INTEREXAMINER RELIABILITY OF A LEG LENGTH ANALYSIS PROCEDURE AMONG NOVICE AND EXPERIENCED PRACTITIONERS

Kelly R. Holt, BSc (Chiro), PGCertHSc,[a] David G. Russell, BSc (Chiro),[b] Nicholas J. Hoffmann, BHlthSci, B Chiro,[c] Benjamin I. Bruce, B Chiro,[d] Paul M. Bushell, B Chiro,[e] and Heidi Haavik Taylor, BSc (Chiro), PhD[f]

ABSTRACT

Objective: The purpose of this study was to evaluate the interexaminer reliability of a leg length analysis protocol between an experienced chiropractor and an inexperienced chiropractic student who has undergone an intensive training program.

Methods: Fifty participants, aged from 18 to 55 years, were recruited from the New Zealand College of Chiropractic teaching clinic. An experienced chiropractor and a final-year chiropractic student were the examiners. Participants were examined for leg length inequality in the prone straight leg and flexed knee positions by each of the examiners. The examiners were asked to record which leg appeared shorter in each position. Examiners were blinded to each other's findings. κ statistics and percent agreement between examiners were used to assess interexaminer reliability.

Results: κ analysis revealed substantial interexaminer reliability in both leg positions and also substantial agreement when straight and flexed knee results were combined for each participant. κ scores ranged from 0.61, with 72% agreement, for the combined positions to 0.70, with 87% agreement, for the extended knee position. All of the κ statistics analyzed surpassed the minimal acceptable standard of 0.40 for a reliability trial such as this.

Conclusion: This study revealed good interexaminer reliability of all aspects of the leg length analysis protocol used in this study. (J Manipulative Physiol Ther 2009;32:216-222)

Key Indexing Terms: *Leg Length Inequality; Chiropractic; Observer Variation; Reproducibility of Results*

The identification and correction of chiropractic vertebral subluxation lies at the heart of many chiropractic practices.[1] Yet, the literature provides little support of the reliability of most commonly used analytical techniques.[2-17] One analytical technique that has shown some promise with respect to reliability is prone visual leg length analysis (LLA).[18-20]

[a] Researcher, Research Department, New Zealand College of Chiropractic, Auckland, New Zealand.
[b] Chiropractic Centre Director, Chiropractic Centre, New Zealand College of Chiropractic, Auckland, New Zealand.
[c] Private Practice, Gold Coast, Australia.
[d] Private Practice, Auckland, New Zealand.
[e] Private Practice, Napier, New Zealand.
[f] Director of Research, Research Department, New Zealand College of Chiropractic, Auckland, New Zealand.
Submit requests for reprints to: Kelly R. Holt, BSc (Chiro), PGCertHSc, Researcher, New Zealand College of Chiropractic, PO Box 113-044, Newmarket, Auckland, New Zealand.
(e-mail: kelly.holt@nzchiro.co.nz).
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There are numerous methods for assessing leg length inequality (LLI). The 3 most commonly used analytical methods are radiographic examination, orthopedic devices (including basic tape measurement), and the 'quick' visual leg check.[21] The choice of method to use depends on what type of LLI the practitioner is assessing for. The 2 types of LLI that are important to chiropractic practitioners are anatomical LLI and functional LLI.

Anatomical LLI is a skeletal asymmetry that exists somewhere in the lower limb and is caused by congenital, traumatic, neoplastic, degenerative, or infectious means.[18,21,22] This has been reported to be present in 90% of the population at an average of 5.2 mm with no sex predilection.[22] The standard approach for determining the presence of an anatomical LLI is radiographic examination.[19,21]

A functional LLI is a more controversial phenomenon[23] and is thought to result from physiological adaptations to distorted biomechanics anywhere along the kinetic chain, such as asymmetric muscle contraction or bony misalignment.[18,19,21] These biomechanical abnormalities are fundamental to many vertebral subluxation models[1,24-26]; therefore, many chiropractic technique packages use tests for functional LLI as a part of their analytical procedure.[18,27,28] Chiropractic functional LLI tests generally combine an observation of the feet in the prone extended knee position as well as the prone flexed knee position to ascertain whether 1 leg appears shorter than the other. The combination of observed LLI in the 2 positions is theorized to offer information that may be of help in making clinical decisions about the nature of vertebral subluxations detected in the spine and the type of corrections that should follow.[19,27,28]

Despite the widespread use of LLA in clinical practice, questions remain about the involvement of functional LLI in musculoskeletal disorders.[18] The New Zealand College of Chiropractic (NZCC) uses LLI analysis in its teaching and clinical program. The protocol used at the college is similar to many of the named chiropractic techniques such as the Derifield-Thompson leg check procedure, the Activator Methods Chiropractic Technique protocol, and the Torque Release Technique protocol.[19,27-29] Although it is based on these common techniques, the protocol taught at the NZCC emphasizes evaluation of small differences in the checking procedure and clinical implications of the outcome of the test.

Although there is still insufficient literature to support the clinical relevance of leg length tests,[23] their widespread use in chiropractic practice[30,31] suggests that LLI testing requires more scientific investigation to establish the reliability and validity of the testing procedures.[22] Previous studies that have shown good interexaminer reliability of LLI analysis procedures have tended to employ experienced examiners.[18,19] There is some contradictory evidence in the literature about the role of experience or training in developing interexaminer reliability.[7,32] One study that employed experienced examiners showed that consensus training can improve the reliability of palpatory tests of the spine from poor or fair to a clinically acceptable range.[7] Another study showed no significant improvement in interexaminer reliability of students performing sacroiliac motion palpation after 1 year of training during their final year at a chiropractic college.[32]

In this study, the authors evaluated whether a chiropractic student, who was a relative novice at analyzing LLI, could be trained to achieve an acceptable level of agreement with an experienced chiropractor over a 16-week training period. The aim of this study was therefore to establish the interexaminer reliability of a LLA protocol between an experienced chiropractor and an inexperienced chiropractic student who has undergone an intensive training program. Of secondary interest to the investigators was to observe if reliability of the LLA protocol changed during the examiner training program because this may be important when considering the way the technique is taught within the NZCC curriculum.

Methods

Setting

Data collection took place in a lecture room at the NZCC over 3 separate sessions. The room had 2 Lloyd integrator portable chiropractic tables positioned on each side of the room opposing each other.

Study Participants

Fifty volunteers were invited to participate in this trial. Participants were recruited from existing patients at the NZCC teaching clinic. Participants included staff and students of the NZCC as well as public patients. To be eligible to be included in this study, the participants had to be 18 years or older, be an existing patient at the NZCC teaching clinic, be able to tolerate lying in the prone position for up to 5 minutes, and agree to participate in the study. Exclusion criteria included the presence of any red flag, illness or condition that affected the participant's ability to lie prone or have their knees flexed comfortably to 90°. They were also excluded if they had received a chiropractic adjustment in the previous 7 days or if no evidence of LLI was detected during a brief screening examination conducted by an experienced chiropractor. The investigators chose to exclude participants with no evidence of LLI as the examiners were asked to classify participants as either left or right short leg with no option of even leg length. This was done for 2 reasons. First reason was to reduce the confounding effect of expecting the examiners to define a cutoff value when determining if an LLI was present when the difference in leg length was considered to be minimal. Secondly, previous studies have found very few or no participants with no LLI,[18-20] which hindered interpretation of the results, particularly with the κ statistic, which becomes unstable if the prevalence of any one finding is too high or too low.[10,18,19,33] Participants were excluded if they had had a recent chiropractic adjustment because pilot testing revealed that these participants were more likely to have variable LLI findings over a short space of time. All participants were familiar with the LLA procedure used in this study because it was routinely incorporated into their chiropractic visits to the NZCC teaching clinic.

Examiners

One experienced chiropractor (DR) and 1 final-year chiropractic student (PB) were the examiners in this study. The experienced chiropractor had 7 years of full-time clinical experience and routinely used the LLA procedure used in this study in practice. Before data collection, the examiners had 8 consensus training sessions that lasted approximately 45 minutes each. These 8 sessions were spread over 16 weeks to allow the student examiner to practice the procedure when seeing patient's in the NZCC teaching clinic. During these sessions, photographs and videotape footage were taken to help compare the technique of the examiners and to work toward a uniform procedure between the examiners (Figs 1 and 2). Pilot data were collected during some of these training sessions to practice the data collection protocol and to establish whether agreement was improving as compared to baseline measures of agreement between the 2 examiners.

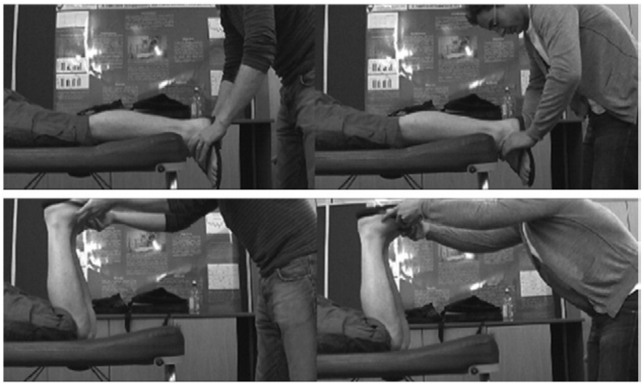

Fig 1. *Example of comparison photos taken during a training session to evaluate consistency of procedure between examiners.*

Fig 2. *Example of comparison photos taken during a training session to evaluate consistency of procedure between examiners.*

Experimental Procedures

Participants were given a brief explanation and an information sheet before taking part in the study. When they presented for data collection, an assistant explained the study again, checked for eligibility, and obtained written informed consent. Participants were then screened for the presence of LLI by a chiropractor with 7 years of clinical experience and excluded if no evidence of LLI was found. A computerized random number generator was then used to determine which examiner examined the participant first. Because of the nature of the data collection procedure, neither participants nor examiners were blinded with respect to examiner order.

Eligible participants were then escorted in pairs into the examination room. Participants were examined wearing closed shoes or barefoot if they presented wearing loose-fitting slip-on shoes. Participants were asked to empty their pockets before being guided to and asked to position themselves on the appropriate examination table. The first examiner then repositioned and examined the participant according to the LLA examination procedure, which is described below.

Participant Positioning. Each participant was positioned so that each foot was equidistant to a central dot marked on the table. The tibial tuberosities of each leg were approximately aligned with the beginning of the wedge cushion on the tabletop. The participant's arms were placed against their sides and were resting on the table.

1. *Examination position 1*: The examiner flexed the legs of the participant twice to 90° then returned them to the extended knee position. The examiner then cupped the cuboid bones of both feet with their thumbs. No contact whatsoever at this time was made with the dorsum of the foot. A downward and cephalad pressure was placed to remove any plantar flexion and supination. The examiner ensured the feet were parallel to the end of the table and looked perpendicularly down at the participant's feet and compared leg lengths using the sole of the shoe as a reference or the heel of the foot if the participant was barefoot. The possible recordable findings were short left or short right leg.
2. *Examination position 2*: The examiner then moved his thumbs distally and contacted the plantar metatarsal shafts of each foot while gripping the feet with the fingers over the corresponding dorsal anatomic structures. Both knees were then flexed evenly to 90° while maintaining the feet in the midline but not allowing any contact between the feet. The examiner then moved his eye level to that of the plantar surface of the foot and looked parallel and cephalad to determine the inequality finding. The side of short leg in position 2 was assigned based on whether the short leg identified in position one became shorter or longer. The observations of leg length in the 2 positions were then combined and assigned a shorthand code similar to those used in the Derifield-Thompson leg check procedure.[19] A right short leg going shorter was referred to as R−, right short leg going longer was referred to as R+, left short leg going shorter was referred to as L−, and left short leg going longer was referred to as L+.

After their evaluation, the examiner recorded their results on a form that remained shielded from the other examiner and the participant. Participants were asked to remain prone without repositioning themselves, and the examiners

Table 1. *Short leg determined by each examiner in the prone extended knee position*

		Examiner 1		
		L	R	Total
Examiner 2	L	12	2	14
	R	4	28	32
	Total	16	30	46

κ = 0.70 (95% CI, 0.49-0.92). Percent agreement was 87%.

Table 2. *Leg that went shorter determined by each examiner when knee was bent to the flexed knee position*

		Examiner 1		
		L	R	Total
Examiner 2	L	16	7	23
	R	1	22	23
	Total	17	29	46

κ = 0.65 (95% CI, 0.44-0.86). Percent agreement was 83%.

swapped tables to examine the other participant. The examiners were asked not to talk to each other or the participants during the procedure, and a research assistant was present throughout the procedure to coordinate the examiners activities and to ensure that the examiners remained blinded to each other's findings. Participants were also blinded to the examiners results.

The examiners were not asked to determine the magnitude of the LLI just the side of short leg. As already mentioned, examiners were unable to classify leg lengths as being even to reduce the need for a cutoff judgment by the examiners with respect to what magnitude of LLI was considered relevant.

Ethical Considerations

All of the participants were given a detailed information sheet and explanation of the study before consenting to take part. Participants received no compensation for taking part in this study. The study was approved by the New Zealand Ministry of Health Northern X Regional Ethics Committee and was conducted in accordance with the Declaration of Helsinki.

Statistical Analysis

Cohen κ was used to calculate the agreement between examiners. It is generally accepted that when assessing for interexaminer reliability between 2 examiners for nominal data, the κ statistic should be used, with a κ value of 0.4 considered to be the minimum acceptable value of concordance.[12,14,15,33,34] κ is a measure of chance corrected concordance and therefore corrects the observed agreement for agreement that is expected by chance alone.[34] The following standard is generally applied to express the strength of agreement for $\kappa \leq 0$, poor; κ = 0.01-0.20, slight; κ = 0.21-0.40, fair; κ = 0.41-0.60, moderate; κ = 0.61-0.80, substantial; and κ = 0.81-1, almost perfect.[33] κ is said to become unstable when there is a large proportion of agreement that is limited to one of the possible rating choices.[34] It was therefore decided that if the mean prevalence of positive findings for any test was less than 10% or greater than 90% for either examiner, the level of agreement would be represented by a 95% confidence interval (CI) for the κ coefficient. A 2-category κ was used for each of the knee positions used, and a 4-category κ was used to evaluate the combination of leg length findings. Percentage agreement between examiners was also recorded.

A minimum sample size of 38 participants was chosen to capture a desired κ of at least 0.4 with an α of .05 and β of .20. The final sample size of 46 participants therefore provided at least 80% power to detect a significant κ value of at least 0.40.

Results

Of the 50 volunteers who were invited to participate, 4 were excluded. Two were excluded because they were unable to lie prone and have their knees flexed due to lower limb abnormalities. The other 2 were excluded due to no discernible LLI being detected during their screening examination. Data were therefore collected from 46 participants, aged 18 to 55 years, including 33 NZCC students and faculty and 13 public patients.

For the knees in the extended position, percentage agreement between the 2 examiners was 87% (40/46) with κ = 0.70 (Table 1). With the knees in the flexed position, percentage agreement was 83% (38/46) with κ = 0.65 (Table 2). When the observations were combined into 1 of 4 categories (L−, L+, R−, R+), percentage agreement was 72% (33/46) with κ = 0.61 (Table 3).

Both examiners found the right leg to be shorter more often than the left in the extended knee position (32 and 30 out of 46, respectively). In the flexed knee position, 1 examiner found the right leg went shorter more often (29/46), but the other examiners' observations were split evenly between each leg (23/46 for each). The summary of results for each position and combined positions is displayed in Table 4.

During a number of the examiner training sessions, pilot data were recorded to observe whether reliability was improving. These data were meant for exploratory analysis only and were not always collected under experimental conditions. Over the 16-week training period, agreement between examiners remained fairly poor and did not improve for the first 12 weeks. At the first training session, the examiners agreed in 8 of 12 volunteers for the knee extended position, but only 4 from 12 for the knee flexed position, which was less than chance. During the following 4 sessions, a number of modifications were made to the student examiners technique with little impact on reliability. Reliability at session 5 was no better than chance for either

Table 3. *Combination of side of initial short leg and leg that went shorter when knees were flexed as determined by each examiner*

		Examiner 1				
		L+	L−	R+	R−	Total
Examiner 2	L+	7	0	0	1	8
	L−	4	1	1	0	6
	R+	1	2	12	2	17
	R−	1	0	1	13	15
	Total	13	3	14	16	46

κ = 0.61 (95% CI, 0.43-0.78). Percent agreement was 72%.

Table 4. *Summary of agreement between examiners for each component of the LLA protocol*

Leg position	κ	95% CI	Percentage agreement between examiners
Knee extended	0.70	0.49-0.92	87
Knee flexed	0.65	0.44-0.86	83
Combined position	0.61	0.43-0.78	72

of the knee positions (5 of 10 for both positions). It was only over the final 4 weeks of training that agreement began to improve and approach the levels found in the final data collection sessions reported above.

Discussion

In this study, the interexaminer reliability of a LLA procedure between an experienced chiropractor and an inexperienced chiropractic student, who had undergone an intensive training program, was substantial for all 3 sets of observations made. These results are consistent with previous studies that have used experienced practitioners as examiners.[18-20] Fuhr and Osterbauer[20] reported fair to substantial κ values (0.31-0.75) when investigating interexaminer reliability between 2 experienced practitioners with patients in the prone knees extended position. Nguyen et al[18] also investigated reliability of LLI observed in patients in the prone knees extended position and reported percentage agreement between examiners for the side of short leg of 85% with a κ of 0.66. Recently, Schneider et al[19] found a percentage agreement of 82% with κ = 0.65 when examining for LLI in the prone extended knee position. Interestingly, Schneider et al[19] also examined their participants in the prone flexed knee position but found an extremely high prevalence (95% of overall observations) of the short leg going longer. This meant the κ values for the agreement between examiners became relatively meaningless due to the high prevalence of the single finding from both examiners causing instability of the κ statistic.[19,34] In this study, we found slightly more overall observations of the short leg going longer (52 of 92), but we found a much higher percentage of the short leg going shorter (43%) than that reported by Schneider et al (3%).[19] This may reflect small differences in the technique used to flex the knees to 90° between the Activator leg check procedure used by Schneider et al[19] and the LLA used in this study. It is also possible that the type of table, in particular the firmness of the foam covering, used in each of the studies resulted in these different results. In this study, we found very few volunteers with no discernible LLI (2 of 50), which is consistent with the previous studies already discussed that reported observations of even leg lengths ranging from 0 of 90 observations[19] to 2 of 68 observations.[18]

The results obtained in this study suggest that with a fairly intensive training program, a chiropractic student can perform a quick visual leg check in a manner that results in acceptable interexaminer reliability with an experienced practitioner. Of note to chiropractic educators was how long it took before acceptable levels of agreement began to occur between the 2 examiners. It took approximately 6 one-on-one sessions between the lead examiner and student examiner, lasting an average of 45 minutes each, before the lead examiner was happy with the level of agreement between the 2 examiners. Up until training session 5, agreement was often no better than chance between examiners, particularly when comparing findings for the prone flexed knee position. This may be important for chiropractic colleges to consider when assigning time and instructors to practical technique courses that teach examination procedures. This may also impact on the implications of this study for general practice. Although previous studies have shown acceptable reliability of various LLA procedures,[18-20] it cannot be assumed that the protocol used in this study will result in the same level of agreement if field chiropractors without intensive consensus training were used as examiners.

Limitations

A limitation of this study was that participants were included irrespective of their pain status. Most patients were pain free during the trial period. Previous research has recommended that the sample used for studies, such as this, should be representative and include patients with neck and low back pain and not a mix of symptomatic and nonsymptomatic participants.[34,35] Recruitment took place in the NZCC teaching clinic in an attempt to gather a representative sample. Unfortunately, scheduling constraints for examiners, research assistants, and potential participants resulted in a sample weighted heavily in favor of asymptomatic students. It is possible that students who are very familiar with the examination protocol may be more compliant during the testing procedure than a usual chiropractic patient, therefore making it easier for the examiners to get reliable results. Another limitation was that participants were excluded if they had a negligible difference in leg lengths as assessed by an experienced examiner. This reduced the variability of the participant pool, which may introduce bias into the study. One of the reasons for excluding these participants was that the examiners were forced to classify the participants as having a short leg with no option for even leg lengths being available. Although there were reasons for doing this in the study, it also means that the external validity of the study is reduced because in practice a chiropractor needs to decide if the result of any given test is relevant. In this case, we were not asking the examiners to make a decision about the magnitude and therefore the perceived relevance of the LLI they observed.

This study did not assess the validity or clinical relevance of the LLA procedure. Although these results regarding the reliability of an LLA procedure are encouraging, the challenge of demonstrating clinical usefulness of the procedure remains. Clinical usefulness is based on reliability, validity, responsiveness, and utility.[36] Considering such a large percentage of the population are known to have an anatomical imbalance in leg lengths, the examiners in this study may just have been reliable at identifying the presence of anatomical LLI. It is also possible that the patient positioning and technique used to detect leg lengths in this study created LLI that was artifact. If this is the case, it is unclear what relevance this has to a functional assessment of the spine. Further work needs to be conducted to understand the clinical usefulness of LLA.[22] Cooperstein et al[23] have shown concurrent validity of a compressive leg check against an artificial LLI, but this still did not answer the question of whether the test is clinically relevant. The authors are currently planning to further investigate the clinical usefulness of LLA by performing a study that uses aspects of the protocols described by Hansen et al[4] and Haas et al[36] in their investigations of the clinical usefulness of motion palpation and end-play assessment of the spine.

Conclusion

This study showed that with an intensive training period, a chiropractic student can perform a visual LLA test in a way that results in a substantial level of agreement with an experienced chiropractor. Students in this study participated in an intensive consensus training period that consisted of eight 45-minute one-on-one sessions over a 16-week period. This may be important for chiropractic colleges to consider when allocating time and instructors for their practical technique classes.

Practical Applications

- Novice examiners may show good reliability of LLA with an experienced examiner when an intensive training program is completed.

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References

1. Ebrall P, Nest A, Walker L, Wright D. Palpatory literacy and the subluxation complex: developing a model to represent what we think and feel. Chiropr J Aust 2006;36:127-36.
2. Hawk C, Phongphua C, Bleecker J, Swank L, Lopez D, Rubley T. Preliminary study of the reliability of assessment procedures for the indications for chiropractic adjustments of the lumbat spine. J Manipulative Physiol Ther 1999;22:382-9.
3. Mior S, King R, McGregor M, Bernard M. Intra and interexaminer reliability of motion palpation in the cervical spine. J Can Chiropr Assoc 1985;29:195-8.
4. Hansen BE, Simonsen T, Leboeuf-Yde C. Motion palpation of the lumbar spine—a problem with the test or the tester? J Manipulative Physiol Ther 2006;29:208-12.
5. Fjellner A, Bexander C, Faleij R, Strender LE. Interexaminer reliability in physical examination of the cervical spine. J Manipulative Physiol Ther 1999;22:511-6.
6. Strender LE, Lundin M, Nell K. Interexaminer reliability in physical examination of the neck. J Manipulative Physiol Ther 1997;20:516-20.
7. Degenhardt BF, Snider KT, Snider EJ, Johnson JC. Interobserver reliability of osteopathic palpatory diagnostic tests of the lumbar spine: improvements from consensus training. J Am Osteopath Assoc 2005;105:465-73.
8. Gemmell H, Miller P. Interexaminer reliability of multidimensional examination regimens used for detecting spinal manipulable lesions: a systematic review. Clin Chiroprac 2005; 8:199-204.
9. Hestbaek L, Leboeuf-Yde C. Are chiropractic tests for the lumbo-pelvic spine reliable and valid? A systematic critical literature review. J Manipulative Physiol Ther 2000;23: 258-75.
10. Haas M. The reliability of reliability. J Manipulative Physiol Ther 1991;14:199-208.
11. Huijbregts P. Spinal motion palpation: a review of reliability studies. J Manual Manipulative Ther 2002;10:24-39.
12. Pool JJ, Hoving JL, de Vet HC, van Mameren H, Bouter LM. The interexaminer reproducibility of physical examination of the cervical spine. J Manipulative Physiol Ther 2004;27: 84-90.
13. Riddle DL, Freburger JK. Evaluation of the presence of sacroiliac joint region dysfunction using a combination of tests: a multicenter intertester reliability study. Phys Ther 2002;82: 772-81.
14. Seffinger MA, Najm WI, Mishra SI, Adams A, Dickerson VM, Murphy LS, et al. Reliability of spinal palpation for diagnosis of back and neck pain: a systematic review of the literature. Spine 2004;29:E413-25.
15. Smedmark V, Wallin M, Arvidsson I. Inter-examiner reliability in assessing passive intervertebral motion of the cervical spine. Man Ther 2000;5:97-101.
16. Potter L, McCarthy C, Oldham J. Intraexaminer reliability of identifying a dysfunctional segment in the thoracic and lumbar spine. J Manipulative Physiol Ther 2006;29:203-7.

17. Deboer KF, Harmon Jr R, Tuttle CD, Wallace H. Reliability study of detection of somatic dysfunctions in the cervical spine. J Manipulative Physiol Ther 1985;8:9-16.
18. Nguyen HT, Resnick DN, Caldwell SG, Elston Jr EW, Bishop BB, Steinhouser JB, et al. Interexaminer reliability of activator methods' relative leg-length evaluation in the prone extended position. J Manipulative Physiol Ther 1999;22:565-9.
19. Schneider M, Homonai R, Moreland B, Delitto A. Interexaminer reliability of the prone leg length analysis procedure. J Manipulative Physiol Ther 2007;30:514-21.
20. Fuhr AW, Osterbauer PJ. Interexaminer reliability of relative leg-length evaluations in the prone, extended position. J Chiropr Tech 1989:13-8.
21. Mannello DM. Leg length inequality. J Manipulative Physiol Ther 1992;15:576-90.
22. Knutson GA. Anatomic and functional leg-length inequality: a review and recommendation for clinical decision-making. Part II. The functional or unloaded leg-length asymmetry. Chiropr Osteopat 2005;13:12.
23. Cooperstein R, Morschhauser E, Lisi A, Nick TG. Validity of compressive leg checking in measuring artificial leg-length inequality. J Manipulative Physiol Ther 2003;26:557-66.
24. Henderson CN, Cramer GD, Zhang Q, DeVocht JW, Fournier JT. Introducing the external link model for studying spine fixation and misalignment: part 1—need, rationale, and applications. J Manipulative Physiol Ther 2007;30:239-45.
25. Owens EF, Pennacchio VS. Operational definitions of vertebral subluxation: a case study. Top Clin Chiropr 2001;8:40-8.
26. Owens E. Chiropractic subluxation assessment: what the research tells us. J Can Chiropr Assoc 2002;46:215-20.
27. Homack DMJ. Technique review: Derifield-Thompson leg length analysis and adjusting protocol. Chiropr J Aust 2005;35:16-20.
28. Nadler A, Holder JM, Talsky MA. Torque Release Technique (TRT): a technique model for chiropractic's second century. Can Chiropr 1998;3.
29. Fuhr AW, Colloca CJ, Green JR, Keller TS. Activator methods chiropractic technique. 1st ed. St Louis: Mosby; 1997.
30. French SD, Green S, Forbes A. Reliability of chiropractic methods commonly used to detect manipulable lesions in patients with chronic low-back pain. J Manipulative Physiol Ther 2000;23:231-8.
31. Walker BF, Buchbinder R. Most commonly used methods of detecting spinal subluxation and the preferred term for its description: a survey of chiropractors in Victoria, Australia. J Manipulative Physiol Ther 1997;20:583-9.
32. Mior SA, McGregor M, Schut B. The role of experience in clinical accuracy. J Manipulative Physiol Ther 1990;13:68-71.
33. Sim J, Wright CC. The kappa statistic in reliability studies: use, interpretation, and sample size requirements. Phys Ther 2005;85:257-68.
34. Haas M. Statistical methodology for reliability studies. J Manipulative Physiol Ther 1991;14:119-32.
35. van Trijffel E, Anderegg Q, Bossuyt PM, Lucas C. Interexaminer reliability of passive assessment of intervertebral motion in the cervical and lumbar spine: a systematic review. Man Ther 2005;10:256-69.
36. Haas M, Panzer D, Peterson D, Raphael R. Short-term responsiveness of manual thoracic end-play assessment to spinal manipulation: a randomized controlled trial of construct validity. J Manipulative Physiol Ther 1995;18:582-9.