Prospective Study

Novel Physical Examination Tests for the Diagnosis of Chronic Sacroiliac Joint Dysfunction and Differentiate It From Lumbar Disc Herniation

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Disclaimer: Thanks for the financial support from Chinese National Key Research and Development Project (2018YFC2002601) in the design of the study and collection, analysis, interpretation of data and in writing the manuscript.

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted manuscript.

Manuscript received: 07-15-2022
Revised manuscript received: 10-20-2022
Accepted for publication: 10-27-2022

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Background: Traditional sacroiliac joint (SIJ) provocation tests have been used to diagnose SIJ pain. However, this can simply be changed to chronic SIJ dysfunction (cSIJD) manifests as mechanical changes in the pelvis and lower extremities in addition to pain. A novel composite of physical examinations based on the iliac pronation, pubic tubercle tenderness, and plantar fascia tenderness tests (IPP triple tests) was designed for the diagnosis of cSIJD.

Objectives: To evaluate IPP triple tests in the diagnosis of cSIJD and differential diagnosis from lumbar disc herniation (LDH) in comparison with traditional provocation tests.

Study Design: Prospective single-blind controlled study.

Setting: This study was conducted at the Department of Spine and Spinal Cord Surgery of China Rehabilitation Research Center in Beijing, China.

Methods: One hundred and sixty-six patients were assigned into the cSIJD group, LDH group, or healthy control group. The cSIJD diagnosis was confirmed by SIJ injection. The diagnosis of LDH was confirmed according to the 2014 North American Spine Association diagnosis and treatment guidelines for LDH. All patients were examined with IPP triple tests and traditional provocation tests. The sensitivity, specificity, positive and negative likelihood ratios, and areas under the curve (AUCs) were used to evaluate the diagnostic accuracy of the composites or single of the IPP triple tests, and traditional provocation tests. The Delong's test was used for the comparison among AUCs. The kappa analysis was used for the IPP triple tests and traditional provocation tests compared with the reference standard (REF). The independent t test and chi-square test were used to analyze the influence factors (i.e., age, gender), and group on diagnostic accuracy.

Results: There was no statistical difference in gender (χ^2 = 0.282, P = 0.596) and age (F = 0.096, P = 0.757) between the 3 groups. The AUC of the iliac pronation test was 0.903 when it was used alone; the AUC of the novel composites of the IPP triple tests was 0.868 (95% confidence interval [CI] = 0.802-0.919); and the diagnostic accuracy of the traditional provocation test was relatively low (AUC = 0.597, 95% CI = 0.512-0.678). The diagnostic accuracy of the IPP triple tests was higher than that of the traditional provocation test, $P < 0.05$. Kappa consistency comparison showed that the kappa value between the IPP triple tests and the REF was 0.229, the kappa between the traditional provocation test and the REF was 0.052. The age of the patients with inaccurate diagnosis was higher than that of the patients with accurate diagnosis in both methods (traditional tests, P = 0.599; IPP:P = 0.553). Different types of diseases (groups) affect the accuracy of diagnosis, the proportion of inaccuracy of traditional provocation tests was higher than that of the IPP triple tests (77.8% vs 23.6%) in cSIJD, while the 2 methods have high differential diagnostic accuracy in LDH (96.77%) and control groups (97.56%).

Limitations: Small size of LDH patients and differences in physical tests among examiners.

Conclusions: The novel composites of IPP triple tests have higher accuracy than the traditional provocation tests in diagnosing cSIJD and both have good accuracy in differentiating cSIJD from LDH. IPP triple tests may be an alternative physical examination for clinical screening of cSIJD.

Key words: Sacroiliac joint dysfunction, low back pain, lumbar disc herniation, provocation test, physical examination, kinematics

Pain Physician 2023: 26:289-298

A lot of evidence support that the sacroiliac joint (SIJ) is a potential pain generator that should be differentiated from low back or buttock pain with leg symptom. The incidence of failed back surgery syndrome is increasing in recent years, and postoperative SIJ dysfunction (SIJD) is reported to be present in 13.8% of lumbar surgeries (1). SIJD has become an increasing concern for clinicians (2-4). Generally, it counts for 15%-25% of the causes of low back and leg pain (5,6). The SIJ block is commonly regarded as the reference standard (REF) for the diagnosis of SIJD, but it has the disadvantage of being invasive. Because of lack of characteristic imaging and invasiveness of SIJ blocks, SIJD is prone to underdiagnosis and misdiagnosis. Therefore, the physical examinations are important for clinical screening of SIJD patients.

Traditional SIJ provocation tests have been used to diagnose SIJ pain, including the flexion abduction external rotation (FABER), compression, thigh thrust, distraction, and Gaenslen tests. If 3 or more of the 5 tests are positive, SIJ pain is a probable diagnosis (7-10). Laslett et al (11) reported its sensitivity, specificity, and positive likelihood ratio (LR) were 91%, 83%, and 6.97, respectively.

However, SIJ pain is a different concept from SIJD (12). SIJ pain is the clinical symptom, the etiology may include SI arthritis, ankylosing spondylitis, rheumatoid arthritis, infection, SIJD, and other causes. SIJD presents the pain not only in the SIJs, but also in the low back, pelvic region, or leg, which could influence muscle strength and endurance, disrupt muscle coordination, and compromise gait patterns (13,14). Some studies (15-17) have argued that the provocation tests are insufficient to serve as evidence for the diagnosis of SIJD (15,16), and the use of SIJ mobility tests in clinical practice is also problematic due to high false-positive rates (17). Nejati et al (18) postulated that the combination of motion palpation and provocation tests may increase specificity and positive predictive values for SIJD, but the palpation test findings did not change after the SIJ blocked, suggesting that the accuracy of diagnosing SIJD cannot be determined using this method.

In the early stage of SIJD, local inflammation of the SIJ is severe, and the pain is localized in the SIJ. The traditional provocation tests are designed to separate, compress, and shear the SIJ, which has a certain diagnostic efficiency for SIJD (7-10). But in the chronic phase of the SIJD, provocation tests may be negative or lack of sensitivity because of relieved inflammation of the local structures. Due to the patient self-adjustment and abnormal kinematic changes, the secondary strain and kinematic changes in the myofascial chain of the pelvis-lower extremities would be the main clinical manifestations. Studies (19,20) have indicated that individuals with SIJD display asymmetrical gait (19) and exhibit altered movement strategies when performing a sit-to-stand task (20). According to these characteristics, we proposed the novel IPP triple tests for diagnosing chronic SIJD (cSIJD) based on the iliac pronation, pubic tubercle tenderness, and plantar fascia tenderness tests, assessing the lumbar spine, pelvis, and lower extremity as a whole.

A cSIJD also tends to be misdiagnosed in clinics because it has overlapping symptoms with lumbar disc herniation (LDH) (11,23) and sometimes coexists with LDH. In this study, we attempt to evaluate the accuracy of the IPP triple tests in the diagnosis of cSIJD and the differential diagnosis of LDH by comparison with the traditional provocation tests.

Methods

One hundred and sixty-six patients were studied prospectively from January 2019 to September 2020 in the Department of Spine and Spinal Cord Surgery of the China Rehabilitation Research Center. Three patients refused the informed consent, 5 patients were unable to receive the SIJ injection, and 14 patients' symptom reliefs were < 75% after the SIJ injection. The rest, 144 patients, were assigned into the cSIJD group (72), LDH group (31), and healthy control group (41). Flow diagram of this study is shown in Fig.1.

Inclusion criteria of the cSIJD group was men or women between ages 20-70. The main complaint of the patients was pain in the posterior SIJ with or without leg discomfort for more than 6 months (21). Lumbar magnetic resonance imaging (MRI) showed no or mild LDH. The cSIJD diagnosis was confirmed by the SIJ injection, with relief of low back pain (LBP) and leg discomfort > 75% (9,15,22) (Fig. 2). Inclusion criteria of the LDH group were men or women between ages 20-70; chronic LBP with mild or moderate radicular pain to the lower extremities for > 6 months; and lumbar MRI with LDH or prolapse. The diagnosis of LDH was confirmed according to the 2014 North American Spine Association diagnosis and treatment guidelines for LDH (23), and the symptoms and signs were consistent with the herniated segment on the MRI. Inclusion criteria of the control group were men or women between ages 20-70; and without any pain of low back, leg, or pelvic region within one year.

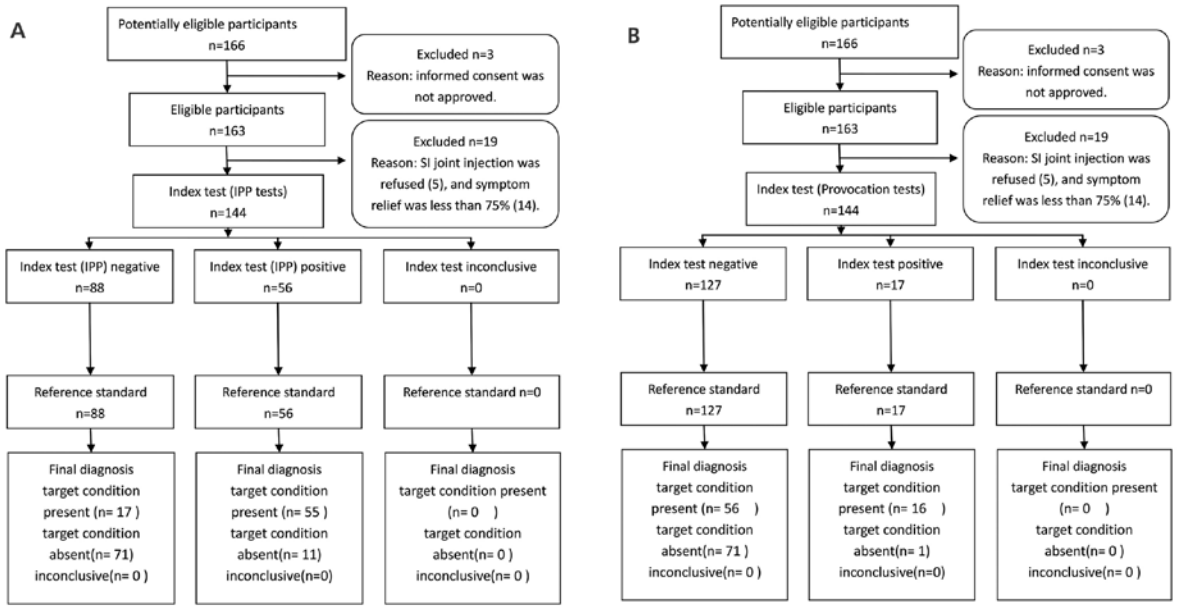

Fig. 1. A) *Flow diagram of IPP triple tests in this study. IPP triple tests, iliac pronation, pubic tubercle tenderness, and plantar fascia tenderness tests. B) Flow diagram of traditional provocation tests in this study.*

The exclusion criteria were: (1) history of fracture, infection, tumor, and surgery in the pelvis, hip joint, and lumbar spine; (2) ankylosing spondylitis or condensing osteitis of the SIJ; (3) hip joint disease; (4) lumbar stenosis, lumbar spondylolisthesis, or lumbar scoliosis; and (5) patients who cannot cooperate with physical examinations.

Each group of patients was examined with the IPP triple tests and traditional provocation tests. The examination was performed by one experienced spine surgeon and one physical therapist. The examiners were blind of the grouping. They were trained to ensure the accuracy of the physical examination methods and tenderness points. The examinations with positive findings were generally repeated twice for confirmation. Suspicious examination results were jointly examined and confirmed by the 2 examiners.

The IPP triple tests are composed of 3 tests (i.e., iliac pronation, pubic tubercle tenderness, and plantar fascia tenderness tests). When all 3 tests were positive, the IPP triple tests were considered positive (Fig. 3).

The iliac pronation test is performed with the patient in the standing position. The feet are separated in parallel, slightly narrower than the shoulder width, with the upper extremities hanging naturally. The examiner stands behind the patient with both thumbs over the posterior superior iliac spines (PSISs) without pressing

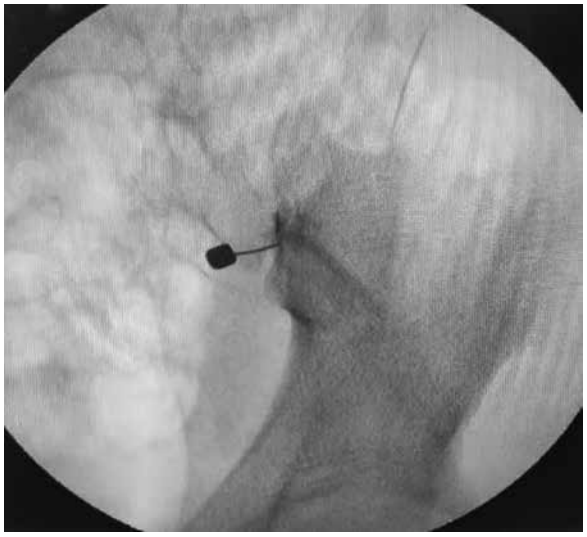

Fig. 2. *Injection of SIJ. The patient was positioned supine and the needle was inserted into the SIJ space under the fluoroscopic guidance. Contrast was used to confirm the position of the needle, then a 2 mL mixture of betamathasone and lidocaine was injected in the space.* SIJ, sacroiliac joint.

hard to observe the height difference between the 2 sides. The patient is then asked to flex slowly, hands reaching toward the toes. When bending forward > 45°, the superior movements of the position of the examiner's thumbs are assessed. If there are asymmetric upward movements of the 2 thumbs (one side elevated higher than other side), it is defined as a positive iliac pronation test (Fig. 3a,3b). This test is similar to the standing flexion test, which has relatively low reliability when applied to SIJD alone, and it is suggested to combine with other tests (24). In this study, we also propose the composites of 3 tests to identify cSIJD, and define either of symptomatic sides cranially or caudally asymmetric movement as positive results, instead of side of moves further cranially as problematic side.

The pubic tubercle tenderness test was performed in the supine position. The legs are naturally placed and relaxed. The patient is palpated gradually with modest pressure from shallow to deep tissue at approximately 1 cm lateral to the pubic tubercle on both sides. If the

Fig. 3. *IPP triple tests. a) Iliac pronation test. The location of the PSIS when the patient is in a standing position; the line of the bilateral PSIS is horizontal. b) Iliac pronation test. When the body is bending forward, normal movement of the 2 thumbs is in a symmetric level; asymmetric upward movement of the bilateral thumbs when the body is bending indicates a positive result. c) Pubic tubercle tenderness test. In the supine position, the patient is palpated approximately 1 cm lateral of the pubic tubercle bilaterally. The examiner should pay attention to the symmetric force when pressing and compare the findings bilaterally. d) Plantar fascia tenderness test. In the supine position, the patient is palpated on the medial front of the calcaneus bilaterally. The examiner should pay attention to the symmetric force when pressing.*
IPP triple tests, iliac pronation, pubic tubercle tenderness, and plantar fascia tenderness tests; PSIS, posterior superior iliac spine.

muscle fascia cord with greater tension can be palpated and tenderness is elicited on the symptomatic side, the test is defined as positive (Fig. 3c). The plantar fascia tenderness test was performed in the supine position. The lower extremities are naturally placed and relaxed. The medial front of the calcaneus was palpated gradually with modest pressure from shallow to deep tissue, beneath of the subtalar joint and close to the plantar fascia. If tenderness is present with greater tension in the muscle fascia on the symptomatic side, the test is defined as positive. (Fig. 3d).

The traditional SIJ provocation tests include FABER, compression, thigh thrust, distraction, and Gaenslen tests. If 3 of the 5 tests are positive, SIJD is diagnosed (8).

This study was approved by the Ethics Committee of the China Rehabilitation Research Center (approval number, 2019-108-1) and the Chinese Clinical Trial Register (ChiCTR2100048513). All patients signed the informed consent.

Statistical analysis was performed with SPSS for Windows Version 25.0 (IBM Corporation, Armonk, NY). One-way analysis of variance (ANOVA) was used for age comparison among the 3 groups, the chi-square test was used for gender comparison among the 3 groups. The sensitivity, specificity, positive LR, negative LR, and area under the curve (AUC) were used to evaluate diagnostic accuracy of the composites or single of the IPP triple tests, and traditional provocation tests. The Delong's test was used for the comparison among AUCs. The kappa analysis was used for the IPP triple tests and traditional provocation tests compared with the REF. The independent t test and the chi-square test were used to analyze the influence factors (i.e., age, gender, and group) on diagnostic accuracy. The 2-sided $P < 0.05$ was the significance threshold for all statistical tests.

Results

Baseline Characteristics of Clinical Data

In 144 patients, there were 72 cSIJD patients (men 18, women 54; age 44.28 ± 13.20 years), 31 LDH patients (men 19, women 12; age 43.29 ± 12.13 years), and 41 healthy patients (men 13, women 28; age 42.24 ± 12.80 years). There were no statistical differences in gender and age among the 3 groups ($P > 0.05$) (Table 1).

Evaluation of Diagnostic Accuracy of Different Tests

There was variation in diagnostic accuracies within the IPP triple tests, as shown in Table 2. The AUC of the iliac pronation test was 0.903 when it was used alone due to the low specificity (i.e., the proportion of false positive was high). The accuracies of the pubic tubercle tenderness test and plantar fascia tenderness test were slightly poor when they were used alone (AUC = 0.764, 0.819, respectively). The AUC of the composites of the IPP triple tests (3 tests combined) was 0.868 (95% confidence interval [CI] = 0.802-0.919), and there was no significant difference between the composites of the IPP triple tests and the iliac pronation test ($P = 0.301$, Table 2), but the composites of the IPP triple tests can

Table. 1. *Characteristics of clinical data.*

Factor	cSIJD	LDH	Healthy	F/χ^2	*P* value
Gender					
Men	18 (%)	19 (%)	13 (%)	0.282	0.596
Women	54 (%)	12 (%)	28 (%)		
Age (y)	44.28 ± 13.20	43.29 ± 12.13	42.24 ±12.80	0.096	0.757

CSIJD, chronic sacroiliac joint dysfunction group; LDH, lumbar disc herniation group; Healthy, healthy patients.

Table. 2. *Evaluation of diagnostic accuracy of different tests.*

Items	Sensitivity	Specificity	Positive LR	Negative LR	AUC	95% CI	AUC_ D1	*P* 1	AUC_ D2	*P* 2
Iliac Pronation Test	1.000	0.806	5.14	0.00	0.903	0.842-0.946	0.306	< 0.001	-0.035	0.301
Pubic Tubercle Tenderness Test	0.889	0.639	2.46	0.17	0.764	0.686-0.831	0.167	< 0.001	0.104	0.003
Plantar Fascia Tenderness Test	0.792	0.847	5.18	0.25	0.819	0.748-0.879	0.222	< 0.001	0.048	0.004
IPP Triple Tests	0.764	0.972	27.50	0.24	0.868	0.802-0.919	0.271	< 0.001	Ref	
Provocation Tests	0.222	0.972	8.00	0.80	0.597	0.512-0.678	Ref			

Positive LR, positive likelihood ratio; Negative LR, negative likelihood ratio: AUC, area under the curve; CI, confidence interval; AUC_D1, the AUC of other diagnosis test minus the AUC of provocation tests; AUC_D2, the AUC of IPP tests minus the AUC of single test; P1, the *P* value of statistical analysis between the AUC of single test and provocation tests; P2, the *P* value of statistical analysis between the AUC of single test and the IPP triple tests; REF, reference standard.

control the false positive of the iliac pronation test used alone.

The diagnostic accuracy of the traditional provocation tests was relatively low (AUC = 0.597, 95% CI = 0.512-0.678). The diagnostic accuracy of the composites of the IPP triple tests was higher than that of the traditional provocation tests, and the difference between the 2 kinds of examination methods was statistically significant. The comparison of them is shown in Table 2 and Fig. 4. Kappa consistency comparison also showed that the kappa value between the IPP triple tests and the REF (SIJ injection) was 0.229, the kappa between traditional provocation tests and the REF was 0.052, and the results showed that the IPP triple tests were more consistent with the REF.

Analysis of Influencing Factors of Diagnostic Accuracy

In order to explore the influencing factors of the diagnostic accuracy of the IPP triple tests and traditional provocation tests, one-way ANOVA analysis was conducted. The results showed that the age of the patients with inaccurate diagnosis was higher than that of the patients with accurate diagnosis in both methods. Although there was no significant difference between the 2 age-related groups, it may suggest that elderly patients might be more difficult to diagnose with SIJD. There was no significant difference in gender between the 2 methods (Table 3).

Different types of diseases (groups) also affect the accuracy of diagnosis. Relatively, the diagnosis accuracy of the 2 methods is lower in the SIJD group (SIJD 86.80%) than in the other 2 groups (LDH 96.77%; Control 97.56%). It showed that the 2 methods have good clinical application value in the differential diagnosis of SIJD and LDH/healthy control groups. The proportion of inaccuracy of traditional provocation tests was higher than that of IPP triple tests (77.80% vs 23.61%) in the SIJD group, indicating that the IPP triple tests have better diagnostic accuracy (Table 3).

Discussion

Previous research (25) indicates that physical examinations cannot diagnose the SIJ pathology. Laslett et al (25) examined the diagnostic power of SIJ pain provocation tests singly and in various combinations, and found sensitivity and specificity for 3 or more of

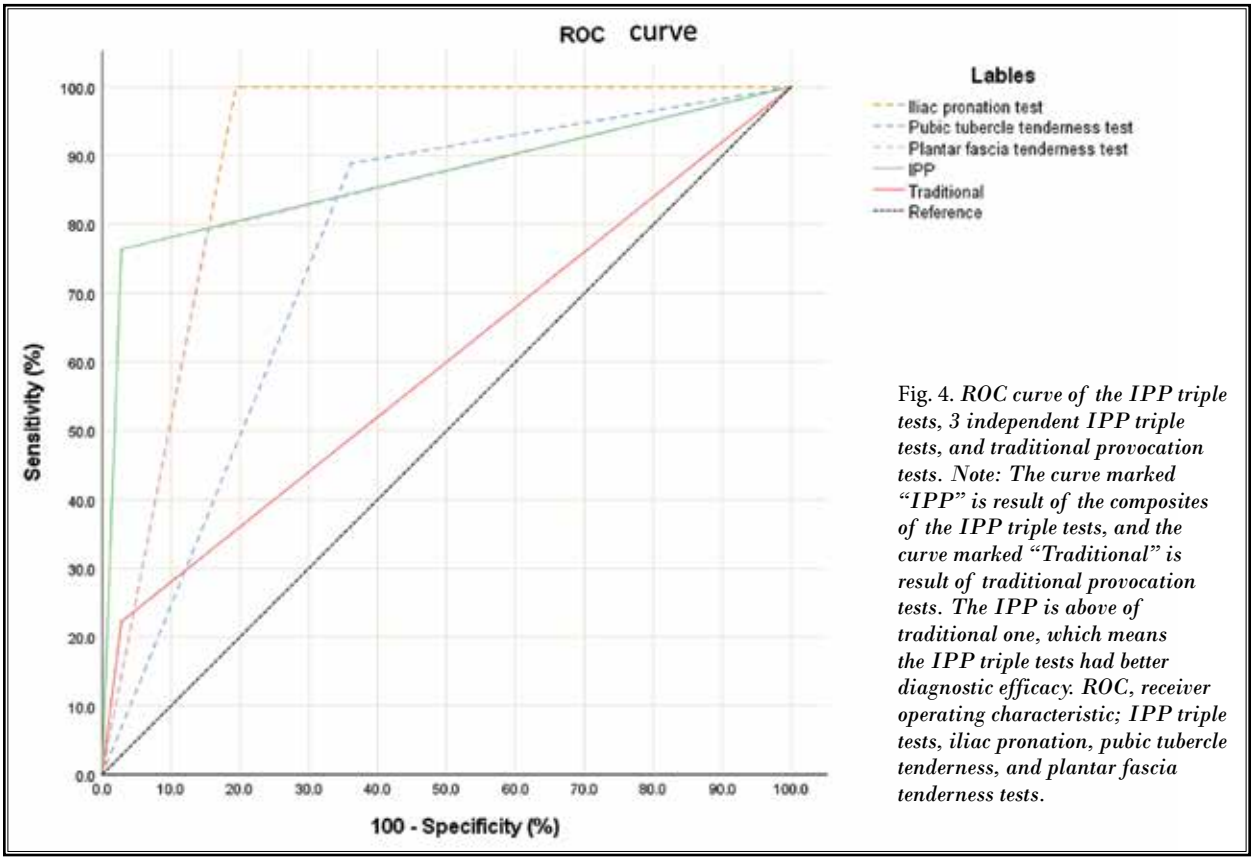

Fig. 4. *ROC curve of the IPP triple tests, 3 independent IPP triple tests, and traditional provocation tests. Note: The curve marked "IPP" is result of the composites of the IPP triple tests, and the curve marked "Traditional" is result of traditional provocation tests. The IPP is above of traditional one, which means the IPP triple tests had better diagnostic efficacy. ROC, receiver operating characteristic; IPP triple tests, iliac pronation, pubic tubercle tenderness, and plantar fascia tenderness tests.*

Table. 3. *Analysis of influencing factors of diagnostic accuracy.*

	Traditional Provocation Tests				IPP Triple Tests			
	Accuracy	**Inaccuracy**	**t/x²**	***P* value**	**Accuracy**	**Inaccuracy**	**t/x²**	***P* value**
Age	43.59 ± 12.49	44.74 ± 13.29	0.527	0.599	43.81 ± 12.81	45.68 ± 12.85	0.595	0.553
Gender			0.742	0.389			0.509	0.475
Women	58 (57.4)	43 (42.6)			89 (88.12)	12 (11.88)		
Men	28 (65.1)	15 (34.9)			36 (83.72)	7 (16.28)		
Type of Patients			84.19	< 0.001			13.65	0.001
Healthy control	40 (97.56)	1 (2.44)			40 (97.56)	1 (2.44)		
LDH	30 (96.77)	1 (3.23)			30 (96.77)	1 (3.23)		
SIJD	16 (22.2)	56 (77.8)			55 (76.39)	17 (23.61)		

IPP Triple Tests, iliac pronation, pubic tubercle tenderness, and plantar fascia tenderness tests; LDH, lumbar disc herniation; SIJD, sacroiliac joint dysfunction.

the 6 positive SIJ tests were 94% and 78%, respectively. When all 6 provocation tests fail to provoke similar pain, the SIJ can be ruled out as a source of the current LBP (25). That study focused on the SIJ pain instead of cSIJD. We often find that the cSIJD patients do not complain of LBP, but discomfort or pain in the anterior pelvis, thigh, or plantar aspect of the foot. Studies (19,20) have indicated that individuals with SIJD display an asymmetrical gait (19) and exhibit altered movement strategies when performing a sit-to-stand task (20), which confirm the abnormality of the kinetic chain in SIJD patients.

Slipman et al (26) reported that the referred pain from the SIJ does not appear to be limited to the lumbar region and buttock, but also radiates to the groin and lower extremities. That indicates symptoms of SIJD are so diversified (27). Because it is difficult to have "typical" clinical characteristics, we tried to combine the subjective complaint of the patient with objective physical examination signs.

Why do SIJD patients have positive results of the iliac pronation test? When the trunk is flexed, both sides of the hip and sacrum pronate forward on the femur as a unit. The normal pelvic pronation can only reach approximately 60°, because tension of the posterior sacrum ligaments, thoracolumbar fascia, and hamstring will limit sacrum rotation. For a normal person, PSIS is parallel in standing and when the trunk is in flexion. But for SIJD patients, if one side of the PSIS is elevated superiorly than the other side, the symptomatic ilium is likely fixed on the sacrum in an inappropriately pronated position, which is defined as positive. It should be noted that the amplitude of PSIS elevation on the affected side can be significantly less than the unaffected side, which would also be defined as positive (28). As a result, asymmetry in bilateral PSIS movement may result in a false positive in iliac pronation. Other false-positive results include increase in upward movement of the PSIS on the unaffected side when continuous high tension of the hamstring limits motion of the ilium; increased tension in the quadratus lumborum may result in ipsilateral PSIS elevation. In this study, the iliac pronation test was combined with other 2 tests as the IPP triple tests, which can reasonably reduce the false-positive rate as supported by the AUC of the iliac pronation test and IPP triple tests.

Tenderness of the pubic tubercle and plantar fascia may be related to instability of the SIJ, resulting from abnormal tension of the related myofascial train. For SIJD patients, the instability of one side of the SIJ may cause slight displacement of the ilium (pronation or supination), which is often offset by the motion of the pubic symphysis, which has 2-mm translation and 1° rotation motion (28). The pectineus muscle and rectus abdominis connected to the pubic tubercle have oblique and lamellar fibers. Therefore, abnormal movement of the pubic bone will cause pain in the muscle fibers lateral to the pubic tubercle. A previous study (29) have found higher prevalence of groin pain in patients with SIJD than in those with lumbar spinal stenosis or LDH.

Plantar fascia tenderness has significant clinical value for diagnosing cSIJD. Studies (19,20) indicated that the patients with SIJD display asymmetrical gait (19) and exhibit altered movement strategies when performing a sit-to-stand test (20), which suggests that SIJD will probably cause dysfunction of the foot, ankle, and knee joint in those patients. We include this test is supported by the theory of the spiral myofascial chain. Patients always suffer abnormal pelvic pronation (supination) with SIJD, which results in functional leg

length discrepancy and excessive pronation (supination) of the foot (30). In the spiral myofascial chain of the lower extremities, the anterior tibial muscle forms a kinetic chain near the anterior ilium through the rectus femoris, part of the sartorius, iliotibial band, and tensor latissimus membranous muscles. And the peroneus longus forms a kinetic chain besides the rear of the ilium through the long head of the biceps femoris and ischial tubercle. The common attachment point of the tibialis anterior muscle and the peroneus longus muscle forms a "stirrup" structure, which prevents collapse of the transverse arch of the foot (30). The reciprocal relationship between the anterior tibial and peroneus longus muscles is such that when the anterior superior iliac spine moves closer to the foot and the pelvis is tilted forward, the tension above the tibialis anterior is weakened and the medial arch of the foot tends to become low. In contrast, when the pelvis is tilted backward, the anterior tibial will be pulled upward, the peroneus longus will be relaxed, and the medial arch of the foot will be raised (30). The abnormal tension of the 2 myofascial trains causes greater tension of the fascia at the common capsule of the medial cuneiform bone and the first metatarsal joint. The fascia around the attachment point of the muscle is too dense to feel obvious pain, while the plantar fascia connected to the attachment point can easily be detected as tenderness in SIJD patients (30). Both zones of tenderness were also noted as referred pain from SIJD in previous studies (26,31), which indicates the relationship between the 2 areas of tenderness and SIJD. An additional study (19) shows that patients with SIJD exhibited both reduced activation of the gluteus maximus during a loading synergy presented in walking and greater asymmetry between legs when ambulating compared with age-matched controls. A cSIJD is not only a pathology of the local SIJ, but also the dysfunction of the pelvis and lower extremities.

In the early stage of SIJD, the pain is located in the SIJ. The 5 traditional provocation tests apply stress to the SIJs from various directions. These tests focus in the areas around the SIJs. For some chronic cases or during the nonacute stage, the provocation tests may not be positive due to less inflammation of the local structures, and the false-negative rate may be increased (15,16). For those patients with cSIJD, the abnormal dynamics in the SIJ may cause some myofascial or mechanical changes in the pelvis and lower extremities. The IPP triple tests examine the relative movement of SIJs and the secondary changes of the myofascial chain of the pelvis and lower extremities. This provides not only a local evaluation of the SIJ, but also comprehensive assessment of the dynamic tension changes of lumbar-pelvis-lower extremity with SIJD. When the patient is standing and walking, the local pathologic conditions of the SIJ may be significantly amplified by the mechanical leverage of the myofascial chain. Therefore, the IPP triple tests improve the accuracy of diagnosis, especially for the patient with cSIJD.

In this study, we analyzed diagnostic accuracy of each of the IPP triple tests, the composites of the IPP triple tests, and the traditional provocation tests for SIJD. The AUC of the iliac pronation test was 0.903 alone with high false-positives proportion, and the composites of the IPP triple tests are more clinical applicable with an AUC = 0.868 (95% CI = 0.802-0.919), which is higher than the diagnostic accuracy of the traditional provocation test (AUC = 0.597, 95% CI = 0.512-0.678) (Table 2).

The factors influencing the diagnostic accuracy, are age, gender, and type of patients. The proportion of inaccuracy of traditional provocation tests was higher than that of the IPP triple tests in the SIJD group. The IPP triple tests have better diagnostic accuracy than the traditional provocation tests for cSIJD ($P < 0.05$) (Table 3).

How could 2 physical examination methods differentiate SIJD from LDH? Symptoms of LDH are caused by inflammatory irritation or compression of involved nerve roots, resulting in sciatica (32,33). The IPP triple tests were designed based on the characteristics of SIJs and their dysfunction, and the pain mechanisms related to the LDH were not considered. The one-way ANOVA analysis of influencing factors of diagnostic accuracy between the IPP triple tests and the traditional provocation tests indicated that different types of disorders (groups) affect the accuracy of diagnosis. In the LDH and the control groups, the IPP triple tests and traditional provocation tests demonstrated high differential diagnostic accuracy, which indicates that the 2 methods have good clinical application value in differentiating SIJD from LDH. But it is difficult to identify the cause of LBP, especially for patients with LDH combined with SIJD, in which the IPP triple tests may be positive. In that case, an SIJ diagnostic block and/or selective nerve root block should be considered to differentiate the etiology of LBP.

Limitations

The number of patients in the LDH group is relatively small. Physical examinations were performed by

different physicians, which may lead to the difference among examiners. While palpation pressure may be the same, the patients' tenderness perception may vary, which may impact the examination results. In future studies, we will increase the sample size, and to evaluate the utility of the IPP triple tests in conditions similar to SIJD, including hip joint disease, piriformis syndrome, and cases which SIJD is concomitant with other lumbar disorders to assess the clinical utility of the IPP triple tests in differential diagnosis of LBP.

Conclusions

The novel IPP triple tests demonstrated higher diagnostic accuracy in cSIJD compared with traditional provocation tests. Both of them have good and similar accuracy in differentiating cSIJD from LDH. The IPP triple tests may be an alternative physical examination method for clinical screening of cSIJD.

Acknowledgments

Thanks to Professor Liyuan Tao from Research Center of Clinical Epidemiology, Peking University Third Hospital and Professor Yanxia Luo from the Department of Epidemiology and Health Statistics, School of Public Health, Capital Medical University (Beijing City, China) for their statistical suggestions in this research.

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