Comparison of lung function between breath-holding diving and non-breath-holding diving fishermen in Ambon city

J Luhulima, E C Oetama* and J Mainase
Faculty of Medicine, Pattimura University, Ambon-Indonesia
*E-mail: evanc1138@gmail.com

Abstract. Breath-hold diving is a traditional method used by fishermen to catch fish or other marine organisms. When humans hold their breath during diving, generally their body will develop physiological changes, and with regular exercise, this can improve the lung function. Based on many studies reported, there is an increase in lung function in breath-hold diving fishermen. The objective of this study was to analyze the comparison of pulmonary function between breath-hold diving fishermen and non-divers fishermen in Ambon. This study uses analytical methods with a cross-sectional approach using primary data of 15 breath-hold divers and 15 non-divers fishermen sample with same background of healthy behavior. The pulmonary function differences between breath-hold diving fishermen and non-diving fishermen were analyzed using t-student test. Pulmonary function parameters i.e. VC, FVC, and FEV1% was measured using spirometer. The results of this study showed that mean value of lung function comparison between breath-hold diving fishermen and non-breath lung function fishermen in vital capacity (VC) ratio was 3.48 ± 0.5 vs. 3.01 ± 0.63 (t2(2)0.05, P = 0.03), forced vital capacity (FVC) was 2.19 ± 0.45 vs. 1.84 ± 0.46 (t2(2)0.05, P = 0.045), and forced expiratory volume in one second (FEV1%) was 91.46 ± 9.12 vs. 83.44 ± 10.3 (t2(2)0.05, P = 0.03). The lung function comparison in breath-hold diving fishermen and non-diver fishermen showed that there is a significant difference in lung function between breath-hold fishermen and non-diver fishermen. The conclusion of the research is, with the same background of life behavior, the lung function of breath-hold diving fishermen is better than non-diver fishermen.

1. Introduction
Breath-hold diving (free diving or apnea diving) is a traditional way to catch fish or other marine products [1]. Breath-hold diving has been practicing since 4500 BC, to obtain economic benefits from collecting marine products, and treasures from sunken ships. Breath-hold diving by fishermen in South Korea and Japan has begun since 2000 years ago and still being carried out to date [2]. Every day, the fishermen dive between 150 and 250 times at the depth of 5 to 20 meters with an average duration of one to two minutes for each dive and interspersed of a surface break for about two to three minutes [3, 4]. The Bajau tribe of Indonesia is known as a breath-hold diving or traditional diver for thousands of years ago like what Ama divers do in Japan. The Bajau tribe can dive by holding their breath for 13 minutes, reaching a depth of up to 70 meters [5].

When diving with breath-holding, a change in organ function will generally occur which is due to changes in hydrostatic pressure if continuously exposed to such a situation. This can lead to an adaptation of the cardiovascular system including bradycardia, decreased cardiac output, increased arterial blood pressure, peripheral vasoconstriction, and centralization of blood volume from the peripheral body. In addition, there is an adaptation of the respiratory system, among others, an increase in maximal inspiration pressure, and tolerance to increase in CO2, thermal adaptation (shivering due to a decrease in water temperature), sensory changes (chemoreceptor activation), and mental status. This physiological change occurs due to the activation of the parasympathetic nervous system that works as a mechanism for oxygen conservation. This mechanism aims to reduce oxygen use in peripheral
tissues. In this situation, oxygen supply is sufficient for vital organs such as the liver and brain, and myocardial perfusion is reduced by about 30% [2, 6].

The physiological changes that occur depend on the length and depth of the dive and this is a mechanism for acute and chronic adaptation of the body [2, 6, 7]. When diving, the chest and lung walls are compressed due to increase in water pressure. There are three main challenges when diving with breath-holding, which are the duration of diving associated with hypoxia; the depth of water which causes mechanical stress on the air-containing cavity; and high gas pressure which has the potential to cause toxic effects [3, 8].

Based on the Basic Health Research (Risksesdas 2013) [9] data, the smoking behavior of the population of 15 years and over has not decreased compared to 2007, and even tend to increase from 34.2 percent in 2007 to 36.3 percent in 2013. The proportion of farmers/fishermen/workers who smoke was 44.5% [9]. Healthy behavior in Maluku Health Profile Results in 2014 showed 39.90% with the highest percentage in Southeast Maluku District at 67.50% and the lowest in MTB at 5, 60% which includes not smoking, sports. Unhealthy living behavior affects the health of both individuals and society [10]. This has led to a pattern of life-related to marine and profession as a fisherman, which is mostly cultivated by the community [11].

In the initial observations made by authors shows that some of the fishermen at the coastal area of South Leitimur Sub-district of Ambon City are a smoker. Based on this background information this study aimed to study the comparison of pulmonary function between breath-resistant fishermen and non-breath-resistant divers fishermen with a poor background of healthy behavior in Ambon City. The study was conducted from June to July 2018.

2. Materials and Method

A cross-sectional analytic approach was used in this study with one time variables measurement i.e. a momentary measurement or at the same time. Data collection was carried out at the villages of Hutumuri, Leahari, Hukurila, and Latuhalat (Figure 1) as a sampling site. The fishermen from these areas are all traditional fishermen with breath-resistant divers and non-breath-resistant divers. The sampling technique used was consecutive sampling, where all subjects who arrived and meet the selection criteria sequentially were included in the study until the required numbers of subjects are fulfilled. The number of samples needed for this study was 30 samples which consist of 15 breath-hold diver fishermen and 15 non-diver fishermen.

Data of respondent characteristics were analyzed descriptively and presented in frequency percentage distribution [12]. Bivariate analysis was conducted to compare the physical characteristics and pulmonary function between breath-hold diving fishermen and non-diver fishermen.

![Figure 1. Map of Ambon showing study sites](image-url)
3. Results and Discussion

3.1. Socio-economic and demographic characteristic of respondent

Socio-economic characteristics of respondent cover the aspect of age, education level, other occupation apart from fishermen, income, and house condition. From data obtained, the age of most of the fishermen of the free diver was between 26 to 60 years with 43.33% was over 40 years old, whilst non-divers at the same age of over 40 years old was 26.66%. This explains that most of the fishermen especially free diver is not at the young age.

From the education background, most of the fishermen have primary school background with 26.67% from the free diver and 20% from non-diver whereas fishermen having higher education represent only 3.33%. With a low education level will certainly affect fishermen health behavior. This will be explained in more detail when comparing the health status and behavior of fishermen. In a much coastal community in Maluku, being a fisherman is not the sole source of income. Interviewed with respondent shows that apart from fishermen, they have other occupation as well and the second most occupation is farmer with 33.33% from free diver fishermen and 20% form, non-diver fishermen.

Other features which might be affecting fishermen health condition is an environmental condition of fishermen house. A majority (86.67%) of the respondent have their own house equip with a sanitary facility such as toilet (90%), 50% having final disposal bin, whole fishermen have a water supply to their house. In general, this explains that the fishermen either free dives and no dive have quite a good house environment quality.

3.2. Health behavior and health status

Variable used to describe health behavior in this study covers smoking behavior, alcohol consumption, and physical exercise. From an interview and questionnaires collected it was found that as a total 83.33% of fishermen are active smoker where 48% smoke more than a pack of cigarettes per day. As a total, 73.34% of free dive fishermen and non-dive fishermen take alcohol and quite frequent. In relation to physical exercise, 90% of fishermen do an exercise and 44.42% do an exercise more than 4 times a week and 25.91% of fishermen do the exercise 1 day per week. From many studies, some habit, alcohol consumption, and physical exercise contribute to human health status. Smoke habit kills 3.5 to 6 million people a year worldwide [15, 16].

Health Organization (WHO) noted that harmful alcohol use is the third leading risk factor for premature deaths and disabilities in the world, accounting for approximately 2.5 million deaths worldwide in 2004 [17]. There are harms associated with drinking too much both on a single occasion and over a lifetime. These can be serious and even life threatening. Many studies shows that serious consequences caused by drinking too much alcohol like digestive disorder, liver disease, dietary deficiencies, brain damage, cardiovascular disease, death, social circumstances [18,19].

There are numbers of epidemiologic evidence that physical exercises are related to the occurrence of several diseases that are major causes of death and disability. Study has suggested physical activity (exercise) may contribute to the prevention and control of several other diseases apart from risk of coronary heart disease and Parkinson [20, 21].

From this study it was found that bot free dive and non-dive fishermen respondent has some habitual in smoking, alcohol consumption and physical exercises with various degrees of level. All these habitual activity has an effect on person health. Table 1 show some parameters measured for evaluating health status of free dive and non-dive fishermen from study site and the conclusion from this analysis was as follows: 50% of free divers and 34.09% of non-divers catagorized in healthy status, whilst 6.82% of free diver and 9.09% of non-divers are catagorized in sick status. Apart from smoke, alcohol, and exercise, many factors which are not analyzed in this study also associates with health status of a person.
### Table 1. Distribution on based health status

|                          | Free Divers | Non-Divers | Total |
|--------------------------|-------------|------------|-------|
|                          | n           | %          | n     | %    |       |
| BMI (kg/m²)              |             |            |       |      |       |
| < 17                     | 0           | 0          | 1     | 2.28 | 2.28  |
| 17 - 18.4                | 2           | 4.54       | 1     | 2.28 | 6.82  |
| 18.5 – 25                | 17          | 38.63      | 8     | 18.18| 56.81 |
| 25.1 - 27.0              | 5           | 11.36      | 5     | 11.36| 22.72 |
| >27.0                    | 1           | 2.28       | 4     | 9.09 | 11.37 |
| Abdomen Circumference (cm)|             |            |       |      |       |
| ≥90 cm                   | 7           | 15.91      | 10    | 22.73| 38.64 |
| <90 cm                   | 18          | 40.91      | 9     | 20.45| 61.36 |
| Blood Pressure (mmHg)    |             |            |       |      |       |
| Hipotension (<90 t. sistole) | 0         | 0          | 0     | 0    |       |
| Normal (90-120/<80)      | 11          | 25         | 12    | 27.27| 52.27 |
| Prehypertension (121-139/81-89) | 11    | 25         | 3     | 6.82 | 31.82 |
| Hypertension I (140-159/90-99) | 2       | 4.55       | 3     | 6.82 | 11.37 |
| Hypertension II (≥160/≥100) | 1         | 2.27       | 1     | 2.27 | 4.54  |
| Pulse Frequency (per minute) |          |            |       |      |       |
| <60                      | 0           | 0          | 0     | 0    |       |
| 60-100                   | 25          | 56.82      | 19    | 43.18| 100   |
| >100                     | 0           | 0          | 0     | 0    |       |
| Conclusion               |             |            |       |      |       |
| Health                   | 22          | 50         | 15    | 34.09| 84.09 |
| Sick                     | 3           | 6.82       | 4     | 9.09 | 15.91 |

### 3.3. Comparison of lung function of free divers fishermen and non-divers fishermen

Table 2 summarized some others physical characteristics (vital capacity – VP, force vital capacity – FVC, and force expiration volume – FEV) of free divers and non-divers fishermen from study site. The result shows that there is significance difference between VP value of free divers and non diver fishermen with free diver fisherman having high VP value. The whole parameters shows that free diver or breath hold diver fishermen having high significant VC, FVC and FEV compared to non-diver fishermen.

### Table 2. Comparison of physical characteristics of free divers fishermen and non-divers fishermen

| Parameter   | Group          | Mean   | Std. Deviation | p value | Min-Max       |
|-------------|----------------|--------|----------------|---------|---------------|
| VC (L)      | Free divers    | 3.48   | 0.502          | 0.03    | 2.8–4.53     |
|             | Non divers     | 3.01   | 0.638          |         | 2.2–4.24     |
| FVC (L)     | Free divers    | 2.19   | 0.456          | 0.045   | 1.53–3.01    |
|             | Non divers     | 1.84   | 0.462          |         | 1.17–2.64    |
| FEV₁ (%)    | Free divers    | 91.49  | 9.127          | 0.03    | 74.06–100    |
|             | Non divers     | 83.44  | 10.3           |         | 62.24–100    |

When divers used to do breath-holding dives, there can be an increase in the threshold for PCO2 above normal which is due to a tendency of divers to ignore the stimuli on chemoreceptors that provide information that the body demands breathing [13,14]. Breath-holding divers of Ama from South Korea and Japan have a Vital Capacity (VC) of 15% greater than women who were not breath-
holding divers [9]. Study on breath-hold diving fishermen and non-diver fishermen in Brazil showed an average lung function i.e. Forced Vital Capacity (FVC) of 4.9 (± 0.61) liters compared to 4.3 (± 0.41) liters (P <0.05) and Forced Expiration Volume in one second (FEV1) of 4 (± 0.5) liters compared to 3.6 (± 0.3) liters [1,13].

Research by Diniz's et al (2014) [1] with 10 subjects from diving fishermen and 11 subjects from non-divers fishermen shows that mean lung function in KVP of divers fishermen was 4.9 L, while for non-divers fishermen the mean value was 4.3 L. The mean value of VEP in dive fishermen was VEP1 4.0 L while non-diver fishermen 3.6 L.1 Ferreti (2003) [13] found that breath-resistant divers had a mean of KV was 4.91 L, while the control group (non-divers) have mean value of KV was 3.06 L. Research by Tetzlaff et al (2008) [22] found that breath-resistant divers had mean KV of 6.85 L, while the control group (non-divers) mean KV value was 5.73 L. In breath-resistant KVP, 6.81 L and not divers found 5.71 L with a value of p = 0.01. Pulmonary function in diver fishermen is higher than that of non-divers fishermen, which is in accordance with the research conducted by Diniz et al (2014) [1] due to the increased in the number of alveoli due to repetitive activities and exposure to underwater environments with higher pressure. Large lung volumes were also associated with increased work of respiratory muscles obtained from diving [1]. Increased in lung inspiration capacity reflected the ability to produce more negative intrapleural pressure during inspiration, and increased maximum inspiratory pressure by the respiratory muscles [13]. Increased hydrostatic pressure due to diving can cause a reflex of the cardiovascular system which includes bradycardia, increased arterial blood pressure, peripheral vasoconstriction, centralization of blood volume from the periphery of the body, mechanism of the lungs (increased maximum inspiratory pressure, tolerance to CO2), thermal adaptation ( shivering due to a decrease in water temperature), sensory changes (chemoreceptor activation) [6,7,13].

Yunani et al (2013) [23] found differences in vital lung capacity before and after swimming with increased in vital lung capacity after swimming. This increase is needed for breathing during physical exercise during swimming where there are several movements of the chest muscles and respiratory muscles. Individual doing swimming exercises regularly indirectly training the respiratory muscles which increase the ability and strength of the respiratory muscles and will produce enough inspiratory pressure to do maximum ventilation so that respiratory function will increase [23]. Research conducted by Numbery et al (2013) [24] shows that diving exposure can cause changes in lung function, which will affect the respiratory tract.

4. Conclusion

The lung functions of diving fishermen in breath-hold diver significantly better than non-diver fishermen, with poor health behavioral backgrounds. Breath-hold diving activities can routinely improve lung function.

References

[1] Diniz C M P, FariasT L, Pereira M C A, Pires C B R, Gonçalves L S L, Coertjens P C and Coertjens M 2011 Chronic adaptations to lung function in breath-hold diving fishermen. *International J Occupational Medicine and Enviromental Health*. 27(2) 216-233.

[2] Lin Y C and Hong S K 2011 *Handbook of Physiology-Enviromental Physiology: Hyperbaria Breath-hold Diving* Vol.2 (New York: Oxford University Press)

[3] Lindholm P and Lundgren C. 2008. The physiology and pathophysiology of human breath-hold diving. *J Appl. Physiol*. 106 284-292

[4] Muth C, Ehrmann U and Radermacher P. 2005. Physiological and clinical aspects of apnea diving *Clin Chest Med* 26(3) 381-94

[5] Llaro M et al. 2018. Physiological and genetic adaptations to diving in Sea Nomads. *Cell*. 173 569-580

[6] Prediletto R, Ndreu R and Pavlickova I 2016 What happens to human lungs during breath-hold diving? *Clin Res Pulmonol* 4(1) 1035-39
[7] Mijacika T and Dujic Z 2016 Sports-related lung injury during breath-hold diving. European respiratory society. *Eur. Respir. Rev.* **26** 506-512. DOI: 10.1183/16000617.0052-2016

[8] Tournat TZ. 2014 Human adaptations: free divers. *UC Merced Undergraduate Research Journal.* **7**(1) 254-262

[9] Kementrian Kesehatan Republik Indonesia 2013 *Riset Kesehatan Dasar tahun 2013* (Jakarta: Kemenkes RI) p 370

[10] Dinas Kesehatan Provinsi Maluku 2015 *Profil kesehatan Maluku tahun 2014* (Ambon: Dinas Kesehatan Provinsi Maluku) p 361

[11] Luhulima M, Nainggolan S and Manuputty J 2015 Faktor risiko kesehatan dan keselamatan nelayan di Maluku. Universitas Kristen Indonesia.

[12] Nichols J 2006 *Introduction to Descriptive Statistics* (Sydney: Mathematics Learning Center, University of Sydney NSW) p 38

[13] Ferrettia G and Costa M. 2003. Diversity in and adaptation to breath-hold diving in humans. *Comp Biochem Physiol A Mol Integr Physiol.* **2136**(1) 205-13

[14] Masuda Y, Yoshida A, Hayashi F, Sasaki K and Honda Y 1981 The ventilatory responses to hypoxia and hypercapnia in the ama *Japanese Journal of Physiology* **31** 187-197

[15] Ferrante M, Saulle R, Ledda C and Pappalardo R 2013 Prevalence of smoking habits, attitudes, knowledge and beliefs among Health Professional School students: a cross-sectional study. *Ann Ist Super Sanità.* **49**(2) 143-149

[16] Papathanasiou G, Mamali A, Papafloratos S and Zerva E 2014 Effects of smoking on cardiovascular function: the role of nicotine and carbon monoxide. *Health Science Journal.* **8**(2) 279-90

[17] Monteiro M G. 2011. The road to a world health organization global strategy for reducing the harmful use of alcohol. *Alcohol Research and Health.* **34**(2) 257-260

[18] Rehm J, and Roerecke M 2011 Alcohol, the heart and the cardiovascular system – what do we know and where should we go? *Drug and Alcohol Review* **30** 335–337

[19] Rosenquist J N, Murabito J and Fowler J H 2010 The spread of alcohol consumption behavior in a large social network. *Annals of Internal Medicine* **152** 426–433

[20] Siscovick D S, LaPorte R E, and Newman J M 1985 The disease-specific benefits and risks of physical activity and exercise. Public Health Report. **100**(2) 180-188

[21] Ellis T D, Cavanagh J T, Farhart G M, Ford M P and Forman K B 2011 Factors associated with exercise in people with parkinson disease. *Phys. Ther.* **91**(12) 1838-48. doi: 10.2522/ptj.20100390

[22] Tetzlaff K, Scholz T, Walterspacher S, Muth C M, Metzger J, Roecker K and Sorichter S 2008 Characteristics of the respiratory mechanical and muscle function of competitive breath-hold divers *Eur J Appl Physiol* **103**(4) 469-75. doi: 10.1007/s00421-008-0731-9

[23] Yunani, Puspitasari D, Sulistiyawati E 2013 Perbedaan kapasitas vital paru sebelum dan sesudah berenang pada wisatawan di kolam renang Taman Rekreasi Kartini Rembang. *Jurnal Keperawatan Medikal Bedah.* **1**(2) 127-131

[24] Numbery E I, Joseph W B S, Maramis F R R and Kawatu P A T 2013 Gambaran volume dan kapasitas paru pada para penyelam profesional di Kota Manado FKM Unsrat pp 33-37