Pelvic floor function in elite nulliparous athletes

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ABSTRACT

Objective There is preliminary evidence linking long-term participation in high-impact exercise with poor performance in labor and increased incidence of stress urinary incontinence, which may be due to altered pelvic floor function. Recent work has shown that HIFIT (high-impact, frequent intense training) athletes have an increased cross-sectional area of the levator ani muscle group as visualized using magnetic resonance imaging (MRI). The aim of this study was to further characterize pelvic floor muscle function and pelvic organ descent in a nulliparous athletic population and compare it with non-athletic controls matched for age and body mass index, using three-dimensional/four-dimensional (3D/4D) pelvic floor ultrasound imaging.

Methods In this prospective comparative study translabial ultrasound imaging was used to assess pelvic floor anatomy and function in 46 nulliparous female volunteers (aged 19–39 years), 24 HIFIT and 22 controls. Two-dimensional (2D) and 3D translabial ultrasonography was performed on all subjects, after voiding and in the supine position. Descent of the pelvic organs was assessed on maximumValsalva maneuver, whilst volume datasets were acquired at rest, during pelvic floor muscle contraction and during a Valsalva maneuver. Participants performed each maneuver at least three times and the most effective was used for evaluation.

Results HIFIT athletes showed a higher mean diameter of the pubovisceral muscle (0.96 cm vs. 0.70 cm, P < 0.01), greater bladder neck descent (22.7 mm vs. 15.1 mm, P = 0.03) and a larger hiatal area on Valsalva maneuver (21.53 vs. 14.91 cm², P = 0.013) compared with the control group. There were no significant differences in hiatal area at rest or on maximal voluntary contraction between the two groups.

Conclusion HIFIT athletes show significant differences in several of the measured parameters for both function and anatomy of the pelvic floor. Further research into the impact of this altered function on childbirth and continence mechanisms is needed. Copyright © 2007 ISUOG. Published by John Wiley & Sons, Ltd.

INTRODUCTION

The role of pelvic floor muscles in supporting the pelvic organs, continence and childbirth has been investigated in several studies1–3. Changes in the function and morphology of the pelvic floor following vaginal delivery, incontinence and prolapse have been demonstrated using magnetic resonance imaging (MRI) and, more recently, three-dimensional (3D) ultrasound imaging4–7. Several authors have suggested that high impact (landing) sport may lead to the development of stress incontinence in nulliparous women who have competed for prolonged periods8–11, suggesting that there may be a functional change in the pelvic floor muscles of highly athletic women. Additionally there is preliminary evidence to suggest that some women undergoing high-impact, frequent intense training (HIFIT) have unexpected difficulties during delivery, which may be attributable to changes in pelvic floor muscles12. It is possible that repeated high impact landing leads to alterations in pelvic floor morphology and function. Sapsford and Hodges13 have shown that the muscles of the pelvic floor are co-activated with the abdominal muscles, particularly transversus abdominis, during exercise or increases in intra-abdominal pressure. The abdominal muscles contract to stabilize the torso during limb movements and landing. Therefore, it is highly probable that the pelvic floor would be activated during landing in athletes involved in high-impact sport.

‘Levator ani’ is the collective term used to describe the deep muscles of the pelvic floor. The levator ani consists primarily of the striated muscles pubococcygeus, puborectalis and iliococcygeus14. As there is some controversy about the nomenclature for the muscles of the pelvic floor, for the purposes of this paper we have adopted the terms defined by DeLancey1, whereby ‘pubovisceralis muscle’ is

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used to represent both the musculus pubococcygeus and musculus puborectalis, as these two muscles cannot be differentiated when using ultrasound or MRI. The levator hiatus is defined as the area bounded by the pubovisceralis muscle laterally and dorsally and the inferior pubic rami anteriorly.

Although it is known that long-term resistance training causes hypertrophy of skeletal muscle\(^{15}\), very little research has been done on the effects of long-term, high-impact training on the function and morphology of the muscles of the pelvic floor in elite female athletes.

We have previously demonstrated that there is an increase in the cross-sectional area of the levator ani muscle as measured by MRI in women who have participated in long-term high-impact sport and exercise\(^{16}\). What is not known is whether this altered morphology results in altered function. Recent developments in 3D ultrasonography have allowed for characterization of the function and morphology of the pelvic floor in nulliparous women\(^{17-20}\). This study utilizes this technique to compare morphology and function of the pelvic floor in HIFIT nulliparous women to an age-matched control group. Our hypothesis was that the HIFIT group would have increased size and altered function of the levator ani complex as compared with the control group.

**METHODS**

Translabial three-dimensional and four-dimensional (3D/4D) ultrasonography was used to assess pelvic floor function in 46 nulliparous female volunteers (aged 19–39 years); 24 were HIFIT athletes and 22 were controls. Recruitment was primarily from advertisement at local university campuses, whereby the participants were matched according to age and body mass index (BMI) scores. All the participating athletes were active in their various sports and at the time of testing had been training for a minimum of 5 years and had reached a national or international level of competition. All training and sports had to include a large component of high-impact (repetitive landing/jumping) and high-intensity training, as it was this aspect of the sport that was thought to lead to pelvic floor muscle change. Sports which were considered appropriate and applicable included sport aerobics, running, netball, basketball, squash, tennis and gymnastics. The participants who acted as controls did not exercise at all, or if they were active it was not more than three times a week in general ‘stretching classes’ at the gym, or walking or swimming. They did not participate in any high-impact activities.

Based on previous work in which the mean hiatal area on voluntary Valsalva maneuver in a group of normal nulliparous women was 14.05 \(\pm\) 5.87 cm\(^2\), a large effect size of 0.8, an alpha of 0.01 (corrected for multiple comparisons) and a power of 0.8, a power calculation (G-power) indicated that 19 subjects in each group would be needed to show any significant differences between the measured parameters.

The participants were interviewed prior to the ultrasound scan to determine symptoms of incontinence, bowel dysfunction or prolapse as well as questions on amenorrhea and performance of pelvic floor muscle exercises.

Joint hypermobility, a potential confounder to some of the measurements, such as bladder neck descent, was assessed using the Beighton scale, which has been modified from the Wilkinson–Carter measures, and includes five distinct characteristics: passive extension of the 5\(^{th}\) finger past 90\(^\circ\); passive apposition of the thumb to the forearm; hyperextension of the elbow past 190\(^\circ\); hyperextension of the knee past 10\(^\circ\); and trunk flexion to allow palms flat on the floor\(^{21}\). Scores > 6 on the Beighton scale are considered diagnostic for hypermobility. Hypermobility syndrome is characterized by an increase in joint laxity and a decrease in tissue stiffness, due to a change in the ratio of Type I to Type III collagen. Type III collagen is more dominant in people with hypermobility syndrome\(^{21}\). Athletes who fall into the hypermobile classification may have a natural predisposition to perform well at sports such as aerobics and gymnastics, where enhanced flexibility is seen as an asset, and as such, the HIFIT group could have an overly high incidence of hypermobile participants. In order to ensure that hypermobility was not the reason for any difference in pelvic floor function between athletes and controls, both groups were assessed retrospectively using the Beighton scale.

Imaging was performed using GE Kretz Voluson 730/730 Expert systems (GE Kretztchnik GmbH, Zipf, Austria) with 8–4-MHz transducers. All subjects were imaged supine, after voiding. Imaging was performed in the mid-sagittal plane with the angle of acquisition set at 85\(^\circ\). Volume datasets were acquired at rest, on pelvic floor muscle contraction and on Valsalva maneuver. The most effective of at least three maneuvers was used for evaluation. Previously published parameters of pelvic floor function and anatomy were used in both groups\(^{20}\). Descent of the pelvic organs was assessed on Valsalva maneuver. This included bladder neck descent, cervical descent and descent of the rectal ampulla on Valsalva maneuver. The levator hiatus was measured at rest, on Valsalva maneuver and on maximum pelvic floor contraction. Figure 1 shows the plane used to determine levator hiatal area. The plane of minimal hiatal dimensions is identified in the mid-sagittal plane as the minimal distance between the posterior aspect of the symphysis pubis and the anorectal angle, or the anterior border of the pubovisceral muscle (Figure 1a). Once the plane had been defined in the mid-sagittal plane, this cross-section of the volume was displayed in the axial plane during post processing. The thickness of the pubovisceral muscle was determined by moving the plane cranially until the maximum thickness of the muscle could be seen in the axial plane. This plane was reached approximately 1 cm above the levator hiatus. A detailed description of the methodology is given elsewhere\(^{20}\).

Data acquisition and analysis were undertaken by two of the authors (J. K. and H. P. D.). Images were saved on DVD, which allowed for later analysis using the software.
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4D View V 2.1 (GE Medical Kretztechnik). Ethical approval was granted by the University of Auckland Human Participants Ethics committee (ref 2004/205).

Statistical analysis was performed using SPSS V 12 for Windows (SPSS Inc., Chicago, IL, USA). T-tests were used to determine significant differences (with \( P < 0.05 \) taken as significant) between the groups in the measured parameters, following normality testing. Intraclass correlation coefficients (ICC) were used to establish agreement.

RESULTS

All the participants were nulligravid and none had a history of pelvic surgery. The results from the questionnaire indicated that all were asymptomatic for prolapse, three of the HIFIT group (12.5%) reported stress incontinence and two (8.3%) urge incontinence more than once a month. Two (9.1%) of the controls reported both stress and urge incontinence more than once a month. Seven (29.2%) of the HIFIT women reported that they thought that they were exercising pelvic floor muscles during training, particularly when performing ‘core stability work’ (defined as the voluntary contraction of the abdominal muscles and the pelvic floor muscles in an effort to increase spinal stability). The general characteristics of the HIFIT and control groups are summarized in Table 1.

Initial measurements were done by the first author (J. K.) and validated by the second (H. P. D.). Interobserver reliability indices were calculated for the biometric parameters of the levator hiatus on a series of 46 volumes. ICC values ranked between 0.57 and 0.81, with the best agreement for levator hiatal area on Valsalva. As the intraclass correlations were good for all measures of the levator hiatus, the ratings of the more experienced assessor (H. P. D.), who was also blinded to the groupings, were used for statistical analysis.

The results of bladder neck descent, uterine descent and descent of the rectal ampulla relative to the symphysis pubis on maximum Valsalva are summarized in Table 2. Mean bladder neck descent for the HIFIT group was 22.7 ± 7.85 mm, compared to 15.1 ± 10.2 mm in the control group (\( P = 0.03 \)). Uterine and rectal descent on Valsalva were more pronounced in the HIFIT group (lower numbers signifying lower organ position on Valsalva), but these differences did not reach significance. The area of the levator hiatus on maximum Valsalva measured 21.53 ± 9.98 cm² and 14.91 ± 7.18 cm² for the HIFIT and control groups, respectively (\( P = 0.013 \)). The spread of data for the HIFIT group was wide, as demonstrated in Figure 2. With respect to hypermobility, 22 of the 24 participants in the HIFIT group were able to be contacted and three of those 22 were found to score greater than 6 on the Beighton scale. None of the 22 control subjects scored greater than 6. The individual data were examined for the three hypermobile participants. Two of these three participants showed an increased size of the levator hiatus on Valsalva, as measured using a

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**Table 1** General characteristics of participants

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean age (years)</th>
<th>BMI (kg/m²)</th>
<th>Hypermobility (n)</th>
<th>Stress incontinence (%)</th>
<th>Urge incontinence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIFIT (n = 24)</td>
<td>28.5</td>
<td>22.3</td>
<td>3 &gt; 6</td>
<td>12.5</td>
<td>8.3</td>
</tr>
<tr>
<td>Control (n = 22)</td>
<td>27.6</td>
<td>23.2</td>
<td>None &gt; 6</td>
<td>9.1</td>
<td>9.1</td>
</tr>
</tbody>
</table>

*Defined as a score > 6 on the Beighton scale. BMI, body mass index; HIFIT, high-impact, frequent intense training.

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Figure 1 Translabial ultrasound image showing identification of the plane of minimal dimensions (represented by the diagonal line) in the mid-sagittal plane (a), and the angled axial plane of the levator hiatus (b). Dotted line indicates area measurement of the hiatus at rest.
Table 2 Biometric indices of the levator hiatus, pelvic organ descent and pubovisceral muscle

<table>
<thead>
<tr>
<th></th>
<th>HIFIT group (mean ± SD)</th>
<th>Controls (mean ± SD)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levator hiatal area at rest (cm²)</td>
<td>12.71 ± 2.49</td>
<td>12.77 ± 2.43</td>
<td>0.727</td>
</tr>
<tr>
<td>Levator hiatal area on PFMC (cm²)</td>
<td>10.59 ± 1.71</td>
<td>9.72 ± 2.11</td>
<td>0.201</td>
</tr>
<tr>
<td>Levator hiatal area on Valsalva (cm²)</td>
<td>21.53 ± 9.98</td>
<td>14.91 ± 7.18</td>
<td>0.013*</td>
</tr>
<tr>
<td>Pubovisceral muscle diameter (cm)</td>
<td>0.96 ± 0.17</td>
<td>0.70 ± 0.11</td>
<td>&lt;0.010*</td>
</tr>
<tr>
<td>Bladder descent on Valsalva (mm)</td>
<td>22.70 ± 7.85</td>
<td>15.10 ± 10.20</td>
<td>0.030*</td>
</tr>
<tr>
<td>Uterine position on Valsalva (mm)</td>
<td>22.70 ± 17.15</td>
<td>28.70 ± 16.90</td>
<td>0.308</td>
</tr>
<tr>
<td>Rectal position on Valsalva (mm)</td>
<td>1.04 ± 17.38</td>
<td>5.37 ± 11.36</td>
<td>0.348</td>
</tr>
</tbody>
</table>

*Statistically significant. HIFIT, high-impact, frequent intense training; PFMC, pelvic floor muscle contraction.

DISCUSSION

This study illustrates a number of functional and morphological differences in the pelvic floor muscles of HIFIT women and a matched control group as imaged using 3D/4D pelvic floor ultrasonography. The results confirmed our previous MRI findings that the HIFIT group has significantly higher diameters of the levator ani muscle. Despite this, HIFIT athletes were able to markedly increase the area of the levator hiatus during a voluntary Valsalva maneuver. There may be several explanations for this, including a probable increased kinesthetic awareness in the HIFIT group, and hence the ability to recruit task-specific muscles, as well as an increased abdominal strength\(^2\) and the concomitant increase in intra-abdominal pressure that high-impact athletes are able to develop.

Previous studies using 3D ultrasound imaging and MRI have evaluated functional and morphological parameters of young nulliparous women. Dietz et al.\(^2\) found the hiatal area in their series of 52 nulligravid women to be 11.25 cm² at rest and 14.05 cm² during Valsalva, while the diameter of the pubovisceral muscle was 0.73 cm. These findings are remarkably similar to those in the control group of this study. Tunn et al.\(^3\) found the hiatal area at rest as measured using MRI to be 12.8 cm² in continent nulliparous women (mean age 30 years), whereas Goh et al.\(^4\), also using MRI, found the pelvic hiatal area to be 20.06 cm² at rest and 27.83 cm² on straining in a group of 25 continent women. This group, however, included parous women and had a mean age of 34 years. Differences between hiatal area estimates on 3D/4D ultrasound imaging and MRI are not surprising, as the MRI studies used a different plane of measurement from the plane of minimal dimensions on Valsalva used by the ultrasound studies. Inevitably, differences in the hiatal measurements will result when different planes are used.

Two-dimensional (2D) ultrasonography has been used to quantify anatomical changes in the pelvic organ mobility of women suffering from stress incontinence and prolapse\(^5,6\). In some of the HIFIT group, ultrasound measurements of organ descent reached similar values to those of symptomatic women in terms of descent of the rectal ampulla, cervix and bladder neck\(^7\). Women with stress incontinence commonly (although not invariably)
show an increase in bladder neck mobility and descent below the level of the symphysis pubis on Valsalva maneuver. Mobility of the bladder neck in the HIFIT group and the levator hiatal area were significantly higher than in our control group and in studies of bladder neck mobility of nulliparous women, yet most of the HIFIT women were asymptomatic for incontinence. One of the HIFIT women developed a significant enterocele on Valsalva but was asymptomatic for clinical symptoms of prolapse. Intuitively one would expect women with increased pelvic organ descent to have ‘weak’ pelvic floor muscles. However, this may not be the case, as our HIFIT group showed a combination of thicker muscle and greater muscle distensibility. The differences observed may be due to differences in connective tissue or muscle biomechanics that may predate or be the consequence of high-impact training.

Although there is a known correlation between hypermobility syndrome and some connective tissue disorders, including increased risk of pelvic organ prolapse, a recent study by Dietz et al. found no association between hypermobility and pelvic organ mobility in a group of nulliparous young women. These findings are similar to those found in our group of HIFIT women, where there was no correlation between Beighton score and biometric indices of hiatal size or pelvic organ mobility.

The demands of improved performance throughout competitive sport and the concomitant increased training schedules seem to increase for every generation. Owing to the benefits of regular body exercise on the whole body, women cannot and should not be discouraged from exercising. Nonetheless, an increase in the general population of women who engage in long-term high-impact sports such as running or aerobics for a significant number of years prior to childbirth means that it is important to understand the consequences of long-term exercise on pelvic floor function. It has been previously suggested that repetitive high impact may overload the muscles of the pelvic floor, which may result in stress injuries to the fascia, muscles or ligaments. In light of the findings from this current study further research into the biomechanical properties of the pelvic floor and the effects of frequent, intense high-impact training is warranted.

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