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The immediate effect of two lumbar stabilization methods on postural control parameters and their reliability during two balance tasks

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ABSTRACT

Background: Lumbosacral orthosis (LSO) and/or the isolated contraction of the transversus abdominis muscle by the abdominal drawing-in maneuver (ADIM) can increase lumbar stiffness, consequently influencing postural control. The purpose of this study was to compare the effects of LSO and ADIM on postural control during two balance tasks and determine their reliability.

Methods: Twenty participants (50% men) randomly performed three experimental conditions: 1) without lumbar stabilization, 2) with LSO), and 3) with ADIM. Each experimental condition was tested in two postural tasks: semi-tandem and one-legged stance on a force platform for 30 seconds, while the Center of pressure postural (COP) parameters were computed.

Results: The two methods of lumbar stabilization were comparable and did not significantly reduce the COP values across time, even though a few individuals presented a change in their COP data above the levels of measurement errors. The reliability of these measurements was generally acceptable and sometimes excellent ($\geq$ 0.90 and ≤10% error measurement).

Conclusions: Both LSO and isolated contraction of the transversus abdominis muscle by ADIM do not change postural control in one-legged stance and in semi-tandem tasks. These results have implications for use or not these methods for postural control on a rehabilitation perspective.

KEYWORDS
Postural control; low back pain; lumbar stabilization; rehabilitation

Introduction

Inadequate lumbar stability is hypothesized as a potential mechanism explaining low back pain (LBP) and disability [1], especially when the spine is in a neutral posture where passive stiffness contributions are minimal. Muscle fatigue or other challenges to trunk muscle coordination can further result in brief uncontrolled intervertebral movements and consequently, lumbar spine instability and back pain [2]. In fact, trunk/spine in parallel to neural control (representing various sensorimotor pathways) work together to ensure stable spine behavior during several daily activities, with or without external load/perturbation [3]. However, there is difficulty to precisely measure intervertebral motion during dynamic activities, which makes the measure of spine stability very challenging [4].

Postural control tasks might thus represent an alternative for indirect measures of spine stability, as balance and spine stability share the same motor control mechanisms [5]. Postural control has been shown to be impaired in participants with LBP, while standing upright on two legs [6,7], one-legged stance [8,9], as well as when sitting on an unstable 'wobbling' chair [10,11]. Poor balance in chronic LBP people (young and older) can be linked to back muscle fatigue, lower proprioception, delayed reflex responses or anticipatory postural adjustments [12–14]. Interestingly, balance deficits in this clinical population are more easily observed in more challenging balance conditions (ex: unstable support surface, one-legged stance, or sitting on a more unstable chair) than simple conditions (ex: standing with two legs) [9,15,16].

From a rehabilitation perspective, the use of a lumbosacral orthosis (LSO) as well as the co-activation of the abdominal muscles, by transversus abdominis (TrA) contraction during the abdominal drawing-in maneuver (ADIM), could help increasing lumbar stiffness and consequently, may influence postural control [17,18]. This might be explained by an improved lumbar proprioception with LSO, which in turn reduces lumbar motions and trunk external moments affecting balance in standing with two legs

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[18]. It would be of interest to know if these findings can be extended for the first time to other challenging standing tasks such as one-legged and semi-tandem stances [9]. Most specifically, the TrA muscle also plays an important role in anticipatory postural adjustments and spine stability, which may in turn enhance postural control [19]. However, a degraded balance performance was observed with abdominal co-contraction during unstable sitting [4], which might be different during standing as the spine is more neutral and consequently more dependent on trunk muscle coordination [20]. It must be interesting generalize these results for balance tasks as one-legged stance, which are closer to activities of daily living (e.g. step walking, turning, climbing stairs and dressing), and determine the reliability of this set of postural control measures using Center of pressure parameters (COP) during different experimental conditions (ex: LSO vs. TrA by ADIM).

The main objective of the present study was thus to compare the immediate effects of LSO (passive method) and ADIM (active method) on postural control measures during two postural tasks (semi-tandem and one-legged stance). A secondary objective was to determine the test-retest reliability of postural control measures as assessed during these challenging tasks.

Methods

Research design

This is a cross-sectional study, using a repeated measures design to test for test-retest reliability.

Participants

Twenty [20] healthy students and local workers (50% women) aged from 20 to 45 years, with no prior history of functional impairment related to neurological, musculoskeletal, vestibular disorders and ankle, knee and hip injuries in the past two years participated in the experiment on a voluntary basis. The specific characteristics of participants are presented in Table 1. This sample size was estimated by a recent study [17], using the Center of Pressure (COP) velocity findings with LSO (0.79 ± 0.11°/s COP velocity) and without LSO (0.94 ± 0.18°/s), considering a confidence interval of 95%, an alpha of 0.05 and an 80% test power. Participants gave their informed consent to participate in the experiment in accordance with the Declaration of Helsinki and the local research ethics committee.

Experimental procedures

Trained evaluators carried out all the procedures in the present study. Anthropometric measures were taken during the first session and the Baecke questionnaire [21] was self-administered by each participant to collect information regarding their level of physical activity at work and in leisure time. A training session was performed to solicit the TrA muscle using the abdominal drawing-in maneuver (ADIM) at a sub-maximal effort before balance testing [22]. A Sonosite M-MSK ultrasound machine (Washington, USA) with a 13–-6 MHz linear transducer with B-mode imaging was used to show/validate the contraction during the training session. During activation of the TrA muscle, the ultrasound was placed horizontally on the left side, halfway between the iliac crest and the lower part of the person’s ribcage, approximately 10 cm from the anterior midline [23]. The transducer’s positioning was adjusted to locate the myofascial medial junction on the sonogram image and to differentiate between the abdominal transverse and internal oblique muscles, allowing the evaluator to see the change in the length (lateral slide) of the transverse abdominal muscle [23]. However, we did not compute quantitively these numerical changes in the muscle length, but used an observational clinical and visual approach of contraction of each individual from screen image (Figure 1). In parallel, the participants were instructed to hold the ADIM submaximal effort for 15 seconds simulating a 3–5/10 (weak-moderate) effort according to the BORG CR-10 Scale, without holding their breath. The Borg CR-10 scale and rating of 3/10 were also chosen to standardize the contraction during postural control tests (i.e. without ultrasound imaging feedback).

For passive stabilization using LSO, a large-sized elastic sacrolumbar Formedica belt with two Velcro flaps was used for all participants during the study (Figure 1). The LSO was positioned by the evaluator in a standing position, under the clothing, arms at a 90-degree abduction angle and then tightened using the Velcro flaps until the maximum tolerable tension was reached, i.e. without perceiving pelvic belt-related pain or discomfort in the standing position. During each lumbar stabilization intervention, participants performed the following postural

Table 1. Characteristics of the study sample.

	Men (n = 10)	Women (n = 10)	Total (n = 20)
Age (years)	29 (6)	29 (7)	29 (6)
Weight (kg)	76 (6)	65 (8)	71 (9)
Height (cm)	173 (5)	164 (7)	169 (8)
BMI (kg/m^2)	25 (2)	24 (2)	25 (2)
Circumference ratio (waist/hip)	0.87 (0.05)	0.82 (0.05)	0.85 (0.05)
Baecke index			
Overall	8 (1)	8 (1)	8 (1)
Work	2 (1)	2 (0.5)	2 (1)
Sports	3 (1)	3 (0.6)	3 (0.7)
Leisure	3 (2)	2 (0.6)	3 (1.5)
Anxiolytic or antidepressants medication			
Absolute frequency	1/10	2/10	3/20
Relative frequency	10%	20%	15%

Data expressed as mean (standard deviation).

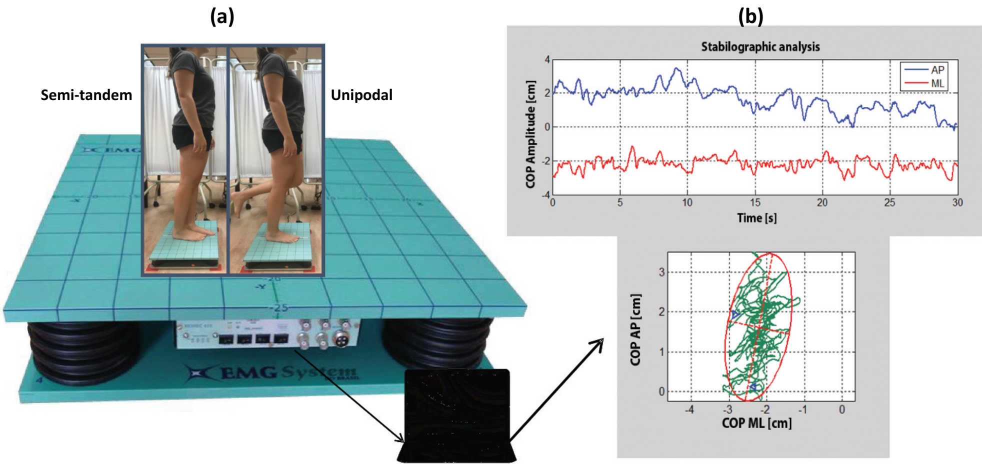

Figure 1. Lumbar stabilization methods: (a) subject with and without isolated contraction of the transversus (TrA) muscle by the abdominal drawing-in maneuver (ADIM), including ultrasonography (US); (b) lumbosacral orthosis (LSO) and their position in a typical subject.

control assessment on the force platform (BIOMEC 400, EMG system do Brasil, Ltda) under three randomized experimental conditions: 1) control (without stabilization), 2) passive lumbar stabilization with a (LSO and 3) TrA activation using the drawing-in maneuver (ADIM).

Postural control tasks consisted in holding two different positions (random order) with open eyes on the force platform (Figure 2): (i) semi-tandem, with the preferred leg in front and (ii) one-legged stance, with the preferred leg on the ground [9]. The preferred leg (commonly named dominant leg) was defined as the leg the participant chooses to kick a ball, or hop or step up [24,25]. The feet (in semi-tandem) and the foot (in one-legged stance) were placed according to similar precise marks on the platform in order to limit the variability in the positioning of the feet between the participants [26] during the whole postural measures (i.e. including conditions, trials and sessions). Each balance task was executed twice for 30 s (2 trials), and the mean was retained for subsequent analysis. Thirty seconds of recovery between trials and 2 minutes of recovery between conditions (Control vs LSO vs ADIM) were established to avoid peripheral and central fatigue [27]. All participants remained seated in a chair during the recovery periods between trials and between conditions for each balance task during both sessions. To estimate test-retest reliability, all participants were asked to return to the laboratory one week later to take the same measurements as the first session. Each session lasted approximately 60 minutes.

COP data processing

The COP-based postural parameters were computed with the use of a validated BIOMEC 400 force platform

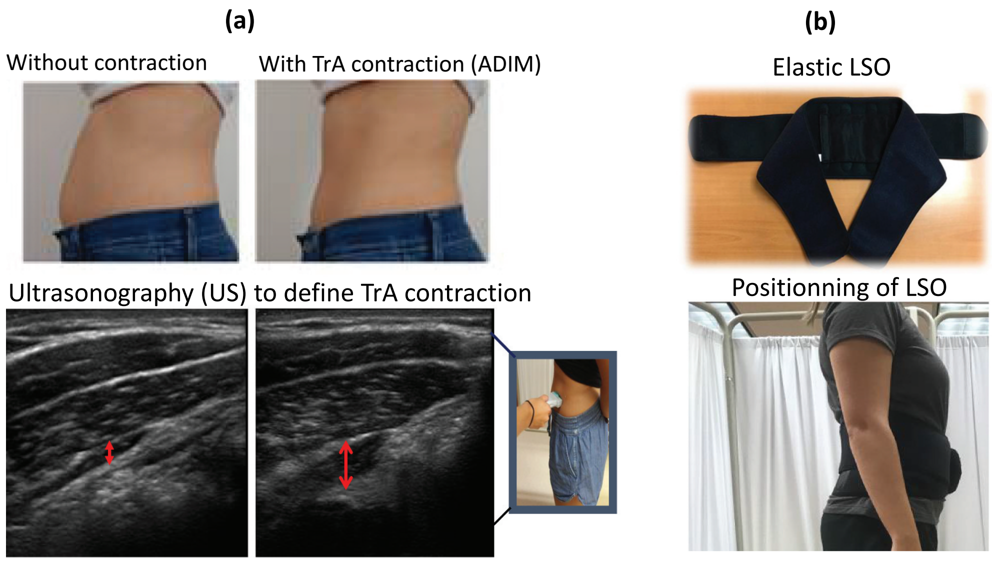

Figure 2. Instrument and measures: (a) the BIOMEC 400 force platform, (b) postural control measurements from COP parameters during two postural tasks: one-legged stance and semi-tandem.a.

containing four strain gauges arrayed in a rectangle. The sensitivity of each sensor is certified to be 0.0015% for a maximum load of 1000 N and the variation of 9.999 N of the force applied to one strain gauge corresponds to a 120-mV variation of the output. The output range runs from 0 to 5 V. Reaction force signals were sampling at 100 Hz and filtered with a 35-Hz low-pass second-order Butterworth filter and converted into COP data using BIOMEC analysis software which was compiled with MATLAB routines (The Mathworks, Natick, MA, USA) in order to retain only the first 15 seconds for all conditions (Control vs LSO vs ADIM). COP computation was based on our previous studies [8,-27–30] as well as following Prieto and Bauer recommendations to ensure the validation of COP data [31,32]. Stabilographic analysis of COP data led to determine the following postural parameters (Figure 2): mean amplitude RMS of COP (named Amplitude: the absolute distance between the max and min center of pressure displacement, in cm) and COP mean Velocity (named VEL: the sum of the cumulated COP displacement divided by the total time, in cm s − 1) in the anteroposterior (AP) and mediolateral (ML) directions of movement as well as 95% confidence ellipse area of COP (named A-COP: the total area covered in the sagittal and frontal planes using an ellipse, cm^2). These parameters have been widely used in order to reflect the postural stability, the efficiency of the postural control system and the postural performance, respectively, in a variety of contexts [8,27–30].

Statistical analysis

After verifying the normality with the Shapiro-Wilk test, the mean of the two trials was retained to determine the differences between the three conditions (control vs LSO vs TrA) for each postural task using a repeated-measures of variance analysis (ANOVA). To assess the reliability of COP variables across the two sessions. The intra-class correlation [ICC(2,k)] was calculated (relative reliability), as well as standard error of measurement (SEM_{eas}, absolute reliability or measurement error) from variance analyses [33]. Briefly, ICCs were calculated using Shrout & Fleiss' model 2,k which refers to the two-way random model on SPSS software [33]. This model was applied for two reasons: first, each subject was tested by the same experimenter, the latter being considered representative of a larger population of similar raters with good experience and training in COP analysis (i.e. over 5 years); then because ICC was calculated by taking an average of 'k' measurements (i.e. two trials per condition) [33]. We considered an ICC below 0.5 as 'poor', between 0.50 and 0.75 as 'moderate', between 0.75 and 0.9 as 'good' and above 0.90 as 'excellent' relative reliability. The pooled coefficients of variation (CV) from the two testing sessions [(pooled standard deviation/pooled mean) *100] were calculated to verify the amount of data dispersion around the mean in our sample, to help in the interpretation of the ICCs and the generalization of our results to future works [34]. Finally, the SEM_{eas}, expressed in the same unit as the measure, was then normalized to the pooled mean of the two sessions (%SEM_{eas}) to facilitate comparisons of the amount of measurement error between the COP variables having different units. Finally, the minimal detectable change (MDC = $SEM_{eas} * 1.96 * \sqrt{2}$) was also calculated to give important knowledge about how much someone's data would need to vary from test to test to consider that the change was greater than the measurement's error, and thus attributable to a treatment effect. To simulate such a clinical application, for each stance position, MDC scores computed from the control postural condition were applied to determine how many subjects were affected by the use of different lumbar stabilization methods [34]. All the statistical analyses were done using the SPSS version 20 program (Armonk, NY, USA) and a significant alpha risk below 0.05.

Results

The immediate effects of lumbar stabilization methods on postural control for two balance tasks are available in Table 2. Postural parameters based on the COP showed no significant difference between conditions (control vs LSO vs ADIM) in the two balance tasks (semi-tandem and one-legged stance).

ICC, CV, SEM_{eas} and MDC data for all experimental conditions and COP parameters are shown in Table 3. From the 30 reliability analyses (5 variables × 2 stances × 3 conditions), 02 presented an ICC $\leq$ to 0.50 (poor relative reliability), while 11 had an ICC between 0.50 and 0.75 (moderate), 12 were between 0.75 and 0.90 (good) and 5 were $\geq$ 0.90 (excellent relative reliability – bold values indicated in Table 3); mainly during the one-legged stance.

Group CVs were relatively similar (range of 10–48%, mostly between 20% and 40%), hence facilitating comparisons of ICC scores between postural tasks and COP variables. Based on our selected benchmarks, the most reliable variables in terms of relative reliability (i.e. highest ICCs and high 95% confidence intervals) were mostly observed for COP velocity variables in both A/P and M/L directions during the one-legged stance. However, no systematic result was observed for ICC data when comparing the LSO versus TrA conditions or when comparing balance tasks (one-legged vs. semi-tandem).

Measurement errors (%SEM_{eas}) were quite homogeneous, ranging from 9% to 28% with most of them between 9% and 20% (Table 3). When considering the arbitrary cutoff of $\leq$ 10% (Beaulieu et al., 2017), the variables presenting with low measurement errors were again COP velocity in both A/P and M/L directions

Table 2. Immediate effects of lumbar stabilization methods on postural control for two balance tasks. ANOVA results.

Variables and balance conditions	Lumbar stabilization conditions			
	Control	LSO	ADIM	*p*-Value (ANOVA)
One-legged stance				
Amplitude A/P (cm)	3.0 (0.7)	2.8 (0.5)	2.7 (0.7)	0.372 ddl = 2,60;F = 1.007
Amplitude M/L (cm)	2.5 (0.5)	2.3 (0.4)	2.3 (0.4)	0.583 ddl = 2,60;F = 0.544
A-COP (cm^2)	5.7 (2.3)	5.0 (1.6)	4.8 (1.3)	0.275 ddl = 2,60;F = 1.320
VEL A/P (cm/s)	2.2 (0.6)	2.1 (0.6)	2.1 (0.6)	0.639 ddl = 2,60;F = 0.451
VEL M/L (cm/s)	3.1(1.0)	2.7(0.8)	2.8 (0.8)	0.420 ddl = 2,60;F = 0.881
Semi-tandem				
Amplitude A/P (cm)	1.7(0.3)	1.6 (0.4)	1.5 (0.3)	0.116 ddl = 2,60;F = 2.241
Amplitude M/L (cm)	2.0 (0.5)	2.0 (0.4)	1.9 (0.4)	0.805 ddl = 2,60;F = 0.218
A-COP (cm^2)	2.9 (1.2)	2.3 (0.9)	2.3 (0.8)	0.099 ddl = 2,60;F = 2.405
VEL A/P (cm/s)	1.1 (0.3)	1.0 (0.2)	1.1 (0.2)	0.832 ddl = 2,60;F = 0.184
VEL M/L (cm/s)	1.2 (0.3)	1.3 (0.2)	1.3 (0.2)	0.993 ddl = 2,60;F = 0.007

Mean values with standard deviation (SD) indicated in parentheses.
ADIM: representing of transversus abdominis muscle contraction through abdominal drawing-in maneuver. A/P: anteroposterior. M/L: mediolateral. A-COP: ellipse área. LSO: lumbosacral orthosis. VEL: mean velocity.

for both balance tasks. Using MDC scores computed from the control postural condition (Table 3), the occurrence of someone reaching MDC levels was quite rare, i.e. only 17 times (3.7% of all trials) in 10 different participants for all of the COP variables and experimental conditions (23 participants × 2 lumbar stabilization conditions × 2 postural tasks × 5 COP variables = total of 460 chances to reach MDC levels). Most of these occurrences happened during the one-legged tests (14 out of the 17), when using the ADIM method (12/17).

Discussion

The present study was the first to compare the effects of two methods of lumbar stabilization on postural control measures during a one-legged and a semi-tandem standing postural task. The results revealed

Table 3. Test-retest reliability of the experimental measurements of each lumbar stabilization conditions.

	Control				LSO				ADIM			
	ICC (95%CI)	CV (%)	SEM_{eas} (%)	MDC	ICC (95%CI)	CV (%)	SEM_{eas} (%)	MDC	ICC (95%CI)	CV (%)	SEM_{eas} (%)	MDC
One-legged												
Amplitude A/P (cm)	0.63 (0.04–0.85)	24	0.52 (17%)	1.46	0.50 (0–0.79)	17	0.40 (13%)	1.11	0.54 (0–0.82)	21	0.47 (17%)	1.31
Amplitude M/L (cm)	0.84 (0.61–0.93)	19	0.23 (9%)	0.66	0.70 (0.23–0.88)	17	0.27 (11%)	0.77	0.62 (0.02–0.85)	18	0.31 (13%)	0.86
A-COP (cm^2)	0.72 (0.29–0.89)	37	1.37 (24%)	3.81	0.62 (0.08–0.84)	29	1.09 (20%)	3.03	0.39 (0–0.76)	27	1.17 (23%)	3.24
VEL A/P (cm/s)	0.88 (0.69–0.95)	28	0.29 (13%)	0.8	**0.91** (0.79–0.96)	25	0.2 (9%)	0.55	**0.92** (0.73–0.97)	28	0.18 (9%)	0.51
VEL M/L (cm/s)	0.81 (0.51–0.92)	30	0.47 (16%)	1.32	**0.93** (0.83–0.97)	28	0.25 (10%)	0.71	**0.93** (0.79–0.97)	28	0.25 (9%)	0.7
Semi-tandem												
Amplitude A/P (cm)	0.54 (0–0.81)	28	0.40 (22%)	1.11	0.78 (0.45–0.91)	25	0.25 (15%)	0.70	0.71 (0.31–0.88)	23	0.24 (15%)	0.67
Amplitude M/L (cm)	0.76 (0.40–0.90)	25	0.33 (16%)	0.92	0.65 (0.13–0.86)	25	0.34 (18%)	0.95	0.56 (0–0.82)	10	0.30 (16%)	0.84
A-COP (cm^2)	0.84 (0.61–0.93)	48	0.76 (25%)	2.12	0.78 (0.47–0.91)	47	0.7 (28%)	1.94	0.72 (0.32–0.89)	37	0.58 (24%)	1.63
VEL A/P (cm/s)	**0.90** (0.74–0.96)	28	0.13 (12%)	0.37	0.84 (0.58–0.93)	27	0.15 (15%)	0.42	0.89 (0.72–0.95)	24	0.1 (9%)	0.27
VEL M/L (cm/s)	0.86 (0.63–0.94)	19	0.13 (10%)	0.37	0.86 (0.63–0.94)	17	0.11 (8%)	0.31	0.75 (0.33–0.89)	16	0.14 (10%)	0.39

ADIM: representing of transversus abdominis muscle contraction through abdominal drawing-in maneuver; CI: Confidence interval; CV: Pooled coefficient of variation; ICC: intra-class correlation coefficient; LSO: lumbosacral orthosis; MDC: Minimal Detectable Change presented in the COP variable's unit. In bold, the 5 COP parameters with excellent reliability (ICC≥0.80); SEM_{eas}: standard error of measurement (absolute error) presented in the COP variable's unit and % (in parentheses).

that the two methods of lumbar stabilization were comparable and did not significantly reduce the COP values across time, even though a few individuals presented a change in their COP data above the levels of measurement errors. The reliability of these measurements was generally acceptable and sometimes excellent. Characterizing reliability metrics allows a more comprehensive understanding of how COP parameters vary within and between participants across these stabilization conditions, hence improving our ability to detect individual changes in the experimental conditions, as well as to propose task-specific recommendations to clinicians and researchers from a metrological perspective for clinical making decision.

In contrast to our findings, previous studies found immediate improvements of postural control measures when using LSO in adults with and without low back impairments. A recent study [17] showed a reduction in COP velocity during the Modified Clinical Test of Sensory Interaction, but assessing only 10 seconds of balance performance which may have limited the reliability of data. In addition, LSO has been shown to impact positively lumbar proprioception in patients with chronic LBP (relative to controls) [35]. These positive results could be explained by the use of a more rigid lumbar belt type compared to elastic LSO as the present study used. A recent study comparing extensible lumbar belt vs. non-extensible reported no group (LBP and control) and condition interaction effects on postural control (using linear and non-linear COP measures) when sitting on an unstable 'wobbling' chair [10]. These authors reported further impaired postural performance for some variables from lumbar belt use. Unfortunately, comparisons with and without rigid or elastic belt were not carried out during standing postural control tasks, which makes the generalization of these findings difficult. On the other hand, a 4-week long-term use of a non-extensible LSO, in combination with routine physical therapy (passive and active treatment modalities), are further beneficial for balance performance in individuals with nonspecific LBP when standing in challenging tasks (ex: foam surface and closed eyes) [36].

To the best of our knowledge, no studies have previously tested the immediate effect of isolated TrA muscle contraction on postural control during challenging postural tasks (one-legged stance and semi-tandem). No beneficial effect was, however, observed on standing postural control. On the contrary, a study [37] showed long-term improvement of postural control, after 8-week thoracic stabilization exercise program involving abdominal muscles, but without emphasis on the TrA. In addition, 4 weeks of lumbar stabilization exercises significantly reduce the COP A/P sway measured when an external disturbance was applied while standing (bipodal) with eyes closed [38]. These lines of evidence might suggest that significant improvements could have been obtained in our healthy sample if tested after repeated training sessions instead of monitoring only the immediate effects, as reported for LSO use [39].

Apparently, an abdominal contraction preceding a functional activity could act as a protective measure of the lumbar region by maintaining lumbar stability [40]. This may be further evidenced for those presenting muscular weakness, motor control disorders and low back pain. Although evaluating healthy adults, we expected that both approaches could increase the efficiency of the spinal neuromuscular system for dynamic instability by allowing the system to be more stable and giving ability in a synergic point to the muscles (i.e. hip/trunk) so they can specifically work on postural control corrections [3]. There are definitely many variables to consider to better understand the effect of LSO or abdominal co-contraction on postural control (subject characteristics; type of LSO or abdominal contraction; duration of LSO exposure or abdominal training; postural control task; COP outcome measures), requiring more comprehensive studies allowing direct comparisons between them.

The reliability data from our study can be used to track within-patient longitudinal changes based on measurement errors (cf. MDCs), or even for diagnostic uses such as staging/grading the severity of postural control impairments (cf. ICCs). In general, the higher ICCs and lowest measurement errors were obtained for COP velocity parameters, hence further supporting their use in future studies in the field. This finding is in accordance with da Silva et al. [30] who reported better reliability metrics for COP velocity (ICC = 0.72–0.85; SEM_{eas} = 0.2–1.3) in both younger and older healthy adults. Contrary to ICCs, MDCs can easily be generalized, as they are completely independent of the between-subject variance [41]. Interestingly, a few participants reached change levels in response to lumbar stabilization that were above MDCs, i.e. greater than the measurement errors. This happened more frequently for the one-legged than for the semi-tandem condition, and more for the ADIM than the LSO methods. No conclusions can be drawn from these findings, as they were rare and not supported by the ANOVA findings. Still, it demonstrates the clinical usefulness of MDCs to track individual changes over time.

Finally, a few limitations should be mentioned. These results were not generalized still for low back pain people. We did not use a Force Sensing Resistor (FSR) or FSR pressure sensor to standardize the tension of the LSO as Larivière et al. [42] did. Instead, we used a clinically accepted approach based on the maximum tolerable tension for the LSO (i.e. the highest applicable belt tautness without perceiving pelvic belt-related pain or discomfort) [27–30, 43]. Furthermore, the ultrasonography (biofeedback – ADIM familiarization) was not used throughout the experiment nor for numerical quantifying of muscle length in association with BORG scale during testing. This decision was made to avoid interfering of transducer with the postural control tasks. Thus, there is a possibility that other abdominal muscles (i.e. obliques) in addition to TrA may have participated to produce a more global bracing-like contraction during balance performance tasks.

Conclusion

The two lumbar stabilization approaches (LSO and ADIM contraction) failed to induce significant changes in postural control using linear COP measures during one-legged and semi-tandem tasks in healthy individuals. Reliability was acceptable with COP velocity being more stable over time parameter for these conditions.

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