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Reliability and validity of a new clinical test for assessment of the sacroiliac joint dysfunction

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Background: Dysfunctional sacroiliac joint (SIJ) has been cited as a source of low backache (LBA). Numerous non-invasive clinical tests are available for its assessment having poor validity and reliability which challenges their clinical utility. Thus, introduction of a new clinical test may be necessary.
Objective: To assess reliability and validity of a new clinical test for the assessment of patients with SIJ movement dysfunction.
Methods: Forty-five subjects (23 having LBA of SIJ origin and 22 healthy asymptomatic volunteers) with mean age 28.62 +/− 5.26 years were assessed by 2 blinded examiners for 3 different clinical tests of SIJ, including the new test. The obtained values were assessed for reliability by intraclass correlation, kappa coefficient and percentage agreement. Validity was assessed by averaging sensitivity and specificity. Positive and negative predictive values and accuracy were assessed.
Results: The new test demonstrates good intra- ($r = 0.81$) and inter-rater ($r = 0.82$) reliability with substantial agreement between raters ($k > 0.60$). It has 79.9% validity, 82% sensitivity, 77% specificity, 79% positive-predictive, 80% negative-predictive value and accuracy.
Conclusion: The new "Shimpi Prone SIJ test" has a good intra- and inter-rater reliability with a substantial rater agreement and a good validity and accuracy for the assessment of patients with SIJ movement dysfunction.

Keywords: Sacroiliac dysfunction; new clinical test; Shimpi test; validity; reliability.

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Introduction

Humans are bipedal locomotor animals who have the gift and the ability to ambulate on the hind limbs whilst functioning with the forelimbs. This adaptation allows humans to perform multiple tasks required for recreation or function or survival. The hind limb allows the person to attain stability as well as movement from one place to other.[1] Technology has enabled humans to invent multiple means and ways of obtaining this ambulation by virtue of the functional adaptation to the bipedal stance.[2]

This adaptation had come at its own costs wherein stability is challenged and compromised by loading the hind limbs with the complete body weight. As against in animals who demonstrate a cross loading of the forelimb and hind limb in slow ambulation and a reciprocal loading of front and hind limbs in fast ambulation, humans have to comprise by alternatively loading the hind limb in slow ambulation by having a double stance phase to an excessive loading in fast ambulation by having a double swing phase.[1] But, these motions alternatively load the lower limbs with 3 to 10 times the body loads and thus have proved to be detrimental in a long run.[2]

The load of the head, arms and trunk (HAT) is transmitted to the lower limbs via the pelvis, which consists of the Ilium, Ischium and the Pubis. This further transmits the body loads to the femur via the hip joint which is a synovial joint having three degrees of freedom of movement. But, the connection of the spine to the pelvis is via the sacroiliac joint (SIJ), which is a fibro-cartilaginous type of a joint with a limited mobility.[3,4] Although there has been a wide assumption that the SI is a joint with minimum mobility, it has been proved that this joint not only aids in load transmission from the axial skeleton to the appendicular skeleton, but also helps in providing motions to the pelvis which assists in effective load distribution and in providing an effective channel for the reduction of the pelvic mobility by absorption of shearing forces during normal ambulation.[2,3]

Low backache (LBA) is one of the most common complaints encountered in routine musculoskeletal practice. Although low back pain has been understood to be associated with a multitude of clinical findings like a prolapsed disc, facetal arthropathy or mechanical in nature, seldom there is a connection established between dysfunction of the SIJ and LBA.[5–7] Reduction in the mobility of the SIJ may result in inability of the spine to efficiently transmit loads to the lower limbs and thus may be a source of symptom.[7] SIJ maintains its stability by virtue of its shape (form closure) and its ability to exert and distribute forces from the trunk to the limbs (force closure). Dysfunction of the SIJ may be either due to the failure of the support system (force closure failure) or due to its inability to move during load transmissions (form closure failure) and thus lead to loss of function in the spine.[4,8,9]

Studies have reported motions in the SIJ from around 1–6 mm (1–9°) which efficiently help in the pelvic motions.[4,8] These motions may vary based on the movement initiation from trunk or the lower limbs.[4] Laslett has introduced multiple test batteries of using three or more tests for identifying SIJ pain. This is due to the fact that these tests are more reliable and valid in identifying SIJ pathology when used together rather than the tests employed for identifying the SIJ motions (dysfunction).[9] Thus, he proposed a variety of clinical tests that help to understand and evaluate the pain associated with dysfunction of the SIJ. Tests like sacral distraction/compression, thigh thrust, Gaenslen, sacral thrust, Patricks FABER, finger point, SIJ pain mapping, etc., have been used to understand SIJ pain with an extremely good efficiency as compared to the Gillet and other palpation-based tests.[9] There is a good validity and reliability for using these pain provocation tests in routine clinical practice.[10–16] But, the dysfunction tests are supposed to have a poor validity, high sensitivity and less specificity.[9] These tests require the performer to either perform active motions which are evaluated by the clinician by assessing the surface motions of the surrounding structures, or are based on elicitation of a clinical response from the patients, which is usually in the form of pain and movement dysfunction in the articular region.[4,6,17] Thus, the presence of pain and assessment of loss of motion have been considered as the source of diagnosis. But, the most common factor shared by almost all of these tests is the performance of specific motions or movements, either passively or actively, requiring a detailed understanding of the motions of the sacrum over the innominate and also understanding and identifying the surface landmarks which may, at times, be challenging. Also, few of these tests may require an appropriate exposure of the surface regions, which may be a challenge in few of the cultures.[4,17,18] Thus, there is a need to develop and understand a clinical test for assessment of SIJ dysfunction which may require the patient to perform controlled motions without exposure of the body parts and to avoid challenges to the examiner in knowing the motions of the surface areas in relation to each other.[19,20]

Methods

Post approval from the institutional ethical committee, a diagnostic study for evaluation of reliability and validity of a new clinical test for assessment of SIJ dysfunction was conducted in a secondary healthcare center in Pune city, India consisting of mixed population. About 128 patients of LBA were referred for Physical Therapy treatment by three Orthopedic Surgeons from July to December 2015 and were screened by an independent post graduate Physical Therapist with eight years of experience and who was not part of the study authors. Thirty-nine subjects from these were considered as patients with SIJ involvement based on non-centralized pain, asymmetry of presentation below L5 spinous process and localizing to the SIJ.[9] Patients who had presented with clinical symptoms of LBA since minimum one month with pain from visual analog scale (VAS) 2–8 of 10, which was non-radiating and localized asymmetrically to the SIJ, were selected. These subjects had been ruled out for any spinal pathology like prolapsed inter-vertebral disc, spinal malignancies, Potts spine, etc. by the concerned referring orthopedic surgeons based on clinical and radiological findings. The independent assessor also assessed the subjects for the basic demographic details and for pain duration (in months) and intensity on a 0–10 VAS.

Healthy subjects who were accompanying their relatives for Physical Therapy and were asymptomatic for any back pain or dysfunction and without any history of LBA in the last three years and willing for voluntary participation in the study without any coercion were also recruited. Post a written informed consent; all the participants were assessed for SIJ mobility by the Gillet test[20–22] (also known as March/Stalk/sacral fixation test), SIJ pain provocation by the Gaenslen test[11,12] and the new test for SIJ dysfunction, termed as the “Shimpi Prone SIJ test” by two independent assessors. Since the objective of the study was to assess the efficacy of the new test (measured by its validity, reliability, sensitivity and specificity) in assessment of SIJ dysfunction as against the current SIJ pain and dysfunction tests, the most common tests used widely for diagnosis of SIJ pathology in the given clinical setup and having a good reliability and validity were chosen.[10,11,22–24] The Gillet test (validity 55.5%[10,23]) and Gaenslen test (validity 48.5%[10]; 56.5%[23]; 65%[25]) were considered as reference tests for the given study as they are being widely used in the current clinical setup rather than the Laslett battery. The gold standard fluoroscopically guided pain block injections test for SIJ dysfunction, which is an invasive procedure by administration of an injection to the SIJ, could not be considered in the present study.[10,18–21]

Assessor 1, who was a Physical Therapist with three years of clinical experience and trained in spinal biomechanical assessment, assessed the subjects twice on day 1 after an interval of 30 min. Assessor 2, who was a Physical Therapist with 11 years of clinical experience and trained in spinal biomechanical assessment, assessed the subjects once on day 2.[10–12] Both the assessors were blinded towards the findings of the other assessor. For subjects presenting with LBA, the SIJ of the painful side was considered for assessment while for the asymptomatic volunteers; any SIJ was taken on a random basis. The patients were asked to give a positive response to pain only if they experienced the familiar pain that they were experiencing due to the SIJ involvement (for the Gaenslen and Shimpi tests).

The Gillets test (March/Stalk/sacral fixation test)[11,22] (Fig. 1) and Gaenslens test[11,12] (Fig. 2) were performed on all the subjects in standing and supine lying position, respectively. The Shimpi Prone SIJ test (new test) was performed with the subject in a prone lying position on a plinth. The assessor palpated for the anterior superior iliac spine (ASIS) and placed the palm of their hand underneath the ASIS. The subject was instructed to extend their hip to around 15° so as to lift the foot just off the examination table (Fig. 3). A normal response to the SIJ movement, i.e., a negative test, was considered when the ASIS was pressed more on the palm of the assessor without the presence of any pain or discomfort. An abnormal response of the SIJ movement, i.e., a positive test, was considered when the ASIS was lifted off the palm of the assessor and concurrently patient experiencing familiar pain or discomfort localized to the SIJ.

Fig. 1. Gillet test for SIJ dysfunction.

Fig. 2. Gaenslen test for SIJ dysfunction.

Fig. 3. Shimpi prone SIJ test.

Statistical analysis

A sample size of 30 was calculated for the study considering the proportion of positive rating for a dichotomous variable by two raters at 0.5 and kappa coefficient set at ≥ 0.6 for a two-tailed test with power at 90%.[26] An independent sample t-test was used to compare the baseline parameters between both the groups with an alpha level set at ≤ 0.05. The obtained results of all participants were assessed for intra-tester and inter-tester reliability by interclass correlation coefficient (ICC) Cronbach's alpha set at 80%[27] and by kappa coefficient set at $k \geq 0.6$[26] by SPSS version 17 (IBM Corporation). The sensitivity, specificity, positive and negative predicted values and accuracy of the tests were set at 80%[25] and were calculated by "Microsoft Office Excel 2010". The Validity was calculated as the average of the sensitivity and specificity and measured in percentages.[23]

Results

Of the 39 patients with SIJ dysfunction, 9 subjects had severe pain with VAS > 8 of 10, acute tenderness on movement with inability to tolerate the tests, and hence were excluded, while 7 patients did not consent for study participation and 23 subjects with LBA having pain from around 1–8 months with intensity from 2–7 on VAS along with 22 healthy volunteers participated in the study (Fig. 4). Both the groups were age matched and comparable post performing an independent sample t-test ($p = 0.26$). The analysis for the intra-rater and intra-rater reliability showed a good correlation by the ICC ($r > 0.8$) and a substantial agreement by the kappa coefficient ($k > 0.6$), both at 95% CI for the Shimpi Prone SIJ test. The test also showed good validity (79.9%) as compared to the other two tests, which was measured in terms of averaging the sensitivity (82%) and specificity (77%), 79% positive predictive, 80% negative predictive values and 80% accuracy (Tables 1–3).

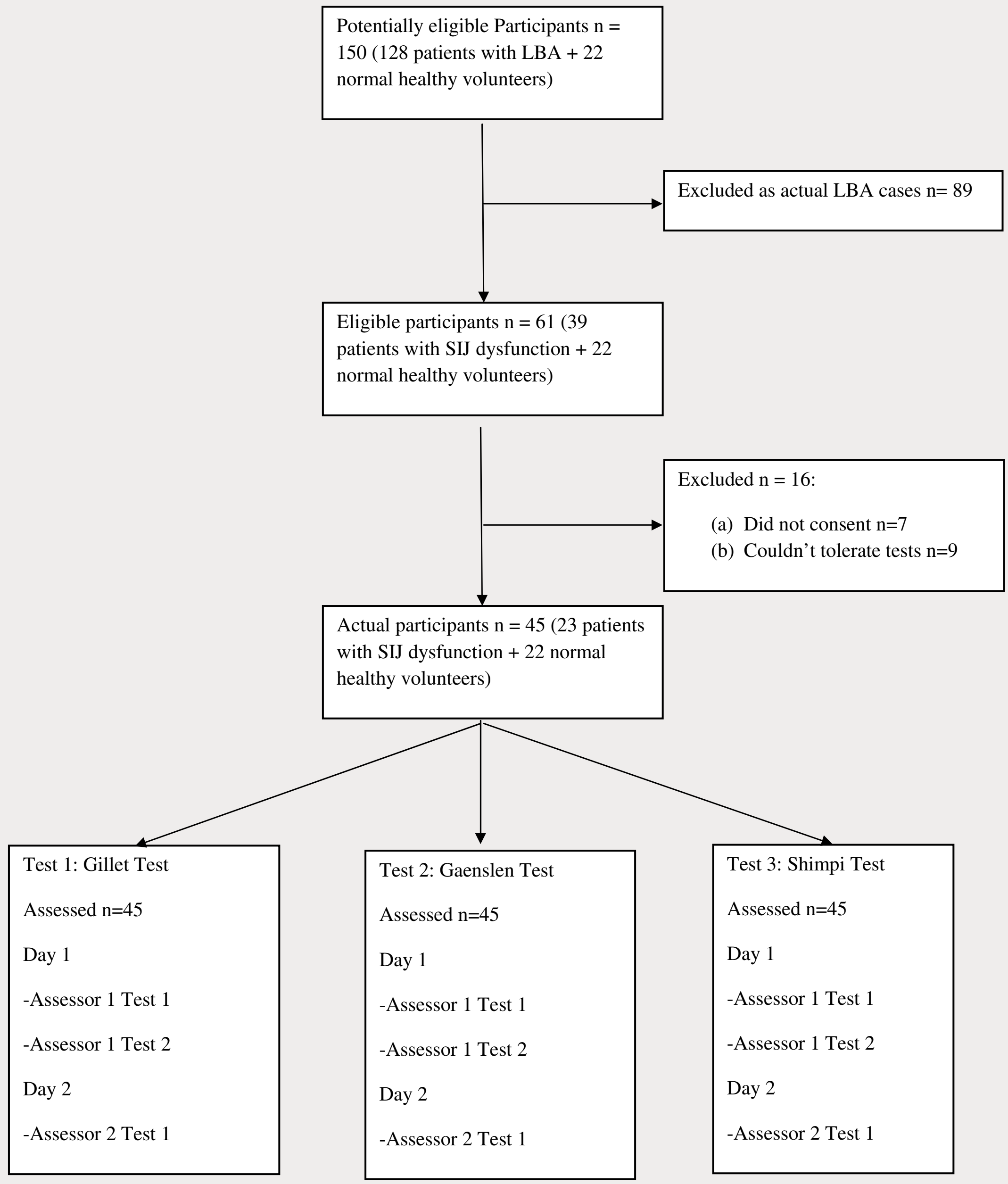

Fig. 4. STARD flowchart of participant's recruitment.

Table 1. Demographic details of the study participants.

Demographics	Subjects with low back pain	Subjects without back pain	Total	P value
Mean age (SD) (in years)	29.4 (4.5)	27.8 (6.1)	28.6 (5.3)	0.265
Females: Males (number)	13:10	13:9	26:19	
Total (number)	23	22	45	
Duration of pain (SD) (months)	4.0 (2.3)	—	—	
Pain intensity (SD) (VAS/10)	4.4 (1.7)	—	—	
Females with history of childbirth (number)	5	3	8	

Note: SD = Standard deviation expressed as +/− mean scores; VAS = Visual analog scale; p = probability value (alpha) significant at ≤ 0.05.

Table 2. Reliability of the Shimpi Prone SIJ test (new test) using ICC and Kappa coefficients.

Test	Intra-rater	95% CI	Inter-rater	95% CI
ICC (r)	0.81	0.66–0.89 ($p = 0.000$)	0.82	0.67–0.90 ($p = 0.000$)
Kappa coefficient (k)	0.68	0.47–0.90	0.69	0.48–0.89
Prevalence index	0.08		0	
Bias index	0.02		0.06	
Percent agreement (%)	84		84	
Unachieved agreement ($1 - k$) (%)	31		30	
Maximum attainable kappa (k max)	0.95	0.85–1.0	0.86	0.72–1.0
Greatest possible agreement (%)	97		93	

Note: ICC = Intraclass correlation coefficient; 95% CI = 95% confidence interval; p = probability value (alpha) significant at ≤ 0.05.

Table 3. Validity of the three tests (averaged with the sensitivity and specificity expressed as percentages) as obtained in present study.

Test	Gillet test	Gaenslen test	Shimpi Prone SIJ test
Validity (%) (SD)	62.54 (20.82)	71.14 (2.23)	79.94 (3.77)

Note: SD = Standard Deviation expressed as +/− mean.

Discussion

The SIJ is poorly understood in its functional role.[28] The dysfunctional SIJ has been cited as a source of low back pain by many authors.[6–19,24,25,28] Symptoms can include pain in the low back, buttock region, pain radiating to thigh region or one side of the body.[29] The primary function of the SIJ is load transfer which is largely dependent on its available mobility and joint stability. It also functions in torque conversion, allowing the transverse rotations that take place in the lower extremity to be transmitted up the spine. The SIJ, like all lower extremity joints, provides a "self-locking" mechanism, where the joint occupies or attains its most congruent position, i.e., the close pack position by the form closure. This helps with stability during the push-off phase of walking. The joint locks (or rather becomes close packed) on one side as weight is transferred from one leg to the other, and through the pelvis, the body weight is transmitted from the sacrum to the hip bone.[30] Compared to the quadruped gait, the bipedal gait needs to have a very strong support to overcome the resistance from gravity. In the upright posture, increased lumbo pelvic compression forces are necessary for stability, which occur at the expense of the joint mobility.[31] This compromise is done by the SIJ.

The SIJ is a true diarthrodial synovial joint, and is unlike any other joint in the body wherein only the ventral third of the joint is a true synovial joint.[29] The pelvis comprises of an arch system which helps in transmitting force across this joint. The posterior arch transmits body weight while the anterior arch provides stability to the posterior arch, and acts as a compression strut for the ground reaction forces which transmits through the femur and across the pubic rami.[32] Normal motions of the SIJ are Nutation and Counter Nutation.[4,29] Nutation of the sacrum is the anterior tilting and rotatory motion of the sacrum wherein the articular surfaces of the innominate move posterior–inferior on the sacrum (Fig. 5). The counter-nutation exhibits the opposite motion. These movements are opposed by the shape of the sacrum, ligamentus system and the friction coefficient of the joint surface. Disturbances in these motions are exhibited as increased linear and angular motions over the lumbosacral junction as well as increased motions of the hip.[33] These movements can never be isolated in a closed chain as the lumbopelvic motions function as an entire biomechanical unit which can be

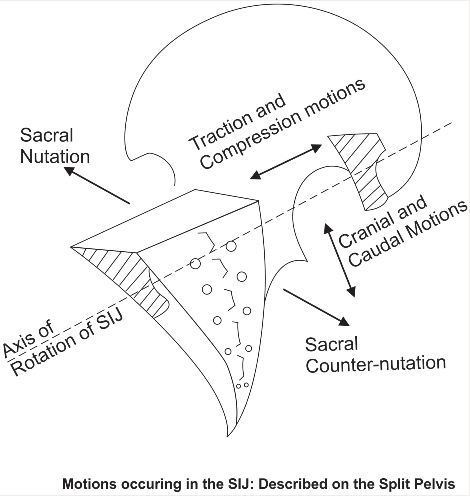

Fig. 5. Normal motions of the SIJ.

understood in many routine activities of daily living, including the normal human bipedal gait.[4] But, these motions are too complicated to be assessed in routine clinical assessments and thus, to examine the SIJ, a series of tests have been proposed in an open-chain fashion. Goode *et al.* have documented extremely minimal movement of the SIJ and have questioned the validity and clinical utility of such movement dysfunction studies, like the Gillet test, which rely on motion production, in diagnosing the SIJ pathology.[4]

Tests for the SIJ basically look at two components: (a) mobility of the SIJ in terms of a translatoric glide (movement based tests) and (b) mobility of the SIJ in terms of traction or compression of the joint surfaces (pain provocation-based tests). Such tests can also be performed by loading the joint surfaces for their ability to transfer loads through the posterior arch system.[34] Most of the movement dysfunction tests of SIJ make it difficult to stabilize the proximal sacral component whilst assessing the movement of the innominate over it. As a closed kinematic system, it may be difficult to restrict motions only to the side being tested and authors feel that there is always a probability of the motions being transferred/translated to the contra lateral SIJ as well. But, the lumbosacral motions, in the absence of clinical motions in SIJ during hypomobile pathology, can be used clinically to establish the diagnosis. Dysfunction of the SIJ may occur due to the reduction in the nutation or counter-nutation motions which may be presented clinically as SIJ pain (radiating or non-radiating to the posterior of the thigh) or rarely as low back pain (due to the transfer of the shearing forces on the lumbosacral junction).[34,35] Thus, there arises a need to identify such SIJ dysfunctions faster and with good accuracy in routine clinical practice.

The “Shimpi Prone SIJ test” is based on a normal versus an abnormal clinical response to SIJ mobility along with pain provocation. The assessor checks the movement of the SIJ in a prone position by asking the patient to actively lift the leg off the examination table (Hip extension to 15°). Also, the patient has to report for the presence of familiar pain in the SIJ during this motion. When this movement is performed actively, the gluteus maximus, assisted by the hamstrings, lifts the leg off to perform hip extension. This can be done only when the back muscles, the multifidi and erector spinae, stabilize the vertebrae thereby allowing the hip extensors to act on the pelvis and the thigh. The gluteus connects to the thoracolumbar fascia and performing the extension motion by the glutei also adds to the SIJ stability by virtue of force closure of the pelvis and obtaining a dynamic stability to it. Also, the deep group of back muscles, the multifidi, helps in dynamically stabilizing the spine thereby preventing any excessive motion in the vertebral column. Such compressive and translatoric forces acting across the SIJ may provoke the pain within the joint region by stimulating the intra-articular nociceptive structures within the joint[35–37] and may be the reason for the pain response in the Shimpi test.

Mobility in the Shimpi test includes movement at the lumbosacral junction and allows extension of the hip (acetabulofemoral) joint by causing a counter-nutation motion of the SIJ. A normal response in performing hip extension is the initiation of extension at the lower lumbar and lumbosacral regions along with an anterior rotation of the pelvis (pelvic nutation) and the extension of the hip. These motions cause the ASIS to move ventrally and press on the palm of the examiner under the ASIS (Fig. 6).[15,18,35] A dysfunctional SIJ would have a reduced motion and thus, when active extension is initiated, the possible movements would be the extension at the lower lumbar, lumbosacral regions along with the hip extension.[18] The absence of pelvic nutation would cause the entire ipsilateral pelvis to get lifted off the examination table (Fig. 6). This mechanism, in addition to the elicitation of pain, is used in the Shimpi test to assess

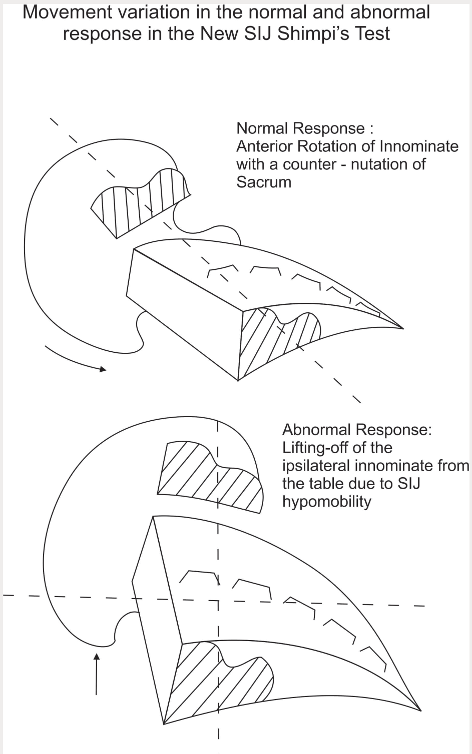

Fig. 6. Normal (above) and abnormal (below) response to the Shimpi test.

SIJ dysfunction. The motion-based tests available currently attempt to assess the minimal motions in the SIJ in isolation which is their limitation.[4] But, using the motions of the lumbar and lumbosacral unit, motion dysfunction at the SIJ can be assessed by the Shimpi test with repeatability and accuracy making it a clinically highly reliable (intra- and inter-rater) and valid (79.9%) motion-based assessment test.

The Shimpi test is fairly identical to the anterior SLR (ASLR) test which assesses the pelvic girdle pain by loading the SIJ during an active leg lift to around 20 cm.[38] The ASLR test would be based on various factors, including the lower limb strength and the abdominal bracing ability.[39] But, as the range of hip flexion is greater than extension, there is no incorporation of pelvic motion till later 2/3rd of its movement. Also, it becomes difficult to identify movement dysfunction with this test. Shimpi test, unlike the ASLR, not only loads the SIJ for elicitation of familiar pain, but also assesses the motion of the pelvic region by ASIS lift and thus provides a double check system for diagnosing SIJ pathology. The Shimpi's test can easily be performed even in obese patients and does not even require exposure of the low back and gluteal region which is ethically acceptable in many cultures. The only pre-requisite is the skill of identification and palpation of the ASIS, which is a bony landmark and an easily recognizable one in most of the population.[33] Also, the patient lies in a comfortable prone position and does not possess difficulties for stability or balance concerns. The motion required is just an active 15° hip extension which can initiate and differentiate between a normal and abnormal response of the SIJ.

The limitations in performance of this test would be the requirement to lie in a prone position. This may be a challenge in severely obese patients or in pregnant females in their 2nd and 3rd trimester who are frequently predisposed to SIJ dysfunction.[14,15,35] Also, patients with weaknesses of the erector spinae, multifidi or gluteus maximus and hamstrings may be unable to perform this movement actively.[36] Also, this test largely relies in the motion of the hip joint and would not be useful in diagnosing SIJ pathologies in the presence of hip joint pathologies like Avascular Necrosis or Hip Osteoarthritis which may limit motions and thus may not be a good tool for assessment in them. The assessor may also need to get conditioned to gauging the pressures exerted by the SIJ during normal and abnormal motions, especially, in conditions with lower cross syndromes, etc. But such skills can be easily gained with training and experience.

Conclusion

The authors would like to conclude by introducing the "Shimpi Prone SIJ test" as an extremely useful non-invasive clinical tool having a good intra- and inter-rater reliability with a substantial rater agreement and having a good validity and accuracy for the assessment of the SIJ in patients with SIJ movement dysfunction.

Conflict of Interest

All contributing authors declare that they have no conflicts of interest.

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Author Contributions

The study concept and design, data acquisition, data analysis and interpretation and manuscript drafting were carried out by Apurv Shimpi. Renuka Hatekar contributed to data acquisition and manuscript drafting. Ashok Shyam contributed to manuscript revision and critical analysis and the project management and manuscript approval were carried out by Parag Sancheti.

References

1. Harcourt-Smith WE, Aiello LC. Fossils, feet and the evolution of human bipedal locomotion. J Anat 2004;204(5):403–16.
2. Niemitz C. The evolution of the upright posture and gait — A review and a new synthesis. Naturwissenschaften 2010;97(3):241–63, doi: 10.1007/s00114-009-0637-3.
3. Shi D, Wang F, Wang D, Li X, Wang Q. 3-D finite element analysis of the influence of synovial condition in sacroiliac joint on the load transmission in human pelvic system. Med Eng Phys 2014;36(6):745–53, doi: 10.1016/j.medengphy.2014.01.002.
4. Goode A, Hegedus EJ, Sizer P, Brismee JM, Linberg A, Cook CE. Three-dimensional movements of the sacroiliac joint: A systematic review of the literature and assessment of clinical utility. J Man Manip Ther 2008;16(1):25–38.
5. Simpson R, Gemmell H. Accuracy of spinal orthopaedic tests: A systematic review. Chiropr Osteopat 2006;14:26.
6. Vleeming A, Albert HB, Ostgaard HC, Sturesson B, Stuge B. European guidelines for the diagnosis and treatment of pelvic girdle pain. Eur Spine J 2008;17(6):794–819, doi: 10.1007/s00586-008-0602-4.
7. Polly DW, Cher D. Ignoring the sacroiliac joint in chronic low back pain is costly. Clinicoecon Outcomes Res 2016;8:23–31, doi: 10.2147/CEOR.S97345.
8. Vleeming A, Schuenke MD, Masi AT, Carreiro JE, Danneels L, Willard FH. The sacroiliac joint: An overview of its anatomy, function and potential clinical implications. J Anat 2012;221(6):537–67, doi: 10.1111/j.1469-7580.2012.01564.x.
9. Laslett M. Evidence-based diagnosis and treatment of the painful sacroiliac joint. J Man Manip Ther 2008;16(3):142–52.
10. Stuber KJ. Specificity, sensitivity, and predictive values of clinical tests of the sacroiliac joint: A systematic review of the literature. J Can Chiropr Assoc 2007;51(1):30–41.
11. Cattley P, Winyard J, Trevaskis J, Eaton S. Validity and reliability of clinical tests for the sacroiliac joint. A review of literature. Australas Chiropr Osteopa 2002;10(2):73–80.
12. Laslett M, Williams M. The reliability of selected pain provocation tests for sacroiliac joint pathology. Spine 1994;19(11):1243–9.
13. Hansen HC, McKenzie-Brown AM, Cohen SP, Swicegood JR, Colson JD, Manchikanti L. Sacroiliac joint interventions: A systematic review. Pain Physician 2007;10(1):165–84.
14. McKenzie-Brown AM, Shah RV, Sehgal N, Everett CR. A systematic review of sacroiliac joint interventions. Pain Physician 2005;8(1):115–25.
15. Szadek KM, van der Wurff P, van Tulder MW, Zuurmond WW, Perez RS. Diagnostic validity of criteria for sacroiliac joint pain: A systematic review. J Pain 2009;10(4):354–68, doi: 10.1016/j.jpain.2008.09.014.
16. Kokmeyer DJ, van der Wurff P, Aufdemkampe G, Fickenscher TCM. The reliability of multitest regimens with sacroiliac pain provocation tests. J Manip Physiol Ther 2002;25:42–48.
17. Bates CK, Carroll N, Potter J. The challenging pelvic examination. J Gen Intern Med 2011;26(6):651–7, doi: 10.1007/s11606-010-1610-8.
18. Simopoulos TT, Manchikanti L, Singh V, Gupta S, Hameed H, Diwan S, Cohen SP. A systematic evaluation of prevalence and diagnostic accuracy of sacroiliac joint interventions. Pain Physician 2012;15(3):E305–44.
19. Mitchell B, Verrils P, Vivian D. Sacroiliac joint pain: Diagnosis and treatment. Australas Musculoskelet Med 2012;17(1):15–24. Availabe at http://search.informit.com.au/documentSummary;dn=482415868079808;res=IELHEA.
20. Cohen SP, Chen Y, Neufeld NJ. Sacroiliac joint pain: A comprehensive review of epidemiology, diagnosis and treatment. Expert Rev Neurother 2013;13(1):99–116, doi: 10.1586/ern.12.148.
21. Savran Sahin B, Aktas E, Haberal B, et al. Sacroiliac pain and CT-guided steroid injection treatment: High-grade arthritis has an adverse effect on outcomes in long-term follow-up. Eur Rev Med Pharmacol Sci 2015;19(15):2804–11.
22. Meijne W, Van Neerbos K, Aufdemkampe G. Intraexaminer and interexaminer reliability of the Gillet test. J Manip Physiol Ther 1999;22:4–9.

23. Mangen J, Folia V. Validity of clinical tests for sacroiliac and lumbar joint dysfunction: A systematic review of literature. 2009. Available at http://kennisbank.hva.nl/document/219268.
24. Arab AM, Abdollahi I, Joghataei MT, Golafshani Z, Kazemnejad A. Inter- and intra-examiner reliability of single and composites of selected motion palpation and pain provocation tests for sacroiliac joint. Man Ther 2009;14(2):213–21, doi: 10.1016/j.math.2008.02.004.
25. Nicholls B, Thompson J. Reliability and validity of selected pain provocation tests at the sacroiliac joint. Available at http://vuir.vu.edu.au/932/1/Thompson_et.al_2003.pdf.
26. Sim J, Wright CC. The kappa statistic in reliability studies: Use, interpretation, and sample size requirements. Phys Ther 2005;85(3):257–68.
27. Domholdt E. Physical therapy research. In: Priniciples and Application. 2nd ed. Philadelphia, PA: WB Saunders Co. 2000.
28. Beal MC. The sacroiliac problem: Review of anatomy, mechanics, and diagnosis. J Am Osteopath Assoc 1982;81:667–79.
29. Kapandji IA. The Physiology of the Joints. Vol 3. New York: Churchill Livingstone, 1974:54–71.
30. Ward C. Interpreting the posture and locomotion of Australopithecus afarensis: Where do we stand? Am J Phys Anthropol 2002;119(S35):185–215.
31. Yin W, Willard F, Carreiro J, et al. Sensory stimulation-guided sacroiliac joint radiofrequency neurotomy: Technique based on neuroanatomy of the dorsal sacral plexus. Spine 2003;28:2419–25.
32. Poley RE, Borchers JR. Sacroiliac joint dysfunction: Evaluation and treatment. Phys Sportsmed 2008;36(1):42–9, doi: 10.3810/psm.2008.12.10.
33. Stovall BA, Bae S, Kumar S. Anterior superior iliac spine asymmetry assessment on a novel pelvic model: An investigation of accuracy and reliability. J Manip Physiol Ther 2010;33(5):378–85, doi: 10.1016/j.jmpt.2010.05.005.
34. Harrison DE, Harrison DD, Troyanovich SJ. The sacroiliac joint: A review of anatomy and biomechanics with clinical implications. J Manip Physiol Ther 1997;20(9):607–17.
35. Ilaslan H, Arslan A, Koç ON, Dalkiliç T, Naderi S. Sacroiliac joint dysfunction. Turk Neurosurg 2010;20(3):398–401, doi: 10.5137/1019-5149.JTN.2612-09.2.
36. Haufe SM, Mork AR. Sacroiliac joint debridement: A novel technique for the treatment of sacroiliac joint pain. Photomed Laser Surg 2005;23(6):596–8.
37. Szadek KM, Hoogland PV, Zuurmond WW, De Lange JJ, Perez RS. Possible nociceptive structures in the sacroiliac joint cartilage: An immunohistochemical study. Clin Anat 2010;23(2):192–8, doi: 10.1002/ca.20908.
38. Liebenson C, Karpowicz AM, Brown SH, Howarth SJ, McGill SM. The active straight leg raise test and lumbar spine stability. PM R 2009;1(6):530–5, doi: 0.1016/j.pmrj.2009.03.007.
39. Hu H, Meijer OG, Hodges PW, et al. Understanding the Active Straight Leg Raise (ASLR): An electromyographic study in healthy subjects. Man Ther 2012;17(6):531–7, doi: 10.1016/j.math.2012.05.010.