashina Y, Yokoyama H, Naghavi N, Hirasawa Y, Takeda R, Ota A, et al. Forced respiration during the deeper water immersion causes the greater inspiratory muscle fatigue in healthy young men. J Phys Ther Sci. 2016;28(2):412-8.
3. Yamashina Y, Hirayama T, Aoyama H, Hori H, Morita E, Sakagami N, et al. Effects of Water Immersion in Different Water Depths on Respiratory Function and Respiratory Muscle Strength among Elderly People: An Observational Study. Advances in Aging Research. 2021;10(4):71-7.
4. Prefaut C, Lupi-h E, Anthonisen N. Human lung mechanics during water immersion. J Appl Physiol. 1976;40(3):320-3.
5. Dahlbäck G, Jönsson E, Liner M. Influence of hydrostatic compression of the chest and intrathoracic blood pooling on static lung mechanics during head-out immersion. Undersea Biomed Res. 1978;5(1):71-85.
6. Buono MJ. Effect of central vascular engorgement and immersion on various lung volumes. J Appl Physiol. 1983;54(4):1094-6.
7. de Andrade AD, Júnior JC, Lins de Barros Melo TL, Rattes Lima CSF, Brandão DC, de Melo Barcelar J. Influence of different levels of immersion in water on the pulmonary function and respiratory muscle pressure in healthy individuals: observational study. Physiother Res Int. 2014;19(3):140-6.
8. Park JH, Kang S-W, Lee SC, Choi WA, Kim DH. How respiratory muscle strength correlates with cough capacity in patients with respiratory muscle weakness. Yonsei Med J. 2010;51(3):392-7.
9. McNamara RJ, McKeough ZJ, McKenzie DK, Alison JA. Water-based exercise in COPD with physical comorbidities: a randomised controlled trial. Eur Respir J. 2013;41(6):1284-91.
10. Felcar J, Probst V, De Carvalho D, Merli M, Mesquita R, Vidotto L, et al. Effects of exercise training in water and on land in patients with COPD: a randomised clinical trial. Physiotherapy. 2018;104(4):408-16.
11. Ogonowska-Slodownik A, Labecka MK, Kaczmarczyk K, McNamara RJ, Starczewski M, Gajewski J, et al. Water-Based and Land-Based Exercise for Children with Post-COVID-19 Condition (postCOVIDkids)—Protocol for a Randomized Controlled Trial. Int J Environ Res Public Health. 2022;19(21):14476.
12. Hammill HV, Ellapen TJ, Strydom GL, Swanepoel M. The benefits of hydrotherapy to patients with spinal cord injuries. African journal of disability. 2018;7(1):1-8.
13. Marinho-Buzelli AR, Bonnyman AM, Verrier MC. The effects of aquatic therapy on mobility of individuals with neurological diseases: a systematic review. Clin Rehabil. 2015;29(8):741-51.
14. Becker BE. Aquatic therapy in contemporary neurorehabilitation: an update. PM&R. 2020;12(12):1251-9.

15. Gurpinar B, Ilcin N, Savci S, Akkoc N. Do mobility exercises in different environments have different effects in ankylosing spondylitis? Acta Reumatologica Portuguesa. 2021;46(4):297-316.
16. Medrado LN, Mendonça MLM, Budib MB, Oliveira-Junior SA, Martinez PF. Effectiveness of aquatic exercise in the treatment of inflammatory arthritis: Systematic review. Rheumatol Int. 2022;42(10):1681-91.
17. Laveneziana P, Albuquerque A, Aliverti A, et al. ERS statement on respiratory muscle testing at rest and during exercise. Eur Respir J. 2019;53(6):1801214
18. Vepo AA, Martinez CS, Wiggers GA, Peçanha FM. Incentive spirometry and breathing exercises were not able to improve restrictive pulmonary characteristics induced by water immersion in healthy subjects. Int J Physiother Res. 2016;4(2):1415-22.
19. Peignot S, Mettay T, Hotton R. Impact of immersion at different levels on respiratory function in healthy subjects. Eur Respir J. 2015;46(suppl 59):PA4212.
20. Chen H, Li P, Li N, Wang Z, Wu W, Wang J. Rehabilitation effects of land and water-based aerobic exercise on lung function, dyspnea, and exercise capacity in patients with chronic obstructive pulmonary disease: A systematic review and meta-analysis. Medicine. 2021;100(33).
21. Agostoni E, Gurtner G, Torri G, Rahn H. Respiratory mechanics during submersion and negative-pressure breathing. J Appl Physiol. 1966;21(1):251-8.
22. Hoshi D, Fukuie M, Tamai S, Momma R, Tarumi T, Sugawara J, et al. Influence of water immersion on the airway impedance measured by forced oscillation technique. Respir Physiol Neurobiol. 2022;295:103779.
23. Kim J-S, Park M-C. Changes in the Respiratory Function of Stroke Patients on the Ground and Immersed under Water. PNF and Movement. 2018;16(3):389-95.