

MAXIMAL RESPIRATORY PRESSURES, THEIR ASSOCIATION WITH SPIROMETRIC PARAMETERS, SWIMMING SKILLS AND CHANGES DUE TO IMMERSION IN WATER

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ABSTRACT

Research background and hypothesis. We checked hypothesis that swimming skill improvement is more dependent on inspiratory muscle strength than endurance volume to be ventilated.

Research aim was to determine associations between maximal static inspiratory (MIP) and expiratory (MEP) pressures, swimming skills, parameters of forced spirometry.

Research methods. Investigation involved 62 female students (age 22.13 ± 1.3 years, height 168.4 ± 6.6 cm, and weight 61.3 ± 7.0 kg) of the Latvian Academy of Sports Education. All of them were non-smokers. Swimming skills in four strokes were evaluated by a swimming coach. MIP and MEP were measured at the mouth level outside the swimming pool and repeated in the swimming pool while the subject was immersed up to the neck level. Forced spirometry was performed according ATS guidelines outside the water.

Research results. Average value for MIP outside the water was 109 ± 30 cm H₂O and for MEP it was 147 ± 33 cm H₂O. There was positive correlation between peak expiratory flow and MIP, MEP, and the rate of increase of both pressures ($p < 0.05$). Forced vital capacity was not related to maximal pressures. Faster rate of inspiratory pressure increase was positively related to forced inspiratory volume in one second ($p < 0.05$). There was a significant decrease of MIP and the rate of increase of inspiratory pressure in the immersion state while no changes of expiratory parameters were observed.

Discussion and conclusions. Swimming skill improvement is more dependent on inspiratory muscle strength than volume to be ventilated. Students with higher PEF have higher respiratory pressure parameters. Immersion in water decreases MIP, IMRPD and increases IMMRR. Changes of these parameters due to immersion are not related to swimming skills.

Keywords: maximal inspiratory pressure, maximal expiratory pressure, swimming education, immersion in water.

INTRODUCTION

During exercise demand for oxygen increases, which stimulates the increase of volume of air exchanged in lungs. Compared to activities not in the water, in swimming time allowed for inspiration is reduced. Respiratory muscle strength and speed of their contraction should be important to breathe the required amount

of air in a short time when swimmers' heads emerge on the surface of the water.

It is known that swimmers can generate greater maximal respiratory pressures and specific training can increase the strength within several weeks (Tzelepis et al., 1999; Sonetti et al., 2001). The effect of specific respiratory muscle training on exercise performance is controversial (Wells et al.,

2005). The information about the relationship between swimming skill development and required respiratory training is not available.

The purpose of this study was to determine the associations of respiratory pressure and spirometric parameters with swimming skills as well as changes of respiratory pressures due to immersion into water to the neck level.

RESEARCH METHODS

Investigation involved 62 female students (the mean age 22.13 ± 1.3 years, height 168.4 ± 6.6 cm, and weight 61.3 ± 7.0 kg) of the Latvian Academy of Sports Education who attended swimming instruction programme, all of them were non-smokers. Competitive swimmers were excluded from the investigation. A written informed consent was obtained from each student. The study was approved by the Ethics Committee of the Riga Stradiņš University.

Swimming skills in four styles (front crawl, back crawl, breaststroke, and butterfly) of each student were evaluated by a swimming coach at the end of 6-week swimming instruction programme. According to the evaluation the students were divided in three groups:

Group 1 – students with the poor swimming skills ($n = 14$);

Group 2 – students with the moderate swimming skills ($n = 32$);

Group 3 – students with the good swimming skills ($n = 16$).

Maximal expiratory and inspiratory pressure measurements at the mouth level were done with Micro RPM (England) at the end of the swimming instruction programme. The MEP, MIP, maximal rate of pressure development during expiration (EMRPD) and inspiration (IMRPD), maximum

relaxation rate in expiration (EMRR) and inspiration (IMMR) were used for the evaluation. The test was repeated three times in the room and in the swimming pool, where the subject was immersed into water to the neck level.

Forced spirometry test according ERS/ATS guidelines was performed in the room. Forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and peak expiratory flow (PEF) were analysed.

The data were analysed using SPSS programme. The differences between parameters in the air and the water were evaluated using Mann – Whitney test. Differences of parameters between students with poor and good swimming skills were determined by Kruskal-Wallis and Wilcoxon tests. The relationships between parameters were assessed using Spearman's correlation. The alpha level of $p \leq 0.05$ was required for statistical significance.

RESEARCH RESULTS

Minimum, maximum, mean and standard deviations of respiratory parameters are given in Table 1.

There were no significant differences in spirometric variables between students of three swimming skill groups. The mean MIP for students with moderate and good swimming skills was greater than that for students with poor swimming skills (Figure 1). The observed mean values of IMRPD and EMRPD were higher for students with moderate and good swimming skills (Figure 2). However, these differences were not statistically significant. There were no significant inspiratory and expiratory MRR differences between students with poor and good swimming skills.

Table 1. Respiratory pressure test and spirometry results

Parameter	Minimum	Maximum	Mean	SD
MEP, cm H ₂ O	90	240	147	33
MIP, cm H ₂ O	55	184	109	30
EMRPD	120	1694	567	325
IMRPD	107	1167	342	192
FVC, l	3.32	5.88	4.46	0.52
FEV1, l	3.16	4.68	3.95	0.35
PEF, l/s	5.10	11.20	7.14	1.15

Note. MIP – maximal inspiratory pressure; EMRPD – maximal rate of pressure development in expiration; IMRPD – maximal rate of pressure development in inspiration; FVC – forced vital capacity; FEV1 – forced expiratory volume in one second; PEF – peak expiratory flow; MEP – maximal expiratory pressure.

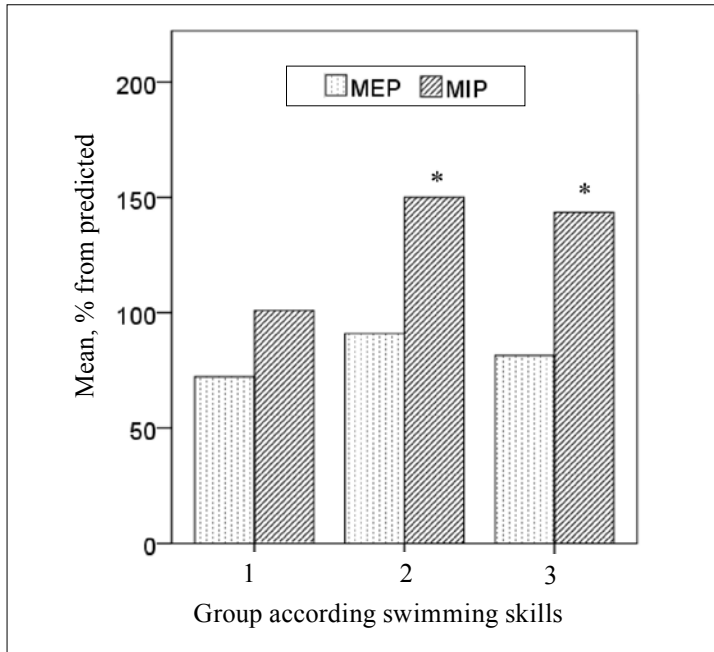


Figure 1. Mean maximal expiratory (MEP) and inspiratory (MIP) pressures in per cent from the predicted value in the room for students with different swimming skills

Note. * – $p < 0.05$ against group 1 due to Mann-Whitney test.

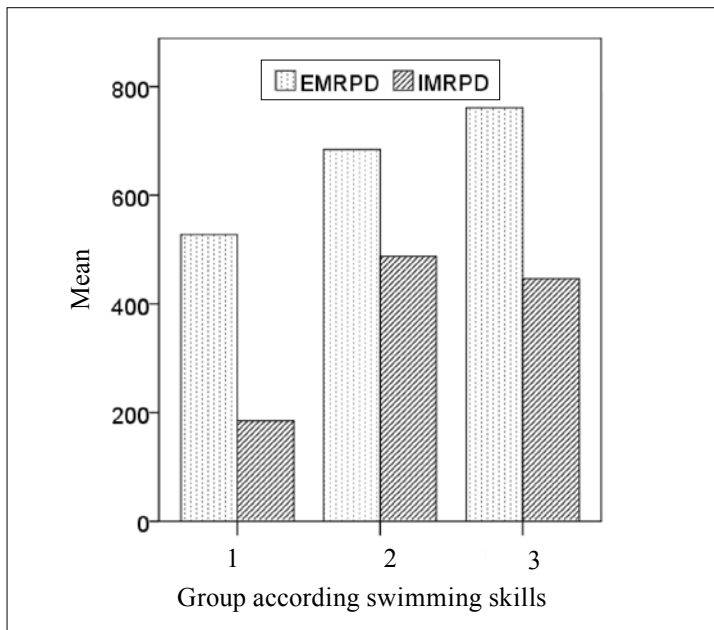


Figure 2. Mean maximal rates of pressure development in expiration (EMRPD) and inspiration (IMRPD) in the room for students with different swimming skills

There was a statistically significant positive correlation observed between maximal respiratory pressures and PEF as well as maximal rate of pressure development in expiration and inspiration and PEF (Table 2), but there were no significant correlations between respiratory pressure test parameters and other spirometric variables.

Table 2. Spearman's correlations between respiratory pressure and spirometric variables

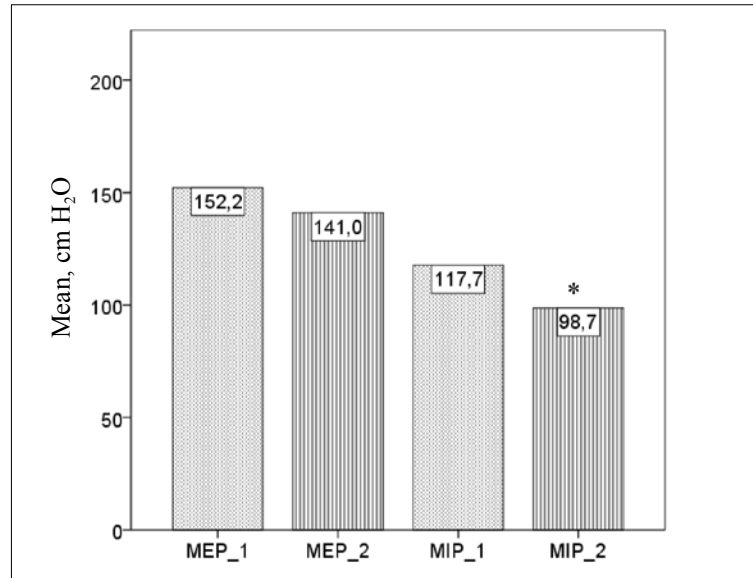
Variables	MEP	EMRPD	MIP	IMRPD
PEF	0.28*	0.32*	0.29*	0.33*
FEV1			0.32*	

Note. * – $p < 0.05$, according to Spearman's correlation test.

At the immersion into the water to the neck level students produced lower MIP, IMRPD and higher IMRR than in the room ($p < 0.05$) (Figures 2, 3 and 4). There was a decrease of expiratory parameters (MEP and EMRPD) observed, however these differences were not statistically significant.

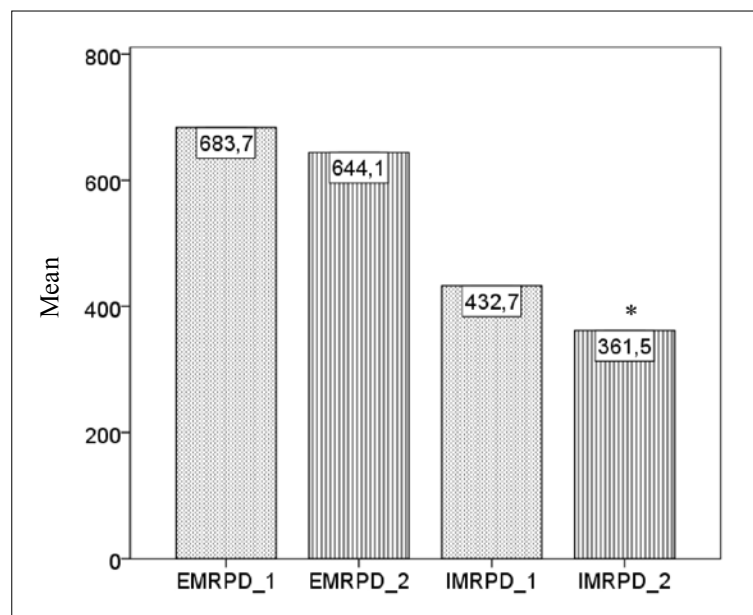
There were no statistically significant differences observed in respiratory pressure test parameters between students of the three groups according to their swimming skills.

Figure 3. Mean maximal expiratory (MEP) and inspiratory (MIP) pressures in the room (_1) and when immersed into the water to the neck level (_2)



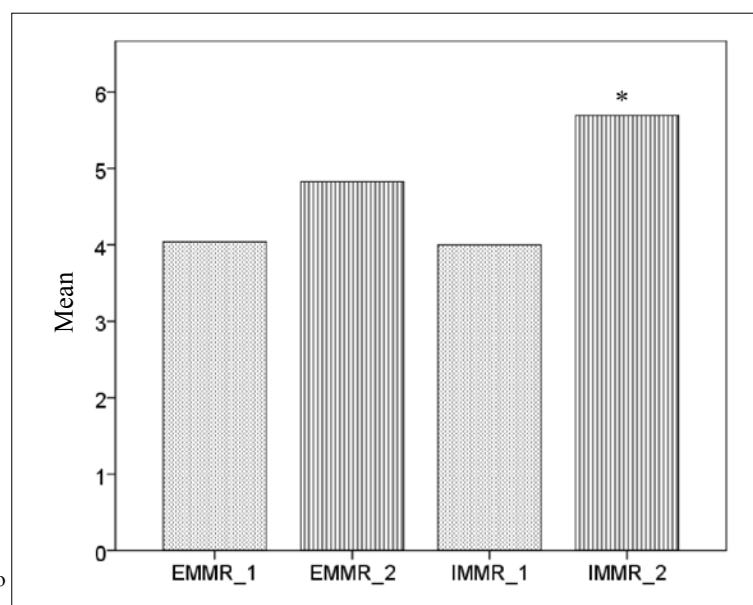
Note. * – $p < 0.05$ compared to MIP_1 according to Wilcoxon paired rank test.

Figure 4. Mean maximal rates of pressure development in expiration (EMRPD) and inspiration (IMRPD) in the room (_1) and when immersed into the water to the neck level (_2)



Note. * – $p < 0.05$ compared to IMRPD_1 according to Wilcoxon paired rank test.

Figure 5. Mean maximal relaxation rates in expiration (EMRR) and inspiration (IMRR) in the room (_1) and while immersed into the water to the neck level (_2)



Note. * – $p < 0.05$ compared to IMRR_1 according to Wilcoxon paired rank test.

DISCUSSION

The lung volumes and respiratory pressures in our study for all the females were normal in respect to predicted values (ATS/ERS – *Statement on Respiratory Muscle Testing*, 2002). There were no statistically significant differences in lung volumes observed between students with different swimming skills. We observed positive association of PEF with maximal respiratory pressures and maximal rates of pressure development in expiration and inspiration. Even stronger relationships were observed by other authors (Harik-Khan et al., 1998) indicating that respiratory muscle strength is an important indicator of the speed of airflow.

It is known that swimming and diving stimulates development of larger than normal static lung volumes and flow rates. These sports strengthen inspiratory muscles that work against additional resistance of the mass of water compressing the chest and increase maximal respiratory pressures (Phervani et al., 1989; Cordain et al., 1990; Kesavachandran et al., 2001).

Higher inspiratory muscle strength in our study was positively related to swimming skill evaluation estimate. While swimming, compared to running or cycling, athlete uses larger tidal volumes and breathes less frequently (Rodriguez, 2000). Persons with greater inspiratory muscle strength can ventilate lungs properly and improve their stroke mechanics. It is known that swimmers also need faster inspiration to inhale enough air in the limited time when swimmers mouth is above the water level. In our study there was no significant difference in the speed of inspiratory muscle contraction between students of different swimming skills. Probably, for the development of proper swimming skill, it is not necessary to

have very fast contractions of respiratory muscles, but if the swimmer wants to achieve the faster speed of swimming, it is crucial (Clanton et al., 1987; Cordain, Stager, 1988; Lomax, Castle, 2011). However, there was a tendency to have faster contractions in the group of students with higher swimming skills. The absence of differences could be explained with small groups of students who had poor and good swimming skills.

The MIP and IMRPD decreased and IMRR increased due to the immersion into the water compared with the values obtained in room. This could be caused by the effect of increased hydrostatic pressure of water on thoracic cavity. The water pressure works against the force created by inspiratory muscles and decreases the absolute value of maximal pressure generated during inspiration as well as the speed of inspiratory muscle contraction. Immersion in upright position causes compression of abdominal cavity, increasing resistance to diaphragm (Schoenhofer et al., 2004) and further decreasing MIP value. The increased pressure from outside increases the pressure in the thoracic cavity, favouring to the faster increase in pressure when inspiratory muscles relax (Cordain, Stager, 1988; Withers, Hamdorf, 1989).

CONCLUSION AND PERSPECTIVES

In conclusion, swimming skill improvement is more dependent on inspiratory muscle strength than volume to be ventilated. Immersion into the water decreases MIP, IMRPD and increases IMRR. Changes of maximal inspiratory pressure test parameters due to immersion are not related to swimming skills.

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MAKSIMALIOJO VALINGO KVĖPAVIMO SLĖGIO ŠAŠAJOS SU KITAIS SPIROMETRINIAIS RODIKLIAIS BEI PLAUKIMO ĮGŪDŽIAIS IR JO POKYČIAI KŪNUI PANIRUS Į VANDENĮ

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SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Tikrinome hipotezę, kad plaukimo įgūdžių tobulėjimas labiau priklauso nuo įkvėpimo raumenų jėgos nei nuo jų ištvėrmės.

Tikslas – nustatyti maksimaliojo valingo kvėpavimo slėgio ir kitų aktyvios spirometrijos rodiklių bei plaukimo įgūdžių sąsajas.

Metodai. Buvo tiriamos 62 Latvijos sporto pedagogikos akademijos studentės (amžius – $22,13 \pm 1,3$ m., ūgis – $168,4 \pm 6,6$ cm, kūno masė – $61,3 \pm 7,0$ kg). Visos jos nerūkė. Plaukimo įgūdžius vertino jų plaukimo treneris. Maksimalusis statinio įkvėpimo ir iškvėpimo slėgis bei aktyvaus valingo kvėpavimo rodikliai buvo matuojami burnos lygyje, tiriamajam esant sausumoje, paskui maksimalusis statinio įkvėpimo ir iškvėpimo slėgis dar kartą matuotas vandenyje, t. y. plaukikei iki kaklo panirus į vandenį.

Rezultatai. Vidutiniškai maksimaliojo statinio įkvėpimo slėgio rodikliai ne vandenyje siekė 109 ± 30 cm H₂O, iškvėpimo – 147 ± 33 cm H₂O. Aptikta teigiama maksimaliojo iškvėpimo ir maksimaliojo statinio įkvėpimo bei iškvėpimo slėgio, abiejų slėgio rodiklių didėjimo greičio koreliacija. Aktyvaus valingo kvėpavimo tūris nebuvo susijęs su abiem maksimaliojo slėgio rodikliais. Greitesnis įkvėpimo slėgio padidėjimo tempas buvo teigiamai susijęs su santykinu aktyvaus valingo kvėpavimo tūriu (per vieną sekundę, $p < 0,05$). Reikšmingai sumažėjo maksimaliojo įkvėpimo slėgis bei jo padidėjimas dėl panirimo į vandenį, tačiau jokių iškvėpimo rodiklių pokyčių nebuvo užregistruota.

Aptarimas ir išvados. Plaukimo įgūdžių tobulėjimas labiau priklauso nuo įkvėpimo raumenų jėgos nei nuo jų ištvėrmės. Plaukikės, kurioms būdingas aukštas maksimaliojo iškvėpimo greičio rodiklis, geba pasiekti ir aukštesnio lygmens kvėpavimo slėgio rodiklius. Panirus į vandenį, sumažėja maksimalusis statinio įkvėpimo bei iškvėpimo slėgis, didėja kvėpavimo dažnis. Šių rodiklių pokyčiai dėl panirimo į vandenį nėra susiję su plaukimo įgūdžiais.

Raktažodžiai: maksimalusis įkvėpimo slėgis, maksimalusis iškvėpimo slėgis, plaukimo mokymas, panirimas į vandenį.

Gauta 2013 m. liepos 10 d.
Received on July 10, 2013

Priimta 2013 m. gruodžio 9 d.
Accepted on December 9, 2013

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