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**Letter to editor**

# Respiratory Muscle Training and Aquatic Sports Performance

**Dear Editor-in-chief**

The recent study by Vašíčová et al. (2017) described novel findings that respiratory muscle training (RMT) improved respiratory muscle strength and swimming performance in an apnea-max swim test in young fin-swimmers. These positive findings are largely compatible with established literature demonstrating increases in respiratory muscle strength following RMT (HajGhanbari et al., 2013; Illi et al., 2012; Shei et al., 2016b) and improvements in swimming performance (Kilding et al., 2010; Wylegala et al., 2007). However, several important points should be considered when interpreting these findings.

First, given that water-based exercise, such as conventional swimming and fin-swimming, requires athletes to exercise while immersed in water, the additional hydrostatic pressure that surrounds the thoracic cavity presents an additional load which must be overcome by the inspiratory muscles in order to generate inspiratory airflow to the lungs. Consequently, swimmers are known to have above-normal spirometry and higher pulmonary diffusion capacity (Mickleborough et al., 2008). Further, regular aquatic exercise may mimic resistive inspiratory muscle training. Elite adult swimmers who engaged in a 12-week competitive swim training program exhibited similar improvements in pulmonary and respiratory muscle function compared to those who completed flow-resistive inspiratory muscle training in addition to the same swim training program (Mickleborough et al., 2008). Comparatively, sub-elite adult swimmers, who had a markedly lower training volume and intensity compared to the elite swimmers, did receive additional benefits from combining flow-resistive inspiratory muscle training and swim training (Shei et al., 2016a), indicating that there may be a dose-response relationship to swim training and its effects on pulmonary and respiratory muscle function. The present study by Vašíčová et al. (2017) did not report training volume and intensity of the youth fin-swimming population that was studied, therefore it is difficult to determine whether the fin-swimming training program they engaged in may have influenced their findings. Further, the study did not include a group that completed placebo RMT, despite the availability of several sham-IMT protocols that have been shown to have no effect on pulmonary and respiratory muscle function (Shei et al., 2016b). Including a placebo RM group would have allowed the authors to parse out differences between fin-swim training alone and fin-swim training with placebo-RMT.

Second, it appears from Tables 1 and 2 in the study by Vašíčová et al. (2017), that the control group (CG) may have had significantly higher spirometry values at baseline, although no statistical measures of variation (SD or SE) or inferential statistics were reported. Similarly, baseline $PI_{max}$ appears to be greater in the CG group at baseline as well. These apparent differences in pulmonary and respiratory muscle function between groups at baseline raises concern about whether group assignment was properly controlled, and may have influenced the results of the study.

Finally, although the authors have speculated at a mechanistic link between increased respiratory muscle strength (increases in $PI_{max}$ and $PE_{max}$) and improved apnea-max swim performance, they failed to record any measures of respiratory muscle endurance such as sustained maximal inspiratory pressure and maximal voluntary ventilation. It is likely that respiratory muscle training influences both respiratory muscle strength and endurance, although presently it is equivocal which is more pertinent to improving performance. However, given that the criterion measure of performance in this study was an apnea-max test, performed for the duration of one single inspiration, it is difficult to determine how increased respiratory muscle strength could affect performance during this task since the subjects were holding their breath (presumably at or near total lung capacity). On one hand, it is possible that improvements in inspiratory muscle strength would allow subjects to complete this breath-hold during the apnea-max swim test at a lower intensity relative to maximal inspiratory pressure-generating capacity (since $PI_{max}$ was higher post-training), however how this influences performance is unclear. Inspiratory muscle training has been demonstrated to reduce the oxygen cost of voluntary hyperpnea in trained cyclists (Turner et al., 2012), however it is presently unknown whether this improvement in respiratory muscle economy would translate to reduced oxygen cost of a single breath hold at or near total lung capacity. If this were the case, this may provide a mechanistic link to explain, in part, the findings of improved apnea-max swim performance observed by Vašíčová et al. (2017).

In summary, the novel findings by Vašíčová et al. (2017) provide an interesting glimpse into how RMT can influence performance in aquatic sports, even during a criterion task that does not require voluntary hyperpnea, but instead, requires a single-breath hold for the duration of the exercise task. Their findings present several interesting areas for future inquiry that are presently unanswered. Future studies should aim to evaluate the mechanistic link between RMT, its effects on pulmonary and respiratory muscle function, and performance.

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## Authors' response

We would like to thanks the author for his comments.

Regarding the training volume and intensity of the youth fin-swimming population:

Both younger and older swimmers had exactly the same training of the length 1.5 hour that contained 15 minutes warm up, technique of the fin-swimming with feedback from the coaches and in some lessons endurance training (e.g. 5 times 200m of crawl with 60% of intensity without fins). Each training ends with floating and stretching of muscles of the whole body.

Regarding the placebo RMT:

We should have set up minimum level of resistance at each device (Threshold IMT 9 cm of $H_2O$ and Threshold PEP 5 cm of $H_2O$) and use them in sham-IMT protocols as it was used in several studies. Nevertheless, each training even against minimal resistance can have an influence on breathing patterns of an individual and that´s why we decided to use respiratory muscle training only in experimental group according to our protocol.

Regarding the higher spirometry values and higher values of respiratory muscle strength at baseline in the control group:

We did not mention in the text but we did not find any statistically significant differences of baseline values between both groups (Table 1).

Regarding the measures of respiratory muscle endurance:

We agree with the author that for clarification of respiratory muscle function these measurements are used but our measurement device ZAN 100 USB Spirometer did not allow us to carry out these measurements.

Regarding the apnea-max swim test:

We decided to measure this distance because the apnea-max swim test is one of the competitive disciplines. Participants in their subjective evaluation of the experiment stated that after the training with the devices, they were able to better control their breathing and they can manage better the strength, volume and velocity of inspiration and expiration. In addition, this is very positive effect. So we think that they are now able to use their maximal lung capacity in this type of fin-swimming discipline.

**Table 1. Differences in ventilatory parameters (median, % of predicted values) in the EG and CG at baseline.**

| | EG (n = 8) | CG (n = 12) | p |
|---|---|---|---|
| **VC** | 103.8 | 112.6 | .26 |
| **IC** | 107.2 | 117.4 | .56 |
| **FVC** | 102.8 | 114.9 | .46 |
| **FEV1** | 104.5 | 115.6 | .25 |
| **PEF** | 87.9 | 91.1 | .49 |
| **PImax** | 124.1 | 147.5 | .62 |
| **PEmax** | 99.5 | 100.8 | .96 |

VC – vital capacity, IC – inspiratory capacity, FVC – forced vital capacity, $FEV_1$ – forced expiratory volume in 1 second, PEF – peak expiratory flow, $PI_{max}$ – maximal inspiratory mouth pressure, $PE_{max}$ – maximal expiratory mouth pressure

Thank you very much for reading and commenting our article and directing future research in this area.


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