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CLINICAL PAPER

Association of the severity of urinary incontinence with bladder neck descent during the Valsalva manoeuvre in parous female runners: a nested case–control study

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Abstract

Background. Stress urinary incontinence (SUI) is a prevalent form of pelvic floor dysfunction in females, particularly athletes, that has a 44% occurrence rate in various sports. Studies of SUI have focused on pelvic floor muscle strength, coordination and bladder neck descent (BND). However, data about BND values among parous female runners who suffer from SUI remains limited.

Aim. The aim of this study was to evaluate the association between the severity of incontinence and BND values in parous female runners with SUI.

Participants and methods. A nested case–control study compared BND values measured during the Valsalva manoeuvre among parous female runners with and without SUI. The study compared 13 and 16 females without and with SUI, respectively, focusing on those who experienced incontinence under various conditions, specifically during running. The group categorization was based on their scores from the International Consultation on Incontinence Questionnaire – Urinary Incontinence Short Form (ICIQ-UI SF), and responses to a clarification question about suffering from SUI during running.

Results. Significantly higher BND values were found in parous female runners with SUI than in those without, as measured with full and empty bladders ($P = 0.001$ and 0.022, respectively). A positive correlation was found between BND values measured during the Valsalva manoeuvre with a full bladder and the total ICIQ-UI SF score ($r = 0.415$, $P = 0.022$). No significant correlation was found between BND values and the number of births, or the total distance run per week (km) with full and empty bladders. The BND measurements demonstrated high intra- and inter-rater reliability, and achieved statistical significance ($P < 0.001$) in both bladder volume conditions (i.e. full and empty).

Conclusions. In parous female runners suffering from SUI, BND values were significantly higher compared to those without SUI. Bladder neck descent values measured during the Valsalva manoeuvre with a full bladder showed a significant correlation with total ICIQ-UI SF scores, indicating an association between the severity of incontinence and BND in parous female runners with a full bladder. The authors recommend using sonographic BND assessment as a reliable and objective tool to evaluate parous female runners with SUI. Additional studies are needed to explore the factors associated with changes in BND.

Keywords: bladder neck descent, female runners, pelvic floor dysfunction, stress urinary incontinence, urethral hypermobility.

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Introduction

Women may experience urinary incontinence (UI) at various stages of their life. This condition is subdivided into urge UI (UUI) and stress UI (SUI). Stress urinary incontinence is defined as a "complaint of involuntary loss of urine on effort or physical exertion [. . .], or on sneezing or coughing" (Haylen *et al.* 2010, p. 5). Studies have shown that SUI is most prevalent during physical activities, particularly high-impact sports, and the condition can also affect young, nulliparous athletes (Bø 2004; Goldstick & Constantini 2014). The prevalence of UI among female athletes ranges from 19% to 76%, with an average of 36%. In particular, SUI has a prevalence rate of 44% among female athletes in various high-impact sports (Teixeira *et al.* 2018). Many women refrain from participating in sports activities as a result of SUI. Furthermore, they often avoid seeking medical help because of embarrassment, making it a "silent condition". These women mistakenly believe that SUI is a natural consequence of ageing or childbirth (Lose 2005; Ng *et al.* 2014).

Numerous studies (Bø 2004; Amarenco *et al.* 2005; Deffieux *et al.* 2008; Leitner *et al.* 2017; Moser *et al.* 2018) have explored the causes of SUI during coughing and various sports activities, focusing on pelvic floor muscle (PFM) strength, coordination and a gradual gradient of muscle activity. Bø (2004) hypothesized that PFMs might not co-contract quickly or strongly enough during exertion, leading to muscle stretching and weakening, which could cause incontinence during high-impact activities. Other researchers have explored the aetiology of incontinence, expanding their investigations beyond PFM function to include the striated urethral sphincter. Studies by Madill *et al.* (2015) and McLean *et al.* (2013) investigated the impact of PFM training on the size of the striated urethral sphincter and its role in maintaining continence. Their findings indicated that a 12-week PFM exercise programme resulted in muscular hypertrophy of the striated urethral sphincter. Specifically, McLean *et al.* (2013) and Madill *et al.* (2015) investigated middle-aged women and those aged >60 years, respectively. Both studies reported significant increases in the cross-sectional area of the striated urethral sphincter, along with notable improvements in continence.

The mechanism underlying continence control is probably more complex than the function of the PFM alone. It involves a combination of ligament stabilization and PFM activation, which leads to the anterior motion of the urethra by compressing it against the anterior sling (DeLancey 1988). Additionally, the structures associated with urethral support were examined in a systematic review by Falah-Hassani *et al.* (2021). Several differences were found between continent and incontinent women, such as altered urethra and bladder neck morphology, lower perfusion, and impairments in urethral neurophysiology. This review also described higher bladder neck descent (BND) values during the Valsalva manoeuvre in incontinent versus continent women. Given the high prevalence of SUI among female athletes, investigating its underlying causes is of interest. However, there is limited research-based evidence on this topic. Bérubé & McLean (2024) examined the acute effects of running on pelvic floor morphology and function in females with and without running-induced SUI. While PFM function, measured by intravaginal dynamometry, remained unchanged, bladder neck height measured at rest, assessed using transperineal ultrasound (TPUS), decreased in both groups after running ($P<0.05$). Bladder neck height during maximum voluntary contraction and Valsalva manoeuvre was lower after running ($P<0.05$) in both groups. This study highlighted the impact of running on passive pelvic floor tissues in female athletes, and there was no significant between-group difference. Other studies focusing on the functional anatomy of the bladder neck have suggested that increased bladder neck mobility is a significant anatomical predictor of SUI (Dietz 2004; Jamard *et al.* 2020; Wieczorek *et al.* 2021). Bladder neck mobility can be assessed by measuring the extent of BND during the Valsalva manoeuvre, which is commonly observed using TPUS (Naranjo-Ortiz *et al.* 2016; Volløyhaug *et al.* 2017). Further research is needed to investigate the degree of bladder neck mobility and its relationship to UI in female runners.

The aim of the present study was to assess the association between BND values on the Valsalva

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manoeuvre and the severity of UI in parous female runners. The authors hypothesize that increased BND values on the Valsalva manoeuvre will be significantly associated with the severity of UI in parous female runners with SUI.

Participants and methods

The present study employed a nested cross-sectional case–control design. The research was conducted at a pelvic floor physical therapy clinic in Lehavim, Israel. The participants were drawn from a cohort of 206 recreational and elite female runners who were recruited through social media or by personal trainers of running teams. This original cohort was established to investigate the prevalence and risk factors associated with UI among female runners. Participants completed the International Consultation on Incontinence Questionnaire – Urinary Incontinence Short Form (ICIQ-UI SF), and data collection questionnaires were sent via Google Forms (Google LLC, Mountain View, CA, USA). All participants received an explanation of the aims and procedures involved in the study, and were asked to sign an informed consent form. In the original cohort, SUI had a moderate prevalence of 45.6%, occurring during activities such as coughing, sneezing and various physical exertions; 24.8% of all women in the sample reported SUI during running. The present authors recruited participants from the original cohort for this nested cross-sectional case–control study. Women who reported SUI during physical activity, particularly during running, were contacted by telephone and told about the study, and its inclusion and exclusion criteria. Seventeen women who reported SUI during running agreed to participate alongside 13 women without SUI, who were matched by age and body mass index.

All recruited participants received a detailed explanation of the aims of and procedures involved in the present study, and signed an informed consent form. Since this was an observational investigation, there was no risk to the participants. The Ethical Committee of Ben-Gurion University of the Negev (Request Sub-Number: 2107-1) approved the study. Each consenting woman was given an anonymous number, and a link to a Google Forms questionnaire.

All participants were assigned a unique research code number. A log folder, which was securely maintained in order to protect the women's data, linked these numbers to the participants' identification data. The log folder was stored in a locked cabinet in compliance with guidelines for good clinical practice. All research measurements were recorded using the assigned research code numbers, ensuring anonymity. Additionally, all research data were safeguarded with password protection to maintain confidentiality.

Ultimately, the study involved 30 women (Fig. 1), which included 13 without SUI during running, coughing, sneezing, laughing or other physical activities, although one participant had UUI. The 17 female runners with UI experienced a range of symptoms, including SUI, while running. Specifically, four women experienced SUI exclusively during running, four had both SUI and UUI, 11 reported SUI during coughing or sneezing, two experienced SUI during laughing, and five experienced SUI while jumping. All participants completed the ICIQ-UI SF questionnaire, and provided information regarding their age, weekly running distance, number of births, height and weight.

Procedure

The participants' BND values were assessed using two-dimensional TPUS. A physical therapist (R.D.C.) used a portable two-dimensional ultrasound device with a convex transducer (GE Healthcare-Logic V2, 2–5 MHz Convex, GE Healthcare Technologies, Inc., Chicago, IL, USA). All participants were instructed to void their bladder 1.5 h before the examination and then consume two glasses of water. Upon arrival at the clinic, each participant was asked to lie supine with a cover on her. The examiner measured bladder volume through transabdominal ultrasound. A volume of > 100 mL was deemed to indicate a full bladder. In the subsequent step, the participant was positioned in a dorsal recumbent posture (lying supine with knees bent at a 90° angle). The transducer, which was adequately coated with gel and a protective cover, was placed in the midsagittal plane against the perineum, just below the pubic symphysis. The aim of this placement was to obtain a clear view of the pubic symphysis, bladder, urethra, vagina and rectum. Before examining the bladder neck movement, an explanation was given to the participant about her pelvic floor image. After this, she was instructed to take a breath, hold it and strongly push her belly downward to obtain an accurate Valsalva manoeuvre (Talasz *et al.* 2012). An optimal Valsalva manoeuvre, performed without co-activation of the levator ani muscles, was achieved using visual feedback provided to each participant. Most women performed the Valsalva

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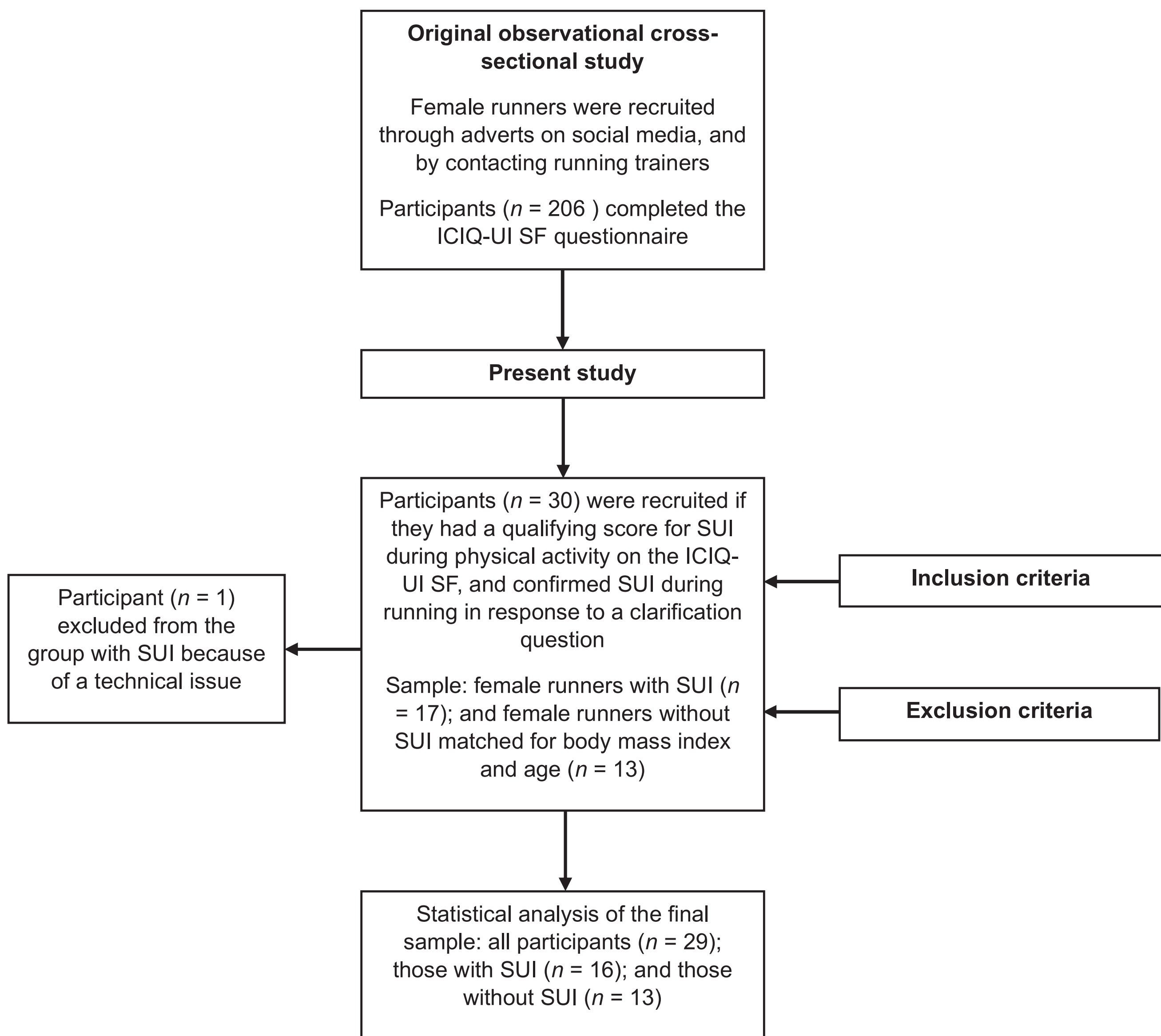


Figure 1. Study recruitment flow chart: (ICIQ-UI SF) International Consultation on Incontinence Questionnaire – Urinary Incontinence Short Form; and (SUI) stress urinary incontinence.

manoeuvre correctly. Some exhibited levator ani co-activation, and were instructed to adjust their performance and given specific guidance on relaxing their PFMs. Visual feedback training was repeated up to two times, and the best performance was used for analysis. A few participants were unable to avoid levator ani contraction entirely, and in these cases, the closest approximation to a relaxed manoeuvre was accepted.

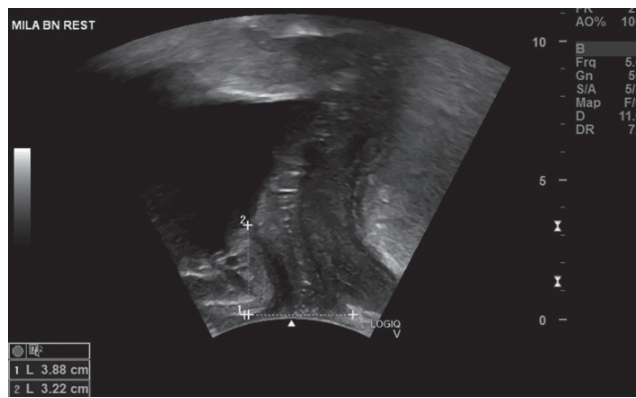
In the next step, the participant was instructed to empty her bladder. To confirm voiding, the examiner measured bladder volume, and < 50 mL was deemed to be empty. After voiding, all participants demonstrated an empty bladder with a residual volume of < 50 mL. After a 5-min rest, the Valsalva manoeuvre was repeated.

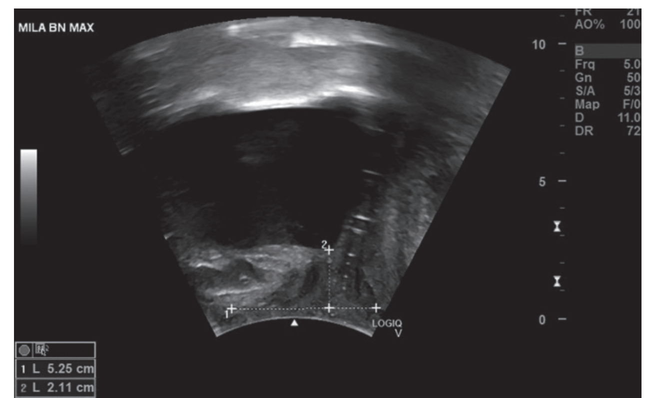
In summary, the Valsalva manoeuvre was performed with both a full and empty bladder. Following the study protocol, all images and video recordings were stored on the ultrasound system. Bladder neck descent values were obtained from the most accurately performed Valsalva manoeuvre, and were measured from recorded ultrasound images 1 month after the initial assessment. Two examiners independently measured BND values using the same ultrasound device, with one examiner aware of the participants' continence status and the other blinded to it. Bladder neck descent values were calculated as the difference between the bladder neck position at rest and during a maximum Valsalva manoeuvre (Fig. 2).

Inter- and intra-rater reliability

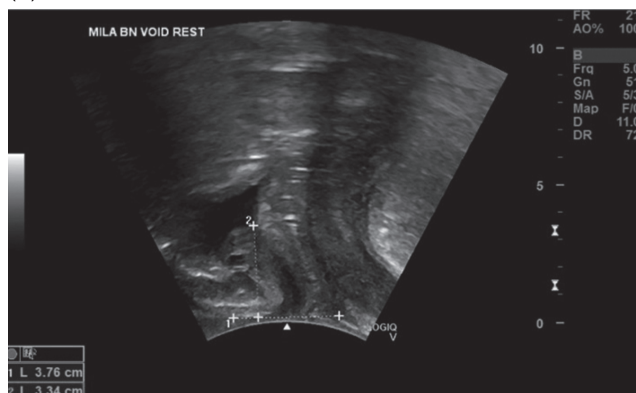
A pelvic floor physical therapist (R.D.C.), who was aware of the participants' condition, performed ultrasound evaluations and

(a)





(b)



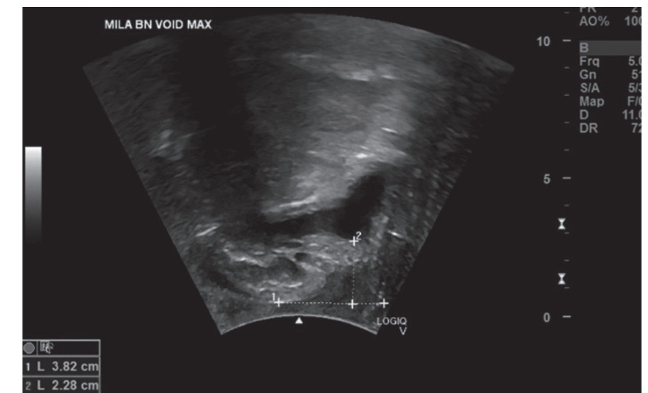


Figure 2. Bladder neck descent (BND) measured by transperineal ultrasound: (a) full bladder [bladder neck position = 3.22 cm (rest) and 2.11 cm (maximum Valsalva); BND = 3.22–2.11 = 1.11 cm]; and (b) empty bladder [bladder neck position = 3.34 cm (rest) and 2.28 cm (maximum Valsalva); BND = 3.34–2.28 = 1.06 cm].

video-recorded the Valsalva manoeuvres. One month later, she and a blinded pelvic floor physical therapist (M.G.) used these recordings to measure BND and assess inter-rater reliability. To evaluate intra-rater reliability, the blinded examiner (M.G.) repeated the measurements 3 months after the initial assessment.

The examiners' training in using transperineal ultrasound

Before the study, the physical therapists, i.e. the non-blinded (R.D.C.) and blinded (M.G.) examiners, underwent training in ultrasound imaging. They participated in an educational programme (SonoSkills, Roermond, the Netherlands) that certifies European Continuing Medical Education Credits. Each examiner practiced TPUS measurements of BND on over 300 women before the present study.

Outcome measures

Bladder neck descent value. Bladder neck descent measurement is regarded as a reliable method, and demonstrates good inter-observer agreement [intraclass correlation coefficient (ICC) (95% confidence interval) = 0.98 (0.94–0.99)] (Dietz *et al.* 2013). In the present study, BND was assessed using two-dimensional TPUS. This technique appears practicable and accessible for measuring BND in clinical practice, particularly when utilizing the methodology outlined by Dietz & Wilson (1998), which identifies the inferior margin of the pubic symphysis as the key bony landmark (Dietz & Wilson 1999; Jamard *et al.* 2020). A convex transducer was positioned perpendicularly to the midsagittal plane of the perineum. A horizontal reference line was drawn through the inferior margin of the pubic symphysis parallel to the screen's border. A vertical line measured the distance between this reference line and the bladder neck. Measurements were obtained at rest and during the maximal Valsalva manoeuvre; the difference between these two measurements was defined as the BND value (Fig. 2) (Dietz & Wilson 1998; Jamard *et al.* 2020).

International Consultation on Incontinence Questionnaire – Urinary Incontinence Short Form score. The ICIQ-UI SF is a simple questionnaire tool for evaluating the severity of UI and its impact on health-related quality of life. Each item in the

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questionnaire receives a score, and the total score ranges from 0 to 21: (0) women without UI; (1–7) mild UI; (8–14) moderate UI; and (15–21) severe UI. In addition, another item is attributed to the type of UI, which is classified as SUI, UUI or mixed UI. The section of the questionnaire that assessing the type of incontinence is not scored (Liebergall-Wischnitzer *et al.* 2015). The ICIQ-UI SF is known for good construct validity and internal consistency, and has a Cronbach's α of 0.95. There is a strong agreement between this tool, and other questionnaires and urodynamic assessments (Seckiner *et al.* 2007).

Statistical analysis

All statistical computations were performed using SPSS Statistics, Version 23 (IBM, Armonk, NY, USA). The significance level was set at $\alpha = 0.05$. Since most variables did not follow a normal distribution and aligned with a Poisson distribution, the Mann–Whitney *U*-test was used to compare categorical and continuous variables. Analysis using Spearman's rank correlation coefficient was done to evaluate associations between continuous variables.

Results

Thirty women were recruited for the present study. One participant with SUI was excluded because of technical issues with visualizing her urethra during ultrasound evaluation, a requirement for assessing bladder neck position. The final sample included 29 parous females ranging in age from 29 to 47 years; 16 had SUI and 13 did not.

The participants with and without SUI exhibited similar demographic characteristics (Table 1). Their mean ages were 38.08 ± 4.72 and 39.88 ± 4.53 years, respectively ($U = 81.50$, $P = 0.333$). Their mean heights were 163.46 ± 5.22 and 164.81 ± 6.38 cm, respectively ($U = 85.50$, $P = 0.426$). Their mean weights were 60.46 ± 8.40 and 63.44 ± 8.16 kg, respectively ($U = 80.50$, $P = 0.312$). Their mean body mass indexes were 22.56 ± 2.39 and 23.35 ± 2.63 kg/m^2, respectively ($U = 85.50$, $P = 0.417$). Their mean numbers of births were 3.38 ± 1.32 and 3.25 ± 1.24, respectively ($U = 103.50$, $P = 0.996$). Their mean total distances run per week were 18.77 ± 8.69 and 15.31 ± 9.07 km, respectively ($U = 76.00$, $P = 0.227$).

The total ICIQ-UI SF questionnaire score revealed a statistically significant difference between female runners without and with SUI, with mean scores of 0.62 ± 2.22 and 10.00 ± 4.44, respectively ($U = 6.50$, $P < 0.001$).

Table 2 presents the inter- and intra-rater reliability (interclass correlation) of the BND measurements. High intra- and inter-rater reliability was observed for both bladder volume conditions (i.e. full and empty), with a significance level of $P < 0.001$.

Table 3 presents a comparison of BND values (measured in millimetres) between the parous female runners groups with and without SUI. The measures of BND values [made by the blinded examiner (M.G.)] showed a significant difference between parous females in the groups without and with SUI ($P = 0.001$ and 0.022 for a full and empty bladder, respectively). The BND values were increased in the group with SUI in both bladder conditions.

When the bladder was full, the measured BND values were positively and significantly correlated with the total ICIQ-UI SF score, a subjective assessment of the UI severity ($r = 0.415$, $P = 0.022$). However, no significant correlation was found: when the bladder was empty ($r = 0.232$, $P = 0.113$); between the number of births and BND values in both bladder conditions ($P = 0.052$); or between the total distance run per week (km), and the BND values in both bladder conditions ($P = 0.322$ and 0.289, respectively).

Table 1. Descriptive statistics for the sample population ($n = 29$): (ICIQ-UI SF) International Consultation on Incontinence Questionnaire – Urinary Incontinence Short Form

Variable	Stress urinary incontinence (mean ± standard deviation)		Comparison (Mann–Whitney *U*-test)
	Without ($n = 13$)	With ($n = 16$)	
Age (years)	38.08 ± 4.72	39.88 ± 4.53	$U = 81.50$, $P = 0.333$
Height (cm)	163.46 ± 5.22	164.81 ± 6.38	$U = 85.50$, $P = 0.426$
Weight (kg)	60.46 ± 8.40	63.44 ± 8.16	$U = 80.50$, $P = 0.312$
Body mass index (kg/m^2)	22.56 ± 2.39	23.35 ± 2.63	$U = 85.50$, $P = 0.417$
Births (*n*)	3.38 ± 1.32	3.25 ± 1.24	$U = 103.50$, $P = 0.996$
Total distance run per week (km)	18.77 ± 8.69	15.31 ± 9.07	$U = 76.00$, $P = 0.227$
Total ICIQ-UI SF score	0.62 ± 2.22	10.00 ± 4.44	$U = 6.50$, $P < 0.001$

Table 2. Inter-rater (interclass correlation) and intra-rater reliability of bladder neck descent measurement: (ICC) intraclass correlation coefficient

	Average measure			
	Intra-rater reliability		Inter-rater reliability	
Bladder	ICC	Significance	ICC	Significance
Full	0.987	$P < 0.001$	0.985	$P < 0.001$
Empty	0.985	$P < 0.001$	0.989	$P < 0.001$

Table 3. Comparison of bladder neck descent (mm) between the women with and without stress urinary incontinence

	Stress urinary incontinence (mean ± standard deviation)		
Bladder	Without ($n = 13$)	With ($n = 16$)	Comparison (Mann–Whitney *U*-test)
Full	4.58 ± 2.09	11.93 ± 7.72	$U = 21.00$, $P = 0.001$
Empty	6.65 ± 4.83	12.52 ± 8.74	$U = 58.00$, $P = 0.022$

Power analysis

A *post hoc* power analysis was conducted based on the results of the present study. With a full bladder, the BND measurements were 11.93 ± 7.72 and 4.58 ± 2.09 mm for the groups with and without SUI, respectively ($P = 0.001$). With an empty bladder, these were 12.52 ± 8.74 and 6.65 ± 4.83 mm, respectively ($P = 0.022$).

Effect sizes. Cohen's *d* was calculated to quantify the magnitude of differences in BND values between the groups. When the bladder was full, the mean difference was 7.35 mm (pooled standard deviation = 5.66 mm, Cohen's $d = 1.30$). When the bladder was empty, the mean difference was 5.87 mm (pooled standard deviation = 7.06 mm, Cohen's $d = 0.83$).

Power calculation. Using the calculated effect sizes, the power of the study was determined. When the bladder was full, the effect size (Cohen's *d*) was 1.30 (total sample size = 29, power = 99%). When the bladder was empty, the effect size (Cohen's *d*) was 0.83 (total sample size = 29, power = 85%).

In conclusion, the *post hoc* power analysis indicates that the present study had sufficient power to detect significant differences in BND values between parous female runners with and without SUI. When the bladder was full, the power was 99%, indicating a high likelihood of detecting a true effect. When the bladder was empty, the power was 85%, indicating a strong likelihood of detecting a true effect. These results confirm the robustness of the present findings, and suggest that the sample size was adequate for detecting significant associations between BND values and the severity of UI in female runners.

Discussion

Bladder neck descent values and stress urinary incontinence

The present study found a significant difference in BND values between the groups of parous female runners with and without SUI in both bladder volume conditions, i.e. full and empty ($P = 0.001$ and 0.022, respectively). Significantly increased BND values were measured in the SUI group for both conditions. These results are consistent with those of other studies (Li *et al.* 2017; Turkoglu *et al.* 2022) measuring BND values in the lithotomy position using the methodology offered by Dietz & Wilson (1998). Both Li *et al.* (2017) and Turkoglu *et al.* (2022) compared women with SUI to a continent group. The present study focuses specifically on parous female runners with SUI, a population who have been underrepresented in previous research, which has typically examined women with SUI across a range of sporting disciplines.

The present authors found a significant positive correlation between the measured BND values when the bladder was full and the total ICIQ-UI SF score, a subjective assessment of UI severity ($r = 0.415$, $P = 0.022$). Volløyhaug *et al.* (2017) explored the potential correlation between the subjective assessment of UI measured by the ICIQ-UI SF questionnaire, and an objective measure of BND values during pregnancy, and 1 and 4 years after birth. Their results 1 year after birth revealed a correlation between the total ICIQ-UI

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SF score and BND values ($r = 0.22$, $P = 0.01$). These results agree with the present findings, and provide further evidence of a correlation between these parameters. The present study identified this correlation among women who were examined at a variety of intervals since birth, whether 1 year after it or more. The relatively weaker correlation reported by Volløyhaug *et al.* (2017) compared to the present findings may be attributed to differences in sample characteristics: their study included primiparous women, whereas the present sample was comprised of multiparous women.

Methodological basis for bladder neck descent assessment

In the present study, BND was measured as the difference in bladder neck height between rest and a maximal Valsalva manoeuvre by using a horizontal reference line tangent to the inferior margin of the pubic symphysis, as initially described by Dietz & Wilson (1998).

Several reference lines have been proposed for BND measurement, each offering distinct advantages and limitations with regard to reproducibility, practicability and anatomical visibility. The German–Austrian–Swiss consensus (Tunn *et al.* 2005) explicitly recommends the central pubic line proposed by Schaer *et al.* (1995) for perineal ultrasound, emphasizing its geometric stability because of two-point fixation through the upper and lower cortices of the symphysis. This central line is considered to minimize the variability in measurements caused by unintended transducer rotation.

However, Tunn *et al.* (2005) acknowledged the validity of the inferior-edge horizontal reference line, the Dietz & Wilson (1998) approach, particularly in cases where full symphyseal visualization is challenging or unachievable.

Subsequently, Hennemann *et al.* (2014) introduced an alternative method that employed a reference line connecting two hyperechoic symphyseal contours. This approach combines geometric stability with enhanced visibility, thereby addressing a critical limitation of Schaer *et al.*'s (1995) technique. Nevertheless, Jamard *et al.* (2020) found that Dietz & Wilson's (1998) method offers excellent inter-observer reliability (ICC ≈ 0.98), and is technically simpler than angle- or vector-based measurement techniques. Since the inferior edge of the symphysis pubis remains visible even when the central symphyseal axis is difficult to identify, Jamard *et al.*'s (2020) review directly supports the Dietz & Wilson (1998) approach as the most practical and universally applicable standard for routine clinical BND assessment.

Considering the advantages and limitations of both Hennemann *et al.* (2014) and Dietz & Wilson's (1998) approaches, and supported by Jamard *et al.*'s (2020) review, the present authors selected the Dietz & Wilson's (1998) inferior-edge horizontal reference line for its superior visibility and ease of use in clinical settings. To ensure the reliability of their measurements, they calculated inter- and intra-rater reliability for BND assessment using ICCs. Consistent with the findings of Jamard *et al.* (2020), the present authors observed high intra- and inter-rater reliability (ICC ≈ 0.99, $P < 0.001$) across both bladder volume conditions, i.e. full and empty, reinforcing the robustness and clinical applicability of the chosen method.

Bladder volume during bladder neck descent measurement

There is a lack of uniformity in bladder volume in the literature on measuring BND. Li *et al.* (2017) measured BND values with an empty bladder volume of < 50 mL, while Turkoglu *et al.* (2022) used a bladder volume of 150–200 mL. These authors opted for a full bladder during the examination, and also ensured that the Valsalva manoeuvre would not be impeded by concerns about UI caused by anxiety. Dietz & Wilson (1999) showed that a full bladder is less mobile than an empty one, resulting in lower BND values and a reduced rotation angle. The present study measured BND values for a full bladder (> 100 mL) and an empty one after voiding (< 50 mL). Bladder neck descent values were significantly different between the groups with and without SUI in both cases, i.e. full and empty. Dietz & Wilson (1999) described a maximum bladder capacity of 355 mL (range = 125–470 mL) since volumes above 300 mL may lead to anxiety about experiencing UI during the Valsalva manoeuvre. Compared to Dietz & Wilson (1999), the participants in the present study had a full bladder volume of 100–300 mL.

Supine position of the bladder neck descent measurement

The present study conducted BND measurements in the supine position, while PFM dysfunction, such as SUI during running, occurred in the erect (standing) position. Lee *et al.*'s (2001) study showed no difference in BND values between the supine and standing positions.

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Dietz & Clarke (2001) demonstrated that the supine position was associated with higher values of BND than the standing position. According to their results, the elasticity and tissue compliance of the pelvic floor, which is probably affected by the subject's position, may influence the mobility of the bladder neck (Dietz & Clarke 2001). The present authors assumed that assessing the function of the pelvic floor in the supine position may not accurately reflect its behaviour during episodes of SUI while running. However, the present study does not provide insight into the specific mechanisms driving the changes in elasticity and tissue compliance. Therefore, further research is needed to understand this relationship better. Additionally, it is essential to remember that the participants were not examined during running, which may have a lasting effect on tissue elasticity and compliance, as shown by Bérubé & McLean's (2024) research.

Possible limitations

Some limitations are attributed to confounding factors that impaired visibility. The accuracy of measurements was sometimes challenging because of factors such as rectal fullness and undiagnosed pelvic floor prolapse.

Levator co-activation during a Valsalva manoeuvre might reduce pelvic organ descent. In the present study, the authors instructed women to perform the Valsalva manoeuvre correctly and to avoid co-activation. However, their assessment was only based on visual observation. Confirming the absence of co-activation would have required measuring levator ani hiatus displacement, which is defined as the distance from the pubic symphysis to the anorectal junction, both at rest and during a maximal Valsalva manoeuvre. However, this measurement was not conducted. The present authors recommend including it in future research. Moreover, further research into more-reliable BND values should consider excluding participants who cannot perform a Valsalva manoeuvre without levator ani co-activation. As previously discussed in the methodological basis for reference line selection in BND assessment, it is important to recognize the inherent subjectivity of this approach. Minor variations in probe angle or the interpretation of the symphysis pubis borders can affect reference line placement. Consistent transducer positioning between rest and the Valsalva manoeuvre is essential for reliable measurements. Additionally, variations in pelvic anatomy and the examiner's ultrasound experience may influence the accuracy of the results.

Another limitation was evaluating the BND values in the supine position rather than standing, which is the actual functional position during running. Future studies should consider measuring BND in both positions to capture a more comprehensive assessment.

The relatively small sample size ($n = 29$) may limit the generalizability of the findings. Although the power analysis indicated that the present study had sufficient power to detect significant differences, more-extensive research is needed to confirm these results and enhance external validity.

The study sample consisted of parous female runners, which may limit the applicability of the findings to nulliparous women or those engaged in different types of physical activities. Including a more-diverse sample in terms of parity and activity levels could enhance the generalizability of the results.

Conclusions

In the present study of parous female runners, those who experienced SUI had significantly higher BND values compared to those without SUI, both with a full bladder and an empty one.

The BND values measured during the Valsalva manoeuvre with a full bladder were significantly correlated with the total ICIQ-UI SF scores, indicating an association between the severity of UI and BND values for a full bladder.

The present findings emphasize the importance of adopting a comprehensive approach to understanding the complex aetiology of SUI. Incorporating objective assessments, such as sonographic BND measurements, can enhance the accuracy of pelvic floor evaluations. Furthermore, assessing BND values alongside PFM strength before and after interventions may provide clinically valuable insights.

Future studies involving more-extensive and diverse samples are needed to clarify the role of BND in the pathophysiology of SUI. Additionally, investigating the effect of high-impact activities such as running on soft-tissue properties, PFM functionality and BND values is warranted to deepen our understanding of this condition.

Authors' contributions

R. Dahan Cohen: primary researcher, conceived and designed the study, revised the article, and gave final approval for the submitted version. L. Tene: drafted and revised the article.

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M. Goldenberg: blind examiner, and drafted and revised the article.
L. Kalichman: conceived and designed the study, revised the article, and gave final approval for the submitted version.

Declaration of interest

None.

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