Is Pelvic Floor Dysfunction Associated With Development of Transient Low Back Pain During Prolonged Standing? A Protocol

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Melanie Dawn Bussey[1], Daniela Aldabe[2], Daniel Cury Ribeiro[2], Stéphanie Madill[3], Stephanie Woodley[2] and Niels Hammer[4]

[1]School of Physical Education, Sport & Exercise Science, University of Otago, Dunedin, New Zealand. [2]School of Physiotherapy, University of Otago, Dunedin, New Zealand. [3]School of Rehabilitation Science, University of Saskatchewan, Saskatoon, SK, Canada. [4]Department of Anatomy, University of Otago, Dunedin, New Zealand.

ABSTRACT

BACKGROUND: Prolonged standing has been associated with an increased prevalence of low back pain (LBP) and is recognized as a potential workplace hazard for employees such as retail staff, assembly line workers, and healthcare personnel. Low back pain is more prevalent in women than in men, and disability due to LBP is worse in women with severe urinary incontinence. However, it is unclear whether pelvic floor dysfunction observed in stress urinary incontinence is a risk factor for LBP. The main purpose of this study is to determine whether co-activation patterns between the pelvic floor and abdominal muscles during a 2-hour prolonged standing task predict transient LBP in women with and without stress urinary incontinence.

METHODS: In this is prospective cohort study, 60 female volunteers will stand in a confined area for 2 hours (120 minutes) while performing tasks such as, 'computer work' and 'small object assembly'. The primary outcome measure is transient LBP, which will be monitored every 10 minutes using a numeric pain rating scale. Surface electromyography (EMG) will be collected from the gluteus medius and internal oblique/transverse abdominis muscles, and an intravaginal electrode will be used to monitor pelvic floor muscle activity. The EMG signals will be divided into 12 10-minute blocks to assess changes in co-activation over time. Cross-correlation analyses will be used to quantify co-activation between the muscle pairs (e.g. pelvic floor and internal oblique/transverse abdominis), and the coefficient of co-activation will be expressed as a percentage for each block. A mixed-model regression analysis will be used to determine whether co-activation patterns can predict transient LBP during the prolonged standing task.

DISCUSSION: The primary objective of this research is to improve current understanding regarding the role of pelvic floor muscles in the onset of LBP and the potential association between stress urinary incontinence and LBP. These findings have the potential to inform prevention and rehabilitation programmes for women with stress urinary incontinence and LBP.

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CORRESPONDING AUTHOR: Melanie Dawn Bussey, School of Physical Education, Sport & Exercise Science, University of Otago, 55 Union Street West, Dunedin 9054, New Zealand. Email: melanie.bussey@otago.ac.nz

Background

Low back pain (LBP) is the most common, costly, and disabling musculoskeletal condition with a lifetime prevalence of up to 80%.[1] Low back pain is more prevalent in women than men with a mean prevalence ratio of 1.2:1.[2-5] Stress urinary incontinence (SUI) is also a common problem that disproportionately affects women,[6] with a mean prevalence of 23.6%.[7] Recent studies have highlighted an association between LBP and urinary incontinence (UI),[8-11] indicating that women with UI are more than twice as likely to experience frequent back pain as those without UI.[12] In addition, women with greater severity of UI also report an increased severity and greater disability related to their LBP.[13]

Standing for more than 30 minutes per hour has been identified as a significant hazard (hazard ratio: 1.9) for LBP in the workplace.[14] In female-dominant occupations such as retail, teaching, assembly line work, and healthcare, prolonged standing for greater than 2 hours, is a significant risk factor for LBP.[14-17] Recent research indicates that prolonged standing might also lead to transient LBP in workers without previous history of back injury.[18-20] Transient back pain by definition exists solely during the exposure time and dissipates quickly once the standing ceases. Yet, during 2-hour prolonged standing laboratory trials, the development of transient LBP was found to be a positive predictor (3.33 OR for 12-month follow up) for future long-term and recurrent LBP.[21,22] Although the mechanism for the development of transient LBP is not well understood, the musculoskeletal characteristic most commonly linked with LBP is aberrant muscle activity.[23-25] Increased bilateral co-activation of

the gluteus medius (GM) muscles has been specifically associated with transient LBP during prolonged standing trials.[19,26,27]

Insufficiency of the pelvic floor muscles (PFMs) is a significant factor in SUI,[28-30] which leads to involuntary urine loss during abrupt increases in intra-abdominal pressure (i.e. coughing, sneezing, lifting, or laughing).[31] Several PFM deficiencies have been identified in women with SUI, such as decreased tonic activity,[32] PMF weakness,[33] and delayed onset of PFM recruitment.[34] Pelvic floor muscle and abdominal muscle synergies are a potentially important mechanism to promote continence by resisting increased intra-abdominal pressure.[35] Furthermore, the muscles of the pelvic floor when acting synergistically with those of the abdominal cavity, particularly the transverse abdominis (TA) and internal oblique (IO), are also important to lumbo-pelvic function and spinal stability.[28,36-39] Co-activation of the PFMs and abdominal muscles contribute to increased spinal stability through spinal column stiffening and increasing the intra-abdominal pressure.[40,41] It is possible that deficiency in the PFM activity alters the neuromuscular connection between the PFMs and abdominal muscles resulting in a disturbed muscle synergy, a mechanism observed in pregnancy and postpartum women.[42] Putatively, this may be seen as a central nervous system (CNS) feedback mechanism to reduce intra-abdominal pressure in an attempt to maintain urinary continence; however, this mechanism may have a detrimental effect on lumbo-pelvic stability potentially increasing the risk for LBP in women with SUI. Partial support for this hypothesis comes from the works of Asavasopon et al[43] and Yani et al,[44] who identified common motor cortical areas associated with PFM and synergistic muscle activity in healthy participants.

The muscles of the pelvic floor are believed to play a duel role in lumbo-pelvic function.[28] The function of the PFMs in supporting continence is well known.[45,46] However, as they are also synergists with the abdominal muscles such as transverse abdominis, they may also play an important role in the mechanical function of the lumbo-pelvic complex.[36,47,48] It is reasonable to expect a relationship exists between PFM function, continence status and the development of LBP. The primary aim of this study is to determine whether co-activation patterns between the pelvic floor and abdominal muscles during a 2-hour prolonged standing task predict transient LBP in healthy women with and without SUI. The secondary aim is to determine whether transient LBP during prolonged standing is associated with changes in PFM activity and lumbo-pelvic stability after 2 hours of standing.

Methods

Experimental design

This is a prospective cohort laboratory design. All participants will provide written, informed consent before taking part in the study. Ethics approval (H18/009) has been granted by the University of Otago Human Ethics Committee (Health). This protocol has been developed in accordance with SPIRIT statement and guidelines.[49]

Sample size estimation

The sample size was estimated for multiple regression analysis, using Pass software (NCSS©, Kaysville, Utah, USA) considering 80% power, an effect size (f^2) of 0.212 attributable to three independent variables using an *F*-test with a significance level (alpha) of 0.05. The variables tested are adjusted for an additional two independent variables. The calculations assume an unconditional (random X's) model. Based on this, a minimum of 60 participants are required.

Participants

We will recruit a minimum of 60 participants, however, to ensure that our study sample is reflective of the population norm we plan to continue recruiting participants until we have at minimum sample proportion of 30% with stress UI symptoms.

Inclusion criteria. We will seek female participants over the age of 18 years who are free from LBP at the time of the study either with or without symptoms of SUI. All participants will be screened during initial phone interview for symptoms of SUI using the Questionnaire for Urinary Incontinence Diagnosis (QUID),[50] and if present, the severity will be examined with the Michigan Incontinence Symptom Index (M-ISI severity domain).[51]

Exclusion criteria. Participants will be excluded if they:

- Have experienced any form of spinal/back surgery or have had recent abdominal or pelvic surgery (<12 months);
- Have experienced any lifetime episode of LBP and/or pelvic girdle pain sufficient to cause >3 days of missed work/school/sport and to seek treatment from a registered health professional;
- Have urge or mixed UI as determined from the QUID questionnaire;
- Report a history of hip pathology that may cause pain with prolonged standing, including osteoarthritis, femoroacetabular impingement, and recent hip surgery (1 year);
- Are currently pregnant or within 6 months postpartum;
- Have been diagnosed with significant prolapse (Stage 2 or greater POP) or experience faecal incontinence;
- Are currently experiencing severe allergies (e.g. hay fever) or upper respiratory infections.

Equipment

Surface electromyography (EMG) will be collected from the TA/IO, GM, and PFMs, using a 16-channel wireless EMG (Ultimum-EMG, Noraxon USA Inc, Arizona, USA). For monitoring the PFMs, surface electrodes will be inserted into the vagina (Periform Intra-Vaginal Probe, Patterson Medical Ltd, Huthwaite,

Sutton-in-Ashfield, Nottinghamshire, England, UK). Raw EMG data will be sampled at 2000 Hz from electrodes adhered bilaterally as per international guidelines (SENIAM).[52] Surface sites for TA/IO and GM will be prepped by first shaving and lightly abrading the area to remove any dead or loose surface skin cells, then the site will be cleaned with alcohol swipes. Electromyography signals will be normalized in the following ways; the TA/IO will be normalized to crook lying bent leg raise,[53] the GM to side bridge[54] and PFM signals will be normalized to muscle activity elicited during maximal voluntary contraction (MVC).

A force platform sampling at 1000 Hz with amplifier gain of 4000 (AMTI, Watertown, MA, USA) will be used to record postural sway. This will be assessed via centre of pressure (CoP) displacement in the anterior-posterior and medio-olateral directions.

Experimental procedures

Demographic information will be collected including age, height, weight, number of prior pregnancies and births, and handedness. Participants will complete an assessment of general physical ability and fitness for the last 7 days with the International Physical Activity Questionnaire (IPAQ) and a Pain Beliefs Questionnaire.[55] Finally, assessment of lumbo-pelvic stability will be performed via the active straight leg raise (ASLR) test as per Mens et al.[56,57] Pelvic floor muscle EMG activity as well as the quality/ability of movement during the ASLR will be assessed for the evaluation of lumbo-pelvic stability. Quality of movement will be assessed using a six-point scale to rate the level of difficulty: 'not difficult at all = 0; minimally difficult = 1; somewhat difficult = 2; fairly difficult = 3; very difficult = 4; and unable to do = 5'. To examine the effect of the prolonged stand on lumbo-pelvic stability, the ASLR outcomes will be re-assessed at primary time point at the end of the 120 minutes.

Standing protocol. Participants will be positioned on a 0.50 m × 0.46 m force platform and instructed to stand in their usual manner for prolonged standing of 120-minute duration. They must stay within the confines of the force platform borders and may not rest limbs on the tray in front of them. Participants will be given a set of tasks similar to those performed in prolonged standing occupations, such as, small item assembly or 'computer work'.[58] Participants will be given the following set of instructions regarding their standing:

> Stand in your usual manner, if standing for an extended period of time. You cannot lean on the table surface. Your feet cannot leave the grey area (force plate) on the floor or overlap one another, but you may move and reposition your feet within the grey surface.

Once collection starts there will be no opportunity for breaks; therefore, participants will be instructed to go to the bathroom if they require before data collection begins. This protocol has been established as a valid tool for predicting risk for long-term LBP in apparently healthy populations.[22,26]

Outcome measures

Primary outcome measure. Pain scores will be used as the primary outcome and measured with a 11-point numerical pain rating scale (NPRS) with end-points of 0 "no-pain" (far left) to 10 "worst pain imaginable" (far right). The NPRS has good construct and predictive validity as a measure of pain intensity.[59-61] Pain scores during the stand will be normalized against baseline and scored as a continuous variable.

Secondary outcome measure. The secondary outcome measure will be pain outcome as assessed at the end of the primary time point (120 minutes) and represented as a dichotomous variable: pain-developer versus non-pain-developer. A change in NPRS score of 2 points or greater is considered a significant change in pain[62]; thus, participants with scores increasing by 2 or more will be considered as pain-developers and those with scores less than 2 will be considered as non-pain-developers.

Time points

The study schedule of enrolment, interventions, and assessments is presented in Table 1. Outcome measures will be assessed at the following time points. *Baseline*, defined as the time before the start of the experimental protocol. *Follow-up* blocks, defined as 12 10-minute blocks occurring between the start of the experimental protocol (time = 0) and the end of the experimental protocol (time = 120 minutes). *Primary time point*, the end of the experimental protocol (time = 120 minutes). At *baseline*, we will assess pain using NPRS, demographic information (including physical fitness, pain beliefs, and UI severity questionnaires) and ASLR. During each of the *follow-up* blocks, we will assess the muscle co-activation and NPRS for primary outcome measure. At the *primary time point*, we will assess final NPRS to be used as the secondary outcome and ASLR.

Predictor variables

Muscle co-activation. We will assess co-activation between the PFMs and the TA/IO and the co-activation between the right and left GM muscles as predictors for the primary outcome variable (continuous NPRS score). Cross-correlation analyses will be used to quantify co-activation between the identified muscle pairs.[58] For each block, the normalized cross-correlation values R_{xy} will be calculated between the EMG signals using equation (1). $R_{xy}(\tau)$ is the normalized cross-correlation of the two muscle signals $x(t)$ and $y(t)$ at a phase shift τ having a value between +1 and −1. The mean cross-correlation value (R_{xy}), across all phase shifts, is calculated for each 10-minute block

Table 1. Schedule of enrolment, interventions, and assessments for prolonged standing protocol.

	ENROLMENT	BASELINE	FOLLOW-UP										PRIMARY TIME POINT	CLOSE OUT
Time point	$-t_1$	0	t_{10}	t_{20}	t_{30}	t_{40}	t_{50}	t_{60}	t_{70}	t_{80}	t_{90}	t_{100}	t_{110}	t_{120}	t_{end}
Enrolment															
Eligibility screening Exclusion criteria	x														
QUID questionnaire	x														
Informed consent	x														
INTERVENTION															
Prolonged stand			x	x	x	x	x	x	x	x	x	x	x	x	
Computer or small item task			x	x	x	x	x	x	x	x	x	x	x	x	
ASSESSMENTS															
M-ISI questionnaire		x													
Measurement of height/weight		x													
IPAQ questionnaire		x													
Pain Beliefs questionnaire		x													
Pain-developer/non-developer[a]															x
Numerical pain rating (NPRS)[b]		x	x	x	x	x	x	x	x	x	x	x	x	x	
ASLR (lumbo-pelvic stability)		x													x
PFM muscle activity		x													x
Muscle co-activation		x	x	x	x	x	x	x	x	x	x	x	x	x	x

Abbreviations: QUID, questionnaire for urinary incontinence diagnosis; M-ISI, Michigan Incontinence Symptom Index; IPAQ, International Physical Activity Questionnaire; ASLR, active straight leg raise; PFM, pelvic floor muscle.
[a]Secondary outcome measure.
[b]Primary outcome measure.

$$R_{xy}(\tau) = \frac{1}{T}\int_0^T \frac{x(t)\,y(t+\tau)\,dt}{\sqrt{Rxx(0)\,Ryy(0)}} \quad (1)$$

This analysis will yield three co-activation coefficients; Right_PFM-TA/IO, Left_PFM-TA/IO, and Left_GM-Right_GM.

Pelvic floor activity during ASLR. Change in lumbo-pelvic stability related to the prolonged stand will be assessed via differences in PFM activity from baseline ASLR assessment to the end of the primary time point ASLR assessment. Change in PFM activity will be used as a predictor for the secondary outcome measure and pain development. To allow appropriate trial-to-trial comparison of ASLR activity, the height of the limb lift will be standardized using an ultrasonic sensor. The ultrasonic sensor (SICK AG© Industrial Sensors, Germany model UM30-13113) has an analogue output for measuring the scanning distance with a resolution of 0.36 mm and accuracy of ⩽2% for limiting scanning distance (Sick, 2006). The sensor emits an auditory beep as soon as the participants attain the threshold height of 10 cm off the floor and the feedback signal sounds for as long as the threshold height is maintained. The EMG integral ($PFM_{integral}$) will be calculated for 3 seconds during the isometric portion of the ASLR task. To allow for trial-to-trial comparisons, the $PFM_{integral}$ will be normalized to the MVC task. The variable will be stored as a continuous variable $\Delta PFM_{integral}$ (equation (2))

$$\Delta\int \mathbf{PFM} = \int_{\mathbf{baseline}} \mathbf{PFM} - \int_{\mathbf{Endpoint}} \mathbf{PFM} \quad (2)$$

PFM onset latency. Muscle onset latency will be assessed to determine if there is a change in motor control of the PFM that is predictive of pain development during prolonged standing. The timing of the PFM activation onset during the endpoint ASLR will be detected via computer algorithm as per Hodges and Bui.[63] Muscle onset is detected at the start of a 50-ms window during which the mean activity is greater than 2.5 SD more than the average EMG signal for the rest period.[63] The time of PFM onset will be normalized to the initiation of heel lift during the ASLR. The data will be stored as a continuous variable PFM_{onset}.

Michigan Incontinence Symptom Index. The baseline assessment of severity of UI symptoms scored from the Severity Domain of the questionnaire. This score will be recorded as a continuous variable and will be included as a covariate for the primary outcome measure and as a predictor for the secondary outcome measure.

Data processing and analysis

All questionnaire and demographic data, including the NPRS, will be collected using an electronic database (i.e. the participant will enter data directly) and verified as complete by the researcher before the participant leaves the laboratory. All data will be stored on a computer hard-drive and backed up on a second external drive. Raw EMG signals will be collected in LabChart (ADInstruments Pty Ltd, Bella Vista, NSW, Australia) and exported to MATLAB for postprocessing. The EMG signals will be divided into 12 10-minute blocks to assess changes in co-activation over time.[58] All EMG signals are processed using purpose written MATLAB scripts (version 2013b). Any electrical noise (50 Hz) will be removed with a 49.5 to 50.5 Hz band stop filter (fourth-order, dual-pass, zero-lag Butterworth filter). Low- and high-frequency noise is removed with a 10 to 500 Hz band pass filter (fourth-order, dual-pass, zero-lag Butterworth filter).[64] The signals are then full wave rectified and filtered through a 6 Hz low-pass filter (fourth-order, dual-pass, zero-lag Butterworth filter) to create a linear envelope.[65]

Statistical analysis

The statistical analysis will be undertaken with *R* (Version 2.15.3, R core team, 2012). Demographic data (age, body mass index (BMI), parity, activity level, and Pain beliefs scores) will be assessed for comparisons between pain-developers and non-pain-developers using independent *t*-tests. The primary analysis will consist of mixed regression models to test the association between pain scores (the primary outcome and continuous variable) and predictors: (1) mean co-activation coefficient between PFM and TA/IO (Left-Right_PFM-TA/IO); (2) mean co-activation coefficient between Left and Right GM; and (3) time, with M-ISI UI score as a covariate. If required, the model may be adjusted for up to two demographic factors that may be revealed as significant in the independent *t*-tests comparing pain-developers with non-pain-developers.

A secondary analysis will include a logistic regression model to examine the association between pain event during the stand (pain-developer vs non-pain-developer) with a potential change in lumbo-pelvic stability with three predictors: (1) change in PFM activity during the ASLR test from baseline to primary time point ($\Delta PFM_{integral}$); 2) muscle onset latency during endpoint ASLR (PFM_{onset}); and 3) M-ISI UI score.

Discussion

The primary objective of this research is to elucidate significant predictors of LBP related to PFM function during prolonged standing. Findings from this study can potentially improve work-related outcome for women presenting with PFM dysfunction.

Issues related to study design

Prospective study outcomes are considered high-level (Level II) evidence. However, large sample sizes are typically required, and they are prone to selection bias. Attrition bias is one problem with prospective studies due to the length of

the follow-up period. We do not expect this to be a problem in our protocol due to the limited nature of the exposure time and confines of the laboratory setting. Another possible issue is the potential of systematic sample bias. While every precaution will be taken by way of exclusionary criteria to ensure sample homogeneity, there could be an underlying covariate within the population which may be associated with the outcome but is unknown to us at the start of the study. Therefore, we have allowed within the statistical design two possible adjustment factors which may arise from the analysis of the demographic data comparing pain-developers with non-pain-developers.

The strength and power of the statistical analysis is dependent on the incidence of LBP reported in the sample. Sample size was determined in part based on previous studies using the prolonged standing protocol to elicit transient LBP symptoms in healthy populations. These studies reported LBP incidence ranging from 39% to 70% in the exposed populations.[19,22,66,67] We expect our population incidence to be similar although we cannot be certain of these outcomes.

We are proposing the use of surface EMG for examining muscle activity in this study. Surface electrode placement for the IO muscle has been shown to have considerable crosstalk with the TA, which limits our ability to differentiate specific muscle fibre action from each of these muscle tissues independently.[68] In the case of this study, we are examining the effect of synergistic muscle action. Therefore, we are making an assumption that there will be some level of the co-activation of the TA and IO muscles that will be reflected in the activity measured using the described electrode placement. Depending on the findings of this study, future work may seek to separate the synergistic action of these two muscles.

Author Contributions

MDB was responsible for the design of the study and is the guarantor. SM, DCR, DA, SW, and NH provided guidance on the design and analysis planned for this study. MDB led efforts for securing funding, with the contributions from DA and DCR. All authors had input into revision of the manuscript for important content and approved the final version.

Availability of Data and Material

Final data used for statistical analysis will be made available on the Open Science Framework.

Data Availability

Final data will be made available on the Open Science Framework.

Ethical Approval and Consent to Participate

This study was approved by the University of Otago Ethics Committee (reference no.: H18/009). All participants will sign an informed consent prior to taking part in the study.

ORCID iD

Melanie Dawn Bussey https://orcid.org/0000-0002-5746-3861

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