Certain Voicing Tasks Improve Balance in Postpartum Women Compared With Nulliparous Women

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ABSTRACT

Background: Postpartum women are at an increased risk of falls. Maintaining standing balance is multifactorial, involving abdominal wall/pelvic floor muscle responsivity, quick generation of intra-abdominal pressure, and glottis position.
Objective: To identify whether using voicing tasks improves balance in postpartum women.
Study Design: Research report.
Methods: Eleven postpartum women and 10 age-matched nulliparous controls stood on a force plate when balance was perturbed to the front or back of their bodies while performing 6 different breathing and voicing tasks. Tasks modified glottis position and lung volume. Primary outcome measure was maximal displacement of center of pressure immediately following perturbation.
Results: When comparing the 2 groups' responses, postpartum women showed worse balance during the "Ah" sound and "normal exhale without breath hold" (P = .049 and P = .031, respectively). When comparing all responses to each task, participants in both groups showed no significantly different response to any tasks when they were perturbed anteriorly. The nulliparous group also had no significantly different responses when perturbed posteriorly. Postpartum women showed a significant difference in response to "normal exhale without breath hold" compared with "counting" (P = .01), with better balance for "counting."
Conclusion: Postpartum women showed improved balance during the "counting" task, which incorporates the glottis into the balance mechanism. Tasks that did not incorporate the glottis (exhalation) and relied more on the abdominal wall/pelvic floor produced worse balance in postpartum women. For recently postpartum women, counting may be a helpful strategy to improve balance and reduce fall risk.
Key Words: counting, standing balance, voicing strategy, women's health

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INTRODUCTION

Falls can be especially dangerous for postpartum women who may be multitasking or carrying an infant.[1,2] Preventing falls by maintaining standing balance in all populations is complex and multifactorial with mechanical, neurologic, vestibular, and visual inputs all playing a role.[3,4] In the postpartum population, less pelvic floor and abdominal muscle stiffness limits the efficacy of one key mechanical strategy—generating intra-abdominal pressure (IAP), and may then require relying on other mechanisms more heavily to aid in supporting balance.[5,6]

Mechanical factors that contribute to maintaining standing balance are complex and include trunk muscle activation and modulation of trunk pressures.[6,7] These 2 factors work in close relationship to each other as trunk muscle activation changes both stiffness and volume of the trunk, which modulates pressure.[8] The trunk functionally acts as one continuous pressure canister with a valve at the top (the glottis, or the space between the vocal folds), a valve at the bottom (the pelvic floor muscles), and the diaphragm in the middle.[9–11] The diaphragm divides the trunk into 2 cavities that are highly interdependent, the abdominal cavity and the thoracic cavity, and serves as the major pressure regulator in the body by constantly changing position between these 2 cavities. The glottis acts as a valve between the lungs and the mouth.[9] Glottis position affects trunk pressure and therefore balance.[6,12] When the glottis is fully open (breathing), pressure is not being modulated by the glottis.[9] When the glottis is closed (breath hold, swallowing), it helps contain or generate pressure.[12,13] When the vocal folds vibrate close together (voicing), they slow and resist the release of pressure through the glottis and can aid in pressure modulation and possibly abdominal muscle recruitment.[12,14,15]

The structures in the trunk coordinate to regulate pressures; the pelvic floor muscles and the larynx coordinate with the diaphragm in a phase-locked pattern where all 3 descend on inhalation and ascend on exhalation.[10,16,17] To support the pelvic organs and accommodate changes in IAP, the deep pelvic floor muscles work with the anterior abdominal wall.[10,18] There is also an anticipatory activation of the abdominal muscles that is associated with maintaining quiet stance.[19] Certain tasks require a stronger balance response, and quick generation of IAP via muscular contraction is a key component of maintaining standing balance after perturbations or trunk loading.[6,20] Another component found to contribute to balance in response to perturbations is glottis position, which is another mechanism that regulates intrathoracic-abdominal pressure.[21–23] To generate IAP, sufficient stiffness and resistance in the abdominal and pelvic floor muscles are needed.[6,24] During pregnancy and delivery, the pelvic floor and anterior abdominal muscles become significantly stretched, losing their stiffness temporarily, and postpartum women, even 12 months postpartum, have increased inter-rectus distance, smaller rectus abdominus muscle thickness and cross-sectional area, and a reduced capacity to generate IAP as compared with nonrecently pregnant women, which may set them up for poorer balance responses.[5,25–27]

To better understand strategies that can improve balance in the postpartum population, and potentially in the future, others with stretched and/or weakened abdominal and pelvic floor muscles, it is useful to investigate glottal contributions to balance in this population. By comparing responses to perturbations under various glottal conditions (closed, open, vibrating) in postpartum and nulliparous women, we may identify whether using a glottal strategy can improve balance in these women. Our hypothesis is that for all subjects, leveraging glottis position will affect balance response to perturbations, specifically that balance response will be better when the glottis is either closed or vibrating as compared with open. Leveraging glottis position for balance will be referred to as a "glottal strategy." Secondarily, comparing postpartum and nulliparous women, we hypothesize the postpartum group will have worse balance response (displacement) across all tasks but particularly for the open-airway tasks. Within the postpartum group, we also hypothesize a better balance response (less displacement) when the glottis is vibrating during voicing or closed, as opposed to open during breathing, which may reduce glottal contribution to balance, potentially placing more stabilizing demand on the abdominal muscles.

MATERIALS AND METHODS

Participants

Participants were recruited form Pennsylvania State University (faculty, students, and staff). Eleven women were between 3 and 12 months postpartum, and 10 nulliparous, healthy, age-matched women served as the control group. Exclusion criteria included recent back pain/problems in the previous 3 months, vocal or respiratory problems in the previous 3 months, or a pacemaker. The study was approved by the Pennsylvania State University Institutional Review Board, and informed written consent was obtained from each participant before participating in the study.

Procedure

The procedure was adapted from the initial study by Massery et al.[23] The original study by Massery et al measured horizontal linear displacement of the thorax, center-of-pressure (CoP) displacement, electromyography of the external oblique and erector spinae muscles, and IAP at the time of perturbation onset. Because of equipment limitations, our study was limited to CoP as the primary outcome measure of balance response. Participants stood on a force plate inside an aluminum frame (Figure 1). A semi-rigid chest harness was secured to the participant's chest with Velcro straps. Cables were attached to the chest harness anteriorly and posteriorly at the level of the xiphoid process and connected via pulleys to electromagnets. Cable weights were adjusted to maintain cables parallel to the ground. Weights (~3% of bodyweight) were attached to the electromagnets and could be dropped with a button set up at a workstation 15 ft away. These weights caused a gentle perturbation, similar to getting bumped in a crowd but not too much to knock participants over, making them step forward or backward on the force plate; weights were adjusted if participants had to step out of the fall after perturbation.[23] The subjects could not identify which weight (anterior or posterior) would be dropped. Weight was adjusted slightly to ensure sufficient perturbation without causing the participant to step forward/backward when the weight was dropped. When the anterior weight was dropped, the

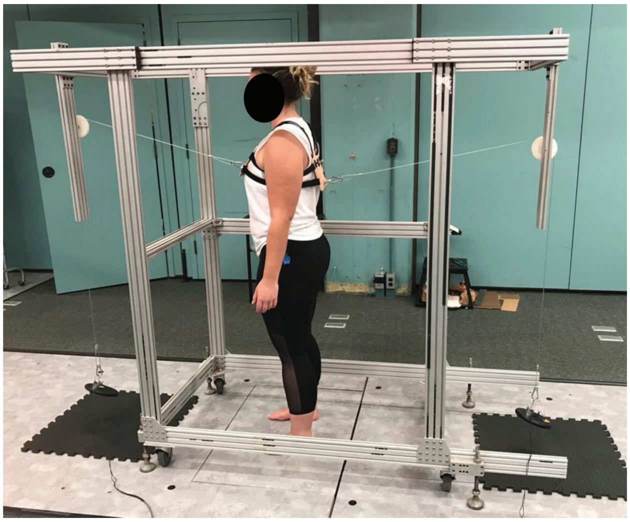

Figure 1. Standing frame with weights suspended in front and back of the subject. The subject standing on force plate. For the study, pulley height was adjusted so the cable from harness was parallel to the ground, not demonstrated in this photograph. This figure is available in color online (https://journals.lww.com/jwhpt).

posterior weight then perturbed the participant backward, and vice versa.

Standing balance was perturbed under 6 different airway conditions (Table 1), which were adapted from the original study of Massery et al. One condition (sigh) was not carried over from the original study due to differences in cuing, which were identified after data collection was complete. For each condition, there were 10 perturbations (5 to the front and 5 to the back). The order of the tasks and perturbations was randomized between participants, and participants were also blind to which direction they would be perturbed for each trial. Participants had up to 4 trials to familiarize themselves with the balance perturbations before beginning data collection and were instructed to quickly return to standing balance. For the analysis, we used the averages of the 5 trials in each direction for each task.

Outcomes Measures

Ground reaction forces were recorded at 4000 Hz with a force plate (model 9287; Kistler Instrument Corp, Winterthur, Switzerland) and used to calculate the CoP displacement (in millimeters) in the anterior and posterior directions. Motion analysis data for the weights dropping were collected at 100 Hz with Eagle EGT-500RT cameras using the Cortex 7 software (Motion Analysis Corporation, Santa Rosa, California).

Data Analysis

The primary outcome measure of postural stability was peak amplitude of CoP displacement (ground reaction force) in response to the perturbations. Data were exported for processing to Matlab (MathWorks, Natick, Massachusetts). Baseline CoP was determined by averaging the CoP for the 50 milliseconds prior to perturbation. Peak amplitude of the displacement after perturbation was identified automatically using custom software. Data were expressed as the maximal displacement for each subject across all conditions.

Statistical analyses were performed with R (R Core Team; 2020). To test the hypothesis that the postpartum group will have greater balance disruption during the glottis open (breathing) tasks than the nulliparous group, we used one-sided independent *t* tests comparing the 2 groups' changes of CoP for each condition. To test the hypothesis that balance will be less disturbed during glottis vibrating or closed (voicing and breath hold, respectively) tasks than open (breathing) tasks, a repeated-measures, one-way analysis of variance (ANOVA) was used to compare responses across conditions separately for each group with Tukey's HSD post hoc test. Significance was set at $P \leq .05$.

RESULTS

The age range of participants was 24 to 37 years. Of postpartum women, 10 had vaginal deliveries and 1 had a cesarean delivery. The average number of

Table 1. Tasks for Each Condition Under Which Balance Was Perturbed[a]

Task	Condition	Glottis Position	Pressure Flow
1. Max-Insp-Hold	Maximum inhalation plus breath hold	Closed/adducted[b]	Full trunk pressure maintained
2. Ah	"Ah" voicing	Vibrating/adducted	Trunk pressure reducing during the task
3. Normal-Breathing	Natural breathing	Open/abducted	In/out
4. Count	Counting out loud at normal speaking volume	Vibrating/adducted	Trunk pressure reducing during the task
5. Norm-Exp-Hold	Normal exhalation plus breath hold	Closed/adducted[b]	Low trunk pressure maintained
6. Norm-Exp-No-Hold	Normal exhalation plus airway open (no breath hold)	Open/abducted	Low pressure in the trunk

[a]Glottis positions gleaned from voice mechanical studies.[12–15]
[b]Small studies have shown inconsistent complete glottal closure on breath hold, while others have shown more consistent closure. Without a camera, it is impossible to know with certainty the glottis position on breath hold, but it is functionally closed.[37,38]

Table 2. Unadjusted Values for One-Sided *t* Tests Comparing Mean Displacement for the Nulliparous and Postpartum Groups for Each Task

Task	Anterior Weight/Posterior Perturbation			Posterior Weight/Anterior Perturbation		
	Average Absolute Displacement Postpartum, mm	Average Absolute Displacement Nulliparous, mm	P[a]	Average Absolute Displacement Postpartum, mm	Average Absolute Displacement Nulliparous, mm	P
1. Max-Insp-Hold	64.74	60.30	.168	76.85	77.99	.591
2. Ah	64.90	57.58	**.049**	76.72	83.45	.846
3. Normal-Breathing	68.45	62.99	.133	76.26	76.31	.503
4. Count	63.32	60.79	.329	75.26	76.15	.586
5. Norm-Exp-Hold	67.02	61.57	.151	79.82	78.22	.383
6. Norm-Exp-No-Hold	72.10	60.97	**.031**	75.91	76.40	.537

Abbreviations: Ah, "Ah" voicing; Count, counting out loud at normal speaking volume; Max-Insp-Hold, maximum inhalation plus breath hold; Normal-Breathing, natural breathing; Norm-Exp-Hold, normal exhalation plus breath hold; Norm-Exp-No-Hold, normal exhalation plus airway open (no breath hold).
[a]The bold values are statistically significant.

weeks postpartum at the time of participation was 32.6 (range, 15-42 weeks).

For all conditions where the posterior weight was dropped (subjects perturbed anteriorly), there were no significant differences between the nulliparous and postpartum groups for any tasks (Tables 2-4); therefore, the remainder of the results being reported will be exclusively for when the anterior weight was dropped (posterior perturbation). One-sided independent *t* tests to compare the balance displacement between the postpartum and nulliparous groups for each condition showed significantly greater perturbation responses for postpartum women for "Ah" and "Norm-Exp-No-Hold" (P = .049 and P = .031, respectively) (Figure 2). These results were unadjusted. For both of these tasks, the postpartum group showed greater displacement and variability in their response to the anterior weight drop. One subject in the postpartum group had a strong influence on the analysis and if she were to be removed from group,

Table 3. Analysis of Variance Results for Postpartum Women Differences in Absolute Displacement Between Tasks

Tasks	Difference	Lower Bound	Upper Bound	Adjusted P[a]
(Count)-(Ah)	−1.59	−9.04	5.86	.99
(Max-Insp-Hold)-(Ah)	−0.17	−7.62	7.28	1.00
(Norm-Exp-Hold)-(Ah)	2.12	−5.34	9.57	.96
(Norm-Exp-No-Hold)-(Ah)	7.20	−0.25	14.65	.06
(Normal-Breathing)-(Ah)	3.54	−3.91	11.00	.72
(Max-Insp-Hold)-(Count)	1.42	−6.03	8.88	.99
(Norm-Exp-Hold)-(Count)	3.71	−3.75	11.16	.68
(Norm-Exp-No-Hold)-(Count)	8.79	1.34	16.24	**.01**
(Normal-Breathing)-(Count)	5.13	−2.32	12.59	.33
(Norm-Exp-Hold)-(Max-Insp-Hold)	2.28	−5.17	9.74	.94
(Norm-Exp-No-Hold)-(Max-Insp-Hold)	7.37	−0.08	14.82	**.05**
(Normal-Breathing)-(Max-Insp-Hold)	3.71	−3.74	11.16	.68
(Norm-Exp-No-Hold)-(Norm-Exp-Hold)	5.08	−2.37	12.54	.35
(Normal-Breathing)-(Norm-Exp-Hold)	1.43	−6.03	8.88	.99
(Normal-Breathing)-(Norm-Exp-No-Hold)	−3.66	−11.11	3.80	.69

Abbreviations: Ah, "Ah" voicing; Count, counting out loud at normal speaking volume; Max-Insp-Hold, maximum inhalation plus breath hold; Normal-Breathing, natural breathing; Norm-Exp-Hold, normal exhalation plus breath hold; Norm-Exp-No-Hold, normal exhalation plus airway open (no breath hold).
[a]The bold values are statistically significant.

Table 4. Analysis of Variance Results for Nulliparous Women Differences in Absolute Displacement Between Tasks

Tasks	Difference	Lower Bound	Upper Bound	Adjusted *P*
(Count)-(Ah)	3.21	−3.61	10.03	.73
(Max-Insp-Hold)-(Ah)	2.72	−4.10	9.54	.84
(Norm-Exp-Hold)-(Ah)	4.00	−2.82	10.82	.51
(Norm-Exp-No-Hold)-(Ah)	3.39	−3.43	10.21	.68
(Normal-Breathing)-(Ah)	5.41	−1.41	12.23	.19
(Max-Insp-Hold)-(Count)	−0.49	−7.31	6.33	1.00
(Norm-Exp-Hold)-(Count)	0.79	−6.03	7.61	1.00
(Norm-Exp-No-Hold)-(Count)	0.18	−6.64	7.00	1.00
(Normal-Breathing)-(Count)	2.20	−4.62	9.02	.93
(Norm-Exp-Hold)-(Max-Insp-Hold)	1.28	−5.54	8.10	.99
(Norm-Exp-No-Hold)-(Max-Insp-Hold)	0.67	−6.15	7.49	1.00
(Normal-Breathing)-(Max-Insp-Hold)	2.69	−4.13	9.51	.85
(Norm-Exp-No-Hold)-(Norm-Exp-Hold)	−0.60	−7.42	6.21	1.00
(Normal-Breathing)-(Norm-Exp-Hold)	1.41	−5.41	8.23	.99
(Normal-Breathing)-(Norm-Exp-No-Hold)	2.02	−4.80	8.84	.95

Abbreviations: Ah, "Ah" voicing; Count, counting out loud at normal speaking volume; Max-Insp-Hold, maximum inhalation plus breath hold; Normal-Breathing, natural breathing; Norm-Exp-Hold, normal exhalation plus breath hold; Norm-Exp-No-Hold, normal exhalation plus airway open (no breath hold).

the following conditions would significantly be different: "Ah," "Normal-Breathing," and "Norm-Exp-No-Hold" (P = .013, P = .045, and P = .011, respectively). However, the subject's observations were not removed from consideration and they are included in all analyses.

The results of the repeated-measures, one-way ANOVA comparing variability of the postpartum

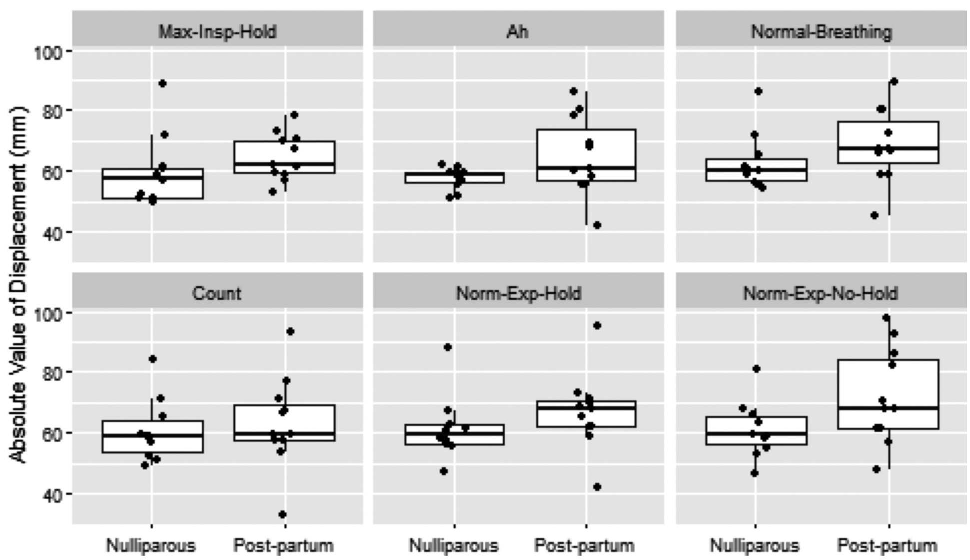

Figure 2. Average displacement (mm) for both the nulliparous and postpartum groups when the anterior weight was dropped for each task. Boxes show the middle 50% of observations, with the thick horizontal line representing the median. Dots represent participant averages. Max-Insp-Hold indicates maximum inhalation plus breath hold; Ah, "Ah" voicing; Normal-Breathing, natural breathing; Count, counting out loud at normal speaking volume; Norm-Exp-Hold, normal exhalation plus breath hold; Norm-Exp-No-Hold, normal exhalation plus airway open (no breath hold).

group's response (including the outlier) with all conditions showed a statistically significant difference of responses between 2 of the 6 tasks: "counting" and "Norm-Exp-No-Hold" ($P = .01$), after accounting for person-to-person differences. There were no significant differences in response to the different tasks for the nulliparous group (Figure 3A). Better balance was observed during counting, and the greatest perturbation response was observed during normal exhalation with no breath hold (glottis open) (Figure 3B).

A power analysis was not performed prior to data collection. An analysis performed post hoc revealed that power was 0.52 and 0.61 for tasks 2 and 6 (Ah and Norm-Exp-No-Hold). For tasks 1 through 6, power was 0.25, 0.52, 0.29, 0.11, 0.27, and 0.61, respectively. To achieve 80% power, the following sample sizes were needed for tasks 1 to 6: 65, 22, 50, 326, 59, and 17, respectively. Given that this study was underpowered, we were unable to detect certain effects that a larger sample may have demonstrated.

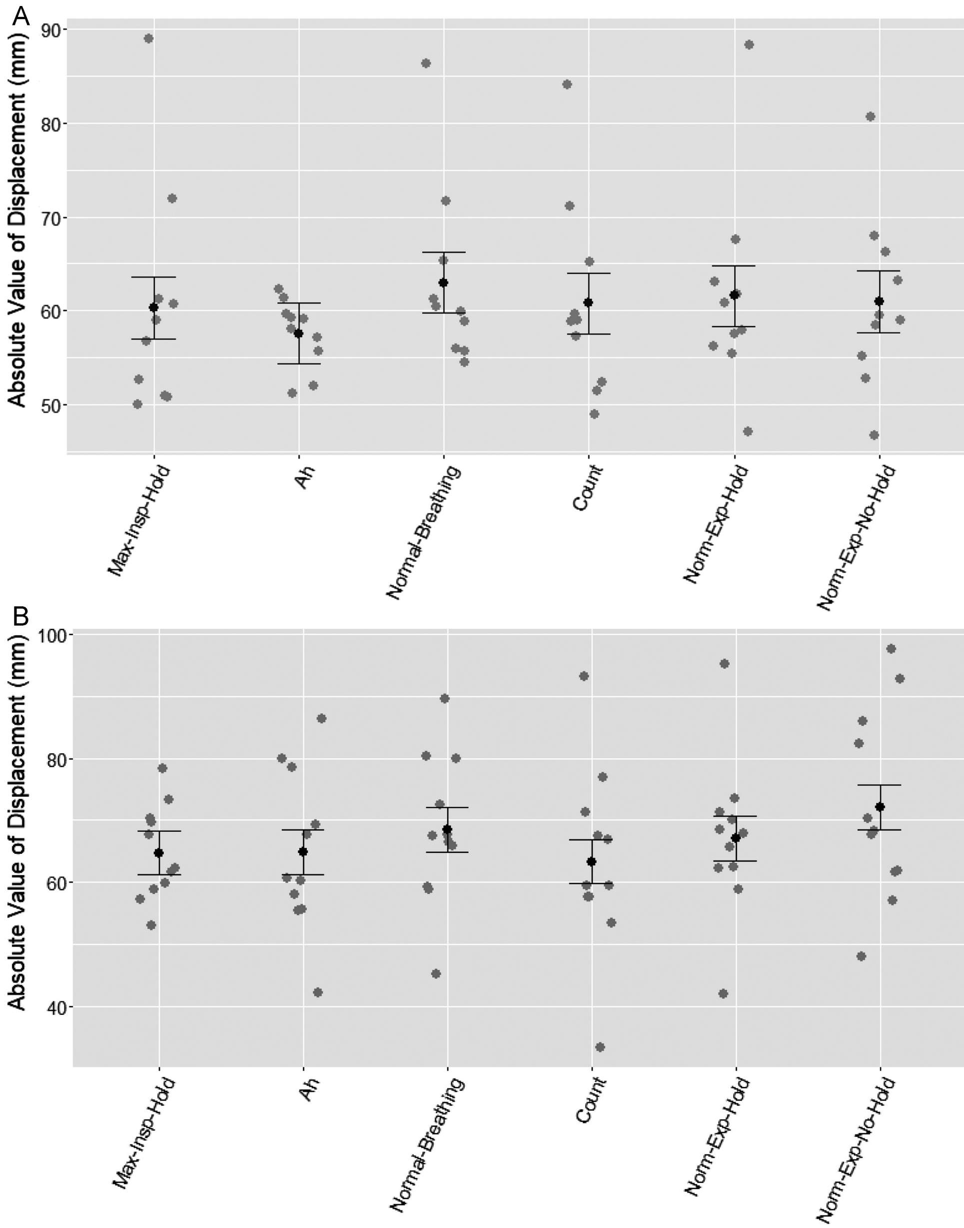

Figure 3. (A) Individual (average) displacement by task for the nulliparous group. (B) Individual (average) displacement by task for the postpartum group. Black dots represent mean displacement for each task, with 95% confidence bounds shown. Max-Insp-Hold indicates maximum inhalation plus breath hold; Ah, "Ah" voicing; Normal-Breathing, natural breathing; Count, counting out loud at normal speaking volume; Norm-Exp-Hold, normal exhalation plus breath hold; Norm-Exp-No-Hold, normal exhalation plus airway open (no breath hold).

DISCUSSION

The evidence is limited directly identifying the risk postpartum women face with falls; however, early research has identified quick, early contraction of the transversus abdominal muscle as a critical component of generating spinal stiffness in response to balance perturbations.[28] Because of the limited capacity in postpartum women to generate stiffness in their abdominal muscles,[5,25–27] the transitive property suggests that these women would be at a greater risk of balance disturbance in response to perturbations. This study is built on the previous work by Massery et al, which initially found the glottis to have a role in standing balance.[23] Because of the role that vocal folds vibration plays in controlling the release of pressure through the glottis, we considered voicing tasks to incorporate a glottal strategy for balance. The abdominal/pelvic floor strategy is dominant in aiding with trunk pressure generation and modulation when the glottis is fully open, and both are involved during a breath hold when the glottis is fully closed.[29] Postpartum women have dramatic changes to the stiffness of their pelvic floor and abdominal muscles, making it more difficult to quickly generate or modulate IAP for stabilizing standing balance.[5,24,27] This study identifies the differences between a glottis-dominant strategy (voicing) and an abdominal/pelvic floor–dominant strategy (breathing) in response to balance perturbations. Ideally, these strategies work together to support balance; however, for postpartum women who may not be able to fully employ the abdominal/pelvic floor strategy, the glottal strategy (voicing) may compensate, which is a convenient and easy tool to incorporate into exercise both in a clinical setting or in a home setting for this population.

Our primary hypothesis built on the findings in the original study of Massery et al, which found that balance was better when the glottis was vibrating than fully open or fully closed.[23] Because of a small sample size and limited statically significant results, our findings may not be generalizable to all postpartum women. We hypothesized that all subjects in our study would follow a similar pattern of better balance during *voicing* compared with the *breath hold*, *no breath hold*, and *natural breathing* tasks. In our study, this pattern was only seen in the postpartum group; the nulliparous group showed no effect of glottis position for balance response to different tasks, as perhaps, the perturbations were not strong enough for the nulliparous women in our study. We interpret this finding as the glottis (voicing) serving as a compensatory strategy for stretched and/or weakened abdominals because the effect of glottis position on balance was only seen in postpartum women. This is consistent with other studies that have linked leveraging glottis position and function for balance, including using a breath hold to balance on tiptoes during an overhead reaching task.[30] The secondary hypothesis was that when comparing the 2 groups, postpartum women would generally have worse balance, with greater balance deficits during the tasks where the glottis maintained an open position (as in "natural breathing" or "no breath hold"), compared with the nulliparous women. We presumed, if this hypothesis was accepted, that removing the glottis from the balance strategy (keeping the glottis open for breathing) would eliminate a balance component and place more demand on the abdominals, which may contribute to worse balance in postpartum women. This did occur when balance was perturbed posteriorly only, the postpartum group responded worse than the nulliparous group, with greater deficits during the "Ah" voicing and "normal expiration without breath hold" conditions. We also posit that tasks with less pressure in the trunk (exhale) and glottis fully open (vs fully closed) are likely to provide even less balance support from a pressure regulation standpoint and will require even more abdominal and pelvic floor responsivity to stabilize balance. This is consistent with Lamberg and Hagins'[30] findings that showed inhalation prior to tiptoe balance tasks, breath hold during balance task, and exhalation following task while lower from toes. This was evident in the postpartum group, which showed a near statistically significant difference in response to "maximum inspiration + breath hold" compared with "normal exhale without breath hold."

The similarities and differences of the 2 groups' responses to directional perturbations demonstrate the contribution of the pelvic floor/anterior abdominal wall strategy. For the anterior perturbation, both groups performed similarly to each other and for all tasks. The differences in the two groups' responses to perturbations only emerged in the posterior direction. We suspect this is related to the pattern of muscle response that is different for an anterior versus posterior perturbation. Anterior perturbations engage the plantar flexors, as well as hip and trunk extensors, to stabilize the trunk, whereas the anterior abdominal wall is more important in response to posterior perturbations.[31] While not statistically significant for each condition, the postpartum group did show greater displacement for all posterior perturbations than the nulliparous group, with significant differences emerging for several glottal conditions. In future studies, greater refinement of the balance challenge may ascertain the differences between the postpartum and nulliparous groups.

For the posterior perturbation, the postpartum group showed greater balance displacement during the "Ah" voicing and "normal expiration without breath hold." The "Ah" voicing task is considered to be a glottal strategy, and we had expected this task to show less balance disruption for both groups.[30] We were surprised by the finding that the postpartum group did significantly worse on this task than the nulliparous group. The "normal expiration without breath hold" condition would be expected to be worse in the postpartum group as the glottis cannot contribute to balance, thus putting more demand on the abdominal wall/pelvic floor. This finding supports our hypothesis. When removing the one outlier from the postpartum group, the rest of the group also shows worse balance than the nulliparous group during normal breathing, which maintains an open glottis position, again increasing dependency on the abdominal wall/pelvic floor. A larger subject group may have improved the power of the results and should be considered in future studies.

When comparing how participants responded to each of the tasks, there was no difference in balance response between tasks for the nulliparous group. This finding was in contrast to the initial study, which found tasks with the glottis fully open were worse than tasks where the glottis was vibrating.[23] Perhaps, the perturbations were not strong enough to elicit a sufficient balance response in this study, and this study did not include a large lung volume, glottal open condition. This is consistent, however, with what was seen in the postpartum group, which showed the best balance during "counting" and the worst balance during "normal exhalation without breath hold." Also, when postpartum women did "max inhale with closed glottis," they were better able to stabilize than when they were doing "normal exhale with open glottis," which is consistent with the previous study by Massery et al as well showing that the glottis closed position stabilized balance better than when open.

Regarding vocal folds vibration, the "Ah" task did not seem to improve balance; however, "counting" did show a stabilizing effect on the postpartum group only and may be further explored as a balance strategy to utilize in those with poor muscle tone in the pelvic floor and abdominal muscles. This finding further supports the interdependency of the glottis, trunk muscles, and pelvic floor to regulate balance and suggests that "counting" (voicing) may aid in stabilizing balance in postpartum women. Perhaps, "Ah" voicing, which is not rote and demands cognitive effort, versus counting, which is rote, may have delayed the body's effective balance response due to novelty.[32] This finding would be consistent with a previous balance study, which showed cognitive challenges increased postural sway response to balance.[33]

Comparing the response to counting versus breathing tasks where the glottis is open, a contributing factor to improved balance may also be the mechanical muscular engagement. To generate enough intrathoracic pressure to make sound for counting, the abdominal muscles must engage, and it may be that the counting strategy is demanding enough from a pressure standpoint to actually facilitate mechanical muscular stabilization. Postpartum women may not be able to adequately recruit abdominal and pelvic floor muscle activation during breathing for optimal balance response due to changes in mechanical properties of the anterior abdominal wall postpartum.[27] Speaking modulates the pressure release through the trunk by overcoming the resistance of adducted vocal folds, which slows trunk pressure release.[34] Thoracic pressure is released quickly when the glottis is fully open (opened valve).[35] *This may be an important strategy to actually generate IAP in the absence of sufficient abdominal muscle tone and stiffness to create IAP*. In postpartum women, who have worse balance than non–postpartum women, this may be a more appropriate stabilizing strategy.[36] Most likely, the mechanism is a combination of these strategies where counting activates the abdominal wall/pelvic floor to help generate, maintain, and modulate IAP to improve balance in the postpartum group. Future research should explore whether utilizing voicing strategies can either compensate for weak pelvic floor and abdominal muscles or help facilitate muscle activation in the early postpartum stages, after abdominal surgery, or in any situation where people have weakness and poor facilitation of these muscles or difficulty generating IAP.

Limitations

While we were measuring balance response to perturbations, we did not perform a standardized balance test prior to the study, nor did we test abdominal muscle strength or other musculoskeletal factors such as ankle mobility or posture. While we may theorize reasons for our findings as related to changes in muscle activation, stiffness, and pressure modulation, this study did not include actual measurements of these outcomes and future research should incorporate electromyography, elastography, and IAP measurements. We did not include a large lung volume with glottis open condition in our study compared with the previous study of Massery et al, which found the largest group difference in response to this task. Our study also had a small sample size and generalizability may be limited. More research with larger groups and varied populations is warranted to research this relationship.

CONCLUSIONS

This study examines different balance strategies to determine whether it is possible to leverage a glottal strategy (voicing) to improve balance in postpartum women with recent stretch-induced changes to abdominal and pelvic floor muscles from pregnancy.[27] The findings in this study suggest that postpartum women with mechanical changes to their abdominal walls have worse balance responses when their glottis is open as compared with nulliparous controls. Counting, which engages the vocal folds in resisting expiratory airflow, showed improved balance in the postpartum population and may be a useful clinical tool to incorporate into balance training in this population.

SUMMARY

Balance is multifactorial; those with insufficiencies in one strategy may rely more heavily on another strategy. In postpartum women, balance response was best with counting, which uses the glottis to help modulate pressure, and worst with normal exhale, which does not utilize the glottis to modulate pressure. In nulliparous women, balance response was not affected by glottis position. The implication for postpartum women is that counting may be a good strategy to improve balance.

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