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Abstract

Background. Low-back pain (LBP) pathophysiological conditions include nociceptive back pain, somatic referred pain, radicular pain (RP), and radiculopathy. Differential diagnosis is challenging; guidance may come from patients' thorough clinical history and physical examination, and particularly, for lumbar RP, from the evaluation of subjective responses of injured lumbar nerves to a strain applied at the buttock (Buttock Applied Strain, BUAS-test).

Methods. In a sample of n=395 consecutive LBP patients, sensitivity, specificity, and prior probability (positive and negative predictive values, PPV and NPV, respectively) of the BUAS-test were evaluated against two Reference tests: the Straight Leg Raising Test (SLRT) and the painDETECT (PD) questionnaire. Multinomial Logistic Regression (MLR) and χ^2 analyses were used to evaluate the BUAS-test outcomes dependence upon independent variables (gender, age group, pain localization, SLRT, and PD outcomes). Cohen's Kappa statistic was used to assess inter-rater agreement.

Results. Against PD, the BUAS-test showed a sensitivity of 92%, specificity, and PPV of 100%, respectively, and NPV of 82%; against the SLRT, sensitivity and NPV of 82%, respectively, and specificity and PPV of 40%, respectively. Interrater agreement Cohen's Kappa was 0.911. Significant associations were found between BUAS-test outcomes and pain localization, SLRT, and PD outcomes, but not with gender or age group predictors. MLR showed significant congruent relationship between BUAS-test and the PD outcomes.

Conclusion. Among LBP patients, the BUAS-test showed satisfactory sensitivity, specificity, Prior Probability, and interrater reliability, and thus, it may be considered a useful adjunctive tool to uncover RP in LBP patients. For results generalization, more research, in different clinical settings other than pain clinics, is needed.

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1 Introduction

Low back pain (LBP) is a frequent disabling clinical manifestation with a an incidence of 51% to 84%.[1–3] The four known pathophysiological lower-back and limb pain conditions are nociceptive back pain, somatic referred pain, radicular pain (RP), and radiculopathy.[4] While the first two are considered nociceptive-pain conditions, the latter two are considered neuropathic-pain (NeP) conditions.[5] In particular, activation of nociceptors within structures of the lumbar spine evokes nociceptive back pain; convergence of such activated nociceptive afferents on the spinal-cord second-order neurons that subtend regions of the lower limb induces somatic referred pain. Ectopic and heterospecific discharges arising from afferents of an injured dorsal root, its ganglion, [5] or inflamed nerve are critical elements of the pathophysiological process of RP;[6–8] conduction block along a spinal nerve or its roots causes a neurological condition named radiculopathy.

RP and radiculopathy typically show neurological signs and symptoms.[5] In particular, RP shows unpleasant abnormal sensations (dysesthesias) with qualities of lancinating or electric shock sensations. Radiculopathy, instead, is accompanied by paresthesias (tingling, skin crawling, or pins and needles feeling) and by negative signs like compromised reflexes, and/or numbness, and weakness when sensory or motor fibers are injured, respectively. Although rare, allodynia may also be present.

Given the high variability and possible coexistence of pathophysiological and clinical patterns, differential diagnosis of LBP pain is complex, and in particular, the distinction between somatic referred pain and RP. Thus, a thorough history and clinical examination are essential in LBP patients. In particular, an accurate neurological examination may guide differential diagnosis.[9]

We report the description and reliability analyses of a simple clinical adjunctive test, namely, the Buttock Applied Strain (BUAS) test, that may facilitate the differential diagnosis of LBP and may uncover the presence of RP in LBP patients.

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2 Methods

2.1 Neurophysiological rationale of the BUAS test for lumbar RP

Lumbar RP commonly radiates into the lower extremity along the course of a spinal nerve roots; in particular, the roots of the sciatic nerve. Causes for this pain are compression, inflammation, and injury to a spinal nerve root due to prevailing conditions including herniated disc, foraminal stenosis and, epidural fibrosis.

Nerve injury induces both adaptive and maladaptive biological responses that alter the nerve's physiological structure and function. Consequently, spontaneous dysesthesias and paresthesias may occur and responses to innocuous and noxious stimuli may be amplified and contribute to developing a NeP condition.[10]

Animal studies suggest that applying strains (squeezing or pulling) on healthy nerve roots do not evoke RP but only a momentary discharge; however, compressing a dorsal root ganglion or an inflamed/injured dorsal root evokes heterospecific discharges in an extended range of somatosensory afferents.[11–13] Moreover, persistent nerve constriction (eg, nerve ligature) leads to axonal atrophy; further, "atrophic nerve fibers distal to a persistent constriction are particularly sensitive to local pressure".[14]

Similarly, in humans, the Tinel's sign is used to detect compromised distal nerves by percussing them and thus eliciting dysesthesias.[15,16] This distal sign of nerve regeneration is frequently positive in carpal tunnel syndrome, tarsal tunnel syndrome, Guyon's canal syndrome, and other similar conditions and thus may be considered a generalized sign to detect injured nerves.[7,8]

Finally, in the literature, the so-called "Valleix's points," are described as "different points along the course of a nerve, about which, applied pressure causes pain in cases of neuralgia".[17] In particular, in the presence of injured L5 or S1 nerve roots, a pressure onto specific points along the course of the sciatic nerve or its branches, may elicit pain or enhance the patient's pain. These points are: the buttock's central zone, the middle portion of the thigh's posterior aspect, the fibula's head, and anterior or inferior regions of the external malleolus, for the L5 root; and, the buttock, the thigh's middle portion, the calf's central zone, and the area of the Achilles tendon, for the S1 nerve root. Of these points, the most reactive are those in the buttock, thigh, and calf.[18] Moreover, in the literature, the Tibial Nerve Compression Test was reported as a tool for the diagnosis of lumbar spinal canal stenosis.[19]

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Given the above it was reasonable to argue that applying a strain on an injured, by the above mentioned conditions, sciatic nerve, may elicit heterospecific discharges, and hence subjective responses, in an extended range of somatosensory afferents and thus evidence the presence of RP. We sought to apply the strain on the sciatic nerve along its course in the buttock, ie, the BUAS test.

2.2 The BUAS test

Landmarks for applying the BUAS test include, with the patient in the prone position, the Posterior Superior Iliac Spine (PSIS), the greater trochanter, and the sacrococcygeal symphysis. Fig. 1 is a semi-schematic anatomical illustration of these landmarks. The examiner traces a line (real, with a marking pen, or imaginary) between the PSIS and the greater trochanter (Fig. 1, dashed line a-b) and hence identifies its midpoint (Fig. 1, point d). Another line is traced between the greater trochanter and the sacrococcygeal symphysis (Fig. 1, dashed line b-c). The latter line intersection with the perpendicular to the former at its midpoint (Fig. 1, dashed line d-e) represents the area onto which the strain should be applied (Fig. 1, arrowhead). A practical version of the BUAS test, used in this study, is to identify the PSIS with the examiner's index or middle finger (for examiners with small hands). Hence, with a full extended hand, the examiner's thumb reaches the greater trochanter; keeping the index or middle finger on the PSIS, the thumb is moved towards halfway between the greater trochanter and the sacrococcygeal symphysis. The thumb thus exerts pressure (ie, the strain) against the underlying bony structures hitting the sciatic nerve. The test is considered positive if the patient reports pain exacerbation different from that of the mere pressure, or reproduction of his/her pain.

2.3 Settings and patients

This retrospective study was held at the acute and CP center of Bologna's Teaching Hospital, Italy. This is an anesthesiology-based pain program that provides outpatient consultation to primary care physicians and specialty services for inpatients. The sample included n=395 consecutive non-cancer LBP outpatients.

2.3.1 Proceedings and instruments

Routinely, upon first visit and before the clinical examination, patients who sign the informed consent complete three questionnaires: Short Portable Mental Status Questionnaire (SPMSQ) to screen for cognitive dysfunctions and abilities, Brief Pain Inventory (BPI) to

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evaluate patients' pain intensity and its interference with quality of life, and the painDETECT (PD) questionnaire; patients are thoroughly instructed on the meaning and how to interpret and fill the questionnaires. Thereafter, a focused clinical history and physical examination for LBP patients are taken. In the latter the Straight Leg Raising Test (SLRT) and the BUAS test are included. Finally, results of the clinical examination and tests are communicated and discussed with the patient and congruent therapeutic measures are hence taken. The retrieved clinical information is stored in the patients' individual chart and in the clinic's database. The sample, according to the inclusion/exclusion criteria (see below), was pooled out of the center's database, which includes over 3000 clinical records of various types of chronic pain patients and covers records from May 2014 up to December 2018. In this study we report only the results of the BUAS test, SLRT, and the PD questionnaire.

Inclusion criteria were: 1st visit outpatients with at least three follow-up visits, ≥18 years of age, with chronic LBP (≥3 months) and good competence of the Italian language, and who signed informed consent. Exclusion criteria were: history or diagnosis of cancer or diabetes upon 1st visit or in the three follow-up visits, SPMSQ score <8 and/or patients with positive clinical signs for the piriformis syndrome (pain recreation with pressure on the piroformis muscle, Frierberg, and Pace signs[20]).

2.3.2 Demographic and clinical predictors

Demographic predictors are: (I) gender: male/female; (II) age groups [in order to avoid unbalanced over representation in wider age interval groups, patients over 35 years of age are divided into 15-year interval subsets: 36–50; 51–65; 66–80 and ≥81 years (classes B-E, respectively); the only subset having a 17-year interval is that of young adults ie 18–35 years of age (class A)].

Pain-related predictors, aside the SLRT and PD outcomes, were retrieved from the BPI in which a human body image allows topographical location of the pain site. Pain site categories were: lumbar spine, lumbar spine and sciatica, lumbar spine associated with diffused pain, and lumbar spine associated with other specific pain sites (cervix, groin, dorsal spine, shoulder, and headache).

The SLRT is routinely used in LBP patients, to uncover lumbosacral RP. With the patient in a supine position, it consists of raising the patient's extended leg (hip flexion with the extended knee). The maneuver is stopped when the patient's pain is reproduced, or at maximum leg flexion. The SLRT is considered positive if the patient's pain is reproduced when the leg is raised between 30 and 70 degrees (provocative phase); the test is confirmed if

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the elicited pain is relieved by the flexion of the ipsilateral knee (confirmative phase). Reproduction of the patient's pain when the unaffected leg is lifted is referred to as a positive "crossed" straight-leg-raise test.[21]

In this study, the SLRT was considered positive if both provocative and confirmative phases were shown, and for either unilateral or bilateral positive responses.

The PD is a clinician-administered and patient-reported screening questionnaire to reveal the likelihood of a neuropathic pain component in LBP patients; it consists of seven items that address neuropathic-pain symptoms' quality with a final score between –1 and 38 (a score of ≤12 implies no neuropathic component, a score of ≥19 implies the presence of neuropathic component, while a score of 13-18 implies that the result is uncertain (yet, not negative).[22–24]

In this study, we first report both PD negative, uncertain, and positive outcomes. For the reliability analyses and the construction of 2x2 contingency tables, we considered uncertain and positive outcomes as positive ones.

2.3.3 Ethics

The study was approved and authorized by the Hospital Ethics Committee, and conducted according to the Helsinki Declaration and the International Association for the study of Pain (IASP)'s guidelines for pain research in animals and humans. All participants were personally and thoroughly informed by the investigators on the aims and the structure of the study. Patients were informed that participation was voluntary, anonymous and would not affect their care; hence, an informed consent to retrieve data from the patients' individual chart was obtained.

2.3.4 Data presentation and statistical analysis

Continuous data are reported as the mean (± SD, standard deviation); category data are expressed as absolute numbers and percentages. The dependence of BUAS-test outcomes upon independent variable categories was determined using χ^2 analysis. Independent variables were gender, age group, pain localization, SLRT, and PD outcomes; when significant, a post-hoc cell contribution analysis was performed, and major contributions for the association were reported. Multinomial Logistic Regression (MLR) was used to classify subjects based on a set of predictor variables. Dependent variables for MLR were the BUAS-test outcome classes where the 'positive' class (the most numerous) was the reference outcome class. Independent variables were those used for the above mentioned χ^2 analysis.

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Statistical significance was defined as $p<0.05$. When appropriate, P values are rounded to three decimals.

The reliability of the BUAS test was assessed by its sensitivity, specificity, and prior probability against two Reference tests, respectively: the SLRT and the PD questionnaire.[25] Prior Probability was defined by calculating the Positive Predictive Value (PPV) and the Negative Predictive Value (NPV). These terms describe the likelihood (positive or negative, respectively) of the condition of interest given the positive or negative test result, respectively.[26]

Sensitivity, specificity, PPV, and PNV are expressed in percentages and reported with their upper and lower Confidential Intervals (CI) and Margin of Error (M). The latter is one-half of the width of the confidence interval and summarizes the width of a CI relative to the whole possible range.[27]

Interrater reliability of the BUAS test was assessed by comparing the test outcomes obtained by two senior pain clinicians and five instructed anesthesia residents, in a subsample of 30 consecutive patients. Each patient was evaluated by a pair of a senior clinician and a resident, for a total of 10 pairs; each pair of raters evaluated three consecutive patients and the pair components were blinded to each other's evaluations. Interrater agreement analysis was thus based on 60 observations. Among the latter, we have defined the prevalence of the index condition (positive BUAS test), and the percentage of the overall agreement. For agreement analysis, Cohen's kappa test was applied.[27] When statistically significant, an absolute kappa value (with its standard error, SE) of 0.1-0.3 is considered mild agreement; 0.31–0.5 as moderate; and 0.51–1.0 as excellent.[25]

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3 Results

Table 1 reports the sample's general features. The sample included n=395 consecutive cases with mean age of 67.9 (±14.7; range 27-95) years; 67.6% (n=267) were females. The most frequent pain localizations was lumbar spine and sciatica 62.0% (n=245).

Table 2 reports, the frequency distribution of the SLRT, BUAS test, and PD questionnaire outcomes. It also reports the number of even cases (ie, concordance between SLRT, BUAS test and, PD outcomes). Positive outcomes (ie, presence of lumbar RP) were reported by a third of the sample with the SLRT and by two thirds with the BUAS test. Negative outcomes (ie, absence of lumbar RP) in the sample were reported by 67.1% (n=265) with the SLRT and by 32.4% (n=128) with the BUAS test. Of the sample, even cases for 'negative outcome' were found in 26.6% (n=105), while even cases for positive outcome were found in18.2% (n=72).

Of the patients who showed negative outcomes with either SLRT and BUAS tests, 60.4% and 18.0%, respectively, showed positive or uncertain outcomes on the PD questionnaire. All patients with positive outcomes with the SLRT or BUAS tests, showed on the PD questionnaire positive (71.5%, 44.6%, respectively) or uncertain (28.4%, 55.4%, respectively) outcomes.

3.1 Associations and MLR

Table 3 reports the results of the association analyses (χ^2-analysis) between the BUAS-test outcomes and independent predictors. It also reports the *post hoc* analyses results as cell contribution for the reported association (the two most influent contributions). No statistically significant associations were found between the BUAS test outcomes and the independent predictors gender and age groups (χ^2-analysis, $p > 0.05$). Statistically significant associations (χ^2-analysis, $p < 0.0001$, respectively) were found between the BUAS-test outcomes and the independent predictors pain site, SLRT and, PD questionnaire, respectively. In particular, post hoc analysis showed that the pain site predictor 'Lumbar spine and Sciatica' was associated with 'positive' BUAS-test outcome followed by the association of 'Lumbar spine' site and 'negative' BUAS-test outcome; 'negative' and 'positive' SLRT outcomes were evenly associated, respectively, with 'negative' and 'positive' BUAS-test outcomes. Finally,

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'negative' PD outcome with 'negative' BUAS-test outcome followed by the association between the 'uncertain' PD questionnaire outcome and the 'positive' BUAS-test outcome.

For the MLR analysis, the BUAS-test outcome was the dependent variable (reference outcome class, 'positive') while gender, age groups, pain site, SLRT and, PD questionnaire outcomes were the predictors. As reported in table 4, The model was found to fit the data significantly (p=0.000) and the predictors SLRT, and PD questionnaire had a significant overall effect on the outcome (Likelihood Ratio Tests, p=0.000, respectively). In particular, for the 'negative' BUAS-test outcome, the predictor PD 'positive' outcome had adjusted odds-ratios (p-values, 95% CI) of 0.120 (p=0.000, 0.042-0.341). Thus, for 'positive' PD questionnaire outcome cases, the risk of 'negative' BUAS outcome to occur decreases versus the Reference test outcome class 'BUAS positive'. In this model, based on the adjusted odds-ratios, the association between SLRT and BUAS test outcomes was not significant.

3.2 BUAS test reliability

Interrater agreement analysis was based on 60 observations. Among the latter prevalence of the index condition was 66.3%, and the overall agreement was 93.2%. Cohen's kappa was 0.911 (SE=0.087), showing excellent agreement.

Tables 5 is a contingency table of the frequency distribution of positive and negative outcomes of the BUAS test, SLRT, and PD questionnaire for the reliability analyses. It also reports, for each Reference test, the results of the sensitivity, specificity, and Prior Probability analyses along with their lower and upper CI and its Margin of Error (M).

Against the PD questionnaire, the BUAS test showed high values of reliability. In particular, sensitivity 92%, specificity and PPV 100%, respectively, and NPV 82% with particularly low M values. Against the SLRT, BUAS test showed relatively high values of sensitivity and NPV (82%, respectively), but low values of specificity and PPV (40%, respectively) with relatively higher, yet low, M values.

Interestingly, we have calculated the reliability of the PD questionnaire against the SLRT in our sample. Similar to the BUAS test, the PD questionnaire showed high sensitivity and NPV values (100%, respectively) but relatively low specificity (40%) and PPV (45%). It seems that the reliability of the BUAS test and the PD questionnaire is somehow undermined when it is tested against the SLRT.

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4 Discussion

This study reports the rationale, description, and reliability analysis of the BUAS test as an adjunctive tool to uncover lumbar RP. Among LBP patients, the BUAS test showed high accuracy and excellent interrater reliability.

RP is one of the four lower back and limb pain pathophysiological conditions.[4] It is considered the result of ectopic and heterospecific discharges arising from afferents of an injured dorsal root, its ganglion, or inflamed nerve.[5] Pathophysiology of lumbar RP may include, (1) Mass Effect, where nerve roots become sensitized to mechanical stimulation after sustained and protracted compression; and, (2) Chemical Radiculitis, where, a chemically mediated non-cellular inflammation affects the nerve roots due to perineural spread of inflammogenic material arising from the nucleus polposus.[28] These distinctive mechanisms, yet not mutually exclusive, may induce maladaptive neuronal responses, which include "focal demyelination, intraneural edema, impaired microcirculation, Wallerian degeneration, partial axonal damage with or without neuroma and thus have the potential to generate abnormal responses from the affected nerve".[29]

A focused history and physical examination findings are crucial elements to guide the diagnosis and management of lumbar RP. Guidelines to uncover lumbar RP are lacking. Recently classification criteria for LBP-related neurologic leg symptoms were proposed, using more items from the clinical examination rather than from symptoms reported by the patient. It differentiates patients with RP caused by lumbar disc herniation from those with lumbar spinal stenosis or non-specific LBP with leg pain.[30] In this proposal, the presence of an SLRT ≤60 is a prominent feature. Although the SLRT is widely used for the diagnosis of RP, clinicians should consider this test with caution as it shows important limitations.[31] First, standard procedure, with known reliability and validity, for carrying out and interpreting the SLRT is lacking; second, the underlying mode-of-action of the SLRT is still unclear; third, some predictors like the patient's age, gender, psychosocial factors, and diurnal variability may compromise its diagnostic reliability; fourth, in case of a herniated disc, SLRT is not straightforwardly correlated with MRI findings. Finally, "the diagnostic value of the SLRT in detecting the presence of lumbar disc herniation may lie primarily in ruling out its presence because the sensitivity of the test (0.8) is far higher than its specificity (0.4)".[31] Albeit, further clinical tools are needed to uncover lumbar RP not merely related to disc herniation.

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The rationale for the application of the BUAS test comes from both animal and human research. Indeed, in the literature, applying a strain on an injured nerve, may elicit heterospecific discharges, and hence subjective responses in multiple somatosensory afferents confirming the presence of RP in various clinical conditions.[7,8,10–13,15,16,19,32] This is particularly true for injured/inflamed lumbar dorsal roots and ganglion.[4,5]

With the BUAS test, we sought to apply the strain on the sciatic nerve along its course in the buttock for several reasons. First, it is reasonable to argue that by applying the strain at this proximal sciatic area, abnormal responses may be more straightforwardly associated with proximal nerve injuries; applying the strain more caudally along the sciatic nerve course (eg, posterior aspect of the thigh, fibula's head, calf central zone, and the Achilles tendon), may raise the doubt that the nerve injury is not necessarily at the lumbar spine. Second, the sciatic nerve is easily identifiable in the buttock following the described anatomical landmarks during routine physical examination. Third, in the buttock, the sciatic nerve lies above solid anatomical structures allowing the strain to be effectively applied. Finally, the sciatic nerve consists of spinal roots axons from the L4-S3 levels, which are often involved in lumbar RP. Albeit, these features contribute to the feasibility and efficacy of the BUAS test.

Information about predictors that may affect the reliability of the BUAS test, the domains it explores, and its content validity comes from the analyses of its outcomes dependence upon independent predictors. No significant associations were shown between the BUAS test outcomes and the gender and age group predictors. These findings imply that the BUAS test outcomes were not affected by the patients' gender or age and thus support the higher reliability of the BUAS test over the SLRT. Indeed, the diagnostic reliability of the SLRT may be affected by the patient's age, and gender.[33] Significant associations were found with the independent predictors' pain site, SLRT and, PD questionnaire, respectively. The pain site predictor 'lumbar spine and Sciatica' was associated with the positive BUAS-test outcome and the 'lumbar spine' site with a 'negative' BUAS-test outcome. These findings confirm the ability of the BUAS test to discriminate and to associate the presence/absence of lumbar RP with the symptoms' anatomical localization as reported by the patients. Negative and positive SLRT outcomes were associated, respectively, with negative and positive BUAS-test outcomes. Finally, negative and positive (including the uncertain) PD questionnaire outcomes were associated, respectively, with negative and positive BUAS-test outcomes. These associations imply that the BUAS test explores domains similar to those of

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the other two tools and thus support its content validity. Indeed content validity of a test comes from a strong association between the studied test and other tests that explore similar domains.[34] Further support to the BUAS test content validity comes from the MLR analysis. Indeed, for positive PD questionnaire outcome cases, the risk of negative BUAS outcome to occur decreases versus the reference outcome positive BUAS test class. The association between SLRT and BUAS test outcomes was not significant. These findings denote that the BUAS test, set to assess the advent of sciatic nerve injury and thus to uncover lumbar RP, has a strong relation to the PD, a tool that is known to detect NeP. In the literature, the PD was reported to be among the most suitable for clinical use; however, it should not replace a thorough clinical examination.[35]

The reliability of the BUAS test was tested by its sensitivity, specificity, prior probability, and interrater reliability.[25,36] In this paper, we tested the reliability of the BUAS test, separately, against two Reference tests, respectively: the SLRT and the PD questionnaire. These tests were chosen as they are both used in the literature to detect RP and NeP, respectively. While the sensitivity refers to the test's true positive rate, specificity refers to its true negative rate. Against the PD questionnaire, the BUAS test showed high values of reliability with a sensitivity of 92% and specificity of 100%; against the SLRT, BUAS test showed moderate values of sensitivity (82%) but relatively low values of specificity (40%). These results confirm the ability of the BUAS test to detect NeP in the territory of the sciatic nerve. The lower reliability shown against the SLRT may depend on the latter's known limitations in detecting the presence of RP caused by a lumbar disc herniation. Indeed, the SLRT, with its low specificity, is more suitable to rule out the presence of RP than to confirm its presence.[31]

Prior probability was calculated to estimate the congruency of the clinical context in which the BUAS test was assessed. PPV and NPV describe the likelihood of the condition of interest given the positive or negative test result, respectively. NPV of the BUAS test was 82% (M=6.7%) with both the PD questionnaire and the SLRT, respectively; PPV was 100% (M=0.0%) with the PD questionnaire and 40% (M=5.9) with the SLRT. Given these results, the sample population in which the BUAS test was developed and tested represents the clinical context in which the test is to be applied, and the spectrum of patients studied (ie, chronic LBP patients) was congruent to the test.[25]

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Study limitations. The external validity of the BUAS test is unknown as the study took place in an outpatient pain clinic of a teaching hospital, and pain clinicians performed the test. It remains unclear if primary care physicians or other professionals would obtain similar results. Further reliability analysis in different clinical settings is needed to assess the BUAS test external validity. Moreover, lumbar RP diagnosis has therapeutic implications that here were not considered. A future confirmative study may investigate the effect of congruent therapy as an *ex-adiuvantibus* confirmation of the diagnostic ability of the BUAS test.

Prior sample size calculations were not made in this study due to its retrospective nature and to the lack of similar trials in the literature. Given the fixed number of available patients, no power analysis could have been done, and no standards for diagnostic test reliability were prospectively considered. Thus, the reported study was intended to convey an exploratory analysis to gather clinical information, to validate the setup of the trial, and to figure out an estimate of the variability of the measurements. Based on the results, a new study can now be planned with satisfactory standards, power analysis, and an adequate sample size to face variability issues.

Conclusions. Among LBP patients, the BUAS test showed satisfactory sensitivity, specificity, prior probability, and interrater reliability. These findings suggest that it may be considered a useful adjunctive tool to uncover RP in LBP patients. More research in different clinical settings, with adequate sample size and congruent standards for diagnostic test reliability, is needed.

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Legend

Fig. 1

Semi-schematic anatomical illustration of the landmarks for applying the BUAS test.

Foot notes:

Dashed line a-b: traced between the PSIS and the greater trochanter;

Point d, midpoint of line a-b.

Dashed line b-c: traced between the greater trochanter and the sacrococcygeal symphysis.

Dashed line d-e: is the perpendicular to line a-b at its midpoint;

Point e, intersection of line d-e with line b-c at its midpoint.

Arrowhead: the area at which the strain should be applied.

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Table 1. Demographic and clinical features of the sample.

		n (%)
Sample		395 (100.0)
Gender		
	Male	128 (32.4)
	Female	267 (67.6)
Age group (years)		
	A (18–35)	13 (3.3)
	B (36–50)	44 (11.1)
	C (51–65)	76 (19.2)
	D (66–80)	186 (47.1)
	E (>80)	76 (19.2)
Pain site		
	Lumbar spine	57 (14.4)
	Lumbar spine and Sciatica	245 (62.0)
	Lumbar spine and diffused pain	55 (13.9)
	Lumbar spine and other specific pain sites	39 (9.6)

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Table 2. Frequency distribution of outcomes from the SLRT, BUAS test and, the PD questionnaire.

		SLRT		BUAS		Even cases	
Outcome	PD	n	%	n	%	n	%
Negative		**265**	67.1	**128**	32.4	**105**	26.6
	Negative	105	39.6	105	82.0	105	100.0
	Positive	33	12.5	7	5.5	0	0.0
	Uncertain	127	47.9	16	12.5	0	0.0
Positive		**130**	32.9	**267**	67.6	**72**	18.2
	Negative	0	0.0	0	0.0	0	0.0
	Positive	93	71.5	119	44.6	51	70.8
	Uncertain	37	28.4	148	55.4	21	29.2

SLRT, Straight Leg Raising Test

BUAS, Buttock Applied Strain test,

PD, painDetect questionnaire.

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Table 3. Association analyses between BUAS test outcomes and independent predictors.

predictor			**Post hoc cell contribution**	
	χ^2	P Value	BUAS Negative	BUAS Positive
Gender	0.324	>0.05		
Age group	6.624	>0.05		
Pain site	26.293	<0.0001		
L			3.495	
LS				4.242
LD				
LSSP				
SLRT	19.149	<0.0001		
Positive				4.376
Negative			4.376	
PD	298.899	<0.0001		
Positive				
Uncertain				8.104
Negative			17.272	

χ^2 – post hoc analysis results are reported as cell contribution for the reported association (the most influent two).

SLRT, Straight Leg Raising Test; BUAS, Buttock Applied Strain test; PD, painDetect questionnaire. L, Lumbar spine; LS, Lumbar spine and Sciatica; LD, Lumbar spine associated with diffused pain, and LSSP, Lumbar spine associated with other specific pain sites.

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Table 4. Multinomial logistic regression, significant results.

Effect / Predictor			χ^2	DF	p	Adjusted Odds Ratio			Risk [b]
						n	95% CI		
							Lower	Upper	
Model fitting (final)			400.617	11	0.000				
Likelihood ratio									
	SLRT outcomes		57.471	1	0.000				
	PD outcomes		355.440	2	0.000				
Parameter estimates [a]									
BUAS Negative	-	PD Positive			0.000	0.120	0.042	0.341	decrease

CI, 95% confidential intervals of the Adjusted Odds Ratio.

[a], Comparison outcomes (PD, positive and negative outcomes) versus reference outcome (BUAS, positive outcome) as yielded by the multinomial logistic regression model.

[b], with regard to the predictor, the risk of the considered comparison outcomes to occur versus the reference outcome (BUAS, positive) decreases when the adjusted odds ratio (and 95% CI lower and upper values) are <1 and increases when the adjusted odds ratio (and 95% CI lower and upper values) values are >1, respectively.

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Table 5. Contingency table for the accuracy analyses (sensitivity, specificity and prior probability) of the BUAS test, against the SLRT and the PD Questionnaire.

BUAS	**SLRT**			**PD**		
	Positive	Negative	*Total*	Positive	Negative	*Total*
Positive	107	160	267	267	0	267
Negative	23	105	128	23	105	128
Total	130	265	395	290	105	395
Accuracy	%	CI	M	%	CI	M
Sensitivity	82	75.4-88.6	6.6	92	88.9-95.1	3.1
Specificity	40	34.1-45.9	5.9	100	100.0-100.0	0.0
PPV	40	34.1-45.9	5.9	100	100.0-100.0	0.0
NPV	82	75.3-88.7	6.7	82	75.3-88.7	6.7

SLRT, Straight Leg Raising Test,

BUAS, Buttock Applied Strain test,

PD, painDetect questionnaire.

PPV, Positive Predictive Value;

NPV, Negative Predictive Value;

CI, Upper and Lower Confidence Intervals expressed in percentage.

M, Margin of Error (one half width of CI)

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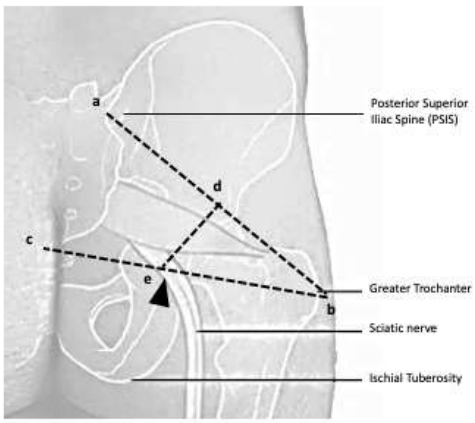

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