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Original Article

Do moderate aerobic exercise and strength training influence electromyographic biofeedback of the pelvic floor muscles in female non-athletes?

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Abstract. [Purpose] To assess the influence of moderate physical exercise on pelvic floor muscle electromyographic (EMG) biofeedback signal in female non-athletes. [Subjects and Methods] A prospective, non-randomized study of 90 adult females (age ≥18 years) divided into three groups: Intervention (I), which began physical exercise upon study enrollment; Moderate Exercise (ME), comprising those who already engaged in physical activity; and Sedentary (S), comprising those who had a sedentary lifestyle. All participants underwent EMG biofeedback of the pelvic floor muscles upon study enrollment (T1) and at the end of the third subsequent month (T2). [Results] Mean age was 35.7 (SD: 7.5) years, with no significant difference between groups. T1 values in groups I and S were significantly lower than in group ME. There was no statistically significant difference between groups S and I. On comparison between groups at T2, values were highest in group I (18.5 µV vs. 15.3 µV in group S, vs. 16.1 µV in group ME). There was no significant difference between groups S and ME. On age-adjusted analysis, group I exhibited the greatest change between T1 and T2 (I, 4.7 µV; ME, 2.1 µV; S, 1.5 µV). [Conclusion] Females who exercise exhibit better pelvic floor muscle function than those who do not engage in physical activity.
Key words: Pelvic floor, Biofeedback, Physical exercise

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INTRODUCTION

The pelvic floor muscles (PFMs) provide primary support for the pelvic organs, stabilize the sacro-iliac joint, and contribute directly to continence, micturition, and defecation mechanisms[1)].

Changes in PFM function and morphology can trigger signs and symptoms of pelvic floor dysfunction, such as urinary incontinence (UI), fecal incontinence, pelvic organ prolapse, and pain during sexual intercourse[1)].

Multiple risk factors for pelvic floor dysfunction have been identified, including pregnancy, type and mode of delivery, aging, pelvic and gynecological surgery, menopause, and obesity[2–4)]. In recent decades, several investigators have documented the role of high-impact exercise and prolonged, high-intensity training as an etiological or aggravating factor for pelvic floor dysfunction in female athletes[5–14)].

Sudden foot-ground contact is an inherent mechanism of several sports. The force resulting from this impact is transmitted to the pelvic floor. When such contact occurs repeatedly, it may damage the pelvic floor structures and tissues and lead to anatomic or functional impairments, such as UI and genitourinary prolapse[12, 15, 16)]. Other mechanisms that explain the high

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prevalence of signs and symptoms of pelvic floor dysfunction in female athletes are related to the chronic nature of the load borne by muscles in this region, to the marked increase in abdominal pressure, and to prolonged recruitment of this muscle group[8–18].

Contradicting the aforementioned findings, some authors use an event known as co-contraction to support the hypothesis that athletes cannot experience weakness of the PFMs due to excess training. Co-contraction refers to a coactivation of the PFMs concomitantly with increasing abdominal pressure or when muscles agonistic and synergistic to the PFMs are activated. Therefore, athletes would not have a higher prevalence of UI or pelvic organ prolapse compared to the non-athlete population, because their pelvic floors would be stronger and more resistant as a result of this constant recruitment[19–21].

Many studies have assessed the occurrence of UI in female athletes. However, information on the effects of moderate physical exercise on the PFMs in non-athletes is lacking. Also, the behavior of these muscle groups in non-athlete women who engage in moderate physical activity is still unknown.

The present study was therefore designed to assess the impact of moderate physical exercise on the PFMs in female non-athletes.

SUBJECTS AND METHODS

This prospective, non-randomized study was approved by the Research Ethics Committee of Universidade de Brasília School of Medicine and was conducted in accordance with the provisions of the Declaration of Helsinki. Participation was voluntary, and written informed consent was obtained from all participants prior to their inclusion in the study.

Ninety women aged 18 years or older were enrolled and allocated to three groups (n=30 each): Intervention (I): consisted of women who had been physically inactive for 6 months or longer before study enrollment. The participants were invited to start a program of physical exercise at a health club or gym at the time of study enrollment and asked to remain in the program for at least 3 months after study enrollment; Moderate Exercise (ME): consisted of women already engaged in physical exercise at a gym or health club for at least 6 months before study enrollment who agreed to continue exercising for at least 3 months subsequently; and Sedentary (S): consisted of women who had been physically inactive for at least 6 months before study enrollment and agreed to remain sedentary throughout the study period.

Pregnant women, women with a history of central or peripheral neurologic injury, and those who had undergone chemotherapy or radiation therapy for pelvic neoplasms were excluded. Participants in groups I and ME who interrupted training for 3 consecutive weeks or longer and who had an attendance rate of fewer than two times a week for 3 or more weeks in a month were also excluded from the study.

Physical exercise was defined any planned, structured physical activity, moderate to vigorous in intensity, performed with the purpose of improving or maintaining physical fitness or achieving aesthetic modifications[22–25]. Two broad exercise modalities were considered for this study: aerobic exercise and strength training. None of the gyms or health clubs where participants exercised provided Pilates or stretching classes. The participants were not specifically instructed to perform any pelvic floor exercises during the study period. All participants' trainers were qualified physical educators and instructed them to exercise to a heart rate consistent with moderate-intensity exercise (70–80% of maximum heart rate).

The International Physical Activity Questionnaire (IPAQ)-Short Form was used to assess the level of physical activity and to objectively characterize participants as sedentary[25]. The questionnaire was administered at the time of study enrollment and at the end of the study period. For the present study, participants were considered sedentary if they engaged in (*a*) physical activity with a frequency and duration less than 30 minutes of vigorous physical activity, three times a week, (*b*) less than 30 minutes of walking or moderate physical activity, five times a week, or (*c*) any activity requiring moderate physical exertion, five times a week.

All participants completed an interview based on standardized questionnaires and forms designed to collect the following data: demographic characteristics; obstetric history; prior gynecological surgery (hysterectomy and perineoplasty); lifestyle factors; and genitourinary, anorectal, and sexual signs and symptoms of pelvic floor dysfunction, such as urinary or fecal incontinence, disordered or difficult defecation, symptoms of genitourinary prolapse (sensation of "heaviness" in the vagina or "sitting on a ball") and sexual complaints (dyspareunia and vaginismus).

PFM activity was then measured by electromyographic (EMG) biofeedback in all participants to quantify the pelvic floor contraction capacity. Assessments were performed at two time points: T1, upon study inclusion; and T2, at the end of the 3rd month following the first measurement.

Biofeedback was performed using a two-channel Miotool Uro USB® system, with a sampling frequency of 1,000 Hz, gain accuracy of 25%, input impedance of 1,010 Ω, analog band-pass filter (20–500 Hz), gain set to 500, and Biotrainer® software (Porto Alegre, RS, Brazil). Gel-free, rectangular (2 × 4 cm), silver/silver-chloride (Ag/AgCl) cardiac monitoring electrodes with clear plastic backing were used (3M® Red Dot™ 2239T, São Paulo, SP, Brazil). Measurements were performed with the participant in the supine position, with knees flexed and legs supported by a foam wedge, so as to keep the hip joint at 45° and the feet off the bed, thus preventing use of accessory muscles. To capture the EMG biofeedback signal, electrodes were placed on the skin surrounding the anal margin, at the 4 o'clock and 10 o'clock positions. The reference (ground) electrode was placed on the right knee.

Then, two printouts of schematic diagrams of the female genitalia were used for a brief explanation about surface anatomy, which was provided alongside verbal and visual instructions about the region participants should contract. To check for proper performance, at the end of the instructions, the investigator elicited a muscle contraction by issuing a verbal command asking the participant to squeeze her anus and vagina closed.

For each measurement, three contractions, each lasting 2 seconds and followed by a 5-second rest, were elicited. The peak muscle contraction value measured by the biofeedback system for each event (peak contraction) was recorded. Then, the arithmetic mean of these three measurements was calculated. Finally, T1 and T2 measurements were compared to each other and between groups.

EMG measurements of PFM activity assessed by biofeedback upon study inclusion (T1) and at the end of the 3rd month following the first measurement (T2) were the primary outcomes of this study. Secondary outcomes were clinical variables collected from an interview based on standardized questionnaires and forms, including prior gynecological surgery, lifestyle factors, and genitourinary, anorectal, and sexual signs and symptoms of pelvic floor dysfunction, disordered or difficult defecation, symptoms of genitourinary prolapsed, and sexual complaints.

Groups were compared by analysis of variance (ANOVA) for quantitative variables with a Gaussian distribution and by the nonparametric Kruskal-Wallis test for non-normally distributed variables. For qualitative variables, comparisons between groups were performed using the chi-square test. Mean muscle activity values at T2 were compared within groups using analysis of covariance (ANCOVA)—the ANCOVA model was constructed with the T2 measurements as the dependent variable, group as the independent variable, and the T1 measurements and age as covariates. Bonferroni correction was applied to the p-values of comparisons between group means. Student's t-test for paired samples was used for within-group comparison of means. A multiple linear regression model was used to evaluate the effect of the following variables: age; body mass index (BMI); number of vaginal and cesarean deliveries; and history of surgical procedures on EMG biofeedback gain. Statistical analysis was performed using SAS, version 9.4 (SAS Institute, Inc., Cary, NC, USA). The significance level was set at $p<0.05$ for all analyses.

RESULTS

The mean (SD) age of participants was 35.7 (9.75) years (group I, 34.70 years, SD 10.07; group S, 35.73 years, SD 9.67; group ME, 36.67 years, SD 9.75; p=0.7412), ranging from 18 to 53 years. The 30-to-39 age group was predominant, with no significant difference between groups (Table 1).

BMI differed significantly between groups. Group S participants had the highest BMI (26.39 [4.54] kg/m^2 in group S vs. 26.44 [4.28] kg/m^2 in group I and 23.77 [4.27] kg/m^2 in group ME, p=0.0297) (Table 1).

Cesarean section was the most prevalent mode of delivery in all three groups. Regarding the number of pregnancies, groups S and ME had a higher prevalence of nulliparous women, while group I had a greater number of women who had delivered twice, regardless of mode. However, comparisons between the three groups did not reveal a statistically significant difference in the number of pregnancies, modes of delivery, or number of miscarriages/abortions (Table 1).

There was no statistically significant difference between groups in history of gynecological surgery. Six women in group I (20%), four in group S (13.3%), and six in group ME (20%) had undergone one or more of the surgical procedures of interest (p=0.7378).

No significant differences between groups were found regarding signs and symptoms of pelvic floor dysfunction as assessed in the study. Overall, 15 women in group I (50%), 12 in group S (40%), and 15 in group ME (50%) reported one or more of these complaints. Among the symptoms assessed, "difficulty with bowel movements" was the most common complaint in all three groups (I, 30%; S, 30%; ME, 26.6%; p=0.6691).

The mean (SD) EMG measurements of PFM activity assessed by biofeedback at T1 were 13.12 (1.9) µV in group I, 13.12 (1.96) µV in group S, and 15.00 (2.44) µV in group ME; this difference was significant between the three groups (p=0.0013). T1 values in groups I and S were significantly lower than those in group ME (p=0.0020 and p=0.0127, respectively). There was no statistically significant difference between groups I and S (p=1.0000), as shown in Table 2.

On comparison of T2 measurements between groups, the highest values were obtained in group I (18.5 µV) as compared to groups S (15.3 µV, $p<0.0001$) and ME (16.1 µV, p=0.0008). There was no statistically significant difference between groups S and ME (Table 2).

The change in EMG activity from T1 to T2 (i.e., T2–T1) was analyzed and adjusted for age. As shown in Table 2, the greatest change was seen in group I, followed by groups ME and S, respectively. Mean EMG measurements of pelvic floor activity were significantly higher in T2 than in T1 in all three groups (Table 2).

On multiple linear regression analysis, age was the only variable to reach marginal significance (p=0.0523), suggesting that advancing age was associated with declining EMG activity gain in the sample (Table 3).

DISCUSSION

In the present study, we sought to assess the influence of moderate physical exercise on electromyographic measurements of PFM activity in female non-athletes. The objective assessment of the effects of moderate aerobic exercise and strength training on the PFMs of non-athlete women represents a novel contribution of this study to the literature. Our findings

Table 1. Age range, body mass index (BMI), and obstetric history in the three study groups

Demographic data	Intervention group (n=30)		Sedentary group (n=30)		Moderate exercise group (n=30)	
Age						
Mean*	34.70 (SD 10.07)		35.73 (SD 9.67)		36.67 (SD 9.75)	
Categories***	(n)	(%)	(n)	(%)	(n)	(%)
18–29	10	33.3	7	23.3	6	20
30–39	12	40	13	43.3	13	43.3
40–49	4	13.3	7	23.3	7	23.3
50+	4	13.3	3	10	4	13.3
BMI (kg/m^2)						
Mean*	26.44 (SD 4.28)		26.39 (SD 4.54)		23.77 (SD 4.27)**	
Categories***	(n)	(%)	(n)	(%)	(n)	(%)
<18.5	1	3.3	0	0	2	6.6
18.5–24.9	9	30	10	33.3	19	63.3
25–29.9	13	43.3	12	40	6	20
30–39.9	7	23.3	8	26.6	3	10
No. of pregnancies*	1.53 (SD 1.25)		1.50 (SD 1.46)		1.40 (SD 1.30)	
No. of vaginal deliveries*	0.73 (SD 1.01)		0.97 (SD 1.03)		0.73 (SD 0.87)	
No. of cesarean sections*	0.67 (SD 0.80)		0.50 (SD 0.86)		0.53 (SD 0.73)	
No. of miscarriages/abortions*	0.13 (SD 0.35)		0.10 (SD 0.31)		0.13 (SD 0.35)	
No. of deliveries***	(n)	(%)	(n)	(%)	(n)	(%)
0	9	30	12	40	10	33.3
1	6	20	1	3.3	9	20
2	11	36.6	10	33.3	7	23.3
3+	4	13.3	7	23.3	4	13.3

*Values expressed as mean and standard deviation (SD) in each study group.
**Significantly different between groups (p<0.05).
***Values expressed as absolute and relative frequencies.

provide additional support for the hypothesis that moderate exercise improves PFM performance.

The EMG biofeedback measurements obtained during baseline assessment were higher among women who already engaged in physical exercise (group ME) than in the women who were initially sedentary (groups I and S). This finding alone already suggests that physical activity may contribute to improved perineal function in women. Also, mean EMG biofeedback measurements of pelvic floor activity were significantly higher in T2 than in T1 in all three groups. Group I, which consisted of initially sedentary women who then began a physical exercise program, achieved the greatest gain in relation to the other groups. This can be attributed to the role of exercise as an agent of functional change.

In a study using subjective measurements, Stach-Lempinen et al.[26] evaluated 82 sedentary and active women with UI. For their assessment, the authors used the Oxford scale, a subjective measure of perineal contraction as assessed by digital vaginal examination, and found an association between the level of physical activity and pelvic muscle contraction; 43.5% of active women achieved good contraction vs. only 27% of less-active women.

The hypothesis that physical exercise may improve PFM function is supported by the work of other authors, including Bø et al.[10] and Tajiri[27], who found that, simultaneously with increased intra-abdominal pressure during physical exercise, a reflex contraction of the PFMs occurs, which ultimately leads to improved conditioning of this muscle group. According to Ree et al.[28], physical exercise can increase PFM volume, giving these muscles the ability to contract during increases in intra-abdominal pressure and, consequently, to contribute actively to continence mechanisms.

In the present study, improvement in mean EMG biofeedback measurements of pelvic floor activity were found in all three groups, with the greatest change observed in group I. The ME group also exhibited greater change in relation to group S. Therefore, both physical exercise groups achieved greater gains than the sedentary group. Considering that the number of motor units that are activated as well as the firing frequency of these units increase with rising force, thus influencing EMG biofeedback signal, and that the electrical activity of a muscle directly reflects its ability to contract, which is a marker of muscle function, the findings of our study provide evidence to validate the role of physical exercise in improving PFM function.

The change observed in women in group S may be explained by the interactive nature of biofeedback. Placing electrodes in the perineal region and providing verbal explanations and commands to elicit PFM contractions can improve perception,

Table 2. Electromyographic activity of the pelvic floor muscles at T1 (study enrollment) and T2 (end of the 3rd subsequent month) in the three study groups: Intervention (I), Sedentary (S), and Moderate Exercise (ME)

				Between-group comparisons		
	Group I	Group S	Group ME	I vs. S	I vs. ME	S vs. ME
Variable		Mean (95%CI)				
T1‡	13.1 (12.4; 13.8)	13.4 (12.8; 14.1)	15.0 (14.1; 15.9)	0.3 (1.0000)	1.9 (0.0020)	1.6 (0.0127)
T2	17.9 (16.6; 19.1)	14.9 (14.0; 15.9)	17.1 (16.1; 18.2)			
T2*# (adjusted)	18.5 (17.6; 19.3)	15.3 (14.5; 16.1)	16.1 (15.3; 17.0)	3.2 (<0.0001)	2.3 (0.0008)	−0.8 (0.4806)

‡p-values for between-group comparisons calculated by ANOVA with Bonferroni correction.
*p-values for between-group comparisons calculated by ANCOVA adjusted for age and T1 measurements, with Bonferroni correction.
#Means adjusted for age and T1 by ANCOVA.

Table 3. Effect of the variables age, BMI, number of deliveries, and history of surgical procedures on electromyographic activity gain (T2–T1) in study participants

Variable	β*	p-value	r^2	95%CI of β
Constant	5.80	0.0040	0.0625	(1.90; 9.70)
Age	−0.08	0.0523		(−0.16; 0.00)
BMI	−0.03	0.6137		(−0.16; 0.09)
No. deliveries	0.63	0.0718		(−0.06; 1.31)
Surgical history	0.71	0.4393		(−1.11; 2.53)

Dependent variable: electromyographic gain (T2–T1); BMI: body mass index; β: slope of the regression line; CI: confidence interval; r^2: coefficient of determination.
Significance accepted at $p<0.05$.

which may contribute to better performance of the requested contractions. However, it should be noted that group S achieved the least gain in muscle activity.

The fact that the greatest gain was achieved among initially sedentary women who began an exercise program (group I), and not in women who already exercised (group ME), is explained by one of the core tenets of exercise physiology—namely, that gains are greatest in the early stages of training. The functional significance of the morphological changes undergone by a muscle that is frequently recruited is believed to translate essentially into increased strength and capacity for power generation. Rapid gains in strength are commonly observed in the early stages of muscle training, particularly in previously untrained individuals. These gains may be attributed to improvement in motor unit recruitment as a result of increased neurological activity[29)]. Therefore, in sedentary individuals starting physical activity, strength is gained faster in the early stages of training. As with other muscle groups, this also happens with the pelvic floor in sedentary women who begin an exercise program. The PFMs are activated by the co-contraction mechanism[8, 27–29)]. Through training, individuals who engage in regular physical activity acquire the ability to activate and contract a greater number of motor units simultaneously, both in the main muscle involved in the desired movement and in the agonist and synergist muscles. Essentially, muscle coordination is improved. Unlike untrained individuals, who are only able to mobilize a given percentage of their muscle fibers at a time, trained individuals can contract a markedly greater number of muscle fibers synchronously and simultaneously; thus, overall muscle strength is much greater than in sedentary individuals[29)].

According to Danforth et al.[30)], advancing age is a determinant of the natural senescence of muscle fibers, with consequent hypotrophy or fatty replacement. In the pelvic floor, this can contribute to weakening and loss of contraction capacity, with consequent impairment of continence mechanisms. As advancing age can interfere with the rate of muscle response (strength gains and/or hypertrophy), we adjusted our analysis of the difference between baseline and final EMG activity levels (T2–T1) for age. Furthermore, much has been discussed in the literature about the impact of route of delivery and parity on the pelvic floor structures. In our sample, neither of these factors differed significantly between the groups. On multivariate analysis, neither factor was an independent variable, i.e., neither was associated with gains.

We believe that the present study has great relevance, as knowledge of the workings of the pelvic floor is of paramount importance to clinical practice. Although this is an increasingly popular research subject, few studies have reported objective assessments of pelvic floor function in non-athlete women who engage in moderate physical exercise or strength training. Future studies may exclude confounding factors and limitations of the present investigation, such as the proprioception of the pelvic floor inherent in physical-therapeutic evaluation and the therapeutic effects of biofeedback, to further elucidate this relationship.

Strengths of this study include the comparative, prospective design, with control for possible confounding variables such as age, overweight and obesity, pregnancy and parity, and history of pelvic and perineal surgery. A clear definition of moderate physical activity was used, engagement was controlled, and effects were measured objectively. Limitations are mainly due to the small sample size and to the use of a single assessment parameter. We suggest that future studies enroll larger samples and distinguish between types of physical activity. Inclusion of other objective methods for the assessment of changes associated with physical exercise would also be helpful.

The results of this study support the hypothesis that women who engage in moderate physical exercise exhibit better PFM function than sedentary women. This provides further evidence that encouraging the practice of physical activity is essential for population health. In addition to its wide range of well-known benefits, exercise can improve pelvic floor function.

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Conflict of interest

The authors have no conflicts of interest to disclose.

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