Effects of low- vs high-volume swimming training on pelvic floor muscle activity in women

AUTHORS: **Marcin Dornowski[1], Piotr Makar[1], Piotr Sawicki[1], Dominika Wilczyńska[1], Inna Vereshchaka[1], Zbigniew Ossowski[1]**

[1] Department of Sport, Gdansk University of Physical Education and Sport, 80-336 Gdansk, Poland

ABSTRACT: This study examined the effects of different training loads on pelvic floor muscle (PFM) activity in swimming. Twelve female swimmers were included in this study (23.71±1.44 y.o.; 167±5.89 cm; 62.05±8.89 kg). They took part in an experiment with two different stages of load in swimming training. For the pelvic floor muscle assessment the Glazer Protocol was used. To assess swimming technique, David Pyne's Stroke Mechanics Test was used. A statistically significant increase in surface electromyography (sEMG) values appeared in the fifth R (rest after contraction) in the quick flick stage of the measurement protocol of PFM at the third measurement time (7.71±4.49 μV) compared to the first measurement time (6.25±4.43 μV) with p≤0.05. Increasing the training load may cause unwanted changes in the level of electrical activity of pelvic floor muscles.

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Corresponding author:
Marcin Dornowski
Department of Sport
Gdansk University of Physical Education and Sport
ul. Kazimierza Gorskiego 1
80-336 Gdansk, Poland
E-mail: mdornowski@awf.gda.pl

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INTRODUCTION

The knowledge of the pelvic floor muscles (PFMs) of young female athletes is limited. Two existing hypotheses regarding the PFMs are completely opposite: one suggests that female athletes have strong PFMs because of the training stimulus from the co-activation of the abdominal muscle, while the other theory postulates that repeated increases in intra-abdominal pressure (IAP) can cause fatigue and weaken the pelvic floor [1]. To date, no equivocal evidence has been presented to support either one. The effects of neither of these hypothesized alterations in PFM function and urethral integrity during sudden IAP increase have been properly tested. The development of pelvic floor morbidity in highly fit women is not an expected or desired phenomenon. Recent studies have suggested that there is a surprisingly high incidence of urinary incontinence in women who have participated in long-term high impact sports [2, 3]. The authors suggest that this change in function might be a result of participation in sport activity. Strenuous physical activity has been suggested as one factor promoting pelvic floor dysfunction in women [4].

Pelvic floor dysfunction can cause urinary and faecal incontinence, pelvic organ prolapse, pain and sexual disorders [5]. Many women engaging in fitness activities, including young nulliparas women, report symptoms of stress urinary incontinence (SUI) [4]. However, to date, there is limited information about the effect of strenuous physical activity on the continence mechanism [6]. Women who are physically active raise their intra-abdominal pressure more frequently than sedentary women. In particular, women participating in sports may risk stress incontinence during physical exertion [7]. However, there has been a general belief that physically fit women have a strong pelvic floor as a result of their regular training, thus preventing urinary incontinence [8]. Ree et al. [9] found that in young nulliparous women (mean age 24.0±1.7 years), after one bout of 90 min of strenuous physical activity, the mean maximum voluntary contraction (MVC) pressure decreased by 17%, indicating pelvic floor muscle fatigue. Top female athletes report a high prevalence of urinary incontinence, especially during sports but also during daily activities.

The prevalence of urinary incontinence ranges from 28% to 80%, with the highest prevalence in high-impact sportswomen such as trampolinists, gymnasts, aerobic gymnasts, hockey players and ballet dancers [2-3, 10-12]. Jumping is the activity that is most likely to provoke leakage. More athletes experience leakage during training rather than competition (95.2% vs 51.2%), possibly because of higher catecholamine levels during competition that act on the urethral α-receptors to maintain its closure [3]. Both stress incontinence and urgency urinary incontinence are prevalent among athletes. Urgency urinary incontinence is most apparent in cyclists and football (soccer) players [12]. Female elite trampolinists report the highest prevalence of urinary incontinence (80%), with large amounts of urine leakage per 15 min session measured by a pad test (urine leak collection): mean 28 g and range 9–56 g. The amount of leakage was not found to be correlated with PFM strength measured by a perineometer [2]. Young female athletes often experience significantly greater and more sudden IAP increases, especially during high-impact activities such as running and jumping [13]. Bo et al. [14] found that 26% of young physical education students reported urinary incontinence during different forms of physical activity, and the same prevalence was found in group fitness instructors including Pilates and yoga instructors [15]. Nygaard et al. [16] reported a 28% prevalence among college athletes. SUI can result in the athlete modifying her technique or even completely abandoning the sport and becoming physically inactive [17] Muscle hypertrophy develops as a consequence of repeated activation under load [18]. However, to the authors' knowledge, there have been no studies that look specifically at muscle changes in the pelvic floor as a consequence of strength training or endurance exercise. MacDougall et al. [19] found that skeletal muscle hypertrophy occurs in response to resistance training by growth and splitting of myofibrils. Alway et al. [20] observed a larger mean fibre area of the gastrocnemius muscle of highly trained endurance athletes compared to sedentary controls. This difference corresponded to the strength differences between the groups. Abdominal muscle strength was shown to be greater in elite athletes whose sports involve a lot of high impact landing such as tennis and gymnastics [21] compared to athletes in lower impact sports such as swimming and bowling.

For the high-fitness athletes reported in the study, the frequency and intensity of their training could be sufficient to result in pelvic floor hypertrophy. The pelvic floor muscles need to be much stronger in elite athletes than in other women. There is a need for more basic research on pelvic floor muscle function during physical activity and the effect of pelvic floor muscle training in female elite athletes [22]. No research is available to show whether elite athletes have stronger pelvic muscles because of increased muscle fitness overall or weaker pelvic muscles or connective tissue because of long-term increases in intra-abdominal pressure [16].

The aim of this study was to estimate the effects of low – vs high – volume swimming training on the levels of pelvic floor muscle activity in swimming.

MATERIALS AND METHODS

Twelve young female athletes (23.7±1.44 years old; height: 167±5.8 cm; body mass: 62.05±8.89 kg) were recruited to the study. All subjects were familiarized with the exercise protocol at least a week before starting the experiments.

All participants took part in the experiment which concerned two different stages of load (volume and intensity) swimming training. The experiment was divided into two parts. In the first part, participants were given high volume training (HVT) with a total volume of 52.2 km. In the second part, low volume training (LVT), the volume was 39.3 km with increased exercise in the A1 zone (aerobic zone) in the intensity AN2 (anaerobic zone). The proportions of the exercises, volume and intensity ranges were as follows (Table 1).

TABLE 1. Proportions of the exercises, particularly intensity ranges, in the researched group.

Intensity zone	Training volume			
	HVT		LVT	
	[km]	[%]	[km]	[%]
Recovery (RC)	7.8	14.94	4.5	11.45
Aerobic 1 (A1)	24.0	45.98	21.0	53.44
Aerobic 2 (A2)	12.3	23.56	6.6	16.79
Endurance 1 (E1)	2.7	5.17	1.8	4.58
Endurance 2 (E2)	2.4	4.6	1.2	3.05
Anaerobic 1 (AN1)	3.0	5.75	1.8	4.58
Anaerobic 2 (AN2)	0.0	0.00	2.4	6.11
Σ	52.2	100.0	39.3	100.0

In the LVT part of the experiment, the total volume of work was decreased, and the percentage of exercises in the A1 range was increased. Additionally, workloads executed using only the lower limbs in breaststroke in the intensity range AN2 were added. Classification of the training loads according to the intensity of executed exercises was done based on a previous study [23].

Before and after each stage two swimming technique tests were executed.

On the day of the swimming test, the subjects had a standard warm-up, consisting of mixed swimming drills: 300 m front crawl, 200 m and 50 m pull/swim, 100 m backstroke and 2 x 25 m with breaststroke leg kicks with increasing velocity. To assess swimming technique, David Pyne's Stroke Mechanics Test [24] was used, with all necessary modifications that enable testing in a 25-meter swimming pool. The experiment consisted of swimming 25 meters with breaststroke leg kicks four times (start every 1 minute) with increasing velocity in each successive repetition. Repetitions were to be done with a steady pace after taking off from the pool wall (omitting the starting jump). The time for five full movement cycles was measured between the 5th and 20th metres of the pool. All swimming trials were recorded using a Sony 8-mm Hi-8 (25 Hz) video camera for later analysis of time and technique. Time measurement was performed using Adobe Premiere Pro v7.0 technology (Adobe Systems Incorporated, USA). The "pause" function was used to mark the sequence in the movie where the time had to be measured. The time of the marked sequence was measured automatically by Adobe software. Calculations were made according to the following formulas: SR [stroke rate] = 60 x 5 / tSR [time of 5 cycles]; v [velocity] = S [distance] / t [time]; SL [stroke length] = v x 60 / SR; SI [stroke index] = v x SL according to the method described previously [25]. The stroke rate, stroke length and stroke index of the technique were calculated by Microsoft Excel.

The PFM sEMG study was conducted in the Laboratory of Physical Effort and Genetics in Sport, Gdańsk University of Physical Education and Sport (AWFiS) in Poland. The principles of the Helsinki Declaration were upheld, and the project received approval from the Bioethics Commission in Gdansk. Each participant provided voluntary written informed consent for the investigation. Muscle electrical activity was assessed using the TeleMyo 2400T Direct Transmission System (DTS), NORAXON EMG and Sensors System (Scottsdale, AZ, USA) TeleMyo DTS. For the pelvic floor, we used vaginal probes (Lifecare PR-02, Everyway Medical Instruments Co., Ltd., Taiwan). Women were asked to insert the probe into the vagina ensuring that each electrode surface pointed towards each hip [26]. The study was conducted based on SENIAM standards for electromyography, deviating from them insofar as the participants were not taught how to correctly perform pelvic floor muscle contractions before EMG assessment. Participants underwent three PFM sEMG tests repetitions: the first , the second after HVT, and the third after LVT. In the test, women received the following instruction: on the command "*Contract"*, immediately contract your pelvic floor muscles as much as you can, keeping your abdominals, legs and buttocks relaxed. During the study, the participants lay in a supine position with hips flexed and knees bent to approximately 90º. The evaluation of pelvic floor muscles with surface electromyography is painless and not invasive, using the Glazer protocol [27]. During the test, the participants from three groups performed 5 quick flick (Q) repetitions, five 10 s contractions, after which the average value of the resting electrical potential was analysed and called rest (R) and a continuous static pelvic floor muscle tension in a one-minute static hold (STA). The value of the pelvic floor muscle electrical potential was also analysed before the baseline study (BASE).

Mean values of the results were compared using a two-way statistical analysis of variance (ANOVA). A Bonferroni post hoc analysis was used to determine the differences between three sEMG tests results. The level of significance was set at $p \leq 0.05$.

RESULTS

The first sEMG test results were taken as output results of the analysed elements in PFM electrical activity to be taken as a comparison level in further analysis. The second sEMG test results after HVT (high volume training) did not significantly influence the level of analysed elements of pelvic floor muscle activity (Table 2).

The third sEMG test results after LVT (low volume, increased exercise in A1 zone – increased speed) compared to the first sEMG test results (output results) showed a significant influence on the level of particular analysed elements of pelvic floor muscle activity. In the quick flick stage of the measurement protocol at the fifth rest time after the fifth contraction, the level of the mean electrical activity value increased statistically significantly (Fig. 1).

The results of the swimming technique test in this research was used to confirm the training volume and intensity effects (muscle fatigue). It confirmed the possible source of the changes in electrical activity of pelvic floor muscles (particular tasks) between the first and third PFM sEMG test results, where we observed an increase of the mean value of the rest phase, which suggests that the examined muscles were fatigued and could not properly relax after contraction.

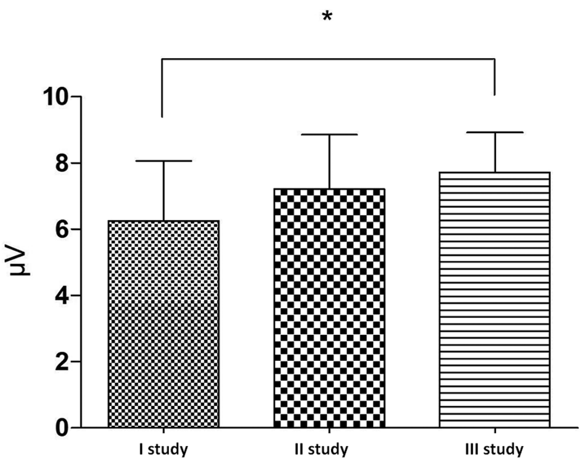

FIG. 1. Mean values of electrical activity of fifth "rest" after fifth "contraction" of PFM in third PFM sEMG test.
Note: * difference statistically significant p≤0.05).

TABLE 2. Pelvic floor muscle activity during particular protocol test stages at three measurement time points.

		BASE	REST	Q1	R1	Q2	R2	Q3	R3	Q4	R4	Q5	R5	STA
First measurement	**average (μV)**	4.76	5.75	9.93	6.35	12.06	6.61	13.08	7.33	13.26	6.74	12.68	6.25	13.9
	SD	2.62	3.62	3.11	4.53	4.89	4.86	5.28	5.04	5.6	4.98	5.31	4.43	4.85
Second measurement	**average (μV)**	5.83	6.63	25.55	8.58	20.29	14.24	17.02	12.67	18.98	7.93	19.42	7.21	16.28
	SD	4.13	3.28	31.94	3.18	16.76	13.36	7.13	9.95	11.88	2.55	12.38	2.92	4.91
Third measurement	**average (μV)**	3.73	5.7	11.49	5.8	11.61	6.7	12.79	6.65	12.27	6.92	12.3	7.71	15.04
	SD	3.22	3.67	2.35	4.21	3.10	3.21	3.8	2.54	4.42	3.43	7.13	4.49	8.24

Q1-5 quick flick 1-5 (10 s contractions), R1-5 rest after contraction 1-5, STA static hold (1 min).

A statistically significant increase in SL and stroke index (SI) during the lowest swimming velocity between the first and second swimming technique measurements was found. The load during that time does not include exercises in the energetic range AN2. Between the second and third measurements, where exercises in the highest energetic intensity were included, a statistically significant increase in the 25 m time trial was found with maximal swimming velocity. The largest number of statistically significant changes was observed in comparison of the values at the first and third measurements, and those were a decrease in stroke rate (SR) and an increase in stroke length (SL) with maximal swimming velocity and an increase in stroke length (SL) at the third intensity.

DISCUSSION

A recent case study reported results from three volleyball players [4, 28] where PFM function was measured in sport and physical education students, with and without UI, and no difference in PFM strength was found. This finding indicates that heavy lifting and strenuous activity may promote SUI in women already at risk, e.g., women with weak collagen tissue [16, 29]. Women with stress urinary incontinence may leak during physical activity and exercise, but they may be continent during their daily activities. Consequently, this issue might lead the women to become inactive, refraining from exercise and recreational activities in order to avoid urine leakage [7]. Swimming and its professional training process, although it is considered a lower impact sport [21] as compared to tennis, gymnastic, acrobatics, and skating, should also receive PFM supervision according to PFM activity. There are some studies that indicate the measurement of possible SUI risk factors according to PFM in physically active women and those participating in elite sports. Kruger et al. [30] reported the results of an MRI test of the muscle morphology of the pelvic floor muscles. Bo and Sundgot-Borgen [31] asked 603 former athletes about SUI incidents during their career, finding that there was no evidence of potential risk factors for SUI in later life in the researched group. These studies show that the specific swimming training process with its specific volume (high and low) and intensity may influence some aspects of PFM function and create possible risk factor for SUI. Today, knowledge allows us to assume that increasing swimming velocity means increasing not only stroke rate (SR) but also stroke length (SL) [32-33]. Only the optimal choices for these two values may lead to improved performance [34-35]. The question is how to train and with what swimming velocity and number of repetitions to improve the effectiveness of the training process. Until now, there have been few publications describing the relation between changes in swimming technique and training loads. An interesting factor appeared to be the stroke index (SI), for which the maximal value is very individually diverse in particular subjects and is related to maximal velocity [36-37]. With this measurement, we see that most of the subjects' velocity was between 80 and 100% of the maximal value for the 25 m distance and showed susceptibility to the type of volume and intensity. Often, the improvement in maximal value influences the maximal velocity value in a positive way, but no significant differences were found, only a change in the expected direction. It can be assumed that fatigue appears based on the muscles that took part in the effort and the attempt to overcome that fatigue by more economical enlargement of the cycle. This situation can be confirmed by the statistically significant increase in PFM sEMG mean values at the fifth rest in the quick flick stage of the measurement protocol at the third test compared to the first one. The influence of applied training volume and intensity in female swimmers demonstrate that swimming training should be controlled also based on possible risk factors. Further measurement according to different stroke specializations, distance and swimming speed used in the LVT may reveal other issues with different types of PFM contraction being connected to speed, strength and coordination of PFM activity.

CONCLUSIONS

The results of this study show that decreasing the training volume and increasing the intensity (more execution in the A1 zone) induce fatigue signs in kinematic variables in swimming training and cause unwanted changes in the level of electrical activity of pelvic floor muscles in researched female athletes. It lowers the ability to relax muscles after their contraction. Taking into consideration possible SUI and future pregnancy, the swimming training process in women groups should be consciously and professionally prepared and controlled.

Conflict of interest

The authors declare no conflict of interest including any financial, personal or other relationships.

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