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Investigation of the effectiveness of the synergism between
trunk stabilizers and pelvic floor muscles

Ph.D. Thesis Booklet

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INTRODUCTION

The multilayered arrangement of the pelvic floor muscles (PFM) is excellent for performing its tasks, which include, in addition to supporting the abdominal organs, closing the pelvic outlet and opening and closing the hiatuses surrounded by the PFM. Weakness of the three-layered muscles composing the PFM can cause emptying problems (urinary, wind and fecal incontinence) bladder, urethra, vagina, rectum, and uterine prolapse. The problem most frequently affects women due to their anatomical and physiological characteristics. Pelvic floor instability increases with age, and additional factors such as genetic background, comorbidities, pregnancy, childbirth, menopause, and lifestyle can also contribute to it. In general,10% of all adult women worldwide are affected, and this already shows a 40% incidence in people over 70 years of age. The first preventive task is to prevent a decrease in muscle strength, thus avoiding weakness and the appearance of symptoms.

The International Incontinence Consultation classified PFM training as Level "A" of Evidence-Based Medicine, so pelvic floor muscle training is also the basis of the first-line treatment of stress incontinence (SI) in domestic guidelines. Several studies confirm that strengthening the diaphragm muscle and the musculus transversus abdominis (TRA) improves incontinence from the horizontal to the vertical position.

EXAMINATION OBJECTIVES

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The purpose of this study was to investigate whether an alternative method, such as Callanetics® exercise, has an effect on the static (isometric) and dynamic (speed) force of the PFM, as well as changes in the circumference of different body parts and continence.

Pelvic Floor Muscle Training

The other purpose was to investigate whether, based on the synergism of the trunk muscles, the function of the PFM would improve in the sitting and lying positions, furthermore, to examine the effect of the PFM training with forced exhalation in the control group. We hypothesized that training posture affects the strength and endurance of the PFM.

ETHICAL IMPLICATIONS

The protocol and consent forms were approved by the Medical Research Council. All participants gave their written consent to participate in the measurements and trainings. The Office of

Health Authorisation and Administrative Procedures authorized the tests (the registration number 019234/2014/OTIG). The amendment of the license and the inclusion of the ultrasound examination was authorized by the Health Registration and Training Center, the legal successor of the Office of Health Authorization and Administrative Procedures (registration number: 096623-002/2015/OTIG).

MATERIALS AND METHODS

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Women (n=5) who gave birth participated in the training program and were randomly selected. An inclusion criterion was previous vaginal delivery and the exclusion criteria were the ongoing performance of PFM exercises and other physical exercises. 3 people had urine dribbling.

Based on the King's Health Questionnaire and the Gaudenz validated questionnaires, we assessed the risk factors among the participants with a questionnaire compiled by us. In addition, we asked about the symptoms of weakness of the PFM, paying special attention to the weakness of the vagina, rectum and urethra, as well as the frequency and extent of urinary retention problems.

The strength of the diaphragm was measured objectively by vaginal surface electromyography (vsEMG) (FemiScan™) using a Periform® vaginal electrode at week 0 (before the first exercise), at week 10 (at the end of the first exercise series, i.e., before the second exercise) and at week 20 (at the end of the second training series). During the measurement, we first requested a maximum isometric tension of 5 seconds and then analyzed the average value of the contraction measured in microvolt. During the second measurement task, the dynamic strength endurance was recorded, where the participants were asked to perform 5 maximum fast contractions. In this case, we evaluated the average of the peak values of the contractions. We asked the participants to relax completely between maximal contractions.

Participants attended a 60-minute group Callanetics® lesson twice a week for the first 10 weeks. Following the 10th week of the training, we again measured the change in the strength of the PFM to detect the changes in the parameters. The values obtained in microvolt (μV) were recorded. After the second measurement, they received detailed information about the PFM exercises, the correct way to stretch the PFM, and related lifestyle advice. During the second 10-week training, we only changed the course of the training to the extent that, before each exercise, we drew the attention of the participants to tilt their pelvis backward with a strong exhalation, then tighten their PFM and deep abdominal muscles, and this pelvic position, as well as they tried to maintain PFM tension even while strengthening individual muscle groups, so we primarily asked for isometric stretching of the PFM and the TRA. We also warned them not to push or press down. After the training, we repeatedly measured and recorded the change in the strength of the PFM. Using a questionnaire, we assessed the occurrence of symptoms and risk factors in the group. Furthermore, before the first training, between the two trainings and after the second training, we measured the circumference of the respective body parts (arms, hips, waist, thighs, knees, ankles).

Pelvic Floor Muscle Training

We included 58 healthy, young, nulliparous women in the study. We divided them into two test groups depending on the strength of the PFM and treated them with complex PFM training in both groups both in lying and sitting positions. The 22 participants with lower muscle strength (below 60 μV) formed the supine group (SUG). The other 22 participants, those with higher muscle strength (above 60 μV) established the sitting group (SIG). The control group (n = 14) (COG) formed the third group, which included 7 subjects with PFM activity below 60 μV and 7 subjects with PFM activity above 60 μV. COG did not change their lifestyle and did not undergo PFM training. Participants who were willing to participate and were able to correctly contract the PFM and the TRA were included in the study groups. Participants were required to maintain their daily activities (attending university lectures, sports activities, etc.). Exclusion criteria were known neurological or rheumatological diseases and previous vaginal or abdominal surgery.

In the study, before and after the training program, we used a self-administered questionnaire based on 3 validated questionnaires (the King's Health Questionnaire, the Incontinence Impact Questionnaire, and the Urogenital Distress Inventory). The questionnaire included risk factors for urinary incontinence (obstetric history, height and weight, stress, level of physical activity, sports, vaginal and abdominal surgeries), as well as questions related to the urinary tract. and the rectal canal (involuntary leakage of urine, cystitis, constipation) and sexual activity (orgasm problems).

Changes in PFM activity were also measured using a vsEMG instrument (FemiScan^{TM}), which measures electronic signals of PFM activity, using a sterile Periform^{TM} intravaginal probe with vsEMG electrodes. The PFM activity was measured twice in the supine position (at week 0 and after 8 weeks). The vsEMG data were recorded in µV. The participants performed 3 tasks: 1. PFM relaxation state for 30 seconds. 2. Maximal Isometric Contraction to Fatigue: Maximal voluntary tonic contraction of PFM 1, held to fatigue, performed once. 3. Dynamic endurance: fast, sudden, repetitive maximum voluntary phasic contraction of the PFM for 1 minute.

A CE 91048 certified diagnostic imaging device from ZONARE Medical System, Inc. (420 North Bernardo Avenue Montain View California 94043 USA - 93/42/EEC, 2007/47/EC) was used to measure the thickness of the TRA, which work synergistically with the pelvic floor muscles. During the abdominal ultrasound examination, we detected a change in the thickness of the local, deep trunk stabilizers (deep abdominal muscles) during the PFM contraction.

The effect of training on the parameters was analyzed by using the Kruskal-Wallis test. Pairwise comparisons were performed with the Mann-Whitney U test and the Wilcoxon rank test with the Bonferroni correction. All statistical analyzes were performed using the R statistical program. Values of $p<0.05$ were considered statistically significant.

A physical therapist supervised the training and performed the evaluation. The treatment consisted of 8 sessions of SUG and

SIG treatment, 1 hour of weekly complex PFM training group exercise, and 15 minutes of individual home practice, six times a week and for 8 weeks. The training program of the training groups took place according to five main aspects: diaphragmatic breathing, muscle strengthening, functional exhalation patterns and functional tasks. We progressed from horizontal positions to vertical positions to functional exercises over the course of 8 weeks. The SUG group performed the home exercises only in supine position while the SIG group only in sitting position.

RESULTS

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3 participants reported previous pelvic surgery. Among the participants, 2 participants were significantly overweight. Among our 38-62-year-old participants (5 people), 3 participants had urine dribbling. Within the group, 2 subjects gave birth once, 2 subjects twice, and 1 subject three times.

The average value of the 5 second isometric tension as a result of the first exercise decreased by 7 µV (from 65.7 µV to 58.7 µV) but it was not significant (p=0.137), however the values measured after the second exercise were significant where17.1 µV increase (from 58.7 µV to 75.8 µV) was shown (p=0.036).

With isometric stretching, we primarily wanted to follow the development of slow fibers.

During the examination of the dynamic strength, by examining the average value of the peak values of the 5 maximal contractions, we found that as a result of the first training, the muscle strength showed a decrease of 18.4 μV (from 83.9 μV to 65.5 μV) (p=0.163). Then, as a result of the second training, muscle strength showed an increase of 11.7 μV (from 65.5 μV to 77.2 μV), but this increase was not significant (p=0.096). With this study, we primarily wanted to monitor the improvement of fast fibers.

No significant changes were detected between the arm, waist, hip, thigh, knee and ankle circumferences measured after the first (weeks 0-10) and second (weeks 10-20) training, but the initial values (week 0) comparing to the values obtained at the end of the second (week 20) training, we found a significant increase in the circumference of the hip (p=0.018), thigh (p=0.012) and arm (p=0.003). We also experienced a decrease in the waist, but difference was not significant. We did not experience significant changes in knee and ankle circumference.

Pelvic floor training

At the beginning of the training program, 15 participants (4 SUG, 8 SIG and 3 COG participants) complained of urinary leakage during stress (coughing). After the training program, urinary leakage stopped in 7 participants (3 SUG and 4 SIG participants), while the symptoms of the COG participants remained unchanged.

During the 8 weeks, the maximum isometric contraction of the PFM until fatigue significantly improved in the training groups, SUG ($p<0.001$) and SIG ($p=0.015$), while this value did not change in the control group ($p=0.499$). The retention time of the maximum isometric of PFM tension improved but it was not significantly in both training groups, SUG ($p=0.972$) and SIG ($p=0.717$), while in the control group ($p=0.132$) not significantly but decreased. The TRA thickness during the PFM maximum isometric contraction increased but did not significantly increase in any training groups, SUG ($p=0.570$) and SIG ($p=0.231$), while in the control group, it decreased significantly($p=0.007$).

The strength and number of repetitions of the maximum fast contractions of PFM within 1 minute increased significantly in SUG ($p<0.001$), in SIG the strength of contractions decreased ($p=0.798$) and the number of repetitions did not change (p=0.813), either of these changes were not significant. In COG, these parameters decreased, but the differences were not significant (p=0.153; p=0.257).

PFM relaxation values improved in both training groups, but the improvement was significant only in the SIG group (p=0.011). This value decreased in the COG group, but not significantly (p=0.851). The TRA thickness under the relaxation function did not change in any training groups, it decreased in COG, but these changes were not significant. The TRA thickness during relaxation did not change in any of the training groups, but decreased in the COG, but not significantly. The data are shown in the table below, i.e. PFM activity at rest and during tonic and phasic contractions in the COG, SIG and SUG groups, and TRA muscle thickness during isometric contraction of the PFM up to fatigue and at rest. Values are the medians [1st-3rd] quartiles of isometric contractions, PFM at rest, TRA and PFM phasic contractions.

	Before training	**After training**	**p-value**
	median [Q_1 – Q_3]		
Maximal isometric contraction of PFM until fatigue (tonic) (µV)			
COG	56.25 [44.23 – 83.62]	58.65 [54.27 – 89.07]	0.499
SIG	91.20 [63.55 – 124.20]	115.60 [84.50 – 131.80]	0.015
SUG	42.90 [27.73 – 53.42]	59.00 [50.10 – 73.85]	<0.001

Retention time of PFM (s)			
COG	21.25 [14.58 – 27.50]	17.00 [12.50 – 19.41]	0.132
SIG	17.00 [12.75 – 27.50]	19.50 [15.50 – 23.00]	0.717
SUG	19.50 [16.50 – 29.75]	21.25 [13.25 – 28.62]	0.972
Dynamic endurance of PFM (phasic) (µV)			
COG	88.16 [62.84 – 97.22]	77.05 [60.23 – 87.83]	0.153
SIG	122.00 [95.30 – 142.20]	115.16 [94.68 – 128.42]	0.798
SUG	53.15 [35.61 – 64.28]	70.97 [56.10 – 83.80]	<0.001
The number of repetitions of fast contractions of PFM (repetitions)			
COG	33.00 [29.25 – 36.00]	31.00 [29.25 – 33.75]	0.257
SIG	29.00 [22.00 – 39.00]	30.00 [23.00 – 35.50]	0.813
SUG	26.00 [21.75 – 33.50]	32.00 [27.25 – 39.75]	<0.001
Relaxation state of the PFM (µV)			
COG	8.60 [6.48 – 17.98]	10.55 [3.85 – 19.40]	0.851
SIG	21.40 [8.35 – 27.05]	12.40 [3.00 – 19.45]	0.011
SUG	13.40 [9.20 – 20.75]	13.25 [6.83 – 18.50]	0.465
TRA (cm) during the relaxation state of PFM			
COG	0.38 [0.33 – 0.44]	0.31 [0.27 – 0.34]	0.209
SIG	0.26 [0.23 – 0.32]	0.26 [0.23 – 0.31]	0.717
SUG	0.28 [0.26 – 0.31]	0.27 [0.25 – 0.31]	0.422
TRA (cm) during maximal isometric contraction of PFM till fatigue			
COG	0.63 [0.61 – 0.74]	0.49 [0.45 – 0.57]	0.007
SIG	0.51 [0.38 – 0.63]	0.56 [0.41 – 0.75]	0.231
SUG	0.53 [0.44 – 0.73]	0.58 [0.46 – 0.68]	0.570

DISCUSSION

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Looking at the results of several international researches, our investigations also supported and verified that the incidence of

SI increases with advanced age. The occurrence of SI is influenced by risk factors and lifestyle.

Biofeedback is effective in the correct implementation of pelvic floor muscle exercises; we also found that vsEMG helped with sensation and neuromuscular improvement. It is worth developing the co-contraction of the trunk capsule so that it is able to pre-tension before the increase in intra-abdominal pressure at any time. As age progresses, the percentage of fast fibers decreases in favor of hypertrophy of slow fibers. Since the mainly static, isometric exercises of Callanetics® gymnastics strengthen the type I fibers, it is recommended to separately practice the isolated phasic activity of the PFM, and it would be worth examining this among young people as well.

Based on the results obtained during our examination, we may conclude that Callanetics® exercise can be an effective treatment in the prevention and rehabilitation of incontinence.

Pelvic floor training

Our results are similar to the international results in relation to diaphragmatic muscle training. According to it, we also suggest that motor relearning is necessary for a complex training of the diaphragm, the TRA and the PFM, which improves the automatic timing within the trunk capsule. This requires the correct breathing technique, inhaling for the conscious relaxation of the PFM and TRA and exhaling for the contraction of these muscles, which we also taught and applied during our training, thus achieving the maximum tension of the PFM.

Some studies have found either horizontal-only, some have found vertical-only, and some have found both body position strengthening to be effective. In our study, as a result of the complex training, the main function of the PFM, the retaining (isometric) function, improved significantly both in horizontal and vertical positions, which was promoted by the strengthening training and increase in thickness of the TRA. On the other hand, the phasic function should be practiced in a horizontal body position, which would be a recommended training situation especially for beginners, while the relaxing function, on the other hand, should be practiced not only in supine position, but also in sitting position.

CONCLUSIONS AND NEW FINDINGS

The two rehabilitation theories of isolated the PFM training or combined strengthening of the TRA and PFM should be considered. Based on our study, we have come to the conclusion that both programs contain effective and useful elements, but an accurate assessment of the individual's condition is essential in terms of posture and the PFM functions, dysfunctions, and motivation.

Our studies point to the importance of posture in terms of controlling the PFM and abdominal muscles. The upright body position requires greater the PFM activity, so special attention should be paid to strengthening the trunk stabilizers. Strengthening the phasic function of the PFM should be practiced initially in a horizontal position. In free time and at work, increasing the PFM tone during the day in sitting and standing would be an effective strategy.

Our results led to the conclusions that:

1. risk factors play an important role incontinence.
2. the symptoms of incontinence improve after the recommend training.
3. the Callanetics® exercises were through the contraction of the synergistic muscles, especially the TRA, has an effect on the tonic and phasic activity of the PFM even without directly stretching thePFM, so even after the first training, the strength of the PFM improve.
4. when Callanetics® exercises were combined with direct perineal muscle stretching, there was a significant increase in muscle strength, so Callanetics® training combined with

PFM exercises could be more effective in increasing the strength of the PFM.

5. as a result of the Callanetics® training and the combined training the circumference of each body region decreased.
6. after completing the PFM training program, the results of conscious relaxation improved in the sitting and supine groups compared to the control.
7. as a result of the pelvic floor muscle training program, the maximum isometric stretching of the PFM until fatigue and the strength of the maximum rapid contractions within one minute (dynamic strength endurance) increased in the gymnastics groups compared to the control group.
8. the diameter of the TRA increased by the end of the pelvic floor muscle strengthening program during isometric stretching, due to the powerful exhalation technique in the exercise groups compared to the control group.
9. when comparing the two groups, the PFM training performed in the sitting position improved the resting tone of the PFM more effectively compared to the supine position, due to the gravitational force acting on the PFM.

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