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The effect of inspiratory muscle training on the maintenance of swimming abilities

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Abstract

Introduction: Swimming, especially competitive, is one of the biggest challenges for the respiratory muscles. Muscles are weaker in the horizontal position, the hydrostatic pressure requires greater muscle force during inhalation, in addition, the respiratory muscles are also involved in stabilizing the torso during swimming. Limited breathing time is an additional challenge. The purpose of our study was to examine weather inspiratory muscle exercise also affects the maintenance of swimming abilities during a swimming break. According to the literature, increasing the strength of the inspiratory muscles has a major impact on improving respiratory and swimming efficiency and performance. *Methods:* The study involved first-year students of the Applied kinesiology program (n = 19, age: 19.7 ± 0.9 years), who were divided into an intervention group (n = 11) and a control group (n = 8). They were included in the program of an eleven-day swimming course, after which we performed the first measurements. The second measurements were performed ten days after the end of the course. In the intervening period, none of the subjects performed any swimming training. The intervention group conducted an inspiratory muscle training program twice a day with the Powerbreathe Plus device. *Results:* The results showed a trend of improvement in maximal inspiratory strength, maximal inspiratory flow, test of CO_2 tolerance, breath holding after a relaxed exhalation (Buteyko test) and in under water breathe holding test. Statistically significant effect of time was shown in the 50-100 m and 0-100 m swimming test. In both tests the result deteriorated in the intervention and control group, but a significant trend was shown. Namely, in both tests the swimming time in the control group was longer than in the intervention group. *Discussion and conclusions:* In the literature reviewed, we found that simultaneous exercises of specific sports and inspiratory muscles for at least four weeks, in most cases, affect the improvement of respiratory functions and results in various sports. Based on the results of our research and the literature reviewed, we can conclude that the inspiratory muscle training in the period without swimming-specific training, shows a trend of positive effect on maintaining swimming results.

Keywords: inspiratory muscles, breathing, maintenance of abilities, Powerbreathe, swimming

Introduction

The aquatic environment is one of the most demanding for respiratory muscles (hereafter RM), and competitive swimming represents one of the biggest challenges for them (McConnell, 2011). Lomax and McConnell (2003) showed that swimming causes a 29% drop in inspiratory muscle (hereafter IM) strength after exercise, compared to "land" sports, where the drop is between 10% and 20%. Breathing with the chest submerged requires greater IM force due to hydrostatic pressure (Wylegala, Pendergast, Gosselin, Warkander, and Lundgren, 2007) and IM are 16% weaker in the horizontal position (McConnell, 2011). The breathing pattern requires a high degree of body mobility in order to minimize the negative impact on stroke mechanics (Lomax and Castle, 2011, Leahy et al., 2019). Due to better hydrodinamics, swimmers strive to reduce the number of breaths and time when the head is out of the watter McConnell (2011), so they must breathe quickly and as deep as possible (Leahy et al., 2019). In addition, during swimming, RM participate in trunk stabilization during propulsive moments (Vašičkova et al., 2017), and muscles with several roles simultaneously, are more susceptible to fatigue, reduced capacity and sport performance (McConnell, 2011).

Inspiratory muscle training (hereafter IMT) is mentioned in the literature as an effective method for improving efficiency and performance in various sports. RM are highly adaptive to repeated exercise and show changes in structure, strength improvement, contraction speed and endurance (Ramirez-Sermiento, 2002; McConnell and Romer, 2003, McConnell, 2011). In a study by Downey et al. (2007), after four to eight weeks of IMT against resistance, biopsy has shown an increase in diaphragm thickness by 12%. In addition they noticed an improvement in inspiratory strength by 24% after four and 41% after eight weeks of exercise.

Some effects of IMT on performance in sports are already known. An improvement in the endurance of underwater (33% - 50%) and surface (38% - 88%) fin swimming was shown, the respiratory volume increased (12%), respiratory frequency decreased by 19% and energy expenditure by 7,8% (McConnell, 2011). In underwater swimmers, the improvement was shown in maximal inspiratory pressure (hereafter MIP), inspiratory volume (hereafter IV) and underwater swam distance (USD) (Pupišova, Pupiš, Jančokova and Pivovarniček, 2014). Kilding, Brown and McConnell (2010) found an increase in MIP and swimming time for 100m and 200m after six-week IMT, the similar results Nahtigal (2015) found in 14- to 16-year olds after eight weeks of training.

The purpose of our study was to examine weather IMT also affects the maintenance of swimming abilities during a swimming break. The purpose of the research is particularly meaningful at the time, when restrictions and recommendations due to the declared epidemic of the covid-19 disease occasionally limited the implementation of swimming activities in swimming pool facilities.

Methods

19 students (5 male and 14 female) of the first year of the undergraduate study program Aplied Kinesiology participated in the research. They were divided into an intervention (n = 11; 6 women, 5 men) and a control group (n = 8; 8 women, 0 men).

As a part of the study course, the participants were included in the eleven-day swimming course program, after which we took the first measurements. The second measurements were taken ten days after the course. In the meantime, no swimming activities were performed. The intervention group performed an IMT with the Powerbreathe Plus device (A division of Gaiam Ltd., Northfield Road, Southam, Warwickshire, CV47 ORD, UK). Exercise consisted of 30 rapid maximum forced inhalations and relaxed exhalations, twice a day. The intensity (resistance on the device) was set to 60% of the maximal inspiratory power (S-index) (McConnell, 2011; Finta, Boda, Nagy and Bender, 2020), which was measured in the first measurements. A specific intensity of 60% MIP has been justified as effective IMT based on optimal response in context of blood flow and generated pressure (Sheel et al., 2001, McConnell and Griffiths, 2010). The subjects were taught the independent and correct use of the training device before the intervention.

Statistical package IBM SPSS Statistics 25.0 (*Armonk, NY:IBM Corp.*) was used for statistical data processing. Shapiro-Wilk test was used to check the normal distribution of variables. Analysis of the differences between the individual variables between the groups in the initial state was performed using the independent samples t-test or its non-parametric version, i.e. the Man-Whitney U-test. The analysis of progress for normally distributed variables was checked with the analysis of variance for repeated measurements (Two-way/Factorial RM ANOVA) with the time and group factors (Field, 2009). We also calculated the interaction of time and group to determine the effect of the intervention. For non-normally distributed variables, we used non-parametric version, the Wilcoxon signed rank test. In accordance with selected test, we calculated the effect size (eta squared (η^2)), defining the effect size as small for values > 0.01, medium for values > 0.06 and large for values > 0.14 (Cohen, 1988; Fritz, Morris and Richler, 2012). After the analysis of variance, we performed a paired-samples t-test, to check statistically significant differences for individual variables within the group with respect to time. Wilcoxon signed rank test was used for non-normal distributions. R-value was used to determine the effect size. Values > 0.3 represented a medium effect size and values > 0.5 a large effect size (Field, 2009). The level of statistical risk was determined at a value of $p < 0.05$.

Results

The results of Wilcoxon signed rank test show that the intervention had a statistically significant effect, with a large effect size (Z = −2.934, p = 0.003; r = −0.626), on the result (11,5%) in maximal inspiratory power in the intervention group (Figure 1). Statistically significant differences (14%) were also found in control group (Z = −2.023, p = 0.043; r = 0.640). Results of the same test show a statistically significant influence of the intervention with a large effect size (Z = −3.413, p = 0.001, r = 0.588) on the result (9,0%) of the intervention group in the maximum inspiratory flow parameter (Figure 2). After ten days the results (10,9 %) also improved in control group (Z = −2,023; p = 0, 043, r = −0,649). Time and group factors could not be calculated in non-parametric tests.

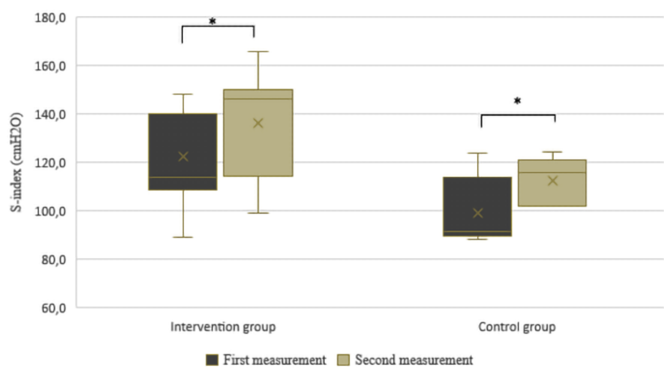

Figure 1: Graphic representation of the box with whiskers for the values of the variable maximal inspiratory power (cmH2O)

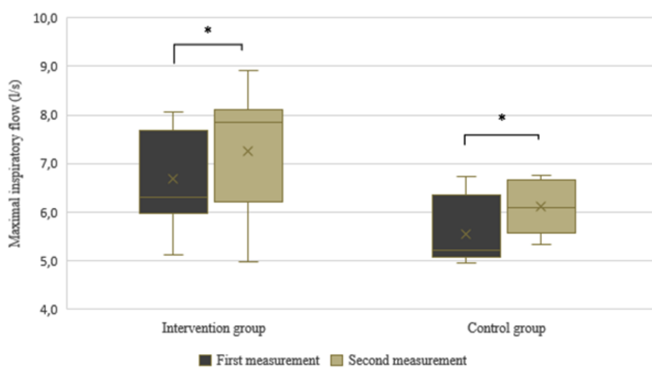

Figure 2: Graphic representation of the box with whiskers for the values of the variable maximal inspiratory flow (l/s)

For the variable FEV1/FEVC ($F(1,14) = 4.600$; $p = 0.019$; $\eta 2 = 0.335$), a statistically significant effect of time with a large effect size was shown (Figure 3). The score decreased in the intervention (–1.8%, $p = 0.255$) and control group (–11.9%, $p = 0.174$). The intervention group showed less deterioration than the control group.

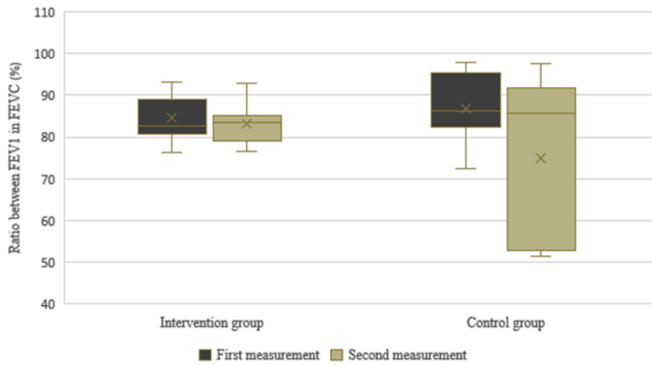

Figure 3: Graphic representation of the box with whiskers for the values of the variable ratio between FEV1 in FEVC

The results of Buteyko control pause test shows statistically significant differences in the effect of time ($F(1,13) = 4.667$; $p = 0.000$; $\eta 2 = 0.661$) and time and group ($F(1,13) = 4.667$; $p = 0.044$; $\eta 2 = 0.278$) with a large effect size (Figure 4). The result increased significantly in the intervention group (52.3%, $p = 0.001$) and insignificantly in the control group (111.3%, $p = 0.052$). Based on the results, we can conclude that the control group was better and the intervention had a negative effect on this variable.

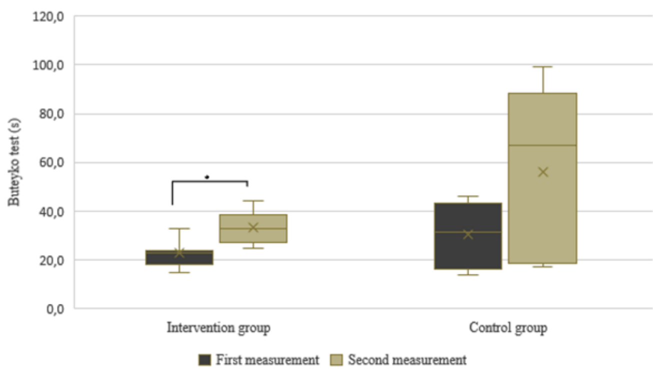

Figure 4: Graphic representation of the box with whiskers for the values of the variable Buteyko test (s)

The results of the test of CO_2 tolerance (hereafter $TTCO_2$) parameter show statistically significant differences in the effect of time ($F(1,14) = 4.600$; $p = 0.005$; $\eta 2 = 0.441$) with a large effect size (Figure 5). The $TTCO_2$ score significantly increased in the intervention (44.2%, p = 0.037) and control group (37.8%, p = 0.001). We observe a trend towards slightly greater improvement in the intervention group.

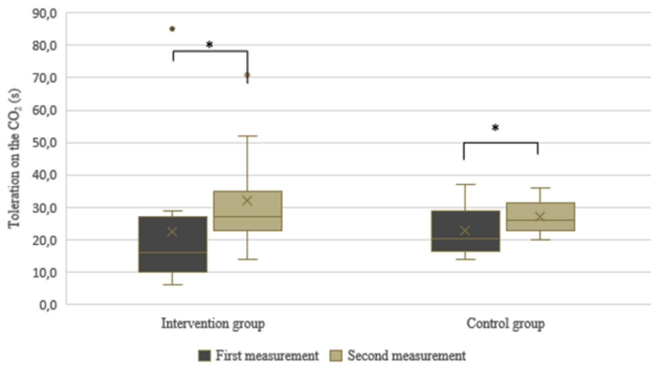

Figure 5: Graphic representation of the box with whiskers for the values of the variable TTCO₂ (s)

For the other variables measured (FVC, FEV1, PEF, IV, counting time after maximum inspiration) there is no statistically significant effect of time or time and group.

The result of the 50-100m swimming time test show statistically significant differences in the effect of time (F (1,14) = 4.600; p = 0.000; η2 = 0.895) with a large effect size (Figure 6). The result of the test increased significantly in the intervention group by 30,7% (p = 0.000) and in the control group by 40,1% (p = 0.001). The trend of a smaller decrease in swimming time in the intervention group is shown.

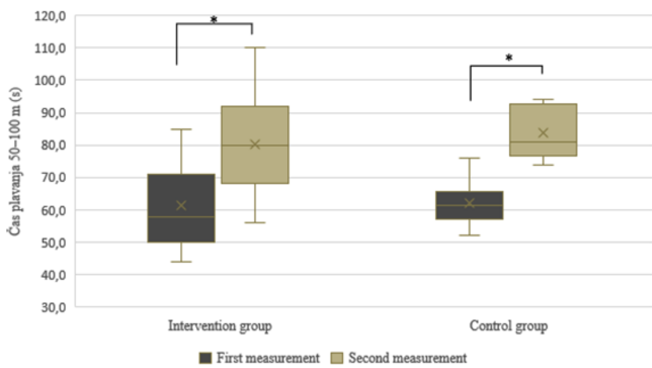

Figure 6: Graphic representation of the box with whiskers for the values of the variable swim time 50–100 m (s)

The results of the 0-100m swimming time test also show statistically significant differences in the effect of time (F (1,14) = 4.600; p = 0.000; η2 = 0.830) with a large effect size (Figure 7). The result increased statistically significantly in the intervention group by 15,5% (p = 0.000) and in the control group by 23.6% (p = 0.007). Trend of a smaller decrease in swimming time in intervention group is shown, and thus the impact of the intervention on swimming skills.

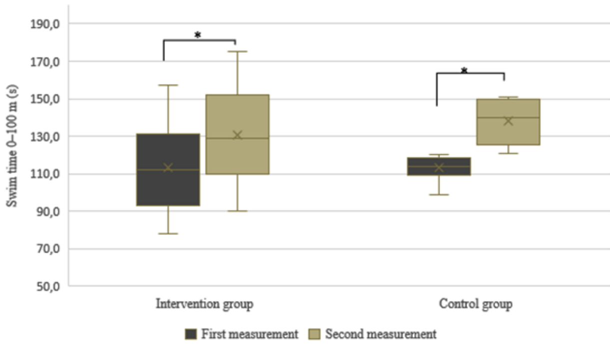

Figure 7: Graphic representation of the box with whiskers for the values of the variable swim time 0–100 m (s)

Despite statistically insignificant differences, we can mention the result improvement in intervention group (15.5%, p = 0.124) and control group (2.3%, p = 0.949) in the breath holding under water test. A trend towards a greater improvement in the result in the intervention group is shown.

For other variables (swimming time 0-25 m, 25-50 m, 50-75 m, 75-100 m, 0-50 m, glide length, USD) there is no statistically significant effect of time or time and group.

Discussion

The analysis of the results showed some changes in variables after the ten-day intervention. Changes in maximal inspiratory strength were statistically significant and the results increased in intervention and control group. Based on the results, we cannot say with certainty that the increase in inspiratory muscle strength is due to the intervention, although the statistical power is greater in the intervention group. Task learning has also an effect, which is reflected in gradual improvement of inspiratory pressures with repeated measurements (McConnell, 2011), but this theory can be refuted, since the subjects had the opportunity to try a few breaths before the first measures. In addition, we considered only the best result achieved. We assume that the intervention time was too short to get larger differences between the group results. The results of our research are consistent with the findings of the reviewed studies (Volianitis et al., 2001, Romer et al., 2002a, Romer et al., 2002b, Griffiths and McConnell, 2007, Kilding et al., 2010, Janssensl et al., 2014, Okrzymovska et al.,2019), from which it is possible to determine the trend of greater progress in relation of time.

Like the previous variable, result change in maximal inspiratory flow was statistically significant and increased in intervention and control group. Based on the obtained results, we cannot claim that the improvement is due to intervention. We can conclude that maximal flow of inhaled air per second increased because of better IM strength, which enable faster and stronger inhalation. Romer and McConnell (2003) claim the exact thing, therefore the peak inspiratory velocity is proportional to inspiratory strength and increases with training and reduction in fatigue response.

The results of the $TTCO_2$ showed statistically significant effect of time but not time and group. The improvement of the result was shown in the intervention and control group. Although the improvement of carrying the CO_2 in the system was greater in intervention group, we cannot certainly say that this is the result of the intervention. Improving CO_2 tolerance means less generalized anxiety perception, lower cortisol levels and thus better physical and mental performance (Crux fitness, 2020).

In Buteyko control pause test the effect of both time, and time and group was statistically significant and the results improved in both groups. Although the improvement in control group was not significant, was greater, therefore we assume that the intervention had a negative effect on this variable. The intervention included just IM, and it seems that expiratory muscle inactivity affected the worse exhalation control. The "assymetry" in strength and stiffness could somewhat affect the performance. Even with Buteyko`s test there is a possibility of experience influencing the second measurements. Subconsciously, a person may exhale less air knowing, that he will have to hold his breathe as long as possible.

As already mentioned, in some articles we found a connection between inspiratory function improvement and certain swimming skills. We were mainly interested in maintaining or as little decrease of swimming abilities as possible.

The analysis showed statistically significant effect of time in the swim time 50-100m and 0-100m test. We observe an increase of time in both groups in both tests. As the time decreased less in intervention group in both tests, we observe a trend of smaller decline in swimming skills after intervention, and conclude that IMT had an impact on maintaining swimming skills.

Considering that S-index and PIF increased in both groups and the swimming result decreased while the effect of time and group was not statistically significant, we cannot confirm the connection between S-index and swimming time. We assume that the intervention influenced on easier overcoming of hydrostatic pressure during swimming, since there is no difference between the groups outside the water. The difference was noticeable only in the water. We did not find any research studying the effect of IMT without simultaneous sport-specific training, but Nahtigal (2015) and Kilding et al. (2010) found improvement in swimming after additional IMT in the training process.

Additional IMT to swimming, improves the ability to maintain a deeper and slower breathing pattern, which improves the efficiency of breath-motor coordination (McConnell, 2011). Ability to inhale faster and maintain a high lung volume is improved. This results better body position and stroke mechanics, it is also possible to reduce number of breaths per stroke, all of which is reflected in faster swimming.

In the underwater breath holding test we can also notice a trend of improvement due to higher result increase in intervention group, but no changes or differences were confirmed in USD test as McConnel (2011) and Pupisova et.al. (2014) detected.

Conclusions

We cannot claim that the improvement of IM strength and PIF is a result of the intervention, however a positive trend of improvement is shown. We can confirm that there is a relation between MIP and PIF. A significant improvement was also shown in the $TTCO_2$ and Buteyko test, where the contribution of the intervention also cannot be confirmed, because of the increase of result in both groups. However, a positive trend towards improvement can be seen. A significant effect of time was shown in 50-100m and 0-100m swimming tests. Although the result deteriorated in both groups and tests, an important trend can be observed, namely, in both tests swimming time in the control group increased more than in the intervention group. The result suggests that the intervention may have an impact on the maintenance of swimming ability during the non-training period.

Based on the reviewed literature and our research, we can conclude that IMT in the period without swimming-specific training shows a trend of positive effect on maintaining the swimming result.

We encountered some limitations that should be improved in next similar research. We suggest a longer intervention period, as we assume the effect would be greater. There should be only one gender included or at least evenly distributed as some studies confirm no differences between gender. There was a dropout of control group subjects, so we could use only measurements of five subjects. Larger number of participants should be provided. A third test is suggested after at least twenty days to control the effect of time. In addition, better monitoring to insure a completely correct implementation would be necessary.

RM exercises offer an additional opportunity to develop the swimmer himself and swimming result. According to the literature, there is a certain protocol (intensity, duration, number of repetitions and number of sets) to achieve the success of such training. This is the way we can make the most progress in the shortest time possible.

References

CRUX FITNESS. (2020). *The CO_2 tolerance test and why you should be working on your lungs.* Acquired 5. 7. 2021 from https://www.cruxfit.com/the-co2-tolerance-test-and-why-you-should-be-working-on-your-lungs/

DOWNEY, A. E., CHENOWETH, L. M., TOWNSEND, D. K., RANUM, J. D., FERGUSON, C. S. and HARMS, C. A. (2007). Effect of inspiratory muscle training on exercise responses in normoxia and hypoxia. *Respiratory physiology and neurobiology,* vol. 156, no. 2, pp. 137–46. Available from: doi: 10.1016/j.resp.2006.08.006/

FIELD, A. P. (2009). *Discovering statistics using SPSS: (and sex and drugs and rock „n" roll)* (3rd ed.). London: SAGE.

FINTA, R., BODA, K., NAGY, E. and BENDER, T. (2020). Does inspiration efficiency influence the stability limits of the trunk in patients with chronic low back pain? *Journal of rehabilitation medicine,* vol. 52, no. 3, jrm00038. Available from: doi: 10.2340/16501977-2645

KILDING, E. A., BROWN, S. and McCONNELl, K. A. (2010). Inspiratory muscle training improves 100 and 200m swimming performance. *European journal of applied physiology,* vol. 108, pp. 505–511. Available from: doi: 10.1007/s00421-009-1228-x

LEAHY, M. G., SUMMERS, M. N., PETERS, C. M., MOLGAT-SEON, Y., GEARY, C. M. and SHEEL, A. W. (2019). The mechanics of breathing during swimming. *Medicine and science in sports and exercise,* vol. 51, no. 7, pp. 1467-1476. Available from: doi: 10.1249/MSS.0000000000001902

LOMAX, M. and CASTLE, S. (2011). Inspiratory muscle fatigue significantly affects breathing frequency, stroke rate and stroke length during 200m front crawl swimming. *Journal of strength and conditioning research,* vol. 25, no. 19, pp. 2691–2695. Available from: doi: 10.1519/JSC.0b013e318207ead8

LOMAX, M. and McCONNELL, A. (2003). Inspiratory muscle fatigue in swimmers after a single 200 m swim. *Journal of sports sciences,* vol. 21, no. 8, pp. 659–664. DOI:10.1080/0264041031000101999

MCCONNELL, A. K. and GRIFFITHS, L. A. (2010). Acute cardiorespiratory responses to inspiratory pressure treshold loading. *Medicine and science in sports and medicine*, vol. 42, no. 9, pp. 1696–703. Available from: doi: 10.1249/MSS.0b013e3181d435cf

MCCONNELL, A. (2011). *Breathe strong, perform better.* United States, Champaign: Human Kinetics. Available from: https://www.researchgate.net/publication/233852299_Breathe_Strong_Perform_Better_-_Table_of_Contents

PUPIŠOVA, Z., PUPIŠ, M., JANČOKOVA, L. and PIVOVARNIČEK, P. (2014). Changes of inspiratory parameters and swimming performance by influence of Powerbreathe plus level3. *Sport science,* vol. 7, no. 2, pp. 12–15. Available from: https://www.researchgate.net/publication/270567073

RAMIREZ-SERMIENTO, A., OROZCO-LEVI, M., GUELL, R., BARREIRO, E., HERNANDEZ, N., MOTA, S. and GEA, J. (2002). Inspiratory muscle training in patients with chronic obstructive pulmonary disease. *American journal of respiratory and critical care medicine,* vol. 166, no. 11, pp. 1491–1497. Available from: doi: 10.1164/rccm.200202-075OC

ROMER, L. M. and MCCONNELL, A. K. (2003). Specificity and reversibility of inspiratory muscle training. *Medicine and science in sports and exercise,* vol. 35, no. 2, pp. 237–244. Available from: doi: 10.1249/01.MSS.0000048642.58419.1E

SHEEL, A. W., DERCHAKA, P. A., MORGAN, B. G., PEGELOW, D. F., JACQUES, A. J. and DEMPSEY, J. A. (2002). Fatiguing inspiratory muscle work causes reflex reduction in resting leg blood flow in humans. *Journal of physiology,* vol. 537, no. 1, pp. 277–89. Available from: doi: 10.1111/j.1469-7793.2001.0277k.x

VAŠIČKOVA, J., NEUMANNOVA, K. AND SVOZIL, Z. (2017). The effect of respiratory muscle training on fin-swimmers performance. *Journal of sports science and medicine,* vol. 16, no. 4, pp. 521–526. Available from: https://pubmed.ncbi.nlm.nih.gov/29238252/

WYLEGALA, J. A., PENDERGAST, D. R., GOSSELIN, L. E., WARKANDER, D. E. and LUNDGREN, C. E. G. (2007). Respiratory muscle training improves swimming endurance in divers. *European journal of applied physiology*, vol. 99, no 4, pp. 393–404. Available from: doi: 10.1007/s00421-006-0359-6