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Pressure biofeedback unit to assess and train lumbopelvic stability in supine individuals with chronic low back pain

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Abstract. [Purpose] To determine if pressure biofeedback unit readings are related to abdominal muscle activation and centre of pressure displacement as well as to test the effects of using it as a biofeedback tool to control lumbopelvic motion. [Participants and Methods] Eighteen volunteers with chronic nonspecific low back pain (21.28 ± 1.41 years old) who performed an active straight leg raising (dynamic postural challenge) with and without pressure biofeedback. Changes in the pressure biofeedback unit and on centre of pressure displacement were assessed, as well as bilateral electromyographic abdominal muscle activity. Participants were not allowed to use a Valsalva manoeuvre. [Results] Pressure variation was not significantly correlated with abdominal muscle activity or with mediolateral centre of pressure displacement. When used as a biofeedback instrument, there was a significant increase in almost all abdominal muscles activity as well as a significant decrease in pressure variation and in mediolateral centre of pressure displacement while performing an active straight leg raising with a normal breathing pattern. [Conclusion] Despite not being an indicator of abdominal muscle activity or mediolateral load transfer in the supine position, the pressure biofeedback unit could have great relevance when used in the clinic for biofeedback purposes in individuals with low back pain.
Key words: Active straight leg raising, Lumbopelvic instability, Lumbopelvic pain

INTRODUCTION

Low back pain has been associated with motor control dysfunction in the area. Indicators of this dysfunction include decreased contraction of the transversus abdominis and multifidus muscles[1] coincident with reduced thickness of the transversus at rest and during contraction[2], reduced cross-sectional area of the multifidus[3] and fat infiltration[4]. An association with altered muscle recruitment patterns[5] and transversus abdominis activation delay[6] was also found, as well as increased back muscle fatigue[7] and altered kinematic patterns in the hips and lumbar area[8].

Considering these indicators and taking into account the Panjabi spinal stabilization model[9] it can be assumed that both the active and neural subsystems are directly affected which in turn leads to stress in the passive system[1, 9].

This lack of stabilization may be clinically detected using an active straight leg raising (ASLR) test, as the inability to control lumbar rotation and the mediolateral load transfer (centre of pressure displacement in the same direction) are indicators of instability in this region[10–13].

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In order to reduce lumbar spine instability and therefore diminish pain, several studies have suggested segmental stabilization training, involving a range of exercises from local segmental control exercises to open-chain segmental control exercises[1, 14]. Given the difficulty of perceiving an isolated contraction of the transversus abdominis required for the local segmental control exercises, biofeedback strategies using electromyography and ultrasound imaging have been used. However, because these strategies are difficult to apply in many clinical environments, the use of a pressure biofeedback unit (PBU) has been suggested. This instrument consists of a non-elastic air bladder that when placed between the supporting surface and the lumbar spine, allows detection of pressure fluctuations inherent to movements in that region[1, 15].

The PBU is by nature a biofeedback instrument and most of the scientific evidence is directed for assessing transversus abdominis muscle function in a prone position[16–19]. The relation between this instrument and the transversus abdominis has also been tested in a supine position by Grooms et al.[15] using ultrasound imaging, employing a selective contraction of this muscle (the drawing-in manoeuvre). Yet this study found no relation between them, indicating the need for a more demanding task.

Another clinical use for the PBU is to help train lumbopelvic stability in individuals with chronic low back pain during open-chain segmental control exercises. In a supine position, the objective is to help individuals maintain lumbopelvic neutral position while motor control is challenged by active movements of the upper or lower limbs[1, 20].

The immediate effect of biofeedback on abdominal muscle activity and pelvic rotation was only observed by Noh et al.[21] during an active straight leg raising test in women with low back pain. Although not the focus of the investigation, they observed that using a PBU for biofeedback lead to a decrease in pelvic rotation with no significant changes in abdominal muscle activity. However no PBU data was collected to see how much pressure variation differed from performing with and without PBU biofeedback, as well as to test if a relation between PBU and abdominal muscle activity exists.

Therefore, the aim of the current study was to evaluate during a dynamic postural challenge with the lower limb (active straight leg raising) without biofeedback, if the PBU can be an indicator of abdominal muscle activity and mediolateral centre of pressure displacement (lumbopelvic stability indicators), and also to investigate the ability of the PBU to be used as a biofeedback tool to control lumbopelvic motion in individuals with chronic low back pain.

PARTICIPANTS AND METHODS

Individuals from 18 to 30 years of age, with chronic nonspecific low back pain were recruited from Campus University. Chronic nonspecific low back pain was defined as pain and discomfort, localized below the costal margin and above the inferior gluteal folds, persisting for at least 12 weeks, that is not attributable to a recognizable, known specific pathology (e.g. infection, tumour, osteoporosis, fracture, structural deformity, inflammatory disorder, radicular or cauda equina syndrome)[22]. A positive ASLR test was also considered an inclusion criterion. An ASLR test was deemed to be positive when the ASLR score (0–not difficult at all; 1–minimally difficult; 2–somewhat difficult; 3–fairly difficult; 4–very difficult; 5–unable to do) reduced with the addition of manual pelvic compression[23, 24]. Exclusion criteria were lumbar, abdominal, or gynaecological surgery in the past year; disc herniation or spinal fracture; irradiated pain to the leg; neurological and respiratory pathologies; pregnancy or postpartum (<6 months); body mass index (BMI) >25, as well as any other condition that would interfere with the ability to perform data collection[11, 18, 23]. Participants who experienced pain during the ASLR were excluded or rescheduled to prevent bias, since that pain could induce motor control changes different from the ones attributed to pain chronicity.

All evaluations were performed at the Center for Rehabilitation Research, Center of Human Movement and Activity in School. The study was approved by the university ethical review committee (approval no.: 0846), and each participant supplied signed informed consent according to the Declaration of Helsinki.

Thus, from 34 volunteers with low back pain, 18 individuals (14 females and 4 males) met the participation criteria. Sample size was determined using G*Power (3.1.9.2; Heinrich Heine Universität Düsseldorf, DE) based on a pilot study with 6 individuals, with the objective being the ability to decrease mediolateral centre of pressure (COP) displacement (an indicator of lumbopelvic stability) with the PBU as a biofeedback strategy. With an effect size of 0.762, α=0.05, and a power of 0.80, the total sample size needed for that objective was 16 participants. Therefore, all individuals who meet the selection criteria were included in the study and their mean age, height, weight, BMI, and numeric pain rating scale were 21.28 ± 1.4 years, 1.65 ± 0.1 cm, 58.78 ± 6.9 kg, 21.66 ± 1.7 kg/m^2 and 3.78 ± 1.1, respectively.

Electromyographic signal (EMG) was collected using a portable electromyographer (biosignals Researcher; PLUX Wireless biosignals SA, Portugal) with a sampling frequency of 1,000 Hz. Skin impedance was verified by an impedance checker (Noraxon USA Inc., Scottsdale, AZ, USA). The external oblique (EO), rectus abdominis (RA), and transversus abdominis/internal oblique (TrA/IO) were assessed from both sides, with the electrode locations halfway between the iliac crest and the ribs at a slightly oblique angle; 2 cm lateral to the umbilicus, over the muscle mass; and 2 cm medially and below to the anterior superior iliac spine[25–27], respectively. Two digital filters with infinite impulse response were used: a 30 Hz high-pass Butterworth 2nd order filter for cardiac signal removal and a 20–450 Hz band-pass Butterworth 2nd order filter for electrical noise and/or cable movements. Root mean square (RMS) with 10 samples was also performed[28, 29].

Mediolateral COP displacement (COPml) of the pelvis was evaluated through a force plate (FP4060-10; Bertec Corp, Columbus, OH USA) with a sampling rate of 100 Hz. A 7 Hz digital infinite impulse response filter −low-pass 2nd order Butterworth was applied to remove electrical noise and/or cable movements[28].

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A PBU (Stabilizer; Chattanooga Group Inc., Hixson, TN, USA) was adapted and connected to the electromyographer. Due to its placement under the lumbar spine, it can detect changes in lumbopelvic motion. A synchronization cable connected the electromyographer and the force plate.

Participants were directed into a supine position with the pelvis over the force plate and their hands resting over their chest to avoid contact with the force plate. The PBU was placed under the lumbar spine (above the posterior superior iliac spines), with a pressure of 40 mm Hg[15]. Participants performed an ASLR, which consisted of raising the dominant leg 20 cm in height with the knee extended and maintained that position for 6 s. The 20 cm height was controlled by a metal bar placed over the ankle. During the task, a typical ventilatory pattern was requested to avoid a Valsalva manoeuvre.

The ASLR was then performed with pressure biofeedback. The instrument display was positioned right in front of the participant, and they were asked to perform an ASLR while trying to maintain the pressure steady at 40 mmHg. A training period was allowed until they were able to perform the task with pressure disturbances bellow 5 mmHg, and without using the Valsalva manoeuvre. If a disturbance of more than 5 mmHg was detected, the procedure was repeated.

The order was not randomized to ensure that the normal ASLR was not influenced by the strategies adopted in the ALSR with biofeedback. Each movement was repeated 3 times with a 30 s rest period and 1 minute to rest between the normal ALSR and the ALSR with biofeedback.

Participants also had to raise both legs simultaneously to a 20 cm height with the knees extended and hold them for 6 s (submaximal activity) for EMG normalization. If pain was triggered and did not pass immediately when returned to a resting position, the subject was assessed, treated, and excluded from the study.

Data analysis was performed in a 3-s interval during the isometric phase with the ankle 20 cm above the ground (maintenance phase). This period started 3 s after the initial change on the ground reaction force vertical component, which corresponded to a stabilization period of this component. A 2-s interval at the resting position was also analysed to calculate mediolateral COP displacement (COPml) and PBU variations. These variables were calculated as the mean difference between the rest and the maintenance phases, being expressed in millimetres (mm) and millimetres of mercury (mmHg), respectively.

Muscle activation intensity was considered as the average RMS followed by its normalization to the average of three submaximal activity trials (RMS average), expressed as a percentage. Final data consisted of the average of the 3 trials.

Statistical analysis was performed using IBM SPSS Statistics (version 21.0; IBM Corp., Armonk, NY, USA), with 0.05 as a significance level. A Pearson correlation test was used to identify correlations between instruments, and a paired t-test to compare ASLR with and without pressure biofeedback. Mean and standard deviation were used as descriptive statistics[30].

RESULTS

Pressure variation detected by PBU was not significantly correlated with abdominal muscle activity and with mediolateral COP displacement ($p > 0.05$).

When ASLR was performed with a biofeedback strategy, there was a significant increase in all abdominal muscle activity ($p < 0.05$), with the exception of TrA/IO, which despite increasing its muscle activity, did not reach statistical significance ($p = 0.068$). Also, a significant decrease in COPml ($p < 0.001$) as well as PBU variation ($p < 0.001$) was observed (Table 1).

Table 1. Comparison of muscle activities (%) between active straight leg raise (ASLR) with and without pressure biofeedback unit (PBU) biofeedback

	ASLR	ASLR with biofeedback
	Mean ± SD	Mean ± SD
Contralateral		
EO*	15.95 ± 10.22	25.12 ± 18.7
RA*	11.39 ± 6.82	16.48 ± 7.71
TrA/IO	18.49 ± 16.72	36.85 ± 49.87
Ipsilateral		
EO*	21.71 ± 15.51	26.11 ± 18.25
RA*	13.08 ± 7.22	18.38 ± 6.87
TrA/IO*	57.59 ± 16.28	69.09 ± 26.06
COPml (mm)*	19.24 ± 5.75	14.06 ± 4.18
PBU (mm Hg)*	2.52 ± 1.94	0.10 ± 1.64

*Significant difference ($p < 0.05$).
COPml: mediolateral centre of pressure displacement; EO: external oblique; RA: rectus abdominis; TrA/IO: transversus abdominis/internal oblique; SD: Standard Deviation.

DISCUSSION

Assuming that both abdominal muscle activity and mediolateral COP displacement during ASLR are key points for lumbopelvic stability[9, 10, 31], the lack of correlations between them and the PBU variations could indicate that this is not a valid instrument to indicate lumbopelvic stability in individuals with low back pain. These results are supported by Grooms et al.[15] who found no association between PBU pressure and transversus abdominis activation (through ultrasound imaging) in a supine hook-lying position when performing a drawing-in manoeuvre. They mentioned the possibility that the drawing-in manoeuvre might not have been sufficiently demanding to test this relationship. Therefore, taking into account that an ASLR could be considered a more demanding task as it imposes a challenge to the lumbopelvic region, it is correct to conclude that this relation may not exist in a supine position. The absent correlation between PBU and mediolateral COP displacement could indicate that this instrument might be more appropriate for detecting changes in the sagittal plane, such as variations on lumbar lordosis or on pelvic tilt, rather than changes on mediolateral COP displacement, which could be interpreted as a surrogate variable for pelvic rotation or mediolateral load transfer[10].

However, this device in a clinical context is used mainly as a biofeedback instrument[1] rather than a way to measure muscle activity and COP displacement. In that manner, when used as biofeedback during an ASLR, an increase in all abdominal muscle activity and a decrease in mediolateral COP displacement were observed, which could be interpreted as an increase in lumbopelvic stability[9, 10, 31]. These two results may actually be connected, because it is possible that an increase in muscle activation could better counterbalance the torque imparted by the limb and prevent pelvic motion[32]. Also, the fact that all abdominal muscles increased their activation may reinforce the idea that lumbopelvic stabilization is achieved through synergy between local and global muscles. Local muscles are more responsible for individual spinal segment stabilization and global muscles have better mechanical advantage for exerting control over lumbopelvic axial rotation in the transverse plane during active straight-leg raise[1, 32, 33].

Similar results were found by Noh et al.[21] during an ASLR with a PBU as a biofeedback tool. They observed a decrease in pelvic rotation but, unlike the present study, found no significant increases in abdominal muscle activity to support the decreased pelvic rotation, describing just a slight increase in average muscle activation. The differences in the muscle activity results could be related to different EMG normalization methods; however, the values were quite similar in almost every muscle at baseline. Another possible reason could be related to the magnitude of PBU variation during biofeedback, which was not collected in this study. Hypothetically, to achieve a smaller PBU variation during an ASLR with biofeedback, a greater muscular activation would be needed. The abdominal muscle activity increase together with a pelvic rotation reduction was found also during ASLR in a research conducted by Park et al.[32], but instead of controlling pelvic motion with a PBU as biofeedback, they used the pelvic control method that uses a self-biofeedback scheme by palpating and controlling the position of the anterior iliac spines. Despite similar effects on lumbopelvic stability, the comparison between the two methods will need to be conducted in a future study since different outcomes were used.

Despite the adequate sample size to detect the effect of using the PBU as a biofeedback strategy, a bigger and more heterogeneous sample could have strengthened the correlation between PBU, abdominal muscle activity, and mediolateral COP displacement. As such, it is important to understand that these findings may not be generalized to individuals with low back pain who do not meet the selection criteria. A kinematic analysis should also be added for a better understanding of the relationship between the kinetic and kinematic variables, especially the pelvic tilt motion. A more equal proportion of males and females would also improve the study. Future research may study the effect of a therapeutic exercise intervention on individuals with low back pain with and without a PBU as a biofeedback strategy.

In conclusion, despite not being an indicator of abdominal muscle activity or mediolateral load transfer in this position, clinicians should consider using this instrument for biofeedback purposes to increase abdominal muscle activity and reduce COP displacement when performing an activity like an ASLR in individuals with low back pain.

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