Effects of Underwater Yoga on Some of Physiological Variables and SCUBA Diving Skills

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Abstract: The effects of underwater hatha yoga on physiological variables, with and without scuba diving equipment, were investigated on 20 healthy sport divers before and after the underwater yoga exercises during 6 weeks. A static apnea test on water surface was applied by facial immersing in water at 2-min intervals, using two different methods of breath-holding which are called GPB and HV, during this test we measured the heart rate and lung function using pyrometer, E.C.G, and the limit of residual air pressure in SCUBA tank after 30min dive. After this test we found an observable increase in the apnea time and residual air pressure in SCUBA tank, and this was attributable to a decrease in heart variables and an increase in lung function. Apnoeic time tended to be larger after underwater SCUBA exercises. This results may increase the efficiency in some SCUBA diver’s skills and also gives more safety and relaxation in SCUBA diving program.

Keywords: Breath-holding, glossopharyngeal breathing, hyperventilation, hatha yoga.

Introduction

The combination of yogic exercise, static apnea (maximal Breath holding at rest), dynamic apnea (maximal underwater swimming distance) affect SCUBA diving, free diving sport, synchrony swimming, in underwater rugby and the diving phase of competitive swimming disciplines. Short periods of apnea may also share in other sport activities, for example during the 100m or 200m dash in track, field athletics, and also in recreational activities (U.Hoffman2005). During the last couple of years, breath-holding diving record have been set using a special respiratory maneuver, called glossopharyngeal insufflation breathing (GPB) and Hyperventilation (HV). GPB, which called frog breathing, is a mean of forcing extra air into lungs to expand chest and achieve a functional cough. The technique involves the use of glottis add to an aspiratory effort by gulping boluses of air into lungs. It can be beneficial for individuals with weak aspiratory muscles and no ability to breath on their own. Divers often refer to this technique as “lung packing. The second technique is hyperventilation (HV), which is three deep and slow inhalations and not more than three. HV cases carbon dioxide loss. The purpose of this maneuver is to start the dive with a very large air volume in the lungs so as to reach the deepest possible depth before the chest and lungs are compressed to the limit of what is subjectively tolerable or mechanically safe (Lindholm, Nyren 2005),(Lindholm GennserM 2005). The effect of underwater yoga breathing technique (glossopharyngeal breathing GPB, hyperventilation HV) training on SCUBA diving may offer insights into useful breathing practices and control of important physiological variables.
The philosophical doctrine of yoga is based on moral precepts, ascetic and meditation techniques and a special type of physical training called hatha yoga, which includes the control of posture and respiration. Its development in India can be traced back to about 500 BC. Yogeic exercises improve body functions through the manipulation of cardiovascular, respiratory, metabolic and other control mechanisms. Yogic practices have been reported to induce a shift in the autonomic balance towards relative parasympathodominance, improved thermoregulatory efficiency and a relative hypo metabolic state (James E.Kennedy 1990). The full inhalation of the complete breath should provide maximum opening of the collapsed lower airways, which may be of particular value to older persons and those with lung impairment. However, the full exhalation will also provide maximum collapsing of airways. For maximum airway opening, the complete breath practice should end after an inhalation, rather than after a full exhalation (Potkin 2007), (Nygren Bonnier 2007). Breathing exercises can help relieve muscle tension around the thoracic area, the back, the shoulders and the neck. Deep breathing will also help stretch out an important dome-shaped muscle, the diaphragm and enhancing a breath –holding time (Plada 2008), (L.Secombe ). The available data also indicates that yogic slow breathing practices promote the dominance of parasympathetic system, which controls stress.

Aims
Our aim was to measure the effect of yoga program, using GBP and HV, on the physiological variables: heart rate lung function, and SCUBA skills at dynamic apneas.

Material and Methods
Subjects
20 healthy divers male sport students volunteered for the study .The subject were 23.9 ± 1.1 years of age, height 1.76 ± 1.07m and weight 76.85 ± 1.22 kg .The subjects have at least 32.85 ± 1.69 dive experience record in SCUBA diving program and during the investigation period all subjects trained on underwater yoga program for six weeks in confined open water and 25–m pool.

Protocol
Subject were tested on tow separate times with spirometer and E.C.G. , with and with out SCUBA equipment on land and in water .The first test on Land and in water, was three apnea after try hyperventilation method of breath–holding and three apnea after try glossopharyngeal breathing GPB method of breath –holding. The second test Slow dynamic apnea SDA , and limit of residual air pressure in scuba tank after drift dive DD by pressure gauge .The sequence of physiological variables of breath- holding with the two methods, GPB and HV, after yoga program, on land and in water, was positively varied.

Lung function and Heart rate measurement
The subjects were lying in supine position and breathed through a spirometer and electro- cardiograph on land, vital capacity, heart rate, cardiac output, was measured during inhalation and exhalation. The subjects performed breath-holding after a maximal conventional inhalation with GPB method, and performed breath-hold after the HV technique three times deep and slow inhalation, all tests repeat try for three times.
Static Apnea
In water the subjects had performed GPB and HV, and they immerged their faces by flexing their necks in the water, and then performed breath-holding as long as they could.

Dynamic apnea
The measurements were performed in a 25-m long pool, water temperature 26 °C, depth 2 m. After warming up which included one or two sub maximal dynamic apneas, the dynamic apnea bouts were performed with mask, snorkel, fins and with SCUBA gear to measure C.E.S.A (control emergency swimming ascent skills). The subjects made the first three dynamic apnea trials with hyperventilated method, at 2min interval between the three apneas, and repeated the experiment after half hour to make dynamic apnea with GPB method. The subjects returned on two other occasions to complete all three dynamic apnea bouts. The length of the dive was recorded to the nearest meter and, apneic time was recorded as described in dynamic static apnea.

Data analysis
A control value for each parameter was calculated as an average value mean and standard deviation ±SD from apnea. For heart rate, an average value was calculated during each apnea and also for the last 10 s of apnea. For SV an average value was calculated for each 5-s period from the beginning of apnea until 10 s after apnea. The relative change for GPB and HV after underwater yoga program was calculated. For each subject, an individual mean value from the three last apneas in each condition was calculated for all parameters. The improvement of apneic time values were compared between, before and after, underwater hatha yoga program, and the apneas in air, with face immerssion. The physiological variables were also compared between GPB and HV method using paired t-test. The level used for accepting significance was *P < 0.05.

Table 1 Characteristics of 20 subjects

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Means ± SD</th>
<th>Characteristics</th>
<th>Means ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [year]</td>
<td>23.9 ± 1.1</td>
<td>Cardiac output [CO]</td>
<td>7.25 ± 0.94</td>
</tr>
<tr>
<td>Height [cm]</td>
<td>176 ± 1.07</td>
<td>Heart Stork volume SV</td>
<td>98.7 ± 4.6</td>
</tr>
<tr>
<td>Weight [kg]</td>
<td>76.85 ± 1.22</td>
<td>Oxygen Volume [O2V]</td>
<td>0.30 ± 0.12</td>
</tr>
<tr>
<td>Training Experience [TE] Num</td>
<td>32.85 ±1.69</td>
<td>Carbon monoxide Volume [Co2V]</td>
<td>0.26 ± 0.13</td>
</tr>
<tr>
<td>Heart Rate HR [bpm]</td>
<td>56.05 ± 2.2</td>
<td>Vital Capacity [VC]</td>
<td>107.4 ±1.42</td>
</tr>
<tr>
<td>Diastolic blood pressure DBP [mmHg]</td>
<td>72.8 ±1.91</td>
<td>Static apnea time [ST]</td>
<td>81.9 ± 2.22</td>
</tr>
<tr>
<td>Systolic blood pressure SBP [mmHg]</td>
<td>126 ±1.89</td>
<td>Slow Dynamic apnea SDA [25 m]</td>
<td>33.45 ± 1.39</td>
</tr>
</tbody>
</table>

Data are means ± SD, n=20
Results

The heart rate gradually decreased during apnea for the subject while HV at the end of apneas in air (51.6±2.82, 48.8 ±7.7 beats/min p < 0.05), but the reduction of heart rate was increase during GPB (75.6±3.5, 80.4±5.3beats/min p < 0.05) for the same subject at the end of apneas in air. Systolic blood pressure [SBP] decreased during apneas for the subject while HV at the end of apneas in air (122.2±10, 120.1±14. 4 mmHg), but was increase during GPB (133.1±4.8, 140.5±7.5 mmHg p < 0.05 significant for the same subject at the end of apneas in air. The diastolic blood pressure [DBP] decreased during apneas for the subject while HV at the end of apneas in air (70.8 ±9.6, 69.2±12.8mmHg), but was decrease during GPB (80.3±4.1, 70.3±10 mmHg not significant (NS) ) for the same subject at the end of apneas in air. The Cardiac output [CO] decreased during apneas for the subject while HV at the end of apneas in air (5.5±0.38, 4.9±6.1L /min), but was decrease during GPB (4.9±0.2, 4.7±0. 6mmmg) not significant (NS) for the same subject at the end of apneas in air. The Heart Stork volume [SV] increased during apneas for the subject while HV at the end of apneas in air (98.06±4.6, 100.36±0.66 ml), but was increase during GPB (99. 01±4.7, 101.3±6 ml) not significant (NS) for the same subject at the end of apneas in air. The oxygen volumen [O2V] increased during apneas for the subject while HV at the end of apneas in air ( 0..30±0.12, 0.35±0.25), but was increase during GPB (0.30±0.13, 0.36±0.27) not significant (NS) for the same subject at the end of apneas in air. The Carbon dioxide Volume [Co2V] increased during apneas for the subject while HV (0.26±0.13. 0.31±0.24), but was increase during GPB (0.27±0.13. 0.33±0.25) not significant (NS) for the same subject at the end of apneas in air. The Vital Capacity [VC] increased during apneas for the subject during HV at the end of apneas in air (107.6±1.42, 111.5±0.07 p <0.05), but was increase during GPB (108.65±0.86,113.5±1.01p< 0.05). Static apnea [ST] time increased for the subject while HV in water (81±2.7, 89 ±2.77p <0.05), but was increase during GPB (84 ±2.20, 90 ±1.68 p< 0.05) for the same subject at the end of apneas in air. Slow dynamic apnea [25m] [SDA] time increased for the subject during HV in water (33.4 ±1.39, 40±0.66p<0.05), but was increase during GPB (34.1 ±1.17. 42 ±0.66 p< 0.05).Control emergency swimming ascent [CESA] time increased for the subject during HV in water (31 ±0.86, 32.3 ±0.89p <0.05), but was increase during GPB (33.8 ±0.98, 36.4 ±0.81p< 0.05). Limit of residual Air pressure in SCUBA tank after drift dive [30 min at15m][DD] increased for the subject (61.8±3 . 77.1±3.6 p <0.05).

Table 2 Characteristics of physiological variables during HV and GPB for 20 subjects

<table>
<thead>
<tr>
<th>Variable</th>
<th>HV Before</th>
<th>HV After</th>
<th>HV T- test</th>
<th>HV Percent rank</th>
<th>GIB Before</th>
<th>GIB After</th>
<th>GIB T- test</th>
<th>GIB Percent rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR</td>
<td>51.6±2.82</td>
<td>48.8 ±7.7</td>
<td>6.6 *</td>
<td>5.7 %</td>
<td>75.6±3.5</td>
<td>80.4±5.3</td>
<td>7.5*</td>
<td>6.3 %</td>
</tr>
<tr>
<td>SBP</td>
<td>122.2±10</td>
<td>120.1±14.4</td>
<td>0.09</td>
<td>1.74 %</td>
<td>133.1±4.8</td>
<td>140.5±7.5</td>
<td>9*</td>
<td>5.5%</td>
</tr>
<tr>
<td>DBP</td>
<td>70.8 ±9.6</td>
<td>69.2±12.8</td>
<td>0.01</td>
<td>2.3 %</td>
<td>80.3±4.6</td>
<td>70.3±10</td>
<td>1.33</td>
<td>14.2%</td>
</tr>
<tr>
<td>CO</td>
<td>5.5±0.38</td>
<td>4.9±6.1</td>
<td>0.01</td>
<td>12.2 %</td>
<td>4.9±0.2</td>
<td>4.7±0. 6</td>
<td>0.03</td>
<td>4.25%</td>
</tr>
</tbody>
</table>
### Table 1: Data on Hemodynamic Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Before Hatha Yoga</th>
<th>After Hatha Yoga</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>SV</td>
<td>98.06±4.6</td>
<td>100.3±0.66</td>
<td>2.3 %</td>
</tr>
<tr>
<td>VO2</td>
<td>0.3±0.12</td>
<td>0.35±0.25</td>
<td>0.02</td>
</tr>
<tr>
<td>VC</td>
<td>107.6±1.42</td>
<td>111.5±1.16</td>
<td>6 *</td>
</tr>
<tr>
<td>V CO2</td>
<td>0.26±0.13</td>
<td>0.31±0.24</td>
<td>0.03</td>
</tr>
<tr>
<td>CO</td>
<td>109.65±0.86</td>
<td>113.5±0.07</td>
<td>2.2 *</td>
</tr>
</tbody>
</table>

Data are means ± SD, n=20

- Significantly different from * P<0.05 , heart rate [HR], systolic blood pressure [SBP], diastolic blood pressure[DBP], cardiac output [CO], heart stork volume [SV], oxygen volume [O2 V], carbon dioxide volume[Co2V],

**Fig 1:** Heart rate before and after hatha yoga during HV

**Fig 2:** Heart Rate before and After Hatha Yoga during GPB

*Space intentionally left blank*
Fig 3: Oxygen Volume [O2 V] before and after hatha yoga during HV and GPB

Fig 4: Carbon dioxide Volume [Co2V] before and After Hatha Yoga during HV and GPB
Fig 5: Vital capacity [VC]. before and after Hatha Yoga during HV and GPB

![Graph showing VC before and after Hatha Yoga during HV and GPB](image)

VC before and *after yoga during HV  
VC before and *after yoga during GBP

Table 3 characteristics of SCUBA diving skills during HV and GPB for 20 subjects

<table>
<thead>
<tr>
<th>Variable</th>
<th>HV Before</th>
<th>HV After</th>
<th>HV T-test</th>
<th>HV Percent rank</th>
<th>GPB Before</th>
<th>GPB After</th>
<th>GPB T-test</th>
<th>GPB Percent rank</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Means ± SD</td>
<td>Means ± SD</td>
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<td></td>
<td>Means ± SD</td>
<td>Means ± SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST</td>
<td>81±2.22</td>
<td>89±2.77</td>
<td>2.8 *</td>
<td>9.8%</td>
<td>84±2.20</td>
<td>90±1.68</td>
<td>3.6*</td>
<td>7.14%</td>
</tr>
<tr>
<td>SDA</td>
<td>33.4±1.39</td>
<td>40±0.66</td>
<td>6.4 *</td>
<td>19.7%</td>
<td>34.1±1.17</td>
<td>42±0.66</td>
<td>3.3*</td>
<td>23.1%</td>
</tr>
<tr>
<td>CESA</td>
<td>31±0.867</td>
<td>32.3±0.89</td>
<td>5 *</td>
<td>4.2%</td>
<td>33.8±0.98</td>
<td>36.4±0.81</td>
<td>7.7*</td>
<td>7.7%</td>
</tr>
</tbody>
</table>

Data are means ± SD, n=20, * significantly different from P<0.05  
Static apnea [ST], Slow dynamic apnea [25m] [SDA], control emergency swimming ascent [CESA].

Fig 6: Static apnea [ST] before and after Hatha Yoga during HV and GBP

![Graph showing ST before and after Hatha Yoga during HV and GPB](image)
7: Slow dynamic apnea before and after Hatha Yoga during HV and GBP

Fig 8: CESA before and after Hatha Yoga during HV and GPB

Fig 9: Limit of residual air Pressure in SCUBA tank after drift dive before and after Hatha Yoga
Discussion

The main new findings of the present study were that hatha yoga underwater with the two different techniques GPB and HV, with SCUBA equipment, can increase lung capacity and apneic time. Also showed that the increasing volume after GPB and HV, by underwater hatha yoga program, was associated with a progressive increase in relaxed airway pressure. High breath-holding ability and underwater hatha yoga training may facilitate the development of greater strength in the respiratory musculature. This may have led to higher lung volumes and increased ventilatory capacity, which was explained by the swim training in the SCUBA divers of the present study. (Lemaitre 2009).

Physiological variable after HV and GPB (Fig1, 2)
We found significant differences in heart rate [HR] variable (P = 6.6) during apnea with HV method after underwater hatha yoga training program with Percent rank 5.7 %, and significant differences for GPB (P = 7.8) percent rank 6.7% for the post measurement. that mean heart rate response showed lower percent for GPB than HV which is in line with findings. Our measurements of heart rate responses during apnea confirmed the findings of earlier studies of a bradycardic response to apnea (Andersson, Schagatay 1998); (Overgaard and Friis2006).

There was a tendency for an increased heart rate with increasing lung volume at the beginning of dry static apnea. This may reflect a response to a decreased venous return at GPB as compared HV because of an increased relaxed airway pressure at higher lung volumes and possibly, because of stimulation of stretch receptors in the lung (Lindholm and Lundgren 2008); (Overgaard and Friis2006); a similar tendency was observed in a study by (Andersson and Schagatay 1998), but there are observations that the blood pressure increase precedes the slowing of the heart frequency.(Muth 2003), suggesting that baroreflex activation plays a role in the development of the bradycardia as may chemoreceptor stimulation from hypoxia during the later part of the breath hold (Lin YC, Shida1983). And study showed no significant differences [NO] in systolic blood pressure [SBP] during HV (P = 0.09) percent rank was showed 1.74% and no significant differences (P = 0.02) percent rank 0.9% for GPB. And showed study no significant differences [NO] in diastolic blood pressure [DBP] for HV(P = 0.01) percent rank was showed 2.3% and significant differences (P = 0.08) percent rank 3.05 % for GPB , this results consistent with the results of a study by (U.Hoffmann 2005), (Lemaitre 2005),(Larsson Anderson 2002),(Johan 2005).The study showed no significant differences [NO] in cardiac output [CO] for HV (P = 0.1) but percent rank was showed 0.55% and no significant differences (P = 0.03) with percent rank 4.25% for GPB , cardiac output that is closely related to the reduction in heart rate . Consequently, the cardiac output would be lower during apneas with GPB than during apneas with HV, (Johan Anderson 2002),(Delapili 2002), (Schagaty 2000), (Pendergast2006),( Carlos2007).

The study also showed no significant differences [NO] in heart stork volume for HV (P = 0.03) percent rank was showed 2.3% and no significant differences (P = 0. 5) Percent rank 2.3% for GPB, (Verschoor1996) and showed study no significant differences [NO] oxygen volume [O2V] (Fig3, 4)for HV (P =0.02) percent rank was showed 16.6% and significant differences (P = 0.3) percent rank 20% for GPB. to increase intrapulmonary oxygen stores and prevent the lungs from dangerous compressions at great depths (Kay Tetzlaff et.all 2008 ),( James A,2004), and the study showed significant differences in carbon dioxide volume [Co2V] for HV(P = 0.03) percent rank was showed 19.2% and significant differences (P = 0.01)
percent rank 22% for GPB(Davis 1987). Hyperventilation [a respiratory exchange ratio higher than the respiratory quotient (RQ)] before the dive reduces CO2 stores in blood and tissues so that the breath-hold dive begins in a state of relative hypocapnia while the oxygen stores, mostly in the lungs, may have increased by a modest 250–300 ml, enough for an additional 10–60 s of breath holding, depending on physical activity (Dariga2006), and the study showed significant differences in vital capacity [VC] for HV (P = 6) percent rank was showed 3.5% and significant differences for GPB (P = 2.2) percent rank 4.5% for GIB, chest expansion increased significantly with glossopharyngeal and improve maximum inspiratory capacity of lung volumes and long-term effects on vital capacity (VC) (Fig5). (Schagaty 2000), (schneeberger 2005), (Bach JR, Bianchi2007), (J Armour, PM Donnelly1993), divers also use GPB and HV on dry land to improve the flexibility of the chest and stretch ability of the diaphragm, (Lindholm 2005). We found significant differences in Static apnea [ST] variable (Fig6) (P = 2.8) during apnea with HV method after underwater hatha yoga training program with percent rank 9.8%, and significant differences for GPB (P = 3.63) percent rank 7.13 % for the post measurement. Also the study showed significant differences in slow dynamic apnea [25m] [SDA] (Fig7) for HV (P = 6.4) percent rank was showed 19.7% and significant differences (P =3.3) percent rank 23.1 % for GPB. Dynamic apnea time was higher at GPB, (Kristian Overgaard 2006), (Nicole Culos2006).

The heart rate was increased during dynamic apnea as compared with dry static apnea, but a significant bradycardic response was still observed during dynamic apnea, which is in line with earlier findings (U. Hoffmann 2005). And showed study significant differences in control emergency swimming ascent [CESA] (Fig8) for HV (P = 5) percent rank was showed 4.2% and significant differences (P=4) percent rank7.7 % for GPB, ( Frederic Lemaître et all 2009). The study showed significant differences in drift dive [30 min at15m][DD] (Fig9) (P = 9 ) percent rank was showed 24.8% hatha yoga exercise due to increased work of breathing, respiratory muscle fatigue, and respiratory muscle training is an intervention that may be able to improve during HV and GPB, ( Gregory D. Wells2005).

Conclusion

GPB can increase lung volume better than HV. The ventilatory and cardiology parameters observed after the glossopharyngeal technique better lung volume, vital capacity and heart rate valuables than HV which affects the apnea performance and SCUBA diving skills. These results became more significant, indicating the positive effect of glossopharyngeal breathing on performance. Using underwater hatha yoga with SCUBA diving equipment can improve breath holding, SCUBA diving skills and improve apnea time for divers in case of the cut of air. Health benefits of Hatha Yoga are balance of strength and flexibility, improved Organ function, better circulation, and relaxation. This study is considered an innovation exercises which the divers suffer form the absence of them.
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