DOI: 10.1111/j.1471-0528.2009.02379.x
www.bjog.org

Pelvic floor function is independently associated with pelvic organ prolapse

IH Brækken,[a] M Majida,[b] M Ellström Engh,[b,c] IM Holme,[a] K Bø[a]

[a] Norwegian School of Sport Sciences, Department of Sports Medicine, Oslo, Norway [b] Akershus University Hospital, Department of Obstetrics and Gynaecology, Lørenskog, Norway [c] Faculty Division Akershus University, University of Oslo, Oslo, Norway
Correspondence: IH Brækken, Norwegian School of Sport Sciences, Department of Sports Medicine, PO Box 4014, Ulleval Stadion, 0806 Oslo, Norway. Email ingeborg.brekken@nih.no

Accepted 20 August 2009.

Objective To investigate the risk factors for pelvic organ prolapse (POP), including physical activity, clinically measured joint mobility and pelvic floor muscle (PFM) function.

Design One-to-one age- and parity-matched case–control study.

Setting Akershus university hospital and one outpatient physiotherapy clinic in Norway.

Population Forty-nine women with POP (POP quantification, stage ≥II) and 49 controls (stages 0 and I) were recruited from community gynaecologists and advertisements in newspapers.

Methods Validated questionnaires, interview and clinical examination, including Beighton's scoring system (joint hypermobility) and vaginal pressure transducer measurements (PFM function), were used. Univariate and multivariate conditional logistic regression analyses for one-to-one matched case–control studies were used, and odds ratios with 95% CIs are reported.

Main outcome measures Pelvic floor muscle function (strength, endurance and resting pressure), socioeconomic status, body mass index, heavy occupational work, physical activity, family history, obstetric factors and markers of connective tissue weakness (striae, varicose veins, bruising, diastasis recti abdominis, joint hypermobility).

Results No significant differences were found between groups with regard to postmenopausal status, current smoking, current low-intensity exercise, type of birth (caesarean, forceps, vacuum), birth weight, presence of striae, diastasis recti abdominis and joint hypermobility. Body mass index (OR 5.0; 95% CI 1.1–23.0), socioeconomic status (OR 10.5; 95% CI 2.2–50.1), heavy occupational work (OR 9.6; 95% CI 1.3–70.3), anal sphincter lacerations (OR 4.5; 95% CI 1.0–20.0), PFM strength (OR 7.5; 95% CI 1.5–36.4) and endurance (OR 11.5; 95% CI 2.0–66.9) were independently related to POP.

Conclusions Body mass index, socioeconomic status, heavy occupational work, anal sphincter lacerations and PFM function were independently associated with POP, whereas joint mobility and physical activity were not.

Keywords Anal sphincter lacerations, body mass index, case–control, joint hypermobility, occupational work, pelvic floor muscle, pelvic organ prolapse, socioeconomic status, varicose veins.

Please cite this paper as: Brækken I, Majida M, Ellström Engh M, Holme I, Bø K. Pelvic floor function is independently associated with pelvic organ prolapse. BJOG 2009;116:1706–1714.

Introduction

The prevalence of pelvic organ prolapse (POP) varies between 2% and 94% in the literature, depending on the definition used and the target population.[1] The highest prevalence of POP is found amongst elderly women. Therefore, in the future, the incidence of prolapse may increase as a result of global aging.[2] In the UK, POP accounts for 20% of women on waiting lists for major gynaecological surgery,[3] and the occurrence of re-operations is high.[4] Although the prevalence of women with POP symptoms has been reported to be much lower (7–23%),[1] the overall high prevalence of POP and related problems indicates a need for the identification of risk factors at an early stage.[5] Research aimed at understanding the modifiable risk factors for the prevention of POP is warranted.[1]

The aetiology of POP is considered to be multifactorial. Based on the recently published integrated life span model,[6] it can be assumed that the development of POP includes predisposing factors (growth and development, genetic factors, connective tissue weakness, joint mobility),[7–12] inciting factors (childbirth, pelvic surgery)[12–18] and intervening factors (age-related changes, obesity, constipation, heavy occupational work, vigorous physical activity).[12,14–24]

Unfortunately, only a minority of these risk factors can easily be prevented.

Impairment of the pelvic floor muscles (PFMs) may lead to a wider opening of the genital hiatus and the development of POP. It has been suggested that increased muscle impairment may lead to increased anterior wall prolapse.[25] To date, the roles of PFM strength[17,19,26] and vaginal resting pressure[26] as risk factors for POP have been investigated sparsely, and studies have shown different results. In addition, PFM endurance may be considered as an important component of PFM function, but, as far as we have ascertained, its association with POP has not yet been investigated. Poor PFM function can be a result of predisposing factors, such as an individual's genetic code, nutrition and environment, a traumatic inciting event, such as childbirth, or intervening factors.[6]

Many of the proposed risk factors have been investigated in postal surveys, interviews and medical registers only, with no clinical data. Search on PubMed has not revealed any studies involving the clinical assessment of joint mobility and PFM function in combination with other risk factors. Furthermore, although vigorous physical activity is considered to be a risk factor,[6] there is little knowledge about its impact on PFM function and the development of POP.[16,19]

The aim of this study was to investigate the proposed risk factors for POP, including physical activity, clinically measured joint mobility and PFM function.

Methods

Design

The study was designed as an individual, one-to-one matched, case–control study.[27] Each woman was matched on age (within 5 years) and parity, and stratified by degree of prolapse. POP was evaluated by a POP-quantification (POP-Q) system[28] and, for the purposes of this study, POP was defined as stage ≥II.[29] The study was approved by the Regional Medical Ethics Committee (S-05146) and the Norwegian Social Science Data Services (200501371 SMRH). All subjects gave written informed consent.

Population

Women attending routine gynaecological examinations were referred to the study by community gynaecologists working in Oslo and Akershus, Norway. Women were also recruited through advertisements in newspapers. The inclusion criteria were more than 1 year since last delivery and the ability to understand Norwegian. In addition, an inclusion criterion in the case group was POP-Q stage II or above, with or without symptoms. Exclusion criteria were previous POP surgery, radiating back pain, neurological disorders, pelvic cancer, psychiatric disorders or untreated urinary tract infection. Depending on the POP-Q value, the women were included in either the POP group (POP stage II or above) or the control group (POP stages 0 and I).

As no comparable studies evaluating PFM function in relation to POP were found, power calculation was based on the prevalence of joint hypermobility from the study of Al-Rawi and Al-Rawi.[9] They found a 66% prevalence of joint hypermobility amongst women with POP, compared with 15% in the control group. We assumed a 50% prevalence of hypermobility amongst women with POP and 25% amongst controls. With 80% power and a 5% significance level, at least 47 women should be included in each group. As a result of possible missing data, we included 49 women in each group.

Outcome measures

Symptoms

A questionnaire from Mouritsen and Larsen[30] covered the frequencies of mechanical, urinary, bowel and sexual symptoms and their impact on the quality of life. It has been validated in a Scandinavian country. The International Consultation on Incontinence Urinary Incontinence Short Form (ICIQ-UI SF) questionnaire[31] was used to assess urinary incontinence and its impact on the quality of life. ICIQ-UI SF has been shown to have good construct validity, acceptable convergent validity and good reliability.[31]

Postmenopausal status

Women were defined as postmenopausal if there had been 12 months since their last period.

Body mass index (BMI)

The BMI was calculated from the measured weight (Tanita BWB 800, Fysiopartner, Oslo, Norway) and self-reported height.

Socioeconomic status

High socioeconomic status was assessed by questionnaire and defined as having an income of 350 000 NOK or more and an educational level at university or higher.

Smoking

Current smoking was assessed by questionnaire asking about current smoking habits; if a woman reported being a smoker, she was asked how many cigarettes she smoked per day.

Heavy work

To be classified as doing heavy occupational work, three variables in the questionnaire needed to be present.

1 Self-report of occupational work as physically heavy.

2 Lifting more than 20 heavy lifts per week.

3 Working in a standing position for more than 50% of the time.

If one or two factors were present, work was classified as moderate.

Family history

A family history of pelvic floor disorders was assessed by the questionnaire, asking: 'Has your mother or grandmother experienced pelvic floor disorders?' ('yes', 'do not know', 'no').

Physical activity

Present and past physical activity was assessed by a semi-structured interview, and included the type of activity, frequency, duration and intensity.[32] Exercise volume was estimated by multiplying the exercise duration by the frequency (hours/week). Current exercise was classified as being of either high or low intensity. High-intensive exercise was defined as physical activity resulting in sweating or being out of breath.

Obstetric factors

A semi-structured interview addressed the recall of obstetric factors. Birth weight and the number and types of birth were registered.

Markers of connective tissue weakness

Varicose veins and a tendency to bruise easily were assessed by questionnaire. The presence of striae was observed during clinical examination and diastasis recti abdominis was diagnosed by palpation (finger width measurements).[33] Beighton's scoring system was used to assess joint mobility, and hypermobility was defined as four or more positive tests out of a total of nine.[34] The nine tests are recommended by the British Society of Rheumatology and have been tested for reliability.[35] The tests include passive extension of each fifth finger past 90°, passive apposition of each thumb to the forearm, hyperextension of each elbow past 190°, hyperextension of each knee past 10° and trunk flexion to allow the palms to lie flat on the floor.

PFM function

The ability to perform a PFM contraction was assessed by visual observation and vaginal palpation,[36] and was confirmed by ultrasound. PFM function was measured by a vaginal balloon catheter (balloon size, 6.7 × 1.7 cm) connected to a high-precision pressure transducer (Camtech AS, Sandvika, Norway).[37] The pressure transducer had conventional, current electronic sensor technology. The pressure values and pressure curves were presented on a personal computer screen. The middle of the balloon was placed 3.5 cm proximal to the vaginal introitus[38] in the vaginal high-pressure zone.[39] Muscle strength was calculated as the mean of three maximal voluntary contractions (Figure 1). The method has been found to be reliable and valid if used with the simultaneous observation of the inward movement of the catheter/perineum during PFM contraction.[37,38] Vaginal resting pressure was measured as the difference between atmospheric pressure and the vaginal high-pressure zone at rest, without any voluntary PFM activity. PFM endurance was defined as a sustained maximal contraction,[40] and was quantified during the first 10 seconds as the area under the curve (cmH_2O seconds) (Figure 1).

Procedure

All participants first completed the questionnaire, followed by a semi-structured interview and clinical examination performed by the same pelvic floor physiotherapist (IHB). At the time of the examination, the physiotherapist did not know whether the women would be classified in the POP

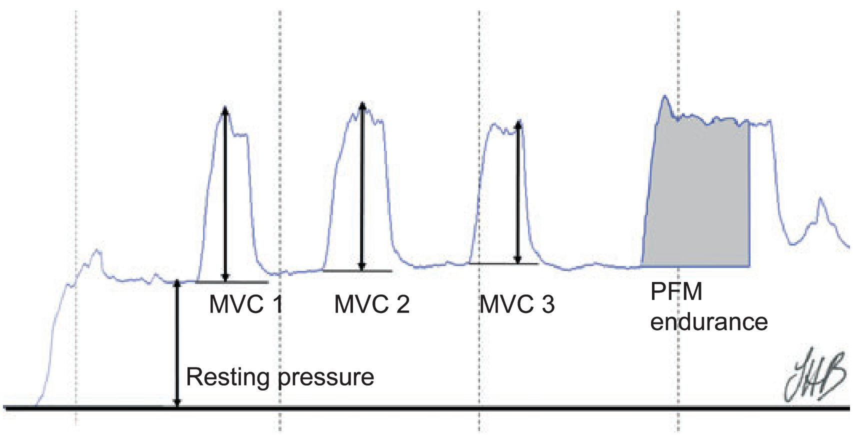

Figure 1. Vaginal squeeze pressure measurements for one woman showing vaginal resting pressure, pelvic floor muscle strength measured as maximal voluntary contractions (MVCs) and pelvic floor muscle (PFM) endurance.

or control group. The final classification of the women was based on the POP-Q values. All POP-Q and ultrasound measurements were performed by one gynaecologist (MM) at the university hospital. The gynaecologist was blind to the clinical and background data of the participants.

Statistics

The categorisation of joint mobility and BMI was made *a priori*. The strength of the PFM was termed weak, medium or strong, the PFM endurance was termed poor, medium or good, and the vaginal resting pressure was termed low, medium or high, based on a division of the values into tertiles (Table 1). The results are given as frequencies for categorical data and means with SD for continuous data. Differences between cases and controls were analysed by Wilcoxon rank paired test for continuous variables. McNemar's test was used for paired categorical data. A special Cox regression model was used to fit a conditional logistic regression procedure for one-to-one, matched, case–control studies. The results are given as odds ratios with 95%

Table 1. Odds ratios of factors associated with pelvic organ prolapse using conditional multiple regressions

	n	Adjusted OR (95% CI)	*P* value
BMI (kg/m^2)*			
≤25	59	Reference	
>25	39	5.0 (1.1–23.0)	0.038
Socioeconomic status**			
High	44	Reference	
Moderate and low	54	10.5 (2.2–50.1)	0.003
Heavy occupational work			
Moderate and light	82	Reference	
Heavy	16	9.6 (1.3–70.3)	0.026
Family history of pelvic floor disorders			0.475***
No	18	Reference	
Do not know	40	1.9 (0.5–7.6)	0.237
Yes	40	2.2 (0.6–8.1)	0.350
Current high-intensity exercise (hours/week)			
OR per SD(2.5) decrease	98	1.64 (0.85–3.18)	0.139
Former exercise (hours/week)			
OR per SD(5.8) decrease	98	1.41 (0.86–2.3)	0.177
Anal sphincter laceration			
No	84	Reference	
Yes	14	4.5 (1.0–20.0)	0.050
PFM strength (cmH_2O)			0.013***
Strong (>40)	33	Reference	
Medium (20–40)	33	3.5 (0.8–15.6)	0.096
Weak (<20)	32	7.5 (1.5–36.4)	0.013
OR per SD (22.5) decrease	98	1.07 (1.01–1.13)	0.028
PFM endurance (cmH_2O seconds)			0.006***
Good (>300)	32	Reference	
Medium (130–300)	35	2.8 (0.7–12.1)	0.167
Poor (<130)	31	11.5 (2.0–66.9)	0.006
OR per SD(193) decrease	98	2.27 (1.19–4.33)	0.013
Vaginal resting pressure (cmH_2O)			0.025***
High (>30)	35	Reference	
Medium (13–30)	30	5.1 (1.1–23.1)	0.036
Low (<13)	33	4.2 (1.1–15.8)	0.034
OR per SD (28.8) decrease	98	1.22 (1.00–1.51)	0.054

Odds ratios are adjusted for body mass index (BMI) and socioeconomic status unless otherwise stated.
OR, odds ratio; PFM, pelvic floor muscle.
*BMI is adjusted for socioeconomic status and heavy work.
**Socioeconomic status is adjusted for BMI and heavy work.
***Tests of trend.

CIs.[41] If the univariate association between POP and a risk factor was significant, it was included in a conditional multiple logistic regression model adjusting for BMI and socioeconomic status. All odds ratios presented were adjusted for BMI and socioeconomic status, unless stated otherwise. They are known to be associated with a risk of POP from other studies.[14–16,18–20,42] We did not adjust for possible markers of connective tissue weakness or symptoms/pain as they may not be considered to play a primary role as risk factors. In addition, because of the design of the study, all analyses were adjusted for age and parity. To test for interaction, a regression model between POP as dependent variable and PFM strength (0,1), PFM endurance (0,1) and the product between the two (strength and endurance) was fitted to the data. A test of significance of the product term was used as a test of interaction. PFM strength and vaginal resting were also tested for interaction. Statistical analyses were performed on SPSS version 15 (SPSS Norway, Oslo, Norway). P values of <0.05 were considered to be significant.

Results

Participants were recruited from May 2006 to September 2008 and enrolled into the present study and/or another trial that was conducted at the same time (randomised controlled trial on women with POP). Of 142 possible participants, 49 pairs of women were consecutively matched according to age (±2.5 years) and parity. The mean age of the 98 participants was 47.1 years (SD 10.57 years) and the mean BMI was 24.9 kg/m^2 (SD 3.8 kg/m^2). Both the women with POP and those in the control group had a median parity of two (range 1–5), and there was no significant difference in age between the groups (47.3 years, SD 11.2 years versus 47.0 years, SD 10.6 years). None of the women had undergone caesarean sections only. Thirty-six participants (36.7%) were postmenopausal. Six of the women with POP and three of the controls were on hormone replacement therapy ($P = 0.45$). Four women in the POP group and two in the control group had undergone a hysterectomy for reasons other than POP. All women, except for two of Asian origin in the POP group, were European. To exclude the possibility that the two women of Asian origin were different and skewed the results, they were removed from the analysis, but the results were essentially unchanged (data not shown). The results presented below include the whole cohort.

In the control group, two women were classified as stage 0 and 47 as stage I on POP-Q. Thirty-one (63%) women in the POP group had stage II, 17 (35%) stage III and one (2%) stage IV on POP-Q. Seventeen (35%) of the women in the POP group had prolapse in one vaginal compartment, whereas 25 (51%) had prolapse in two and seven (14%) had POP in all three compartments.

Significantly more women with POP than controls reported mechanical symptoms (vaginal bulging, pelvic heaviness) (36 versus 9, $P < 0.01$), defecation difficulties (17 versus 7, $P = 0.02$), incontinence of flatus (13 versus 4, $P = 0.02$) and faecal incontinence (13 versus 4, $P = 0.03$). No significant difference was found in reports of stress and urge urinary incontinence. Significantly more women with POP than controls reported low back pain (35 versus 23, $P < 0.01$), low abdominal pain (25 versus 15, $P = 0.03$) and pelvic floor pain (25 versus 12, $P = 0.02$) during the last 6 months.

In the univariate analysis, there were no statistically significant differences between the groups with regard to postmenopausal status, current smoking, current low-intensity exercise, type of birth (caesarean, forceps, vacuum), birth weight, presence of striae, diastasis recti abdominis and joint hypermobility (Table 2). Significant differences were found for BMI, socioeconomic status, heavy occupational work, family history of pelvic floor disorders, current participation in exercise with high intensity, former exercise, anal sphincter lacerations, varicose veins, bruising, PFM strength, PFM endurance and vaginal resting pressure (Table 2). The number of women having strong PFM, good PFM endurance and high vaginal resting pressure was significantly lower in the POP group than in controls (9 versus 24, $P = 0.001$, 9 versus 23, $P < 0.001$ and 10 versus 25, $P = 0.048$, respectively).

The results of the multivariate regression analysis are presented in Table 1. The associations between POP and a family history of pelvic floor disorders, current high-intensity exercise participation, former exercise and vaginal resting pressure were lost after adjustments for BMI and socioeconomic status. Combining current high-intensity activities and former exercise resulted in an odds ratio of 5.4 (95% CI 1.4–20.9, $P = 0.02$) for women who had never been active compared with women who had always been exercisers (test of trend $P = 0.06$). Heavy occupational work, anal sphincter lacerations, PFM strength and PFM endurance were significantly associated with POP after adjusting for BMI and socioeconomic status. In addition, BMI and socioeconomic status were independently associated with POP, when adjusted for heavy work (Table 1).

Significant interactions were found between PFM strength and vaginal resting pressure ($P = 0.02$), but not between PFM strength and endurance. The combination of a weak PFM and a low vaginal resting pressure gave a much higher odds ratio than a strong PFM and high vaginal resting pressure, strong PFM and low vaginal resting pressure or weak PFM and high vaginal resting pressure.

Discussion

In this age- and parity-matched case–control study, women with POP were more likely than controls to experience

Table 2. Characteristics of 49 women with pelvic organ prolapse (POP) stage II or above (cases) and 49 controls

	Women with POP	Controls	*P* value
Postmenopausal	20 (55.6)	16 (32.7)	0.180
Body mass index ≤25 kg/m^2	24 (49.0)	35 (71.4)	0.049
High socioeconomic status	12 (24.5)	32 (65.3)	0.000
Current smoking	9 (18.4)	5 (10.2)	0.549
Heavy occupational work	13 (26.5)	3 (6.1)	0.044
Family history of pelvic floor disorders	24 (49.0)	16 (32.7)	0.023
Physical activity			
Exercise with high intensity (hours/week)	1.2 ± 2.1	2.6 ± 2.7	0.010
Exercise with low intensity (hours/week)	2.3 ± 3.0	2.2 ± 3.1	0.688
Former exercise (hours/week)	2.4 ± 3.5	5.3 ± 7.2	0.020
Recall of obstetric factors			
One or more caesarean sections	6 (12.2)	9 (18.4)	0.317
Forceps	6 (12.2)	4 (8.2)	0.405
Vacuum	7 (14.3)	7 (14.3)	1.000
Anal sphincter laceration(s)	11 (22.4)	3 (6.1)	0.048
Highest birth weight (g)	3741 ± 491	3713 ± 474	0.959
Possible markers of connective tissue weakness			
Presence of varicose veins	20 (40.8)	7 (14.3)	0.005
Bruising	23(46.9)	10 (20.4)	0.001
Observed striae	23 (46.9)	32 (65.3)	0.064
Palpated diastasis recti abdominis	38 (77.6)	38 (80.9)	1.000
Hypermobility (≥4 of Beighton's 9 tests)	17 (34.7)	21 (42.9)	0.678
Pelvic floor muscle function			
PFM strength (cmH_2O)	26.6 ± 19.5	42.7 ± 22.6	0.001
PFM endurance (cmH_2O seconds)	178 ± 151	333 ± 146	0.000
Vaginal resting pressure (cmH_2O)	26.7 ± 7.1	30.9 ± 8.5	0.048

Results are presented as means with SD and as numbers with percentages (%).
PFM, pelvic floor muscle.

mechanical and bowel symptoms, but not bladder symptoms. The occurrence of low back pain, low abdominal pain and pelvic floor pain was higher in the POP group than in the control group. The presence of varicose veins was the only factor independently related to POP of the five possible markers of connective tissue weakness (varicose veins, bruising, stria, diastasis recti abdominis and joint hypermobility). BMI, socioeconomic status, heavy occupational work, anal sphincter lacerations and poor PFM function were independently associated with POP.

The strengths of the present study are that PFM function was measured with a method found to have good reliability and validity,[37,38] and that validated questionnaires and clinical assessment tools were used. We also followed the recommendation of Bland and Altman[27] to use a matched pair design with small samples. Possible limitations are the relatively small sample size, women in the POP group had a relatively mild degree of POP (63% with grade II), a risk of overestimation of self-reported height, a risk of recall bias in the assessment of obstetric history, family history of pelvic floor dysfunction and past physical activity, and the measurement of vaginal squeeze pressure had not been validated in women with POP. Considering the latter point, the presence of POP has seldom been assessed in former methodological studies and in randomised controlled trials evaluating the effect of PFM training on stress urinary incontinence.[43] As a result of the high prevalence of POP, it is likely that many of the participants in previously published studies had POP in addition to stress urinary incontinence. In severe cases of POP, the prolapsed tissue may fill up the levator hiatus and may theoretically influence the measurements of PFM function. Further studies are needed to compare the measurements of PFM function in women with and without POP. Recent studies have suggested that dynamometers are a better method for the measurement of PFM strength as they measure force directly.[44] However, these devices are not yet commercially available.

It has been demonstrated that pelvic floor-related symptoms may not predict the stage or anatomic location of POP.[30,45] However, mechanical symptoms, such as vaginal bulging/pelvic heaviness, seem to be specific symptoms for POP.[46] Hence, bladder and bowel symptoms may coexist with POP without a known cause–effect relationship.[47] As expected, the present study found a higher occurrence of mechanical and bowel symptoms amongst women with POP than in controls, but, interestingly, bladder symptoms were present equally in both groups. This suggests that the pathophysiology of bladder dysfunction and POP may not be the same. As expected, we found a higher occurrence of low back pain, pelvic floor pain and low abdominal pain amongst women with POP. This is in agreement with the observations of other research groups, who showed more complaints of low back pain amongst women with POP than in controls.[9]

The mechanical stability of the genitourinary tract depends on the quality of collagen fibres in the ligaments and faciae, and there is some evidence suggesting that changes in the connective tissue in the pelvic structures are associated with POP.[48,49] It has been hypothesised that joint mobility,[11] varicose veins,[35] striae,[35] diastasis recti abdominis[12] and bruising[50] are markers of systemic alterations in connective tissue. These factors have not been the focus of previous POP research, but may be future meaningful clinical markers to predict women with an increased risk of POP. The present study showed differences amongst women with POP and controls with regard to bruising and varicose veins, the latter being strongly associated with POP. Associations between joint hypermobility and POP[9–11] have been reported previously, with a prevalence of up to 66% versus 43% for Iraqi women with and without POP.[9] Surprisingly, the present study did not support these results. The discrepancy in results may be caused by ethnicity. However, the prevalence of hypermobility amongst women without POP was similar in both studies. Women with POP-Q stages III and IV have been shown to demonstrate a higher prevalence of joint hypermobility than have women with stages I and II.[10] The majority of women with POP in the present study had POP grade II. Hence, our results may not be generalisable to women with more severe POP. However, our findings are in agreement with a study showing no significant relationship between joint hypermobility and POP in women with Ehlers–Danlos syndrome.[51]

The present study showed successful matching with regard to age and parity, and all other proposed risk factors were adjusted for these two variables. The present study failed to demonstrate any independent associations between POP and postmenopausal status, current smoking, family history of pelvic floor disorders and most of the obstetric factors. As a result of the wide confidence intervals and the fact that the study was powered to assess joint mobility, this lack of association may be caused by the small sample size, and further studies are warranted. A similar study design with a larger sample size could be used in the future to investigate associations between types of delivery (caesarean, forceps, vacuum), birth weight and short or prolonged second stage of labour. In the present study, recall of anal sphincter lacerations was the only obstetric factor associated with POP, with more than a four-fold elevated odds ratio.

The present study is in agreement with the observations of other research groups, who showed that a high BMI[14–16,18] and a low socioeconomic status[18,19,42] were associated with prolapse, but contradict the findings of Mant *et al.*[14] with regard to educational level and Samuelsson *et al.*[17] and Rinne and Kirkinen[12] who found no association between BMI and POP.

Our results support other studies that have found an association between heavy work and POP.[21,22] Based on this association, it could be hypothesised that vigorous physical activity may also be a risk factor. However, although two studies reported no association between current exercise or the self-report of past strenuous exercise and POP,[16,19] details of relevant data, such as the type of activity, frequency, duration and intensity, were not described. The present study revealed that women with POP had participated less in exercise when they were younger when compared with controls, suggesting that being a former exerciser is not associated with POP. The lower occurrence of current high-intensity exercisers among women with POP compared with controls may be explained by a possible withdrawal from physical activity because of symptoms. However, a higher occurrence of high-intensity exercisers among women without POP in the present study indicates that vigorous activity alone is not sufficient to predispose women to POP. The results of the present study suggest that heavy occupational work may be a risk factor, but they do not support the thesis that either former or current vigorous physical activity is a risk factor for POP.

The PFM is considered to be an important part of the pelvic organ support system.[5] Vaginal resting pressure may be an important marker of 'muscular closing' of the levator hiatus.[26,52] Reduced PFM strength in women with POP has been demonstrated,[17,26] and the severity of POP seems to increase with increasing PFM dysfunction.[5,25,52] The present study found that approximately 30% fewer women had strong PFM, good PFM endurance and high vaginal resting pressure in the POP group compared with the control group. However, the fact that about 20% of women with POP had good PFM function suggests that the POP process must also include factors other than PFM injury or weakness.[6] Our findings contradict the results of Nygaard *et al.*,[19] who did not find a reduced PFM strength in women with POP. The discrepancy in the results may be caused by a different assessment methodology, and vaginal palpation may have a lower responsiveness, validity and reliability than vaginal squeeze pressure measurements.[53]

Longitudinal studies are needed to determine whether, and to what extent, mild forms of POP progress. The present study showed that PFM function, BMI, socioeconomic status, heavy occupational work and anal sphincter laceration were the most prominent factors. From the perspective of prevention and treatment, BMI and PFM function are two of the few modifiable factors that can be altered by a woman herself. Women with poor PFM function were 4–11 times more likely to experience POP compared with women with good PFM function. This supports the hypothesis that PFM training may be an important element in the prevention and treatment of POP. To date, there have been few randomised controlled trials on the effect of PFM training in the prevention and reversal of POP, and further high-quality trials are warranted.[54]

Conclusion

Pelvic floor muscle function, BMI, socioeconomic status, anal sphincter laceration and heavy occupational work were independently associated with POP. PFM function is an important clinical associate of POP and future studies should include this factor.

Disclosure of interest

The authors have no conflicts of interest.

Contribution to authorship

All the authors met the following criteria: (i) substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; (ii) drafting the article or revising it critically for important intellectual content and (iii) final approval of the version to be published.

Details of ethics approval

The study was approved by the Norwegian Regional Medical Ethics Committee (S-05146) on 23 August 2005. All subjects gave written informed consent.

Funding

EXTRA funds from the Norwegian Foundation for Health and Rehabilitation and the Norwegian Women's Public Health Association.

Acknowledgements

We thank Dr Patricia Neumann (Centre for Allied Health Evidence, University of South Australia, Adelaide, Australia) for English revision of the manuscript. In addition, we gratefully acknowledge support for this research through the EXTRA funds from the Norwegian Foundation for Health and Rehabilitation and the Norwegian Women's Public Health Association. ■

References

1 Hunskaar S, Burigo K, Clark A, Lapitan MC, Nelson R, Sillen U, *et al.* Epidemiology of POP. In: Abrams P, Cardozo L, Khoury S, Wein A, editors. *Incontinence*. Plymouth: Health Publication Ltd, 2005,290–8.
2 Luber KM, Boero S, Choe JY. The demographics of pelvic floor disorders: current observations and future projections. *Am J Obstet Gynecol* 2001;184:1496–501.
3 Thakar R, Stanton S. Management of genital prolapse. *Br Med J* 2002;324:1258–62.
4 Olsen AL, Smith VJ, Bergstrom JO, Colling JC, Clark AL. Epidemiology of surgically managed pelvic organ prolapse and urinary incontinence. *Obstet Gynecol* 1997;89:501–6.
5 DeLancey JO. The hidden epidemic of pelvic floor dysfunction: achievable goals for improved prevention and treatment. *Am J Obstet Gynecol* 2005;192:1488–95.
6 DeLancey JO, Low LK, Miller JM, Patel DA, Tumbarello JA. Graphic integration of causal factors of pelvic floor disorders: an integrated life span model. *Am J Obstet Gynecol* 2008;199:610–5.
7 McLennan MT, Harris JK, Kariuki B, Meyer S. Family history as a risk factor for pelvic organ prolapse. *Int Urogynecol J Pelvic Floor Dysfunct* 2008;19:1063–9.
8 Visco AG, Yuan L. Differential gene expression in pubococcygeus muscle from patients with pelvic organ prolapse. *Am J Obstet Gynecol* 2003;189:102–12.
9 Al-Rawi ZS, Al-Rawi ZT. Joint hypermobility in women with genital prolapse. *Lancet* 1982;1:1439–41.
10 Bai SW, Choe BH, Kim JY, Park KH. Pelvic organ prolapse and connective tissue abnormalities in Korean women. *J Reprod Med* 2002;47:231–4.
11 Norton PA, Baker JE, Sharp HC, Warenski JC. Genitourinary prolapse and joint hypermobility in women. *Obstet Gynecol* 1995;85:225–8.
12 Rinne KM, Kirkinen PP. What predisposes young women to genital prolapse? *Eur J Obstet Gynecol Reprod Biol* 1999;84:23–5.
13 Tegerstedt G, Miedel A, Maehle-Schmidt M, Nyren O, Hammarstrom M. Obstetric risk factors for symptomatic prolapse: a population-based approach. *Am J Obstet Gynecol* 2006;194:75–81.
14 Mant J, Painter R, Vessey M. Epidemiology of genital prolapse: observations from the Oxford Family Planning Association Study. *Br J Obstet Gynaecol* 1997;104:579–85.
15 Swift SE, Woodman P, O'Boyle A, Kahn M, Valley M, Bland D, *et al.* Pelvic Organ Support Study (POSST): the distribution, clinical definition, and epidemiologic condition of pelvic organ support defects. *Am J Obstet Gynecol* 2005;192:795–806.
16 Hendrix SL, Clark A, Nygaard I, Aragaki A, Barnabei V, McTiernan A. Pelvic organ prolapse in the Women's Health Initiative: gravity and gravidity. *Am J Obstet Gynecol* 2002;186:1160–6.
17 Samuelsson EC, Victor FT, Tibblin G, Svardsudd KF. Signs of genital prolapse in a Swedish population of women 20 to 59 years of age and possible related factors. *Am J Obstet Gynecol* 1999;180:299–305.
18 Progetto Menopausa Italia Study Group. Risk factors for genital prolapse in non-hysterectomized women around menopause. Results from a large cross-sectional study in menopausal clinics in Italy. Progetto Menopausa Italia Study Group. *Eur J Obstet Gynecol Reprod Biol* 2000;93:135–40.
19 Nygaard I, Bradley C, Brandt D. Pelvic organ prolapse in older women: prevalence and risk factors. *Obstet Gynecol* 2004;104:489–97.
20 Lawrence JM, Lukacz ES, Nager CW, Hsu JW, Luber KM. Prevalence and co-occurrence of pelvic floor disorders in community-dwelling women. *Obstet Gynecol* 2008;111:678–85.
21 Larsen WI, Yavorek T. Pelvic prolapse and urinary incontinence in nulliparous college women in relation to paratrooper training. *Int Urogynecol J Pelvic Floor Dysfunct* 2007;18:769–71.
22 Jorgensen S, Hein HO, Gyntelberg F. Heavy lifting at work and risk of genital prolapse and herniated lumbar disc in assistant nurses. *Occup Med (Lond)* 1994;44:47–9.

23 Arya LA, Novi JM, Shaunik A, Morgan MA, Bradley CS. Pelvic organ prolapse, constipation, and dietary fiber intake in women: a case–control study. *Am J Obstet Gynecol* 2005;192:1687–91.

24 Slieker-Ten Hove MC, Pool-Goudzwaard AL, Eijkemans MJ, Steegers-Theunissen RP, Burger CW, Vierhout ME. Symptomatic pelvic organ prolapse and possible risk factors in a general population. *Am J Obstet Gynecol* 2009;200:184–7.

25 Chen L, Ashton-Miller JA, Hsu Y, DeLancey JO. Interaction among apical support, levator ani impairment, and anterior vaginal wall prolapse. *Obstet Gynecol* 2006;108:324–32.

26 DeLancey JO, Morgan DM, Fenner DE, Kearney R, Guire K, Miller JM, *et al.* Comparison of levator ani muscle defects and function in women with and without pelvic organ prolapse. *Obstet Gynecol* 2007;109:295–302.

27 Bland JM, Altman DG. Matching *Br Med J* 1994;309:1128.

28 Bump RC, Mattiasson A, Bo K, Brubaker LP, DeLancey JO, Klarskov P, *et al.* The standardization of terminology of female pelvic organ prolapse and pelvic floor dysfunction. *Am J Obstet Gynecol* 1996;175:10–7.

29 Weber AM, Abrams P, Brubaker L, Cundiff G, Davis G, Dmochowski RR, *et al.* The standardization of terminology for researchers in female pelvic floor disorders. *Int Urogynecol J Pelvic Floor Dysfunct* 2001;12:178–86.

30 Mouritsen L, Larsen JP. Symptoms, bother and POPQ in women referred with pelvic organ prolapse. *Int Urogynecol J Pelvic Floor Dysfunct* 2003;14:122–7.

31 Avery K, Donovan J, Peters TJ, Shaw C, Gotoh M, Abrams P. ICIQ: a brief and robust measure for evaluating the symptoms and impact of urinary incontinence. *Neurourol Urodyn* 2004;23:322–30.

32 Bouchard C, Shephard RJ. Physical activity, fitness, and health: the model and key concepts. In: Bouchard C, Shephard RJ, Stephens T, editors. *Physical Activity, Fitness, and Health, Consensus Statement*. Champaign, IL: Human Kinetics; 1994. pp. 11–23 .

33 Bursch SG. Interrater reliability of diastasis recti abdominis measurement. *Phys Ther* 1987;67:1077–9.

34 Beighton P, Solomon L, Soskolne CL. Articular mobility in an African population. *Ann Rheum Dis* 1973;32:413–8.

35 Remvig L, Jensen DV, Ward RC. Are diagnostic criteria for general joint hypermobility and benign joint hypermobility syndrome based on reproducible and valid tests? A review of the literature *J Rheumatol* 2007;34:798–803.

36 Bo K, Sherburn M. Evaluation of female pelvic-floor muscle function and strength. *Phys Ther* 2005;85:269–82.

37 Bo K, Kvarstein B, Hagen R, Larsen S. Pelvic floor muscle exercise for the treatment of female stress urinary incontinence:I. Reliability of vaginal pressure measurements of pelvic floor muscle strength. *Neurourol Urodyn* 1990;9:471–7.

38 Bo K, Kvarstein B, Hagen R, Larsen S. Pelvic floor muscle exercise for the treatment of female stress urinary incontinence:II. Validity of vaginal pressure measurements of pelvic floor muscle strength and the necessity of supplementary methods for control of correct contraction. *Neurourol Urodyn* 1990;9:479–87.

39 Guaderrama NM, Nager CW, Liu J, Pretorius DH, Mittal RK. The vaginal pressure profile. *Neurourol Urodyn* 2005;24:243–7.

40 Bo K, Aschehoug A. *Pelvic Floor and Exercise Science – Strength Training*. In: Bo K, Berghmans B, Morkved S, Kampen MV, editors. *Evidence-Based Physical Therapy for the Pelvic Floor*. Edinburgh: Churchill Livingstone Elsevier; 2007. pp. 119–32 .

41 Norusis MJ. *SPSS 13.0 Advanced Statistical Procedures Companion*. Chicago, IL: Prentice Hall, Inc., 2005.

42 Woodman PJ, Swift SE, O'Boyle AL, Valley MT, Bland DR, Kahn MA, *et al.* Prevalence of severe pelvic organ prolapse in relation to job description and socioeconomic status: a multicenter cross-sectional study. *Int Urogynecol J Pelvic Floor Dysfunct* 2006;17:340–5.

43 Dumoulin C, Hay-Smith J. Pelvic floor muscle training versus no treatment for urinary incontinence in women. A Cochrane systematic review. *Eur J Phys Rehabil Med* 2008;44:47–63.

44 Dumoulin C, Gravel D, Bourbonnais D, Lemieux MC, Morin M. Reliability of dynamometric measurements of the pelvic floor musculature. *Neurourol Urodyn* 2004;23:134–42.

45 Miedel A, Tegerstedt G, Maehle-Schmidt M, Nyren O, Hammarstrom M. Symptoms and pelvic support defects in specific compartments. *Obstet Gynecol* 2008;112:851–8.

46 Gutman RE, Ford DE, Quiroz LH, Shippey SH, Handa VL. Is there a pelvic organ prolapse threshold that predicts pelvic floor symptoms? *Am J Obstet Gynecol* 2008;199:683–7.

47 Mouritsen L. Classification and evaluation of prolapse. *Best Pract Res Clin Obstet Gynaecol* 2005;19:895–911.

48 Jackson SR, Avery NC, Tarlton JF, Eckford SD, Abrams P, Bailey AJ. Changes in metabolism of collagen in genitourinary prolapse. *Lancet* 1996;347:1658–61.

49 Soderberg MW, Bystrom B, Kalamajski S, Malmstrom A, Ekman-Ordeberg G. Gene expressions of small leucine-rich repeat proteoglycans and fibulin-5 are decreased in pelvic organ prolapse. *Mol Hum Reprod* 2009;15:251–7.

50 Russek LN. Hypermobility syndrome. *Phys Ther* 1999;79:591–9.

51 McIntosh LJ, Mallett VT, Frahm JD, Richardson DA, Evans MI. Gynecologic disorders in women with Ehlers–Danlos syndrome. *J Soc Gynecol Invest* 1995;2:559–64.

52 Zacharin RF. Pulsion enterocele: review of functional anatomy of the pelvic floor. *Obstet Gynecol* 1980;55:135–40.

53 Bo K, Finckenhagen HB. Vaginal palpation of pelvic floor muscle strength: inter-test reproducibility and comparison between palpation and vaginal squeeze pressure. *Acta Obstet Gynecol Scand* 2001;80:883–7.

54 Hagen S, Stark D, Maher C, Adams E. Conservative management of pelvic organ prolapse in women. *Cochrane Database Syst Rev* 2006;4:CD003882.

