Differences in Forced Vital Capacity between Groups of Elite Croatian Swimmers, Water Polo Players and Breath Hold Divers

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Abstract

The purpose of this study was to determine the differences in forced vital capacity (FVC) between groups of elite swimmers, elite water polo players and elite breath-holding divers. The present study was conducted on 45 top level male athletes (15 swimmers, 15 water polo players and 15 breath-holding divers), all of which in constant training sessions. All athletes were categorized according to the rules of the Croatian Olympic Committee (COC). The age of athletes was between 16 to 37 years. In order to characterize subject samples and the accomplishment of research goals we used a total of 3 variables: body height (cm), body weight (kg) and forced vital capacity (FVC/l). Statistical procedures for this research were selected in accordance with set objectives and hypotheses and the appropriate nature of problem. In order to test hypotheses we used the univariate analysis (ANOVA) breath-holding divers had the highest average value of the FVC (X = 7.98±0.99), then swimmers (X = 7.68±0.81) and the lowest values were in water polo players (X = 7.49±0.79). In the research referred to the measurement of FVC there wasn’t a statistically significant difference between the groups (p=0.30). Based on the obtained results it is possible to conclude that statistically significant differences do not exist between Croatian water polo national team representatives, as well as swimming and breath-holding diver representatives probably because of the nature of the sports that were taken in the study and the sample.

Key words: water polo, breath-holding diving, swimming, forced vital capacity

Introduction

Main rules of body behavior in water are very complex and specific in relation to air medium. Density is a physical property which causes numerous specific features when moving through water. Compared to air, water has a much higher density. At the temperature of 25°C water density is 997.0479 kg/m³ while the density of air at the same temperature is 1.204 kg/m³ (Jones & Harris 1992). Water is therefore about 830 times thicker than air, which significantly complicates moving through it (Byden et al., 2004). Analogously, this also results in different biomechanical, structural and functional indicators among sportsmen who are active in the air medium and those in the water medium.

This difference in density is also manifested through shortness of breath because the muscles which are involved in respiration must perform additional physical activity in water. At water sports, breathing is limited and therefore swimmers swim with a lower respiration rate and larger respiratory capacity (Rodriguez, 2000; Štrumbelj, 2005).

The work of respiratory muscles during swimming is less economical (Kapus et al., 2004) and more difficult due to water pressure. Because of the water pressure, exhalation in the water is accentuated and causes a greater load on respiratory muscles when inhaling during swimming.

This leads to the conclusion that respiration at sports such as swimming, water polo and breath-hold diving is different from respiration at sports out of water (Lomax & McConnell, 2003). Based on conducted research, it can be stated that athletes doing water sports show large values of forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV1), compared to athletes on middle distance and long distance (Sable et al., 2012). This occurrence is caused by changes in lung and chest muscle elasticity which results from the larger external water pressure than the one caused by air.

One of possible causes is the fact that respiration in water is much more difficult and the incomplete hypoxia occurs (Mehrotra et al., 1998). Swimming promotes conductivity of oxygen through airways and a hyperplasia of alveoli can occur as a result of alternating hypoxia caused by limited respiration (Hulke & Phatak, 2011). Due to the increased number of alveoli, swimmers also develop larger lungs compared to runners (Nygren-Bonnier, 2007).

Considering the structure of individual sports, the aim of this research is to establish differences in FVC among elite swimmers, elite water polo players and elite breath-holding divers.
Methods

Subjects and variable samples
The test sample consisted of three groups: elite swimmers (N=15), elite water polo players (N=15) and elite breath-hold divers (N=15). All examinees were male. The variables pattern consisted of forced vital capacity (FVC), body weight (ATT) and height (AVT).

Statistical analysis
The results obtained by measuring the examinees were processed by STATISTICA program (data analysis software system), version 10.0. For variable description, the following parameters were calculated: Mean – arithmetic mean, SD – standard deviation, Min – minimum result, Max – maximum result, SKEW – skewness, KURT – kurtosis. For hypotheses testing (H0 – There is no statistically significant difference in vital capacity among water polo players, free divers and swimmers), a univariate analysis of variance (ANOVA) was used to determine the statistically significant difference among groups with p – a 0.05 error.

Results

Table 1. Descriptive statistical parameters

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>A.S.</th>
<th>MIN</th>
<th>MAX</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATV breath-hold divers (cm)</td>
<td>15</td>
<td>183.95</td>
<td>173.50</td>
<td>180.00</td>
<td>4.43</td>
</tr>
<tr>
<td>ATT breath-hold divers (kg)</td>
<td>15</td>
<td>83.03</td>
<td>70.50</td>
<td>90.90</td>
<td>4.71</td>
</tr>
<tr>
<td>ATV swimmers (cm)</td>
<td>15</td>
<td>188.15</td>
<td>179.00</td>
<td>194.20</td>
<td>4.13</td>
</tr>
<tr>
<td>ATT swimmers (kg)</td>
<td>15</td>
<td>84.06</td>
<td>66.50</td>
<td>104.30</td>
<td>8.69</td>
</tr>
<tr>
<td>ATV water polo players (cm)</td>
<td>15</td>
<td>194.87</td>
<td>188.00</td>
<td>203.00</td>
<td>5.81</td>
</tr>
<tr>
<td>ATT water polo players (kg)</td>
<td>15</td>
<td>95.87</td>
<td>85.00</td>
<td>110.00</td>
<td>7.84</td>
</tr>
<tr>
<td>FVC breath-hold divers (l)</td>
<td>15</td>
<td>7.98</td>
<td>6.26</td>
<td>9.46</td>
<td>0.99</td>
</tr>
<tr>
<td>FVC water polo players (l)</td>
<td>15</td>
<td>7.49</td>
<td>5.87</td>
<td>9.17</td>
<td>0.79</td>
</tr>
<tr>
<td>FVC swimmers (l)</td>
<td>15</td>
<td>7.88</td>
<td>6.37</td>
<td>8.66</td>
<td>0.81</td>
</tr>
</tbody>
</table>

The table also shows that the variable describing the total vital capacity (FVC) in breath-holding divers 7.98 on average, while the minimum result is 6.26 and the maximum 9.46 liters. In water polo players, the average value is 7.49 liters, while the minimum result is 5.85 liters and the maximum 9.17 liters.

The total vital capacity (FVC) in swimmers shows the average value of 7.68 liters, while the minimum result is 6.37 liters and the maximum 8.66 liters. Furthermore, regarding the body height variable (AVT) and body weight variable (ATT) in breath-holding divers, the mean values is 183.95 cm and 83.03 kg, while the minimum result is 173.50 cm and 83.03 kg and the maximum 189 cm and 90.9 kg. In water polo players, the mean value is 194.67 cm and 95.87 kg, while the minimum result is 186 cm and 85 kg and maximum result is 203 cm and 110 kg. In swimmers, the mean body height and weight value is 188.15 cm and 84.06 kg, while the minimum result is 179.9 cm and 66.5 kg and maximum 194.2 cm and 104.3 kg.

Table 2. Statistical significance of differences among groups for the "vital capacity" variable

<table>
<thead>
<tr>
<th></th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC</td>
<td>1.85</td>
<td>2</td>
<td>0.92</td>
<td>31.62</td>
<td>42</td>
<td>0.75</td>
<td>1.23</td>
<td>0.302</td>
</tr>
</tbody>
</table>

FVC – vital capacity, df – levels of freedom, p – level of statistical conclusion error (p < 0.05)

Table 2 shows that there is no statistically significant difference between arithmetic means of groups at error level of p<0.05 in the vital capacity variable (FVC; p = 0.302).

Discussion and conclusion

Although the correlation of the body height and vital capacity is extremely high (Hraste et al., 2008, 2009) and water polo players stand out by their body height compared to swimmers and breath-hold divers, in determining the vital capacity the body height was taken as a criterion. Breath-hold divers have a higher average body height of 183.95 cm. Although their longitudinal skeleton dimensionality is much smaller than the average value in water polo players (194.67), breath-hold divers have shown the average highest values in vital capacity variable (7.98), most probably due to training stimuli which are maximum expiries and hypoxic conditions that the breath-hold divers often encounter. It is a fact that breath-hold diving is performed with extremely slow, maximum relaxed moves, which indicates a predominantly aerobic quality of the activity. The existence of high correlation between the ability of breath-holding and vital capacity of the lungs which is larger in more aerobic athletes (Gaultier & Carapo, 1997, according to Drviš, 2012) also speaks in favor of the premise that breath-hold diving is an aerobic sport. When diving, the respiratory system encounters the enlarged gas density, which results in the respiratory mechanical load increase. Breath-hold divers have unusually large lung capacity with a low ratio of the forced expiratory volume in 1 second (FEV1) and the forced vital capacity (FVC) (Adir et al., 2005). This ratio can be the result of the air way obstruction but can also indicate occurrence of "large lungs" in breath-hold divers. If it is the case of large lungs, the ration of the...
FEV1% and the FVC is low but the total lung capacity (TLC), the forced vital capacity is increased at the same time (Adir et al., 2005). According to the obtained mean results of the force vital capacity it can be concluded that breath-hold divers and swimmers have somewhat better results and higher values than water polo players. This also indicates that water polo players most probably have a smaller training capacity of aerobic stimuli (Hraste et al., 2008, 2009). According to the structural analysis, water polo players move horizontally in water during the game. These movements include swimming with a constant change in pace, direction, body position, performance technique, prevailing modified front crawl stroke where the player swims with the head above water surface to obtain better visibility of the game. What is also present is vertical movement in water, characterized by fly-outs from all positions and in all directions, ball kicking and ball passing from all positions which is varied and of different type and mere floating on water with treading. The specific feature of water polo and its correlation to diving could be recognized in occurrence of hypoxia due to inability of breathing while swimming or fighting for position under the water surface. There are significant differences in mean vital capacity values among groups but they do not suffice for a statistical difference. Table 2 shows that there is no statistically significant difference between arithmetic means of groups at error level of p<0.05 in the vital capacity variable (FVC; p = 0.302). Statistical significance among groups has not been proven due to the nature of sports included in the research and the sample itself. The similarity of these sports comes to the fore mostly during the training process where all sports include swimming elements. Water density and water pressure cause difficulties in breathing and moving which can result in hyperplasia of alveoli due to alternating hypoxia (Hulke & Phatak, 2011).

Muscles work under greater load, which may result in broadening of the chest and increasing of lung capacity (Adir et al., 2005). One of the possible reasons is that the research was conducted on a pertinent sample which included Croatian national team players, elite athletes who have been undergoing a regular training process for years which enables the adjustment of the respiratory system to extreme efforts such athletes are subjected to within training process units. Main goal of this research was to determine differences in force vital capacity among elite water polo players, elite swimmers and elite breath-holding divers. The results of univariate analysis of variance have shown that there is no statistically significant difference in vital capacity among examinee groups, which has also confirmed the hypothesis (H0 – There is no statistically significant difference in vital capacity among water polo players, free divers and swimmers). It can be concluded that, due to water as a medium of conducting the activities, long-standing training process in water and mostly homogenous groups, groups of swimmers, water polo players and breath-hold do not show statistically significant differences in vital capacity variable.

References


RAZLIKE U FORSIRANOM VITALNOM KAPACITETU IZMEĐU GRUPA ELITNIH HRVATSKIH PLIVAČA, VATERPOLISTA I RONIOCA NA DAH

Sažetak
Svrha ovog istraživanja bila je eliminirati razlike u forsiranom vitalnom kapacitetu* (FVC) između grupa elitnih plivača, elitnih vaterpolista i elitnih ronioca na dah. Sadašnje istraživanje je provedeno na 45 vrhunskih sportaša (15 plivača, 15 vaterpolista i 15 ronioca na dah), od kojih su svi konstantno trenirali. Svi sportaši su bili kategorizirani prema pravilima Hrvatskog olimpijskog odbora (HOO). Dob sportaša je bila između 16 i 37 godina. U svrhu opisa uzorka subjekata i postignuća ciljeva istraživanja koristili smo ukupno 3 varijable: tjelesna visina (cm), tjelesna težina (kg) i forsiran vitalni kapacitet (FVC/l). Statističke procedure za ovo istraživanje su bile odabrane u skladu sa ciljevima i hipotezama i prikladnom prirodom problema. U svrhu hipoteza testa koristili smo univarijantnu analizu (ANOVA) ronioca na dah koji su imali najvišu prosječnu vrijednost FVC-â (7,98±0,99), zatim plivača (7,68±0,81) i najniže vrijednosti su postojale kod vaterpolista (7,49±0,79). U istraživanju koje se odnosilo na mjerenje FVC-a nije bilo statistički značajne razlike između grupa (p=0,30). Temeljem prikupljenih rezultata moguće je zaključiti da statistički značajne razlike ne postoje između državnih reprezentativaca hrvatskih vaterpolista, kao ni plivača i ronioca na dah, vjerojatno zbog prirode sportova koji su uzeti u istraživanju i uzorku.

Ključne riječi: vaterpolo, ronjenje na dah, plivanje, forsirani vitalni kapacitet

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