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ORIGINAL ARTICLE

Assessment of abdominal and pelvic floor muscle function among continent and incontinent athletes

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Abstract

Introduction and hypothesis Studies have shown that there is a co-contraction between the pelvic floor and abdominal muscles. This study aimed to evaluate pelvic floor and abdominal muscle function in continent and incontinent female athletes and to investigate the association between these muscle groups.

Methods This was a cross-sectional study. Forty nulliparous professional female athletes who competed at the municipal level or above participated in this study. All participants underwent a pelvic floor muscle (PFM) and abdominal muscle assessment. PFM function and strength were assessed using the modified Oxford Scale and a perineometer. Abdominal muscle function and strength were assessed using a 4-Pro isokinetic dynamometer. To assess athletes' urinary continence, the International Consultation on Incontinence Questionnaire Short-Form (ICIQ-UI-SF) was used.

Results There was a positive association between PFM and abdominal muscle strength among the incontinent athletes ($p = 0.006$; $r = 0.577$). The incontinent athletes had greater PFM strength than the continent athletes ($p = 0.02$). There was no difference in abdominal muscle function between the groups.

Conclusions We found that incontinent athletes have greater PFM strength than continent athletes. This suggests that urinary incontinence in this population is not due to PFM weakness. The positive association between abdominal and PFM strengths in incontinent athletes may be due to frequent co-contraction between these muscle groups.

Keywords Athletes · Abdominal muscles · Pelvic floor · Urinary incontinence

Introduction

The core region is the area bounded anteriorly by the abdominal muscles, posteriorly by the lumbar multifidus, superiorly by the diaphragm, and inferiorly by the pelvic floor muscles (PFM) [1]. Due to the anatomic connections between these core muscles [1], several studies have investigated the influence of the abdominal muscles on the PFM [2–5], suggesting that co-contraction between the PFM and abdominal muscles allows them to work synergistically. Besides, researchers have attributed the higher increase in intra-vaginal pressure to the co-activation of PFM and abdominal muscles rather than PFM contraction alone [2]. Therefore, strengthening the abdominal muscles could improve PFM function and possibly treat PFM dysfunction [6, 7].

Urinary incontinence (UI) is defined as any involuntary leakage of urine [8] and is the most prevalent type of PFM dysfunction among women [9]. A higher prevalence of UI has been found in female athletes [10], and they appear to have a 2.53 times greater risk [95% confidence interval (CI), 1.3–2.7] of having UI than physically inactive women [11]. A possible

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explanation for these higher rates is that intense physical activity promotes an increase in intra-abdominal pressure and the repetitive increases may lead to weakness and stretching of the PFM and consequently to UI [12]. However, studies also showed that intense physical activity could strength the PFM through the co-contraction between them and the abdominal muscles [12]. Since these muscles work together, it is expected that training the abdominal muscles will also strengthen the PFM.

No previous studies have investigated the relationship between the pelvic floor and abdominal muscles using objective measures. The Biodex System 4-Pro is a valid and reliable device that quantitatively measures the physical parameters of muscular function such as strength, power, and resistance [13]. The system has a back-abdomen unit for the evaluation of abdominal wall strength. Considering the relationship between PFM and abdominal muscles, it is possible to use this tool to compare abdominal function between continent and incontinent athletes. An assessment of the PFM's voluntary contraction would enable us to verify the relationship between pelvic floor and abdominal muscle function. Therefore, this study aimed to evaluate PFM and abdominal muscle functions and to determine the relationship between these muscle groups and urinary continence status in female athletes.

Methods

Study design and participants

This is a cross-sectional study with 40 nulliparous female athletes from 12 different sports: athletics ($n = 2$), basketball ($n = 4$), running ($n = 3$), CrossFit ($n = 1$), futsal (n = 1), gymnastics ($n = 5$), martial arts (n = 5), volleyball (n = 5), rowing (n = 4), swimming (n = 3), dancing (n = 5), and cycling ($n = 2$).

The sample size was calculated for an association between abdominal trunk strength and clinical evaluation of PFM contractions. Considering for alternative hypothesis H_1 correlation $r = 0.5$, $\alpha = 0.05$, and power = 0.95 and no correlation as H_0, the sample size needed to be 38 subjects. This calculation was performed using the GPower 3.1 software [14].

The survey period was from October 2016 to May 2017. All the participants were nulliparous athletes and sexually active, competing in city league or higher levels. The exclusion criteria were: younger than 18 years of age and women with a history of pelvic surgery or current treatment for any gynecological condition. All participants provided informed consent. This study was approved by the Research Ethics Committee of Santa Catarina State University (UDESC) (protocol: 52885915.7.0000.0118) and conducted according to the Declaration of Helsinki.

Each participant completed two surveys before the PFM and the abdominal assessment. The first survey was designed to collect information regarding their demographic (age, obstetrics data, gynecological surgery or pathology, and sexual activity) and training (years of training, hours of training per day, and frequency of training per week) information. The second survey assessed the urinary continence status, using the International Consultation on Incontinence Questionnaire Short Form (ICIQ-UI-SF). Anthropometric characteristics (body weight, height, and waist and hip circumference) were measured using a weighing scale and tape measure.

Clinical evaluation—pelvic floor muscles

Pelvic floor muscles assessment was performed on all athletes. First, through vaginal palpation, a physiotherapist evaluated the athlete's ability to perform a correct PFM contraction without giving any instructions and classified the contraction as: correct, only with co-contraction of accessory muscles, in the opposite direction (Valsalva or straining maneuver), or no visible contraction. Then, the athlete was instructed to perform a correct PFM contraction, and the contraction was measured using the modified Oxford Scale and the perineometer (Perina 996-2®, Quark, Piracicaba, São Paulo, Brazil). For both assessment methods, three consecutive squeezes were recorded with a 10-s interval between efforts [15]. The best of the three contractions were recorded. The modified Oxford Scale was performed using two fingers with the two distal phalanges inside the introitus vagina, and the PFM contraction was classified as follows: 0, no contraction; 1, flicker; 2, weak; 3, moderate; 4, good; 5, strong [16].

All measurements were performed in a crook lying position and subjects were asked to contract their PFM as hard as possible (maximum strength). To ensure valid measurement during the examination, no visible contraction of other muscles (gluteal, hip adductor, or rectus abdominis muscles) was allowed. Only contractions with simultaneous observable inward movement of the perineum were considered valid [17]. The physiotherapist assessing PFM function was blinded to participants' continence status and the background data.

Abdominal muscle strength assessment

The isokinetic trunk protocol was performed on a dynamometer with a back-abdominal unit (Biodex System 4 Pro, Biodex Medical Systems, Shirley, NY, USA). This dynamometer was used to measure the net abdominal muscle torque during three sets of five consecutive maximum concentric trunk flexion and extension movements at an angular velocity of 60°/s with 30-s intervals between sets [18]. The system has been previously evaluated and tested for reliability for evaluation of extension and flexion of the trunk [19]. Participants sat on the equipment in a chair-line position (Fig. 1). Straps were placed across the upper trunk, pelvis, and thighs to stabilize the body segments and avoid compensatory movements during the test. Subjects were asked to keep their arms crossed over their chest during the protocol. Their legs were fixed distally with knees flexed at 90°. The protocol suggested by the manufacturer, such as positioning, calibration, familiarization, and vigorous verbal encouragement, was performed. The same researcher performed all trials. The test began with the athlete sitting at 90° and finished in the same position. Before the test, all participants performed a warm-up set to familiarize themselves with the equipment.

Statistical analyses

The data were analyzed using the Statistical Package for Social Sciences software (SPSS, version 20.0, SPSS Inc., Chicago, IL, USA). The absolute and relative frequencies and the mean and standard deviation were used to describe the data. The Kolmogorov-Smirnov test was used to determine normality. To compare continent and incontinent athletes on the basis of age, anthropometric data, training, and muscular function, the *t*-test or Mann-Whitney *U* test was used when appropriate. The chi-square test was performed to compare continent and incontinent athletes for the categorical variables, including level of schooling, amenorrhea, smoking and alcohol consumption. Pearson correlation was used to determine the relationship between the perineometer and isokinetic values. Spearman correlation was used to determine the relationship between the modified Oxford Scale and isokinetic values. The level of correlation was classified as weak, moderate, and strong as suggested by Cohen, (1988) [20]. The significance level was set at $p < 0.05$.

Results

Forty nulliparous female athletes participated in this study, with ages ranging from 17 to 36 years old. Of the 40 athletes, 21 (52.5%) self-reported UI. The characteristics of the continent and incontinent athletes are presented in Table 1.

As summarized in Table 1, the continent and incontinent groups were similar with respect to age ($p = 0.80$), BMI ($p = 0.69$), anthropometric characteristics ($p > 0.05$), training variables ($p > 0.05$), marital status ($p = 0.94$), education ($p = 0.13$), isokinetic strength ($p > 0.05$), PFM strength measured by the Modified Oxford Scale ($p = 0.56$), and PFM endurance ($p = 0.67$). The continent group showed statistically significantly lower rates of maximum voluntary contraction measured by the perineometer (Table 1).

Regarding the relationship between PFM function (perineometer and modified Oxford Scale) and abdominal muscle strength, the results point to significant correlations, especially among incontinent athletes, as shown in Table 2.

Among the athletes who self-reported as continent, no significant correlations were found between the Modified Oxford Scale and isokinetic evaluation (Table 2). Again, athletes who were considered continent were found to have significant and positive correlation between the perineometer results with the peak torque and with the peak torque/bodyweight measured by the isokinetics. However, incontinent athletes presented a significant and positive correlation between all isokinetic measurements and the perineometer results and with almost all variables of the Modified Oxford Scale (Table 2). Considering the effect sizes for correlation analysis using the coefficient of determination r^2 (Table 2), correlations for the incontinent group had moderate to strong effect sizes, while for the continent group,

Fig. 1 Isokinetic evaluation

Table 1 Characteristics of the continent and incontinent athletes ($n = 40$)

	Continent $n = 19$	Incontinent $n = 21$	p value
Age (years)	24.3 ± 5.0	24.0 ± 4.9	0.806¥
Weight (kg)	60.6 ± 8.9	65.2 ± 10.7	0.147 Ω
BMI (kg/m^2)	22.3 ± 2.4	22.6 ± 3.2	0.694 Ω
Abdominal circumference (cm)	75.0 ± 9.5	74.7 ± 7.1	0.911 Ω
Hip circumference (cm)	97.2 ± 6.8	100.0 ± 9.6	0.302 Ω
Waist/hip ratio (cm)	0.7 ± 0.0	0.7 ± 0.0	0.282 Ω
Years of training	9.0 ± 5.5	9.8 ± 6.1	0.675 Ω
Age of training start	15.7 ± 6.8	13.5 ± 6.8	0.193¥
Hours of training/day	2.4 ± 1.2	2.3 ± 1.5	0.369¥
Frequency of training/week	4.4 ± 1.5	4.9 ± 2.3	0.675¥
Amenorrheic (%)	4(21.1)	8(38.1)	0.240£
Smoking (%)	0 (0)	1 (4.8)	0.386£
Alcohol consumption (%)	12 (63.2)	14 (66.7)	0.816£
Education			0.137£
Complete high school (%)	5 (21.1)	1 (4.8)	
Incomplete university (%)	7 (36.8)	10 (47.6)	
Complete university (%)	7 (36.8)	10 (47.6)	
Menarche (years)	13.0 ± 1.2	12.9 ± 1.8	0.535¥
Modified Oxford Scale	3.2 ± 1.1	3.4 ± 0.7	0.562¥
PFM endurance	3.8 ± 2.6	4.0 ± 2.2	0.679¥
Perineometer (cmH_2O)	25.4 ± 12.8	33.9 ± 10.1	0.028*Ω
Isokinetic strength			
Peak torque (Nm)	124.1 ± 28.9	124.7 ± 53.6	0.966 Ω
Peak torque/bodyweight (%)	206.3 ± 43.7	195.6 ± 86.7	0.634 Ω
Work (J)	95.5 ± 31.4	94.7 ± 43.4	0.949 Ω
Average power (watts)	36.4 ± 14.2	40.8 ± 22.8	0.467 Ω

Data are presented as mean ± standard deviation or number (%), where appropriate

¥ Mann-Whitney U test. Ω Independent t test. £ Chi-square test. *Statistically significant difference. BMI: body mass index

correlations had weak (perineometer and power; Oxford Scale and all variables) to moderate effect sizes (perineometer and peak torque, peak torque/body.

During the first PFM contraction assessment, 35% ($n = 14$) realized a correct contraction, 55% ($n = 22$) performed the contraction with co-contraction of other muscles, 7.5% ($n = 3$) performed a Valsalva maneuver, and 2.5% (n = 1) did not perform any contraction. All the athletes performed a correct contraction after instruction by the physiotherapist.

Discussion

The influence of the abdominal muscles on the PFM has been studied in the last years [2–5]. However, until now, only subjective measurements to evaluate the abdominal muscles were used. The present study used the perineometer to evaluate the PFM and isokinetic equipment to assess the abdominal forces, and two main findings were found. The first one was that incontinent athletes have greater PFM strength than the continent ones, and the second was the positive correlation between abdominal and PFM strength in incontinent athletes, suggesting that the UI in athletes is not due to PFM weakness and that there are constant synergic contractions between these muscles.

According to previous studies [10, 21–23], the present study also found a high prevalence of UI among female athletes (52.5%). Goldstick [24] in a literature review demonstrated that the prevalence of UI can range from 28 to 80% in sports such as trampolining, gymnastics, aerobic gymnastics, hockey, and dance.

The present study found stronger PFM in incontinent athletes assessed by a perineometer, suggesting that in incontinent athletes the maximal voluntary contraction, which is related to the slow fibers of the PFM, was not compromised [21]. In a recent study with mid-pregnancy women, Bø et al.

Table 2 Correlation values of the perineometer and Oxford Scale with the isokinetic evaluation in continent and incontinent athletes (n = 40)

	Continent n = 19	Strength of correlation	Incontinent n = 21	Strength of correlation
Perineometer				
Peak torque (Nm)	$p = 0.031$* ($r = 0.496$; $r^2 = 0.246$)	M	p = 0.006* ($r = 0.577$; $r^2 = 0.332$)	S
Peak torque/bodyweight (%)	p = 0.031* ($r = 0.494$; $r^2 = 0.244$)	M	$p = 0.028$* ($r = 0.478$; $r^2 = 0.228$)	M
Work (J)	$p = 0.158$ ($r = 0.337$; $r^2 = 0.113$)		$p = 0.002$* ($r = 0.646$; $r^2 = 0.417$)	S
Power (Watts)	$p = 0.368$ ($r = 0.219$; $r^2 = 0.047$)		$p = 0.005$* ($r = 0.591$; $r^2 = 0.349$)	S
Oxford Scale				
Peak torque (Nm)	$p = 0.288$ ($r = 0.257$; $r^2 = 0.066$)		$p = 0.035$* ($r = 0.463$; $r^2 = 0.214$)	M
Peak torque/bodyweight (%)	$p = 0.322$ ($r = 0.240$; $r^2 = 0.057$)		$p = 0.072$ ($r = 0.400$; $r^2 = 0.160$)	
Work (J)	$p = 0.515$ ($r = 0.159$; $r^2 = 0.025$)		$p = 0.036$* ($r = 0.460$; $r^2 = 0.211$)	M
Power (Watts)	$p = 0.460$ ($r = 0.180$; $r^2 = 0.032$)		$p = 0.008$* ($r = 0.566$; $r^2 = 0.320$)	S

*Statistically significant difference. Perineometer = Pearson correlation. Oxford = Spearman correlation. Strength of correlation: M = moderate; S = strong

[25] showed that those that practice regular exercise (exercise ≥ 30 min ≥ 3 times per week) have stronger PFM than their sedentary counterparts. In contrast, Borin et al. [26] demonstrated that lower perineal pressure correlates with increased symptoms of UI and pelvic floor dysfunction in athletes. Fast twitch muscle fiber activity is essential when physical activity produces a sudden increase in intra-abdominal pressure. It is possible that in the incontinent athletes the stretch-reflex has been decreased, leading to a loss of urine during sports even in athletes with a higher maximum voluntary contraction on the PFM assessment [27].

Regarding the relationship between the PFM and abdominal muscles, Junginger (2014) evaluated the effectiveness of a PFM program with transverse abdominis muscle contraction. Of 46 women with stress UI, 67% either improved or were cured. Their bladder, bowel, and sexual function improved significantly after 1–6 sessions (median of 2). The authors concluded that this rehabilitation program was effective for UI [28]. In the current study, while a significant association was found among the incontinent athletes and the maximal voluntary contraction of the PFM (perineometer and Oxford Scale) with almost all isokinetic variables (Table 2), the continent athletes only demonstrated a significant association between the results of the perineometer with the peak torque and the peak torque/bodyweight. However, no difference was found in the abdominal muscle function between continent and incontinent athletes (Table 1). We cannot explain why we saw those results. Recently, a systematic review was performed to clarify if there is evidence for a synergistic co-contraction between the transverse abdominis muscle and the PFM in women with UI and whether there is evidence to recommend transverse abdominis muscle training as an intervention strategy [29]. The authors concluded that there is insufficient evidence for the use of transverse abdominis muscle training to treat women with UI. They stated that only PFM training is effective for improving UI [30–32]. No other study was found in the literature that used isokinetic equipment to evaluate the abdominal muscles, so further studies are necessary.

Kandadai, O'Dell, and Saini (2015) assessed how often correct PFM exercises were performed by women who reported prior experience with PFM exercises. The voluntary contraction was assessed using the Oxford Scale. Of the 83 participants, 23% performed the PFM exercises incorrectly. Prior instruction (odds ratio, 3.0; 95% confidence interval, 1.6–5.7; $p < 0.01$) and prior feedback (odds ratio, 3.5; 95% confidence interval, 1.0–12.0; $p < 0.05$) were associated with correct PFM performance [33]. In the present study, a large part of the sample (65%) performed an incorrect contraction of the PFM prior to instruction. This result shows that athletes have poor knowledge of correct PFM contractions. After instructions, all the athletes performed a correct PFM contraction. It seems that providing instructions and feedback can lead to correct performance and should be incorporated into pelvic examinations [33].

Some of the limitations of this study should be highlighted. First, during the isokinetic dynamometer assessment, it was not possible to isolate the other muscles that assist in trunk flexion. Even though the abdominal group is the primary trunk flexor, other muscles, such as the iliopsoas, also contribute to trunk flexion and may have influenced the strength measurements. Likewise, in the PFM evaluation, the contraction of accessory muscles was monitored by visual inspection. It may be better to monitor the co-contraction muscles with electromyography. Indeed, assessing the PFM and abdominal muscles simultaneously with a large sample would provide more reliable information concerning their relationship. Finally, we did not measure the intra-abdominal pressure variation during the PFM contraction and the isokinetic evaluation. Correlations for the continent group should be considered more carefully compared with the incontinent group because of their smaller effect size. Therefore, future studies should perform the assessment at the same time and measure the intra-abdominal pressure and also assess the baseline vaginal pressure. Comparing the continent and incontinent athletes would provide additional objective outcomes.

Conclusion

Our results demonstrated that incontinent female athletes could achieve a stronger maximum voluntary contraction of the PFM, as evaluated by a perineometer, than continent athletes. The present study adds to prior research by showing that before any instruction most of the athletes had difficulty performing a correct PFM contraction. However, all of them performed a correct contraction after receiving instructions from the physiotherapist, proving that giving appropriate instructions is mandatory to assess PFM strength. No difference in abdominal muscle function was found between the continent and incontinent athletes. Among the incontinent athletes, a positive correlation between PFM strength and the isokinetic evaluation of trunk flexion strength was found.

Compliance with ethical standards

Conflicts of interest None.

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