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Would adopting a revised landmark rule for the spinal level of the iliac crests improve the accuracy of lumbar level identification?

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This is a secondary analysis of two previous systematic reviews demonstrating cephalad bias in using palpation to enumerate lumbopelvic levels, based on the conventional landmark rule that the spinal level of the palpated iliac crests=L4. Our study included 7 articles which enumerated lumbopelvic levels based on this rule, and furthermore reported data such that the direction and magnitude of errors could be abstracted from the article. The primary goal was to determine if enumeration accuracy would have improved had examiners known that the spinal level of palpated crests was closer to the L3-4 or L3 spinal level, as shown in our previous review. For the articles included, the mean error in spinal level enumeration diminished from 0.79 to -0.21 spinal levels, while accuracy increased from 26.3% to 46.9%. Since accuracy remained <50%,

Il s'agit d'une analyse secondaire de deux études méthodiques antérieures démontrant un biais céphalique dans l'utilisation de la palpation pour dénombrer les niveaux lombopelviens, basée sur la règle repère conventionnelle selon laquelle le niveau spinal des crêtes iliaques palpées est de L4. Notre étude comprenait sept articles qui énuméraient les niveaux lombopelviens basés sur cette règle, et qui, de plus, rapportaient des données telles que la direction et l'ampleur des erreurs. Ces éléments peuvent être extraits des articles. L'objectif principal était de déterminer si l'exactitude du dénombrement se serait améliorée si les examinateurs avaient su que le niveau spinal des crêtes palpées était plus près du niveau spinal L3-4 ou L3, comme nous l'avons démontré dans notre étude précédente. Pour les articles en question, l'erreur moyenne dans le dénombrement du niveau spinal a diminué de 0,79 à - 0,21, tandis que la précision a augmenté de 26,3 % à 46,9 %. Étant donné que la précision est restée inférieure à 50 %, il est peu probable que d'autres

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further refinements in iliac crest palpation are unlikely to improve enumeration accuracy, suggesting another method might best be sought.

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améliorations dans la palpation de la crête iliaque augmentent la précision du dénombrement, ce qui suggère la recherche d'une autre méthode.

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MOTS CLÉS : chiropratique, ilium, imagerie, vertèbre lombaire, palpation, radiographie

Introduction

It is widely believed that the spinal level of the iliac crests corresponds to the L4 spinous process (SP) or the L4-5 interspinous space[1]. A previous meta-analysis[2] conducted by the authors found that on *imaging* the iliac crests were found to be nearest the L4-5 interspace in females and the L4 spinous process (SP) in males. This same study found that the spinal level of the *palpated* iliac crests is cephalad to the imaged crest, nearest to the L3-4 interspace in both males and females. The palpated crest line was 0.7 levels cephalad to the imaged crest line in males, and 1.0 levels cephalad to the imaged line in females. The apparent reason why the palpated iliac crest is cephalad to the imaged crest is that during manual palpation an examiner's fingers contact soft tissue overlying the iliac crests, thereby reaching the L3-4 spinal level rather than the assumed L4-5 level. The greater discrepancy in females than males between the palpated and imaged iliac crests can be explained by the greater amount of suprapelvic subcutaneous fat in females compared to males.[1, 3-7]

All 12 of the included palpation studies in our previous meta-analysis[1, 3, 7-16] reported how often in percentage terms the examiner found the iliac crest to identify the L4 spinal level, and usually the percentage of caudal and cephalad errors. Since percentage reporting can be misleading, our previous study performed a secondary analysis of the included articles to calculate the mean difference between the palpated and imaged iliac crests. We were not aware of any other systematic reviews of this literature that summarize how often the spinal level of the iliac crest is at L4, in either percentage terms or as mean differences. Although some of the included studies, in addition to addressing the spinal level of the iliac crests, addressed the accuracy of identifying sacral and spinal levels other than L4 (in some cases including the lower thoracic spine), our meta-analysis only addressed the accuracy of identifying the L4 level. By comparison, our present study investigates accuracy in identifying spinal levels in a wider sense, both as originally reported and as might have been reported had the landmark rule for identifying spinal levels been different, as per our previous research on the actual spinal level of the palpated crest.

It may be assumed that an examiner who is unaware that the palpated iliac crest is generally cephalad to the imaged crest is likely to make many errors in in numerating lumbopelvic and thoracic spinal levels, and furthermore exhibit a systematic bias toward cephalad errors. As expected, most studies on the accuracy of lumbar spinal palpation have reported just that; errors are very common and tend to be cephalad.[1, 9, 14-18] Although examiner enumeration errors in these studies were no doubt due partly to random mistakes and patient variability, the cephalad systematic bias in these studies suggested there was also a flaw in the method by which the subjects were examined.

We hypothesized that reported accuracy rates and cephalad bias could be re-interpreted (i.e., recalculated) by assuming the palpators were not so much errant in their palpatory skills as at the mercy of a flawed landmark rule. Reported accuracy might have been higher had the palpators deployed a revised landmark rule whereby the palpated iliac crest identified the L3-4 interspace, instead of either the L4 SP or L4-5 interspace. Chakraverty, who was well aware of this cephalad bias, had suggested as follows: "It may be more appropriate to consider that palpation of the intercristal line [a line drawn across the iliac crests] is a guide for identifying the L3 or L3–4 spinal levels rather than the L4 or L4–5 levels, particularly in females and patients with higher body mass indices"[1].

The primary objective of the present study was to perform a secondary analysis of previous studies on the accuracy of lumbopelvic level numeration based on palpation of the iliac crests, to determine if revising the customary understanding that this level is L4 (given evidence that the actual spinal level of the palpated iliac crests is more cephalad) could improve accuracy in identifying lumbar spinal levels.

Methods

The first author had conducted two earlier studies on the accuracy of static spinal palpation. The first study concerned the accuracy of using a variety of palpatory methods to identify cervical, thoracic, and lumbar spinal levels compared with an imaging reference standard.[19] The second study focused on the spinal level of the iliac crests as established by imaging, as compared with the spinal level of the palpated iliac crests.[2] For an article to be included in these prior reviews it had to concern the accuracy of enumerating various spinal levels (first study) or the spinal level of the palpated and/or imaged iliac crests (second study) using static palpation. Cadaveric studies (e.g, Windisch [20]) were excluded.

The two prior studies combined included a total of 28 unique articles.[1, 3, 6-18, 21-33]. Starting from this body of articles, we selected a subset of articles in which it seemed the examiners may have explicitly relied either entirely or primarily on iliac crest palpation to enumerate lumbopelvic levels, according to the rule the iliac crests identify L4. Articles in which the palpatory method did not uniquely or primarily depend on iliac crest palpation were excluded[17, 23, 30], because the clinical utility of this specific palpatory method was the primary focus of this article. Also excluded were articles in which the subjects were pregnant[13-15, 29] or pediatric[8, 21, 22], since our previous study[2] had demonstrated that the spinal level of the imaged and palpated iliac crests in these special populations differed from what is seen in a more general population of males and females. We also excluded studies that reported data in ways that precluded the calculation of the magnitude and direction of errors [24, 26-28, 31] or involved imaging but not palpation[6, 12, 32, 33].

We also excluded two studies with obvious bias, Duniec *et al*.[25] and Furness *et al*.[10]. In the Duniec study[25], the authors themselves stated the examiners had been biased and had urged caution in interpreting the results of their study; the anesthesiologists performing ultrasound imaging were not experienced, and furthermore were not blinded as to the results of the palpation performed by another anesthesiologist. In the Furness study[10], the examiners were aware of previously published articles finding cephalad bias in enumerating lumbar levels, suggesting they may have shifted their findings in a caudal direction to take this into account.

Although the articles we selected for this study reported data in a variety of tabular and graphic formats, we extracted the data from each study such that we could determine how often an attempt to identify a lumbopelvic spinal had been accurate, and to what extent errors were made in a cephalad or caudal direction. All seven studies provided a percentage estimate for exact accuracy in enumerating lumbopelvic levels, in addition to providing data as to the direction and frequency of errors. The provision of the raw data permitted us to calculate re-analyzed error rates, according to the hypothetical use of a revised landmark rule. A weighted average was calculated to determine the mean error in identifying lumbopelvic landmarks, both as originally reported and in accordance with the hypothetical revised spinal landmark rule.

For group analysis, we divided the studies into two subgroups. In the first group, the studies identified spinal levels to the nearest SP or interspinous space, using increments of half a spinal level. In the second group, the studies simply identified the nearest SP, thus using increments of a full-spinal level. After tabulating the accuracy of lumbopelvic enumeration based on the traditional understanding that the iliac crests identified the L4 SP, we then determined the hypothetical accuracy that would have been achieved if the examiners had used a revised landmark rule, whereby the spinal level of the palpated iliac crests corresponded to the L3 SP (for studies reporting data in full-level increments) or the L3-4 interspace (for studies reporting data in half-level increments). For each of the two groups a weighted average was calculated to provide a heuristic estimate of the difference between the palpated and the imaged lumbopelvic levels.

Results

Seven articles (Table 1) satisfied the inclusion criteria, including a total of 668 enumerations of a lumbopelvic level based on iliac crest palpation as a landmark. Table 2 provides the raw data extracted from the included articles, indicating the frequency and magnitudes of differences, in terms of the number of spinal level off in lumbopel-

Table 1.

Included studies on the accuracy of spinal level enumeration using static palpation.

	Subjects*	Method	Reference standard
Amin, 2014[3]	100 patients: 94 males, 6 females. Age 37 (9) both genders; BMI 26.6 (SD not provided)	Examiners identified spinal level of the iliac crests.	Videofluoroscopy, supine; palpated level identified with A radio-opaque marker
Broadbent, 2000[9]	200 patients, both genders; age 52 (range 18-87], BMI 26 (range 19-40)	Examiners asked to identify various lumbopelvic/thoracic spinal levels T11-S1.	MRI, supine; palpated level identified by fish oil capsule used as marker
Chakraverty, 2007[1]	75 patients, 65% female; age 45.0 (range 18–71), BMI 25.8 (range 19-38)	Examiners identified spinal level of iliac crests.	Videofluoroscopy, prone; palpated level identified with a radio-opaque marker
Kim, 2007[11]	72 volunteers: 19 males, mean age 25.4 (6.5), mean BMI 21.9 (3); 53 female, mean age 36.2 (11.6), BMI 20.9 (2.6)	Examiners identified spinal level of iliac crests.	X-ray, anterior to posterior (prone?); palpated level identified with A radio-opaque marker
Lin, 2015[7]	52 patients. 17 males, age 46.9 (16.8), BMI 23.4 (4.3); 35 females, age 48 (14.5), BMI 23.4 (3.7)	Examiners identified L2-3 or L3-4 spinal levels.	X-ray, anterior to posterior, sagittal; palpated level identified with A radio-opaque marker
Parate, 2016[18]	122 patients, 35% female. Age 40.52 (13.23), BMI 25.35 (3.99)	Examiners identified lumbopelvic/thoracic spinal levels, T12-L1 to L5-S1.	Ultrasound, sitting (posterior to anterior) or lateral; palpated level identified by skin mark identified palpated level
Whittey, 2008[16]	101 post-partum; age not reported. BMI 28 (5)	Examiners identified L2-3, L3-4, or L4-5 spinal levels.	Ultrasound, posterior to anterior, sitting; palpated level identified by puncture mark related to neuraxial procedure
*Values in parentheses indicate Standard Deviation unless range is denoted.			

Table 2.

Frequency and magnitude of errors in lumbopelvic spinal enumeration based on iliac crest palpation in previous studies.

SLMs	Full-spinal level studies:				Half-spinal level studies		
	Broadbent[9]	Whittey[16]	Lin[7]	Parate[18]	Amin[3]	Chakraverty[1]	Kim[11]
4	1						
3.5							
3	2						
2.5							
2	31	39		2	1	3	1
1.5					7	12	2
1	102	67	12	16	13	34	11
0.5					67	17	32
0	**58**	**15**	**30**	**26**	**12**	**9**	**26**
-0.5							
-1	6		10	4			
-1.5							
-2	0						
Subjects N=668	200	121	52	48	100	75	72

In far-left column, SLMs=magnitude of Spinal Level Misidentification, the error in terms of the number of spinal levels. The number in each cell represents the frequency of this SLM in each of the included studies. A positive number signifies cephalad misidentification, and a negative number caudal misidentification. Numbers in bold type signify zero error, the number of times there was no error in spinal level identification.

Table 3.
Reported and re-analyzed accuracy rates in lumbopelvic enumeration.

Study	N	Reported accuracy	Re-analyzed accuracy
Studies reporting data in 1/2 spinal level increments			
Amin[3]	100	12 (12.0%)	67 (67.0%)
Chakraverty[1]	75	9 (12.0%)	17 (22.7%)
Kim[11]	72	26 (36.1%)	32 (44.4%)
Sub-total	247	47 (19.0%)	116 (47.0%)
Studies reporting data in full-spinal level increments			
Broadbent[9]	200	58 (29.0%)	102 (51.0%)
Lin[7]	52	30 (57.7%)	12 (23.1%)
Parate[18]	48	26 (54.2%)	16 (33.3%)
Whittey[16]	121	15 (12.4%)	67 (55.4%)
Sub-total	421	129 (30.6%)	197 (46.8%)
GRAND TOTAL	668	176 (26.3%)	313 (46.9%)

vic spinal enumeration. The bolded row where the spinal level error=0 indicates perfect accuracy, when palpation and imaging perfectly agreed. Table 3 summarizes the accuracy of identifying lumbopelvic spinal levels both as reported and as might have been reported had a revised landmark rule been used ("re-analyzed accuracy"). Combining the data for all studies (Table 2), the examiners were reported to have been accurate 26.3% (range 12.0, 57.7%) of the time. Assuming the hypothetical use of a revised landmark rule, the examiners would have been accurate 46.9% (range 22.7, 67.0%) of the time.

Table 4 sums up the frequencies of accurate, caudal, and cephalad enumerations across all seven included studies, both as reported and for re-analyzed data. It reports data from studies reporting to the nearest half-spinal level separately from those reporting to the nearest full-spinal level. Both subsets of articles clearly demonstrated a systematic cephalad bias as originally reported: the accuracy of examiners in the pooled data for all seven studies was 26.3%; caudal errors occurred 3.0% and cephalad errors 70.7% of the time. Assuming the hypothetical use of a revised landmark rule, the examiners would have been accurate 46.9% of the time; erring in a caudal direction 29.3% and cephalad direction 23.8% of the time.

Table 5 provides the mean difference between the reported and re-analyzed spinal level differences between

Table 4.
Frequencies of accurate, caudal, and cephalad lumbopelvic level enumeration.*

	As reported	Re-analyzed
Studies reporting data in 1/2 spinal level increments		
Accurate	47 (19.0%)	116 (47.0%)
Caudal	0.0%	47 (19.0%)
Cephalad	200 (81.0%)	84 (34.0%)
Total	247	247
Studies reporting data in integer spinal level increments		
Accurate	129 (30.6%)	197 (46.8%)
Caudal	20 (4.8%)	149 (35.4%)
Cephald	272 (64.6%)	75 (17.8%)
Total	421	421
Combined data for all included studies		
Accurate	176 (26.3%)	313 (46.9%)
Caudal	20 (3.0%)	196 (29.3%)
Cephalad	472 (70.7%)	159 (23.8%)
Total	668	668

*"Accurate" signifies correct identification of spinal level; "cephalad" and "caudal" signify identifying levels above or below the intended level, respectively.

Table 5.
Reported and re-analyzed mean difference between spinal level enumerated by palpation and imaging.

	Reported mean error	Re-analyzed mean error
Studies reporting data in 1/2 spinal level increments		
Amin[3]	0.59	0.09
Chakraverty[1]	0.89	0.39
Kim[11]	0.44	–0.06
Weighted mean error	0.64 (0.44, 0.89)	0.14 (–0.06, 0.39)
Studies reporting data in full spinal level increments		
Broadbent[9]	0.84	–0.16
Lin[7]	0.04	–0.96
Parate[18]	0.33	–0.67
Whittey[16]	1.20	0.20
Weighted mean error (range)	0.79 (0.04, 1.20)	–0.21 (–0.96, 0.20)
GRAND TOTAL, n=668	0.73 (0.04, 1.20)	–0.08 (–0.67, 0.20)

palpation and imaging for each of the included studies, reporting data from studies reporting to the nearest half-spinal level separately from those reporting to the nearest full-spinal level. Weighted by sample size, the mean error for the three half-level studies was 0.64 (range 0.44, 0.89) spinal levels as reported and 0.14 (range –.06, 0.39) spinal levels after re-analyzing. The mean error for the four full-level studies was 0.79 (range 0.04, 1.20) as reported, and –0.21 (range –0.96, 0.20) spinal levels after re-analyzing. The mean error for all seven included studies was 0.73 (range 0.04, 1.20) spinal levels as reported, and –0.08 (range –0.67, 0.20) after re-analyzing the data.

Four[1, 7, 9, 18] of the included studies investigated the impact of Body Mass Index (BMI) on the accuracy of lumbar level identification, with results varying from modest to no impact. Where there was an effect[1, 7, 9], larger BMI was associated, as might have been expected, with larger differences between the spinal levels identified by palpation and by imaging.

Discussion

This study hypothesized that systematic bias could be decreased, and enumeration accuracy increased through the adoption of updated anatomical research on the spinal level of the palpated iliac crests. Since the weighted mean difference between the imaged and palpated iliac crest in the half-spinal level studies was 0.64 levels, we rounded this off to one-half spinal level to derive the revised landmark rule applicable to these studies. Since the weighted mean difference between the imaged and palpated iliac crest in the full-spinal level studies was 0.64 levels, we rounded this off to one full level to derive the revised landmark rule applicable to these studies. The full-spinal level studies tended to achieve higher accuracy rates. This was not surprising, since in the half-spinal level studies an examiner who was nearly half a level off from the intended spinal level would have been judged to have been "inaccurate", while the same error would have been rounded off to the nearest level in the full-spinal level studies, so the examiner would have been judged "accurate".

For all 668 observations, although accuracy increased from 26.3% to 46.9% assuming a revised landmark rule, the examiners would still have identified the wrong level most of the time. The reason the improvement was not more dramatic is because there was considerable random variability in addition to the systematic bias. This was due to several factors, starting with the fact that the patient populations were varied in their age, gender, BMI, and clinical status. Furthermore, the studies differed in their methods, some reporting to the nearest full-level and others half-spinal levels.

The mean error of 0.62 spinal levels in the data as originally reported is broadly consistent with the results of our previous study[1], in which there was 0.88 spinal levels difference between the imaged and palpated iliac crests for a mixed population of males and females. We did not expect the magnitudes of the mean error in the current and prior study to necessarily agree, because the prior study only concerned errors in identifying L4, whereas the current study focuses on the accuracy of identifying *any* lumbopelvic spinal level based on an iliac crest landmark. Perhaps examiners, when asked to enumerate levels relatively distant for the crest level, draw upon other cues that slightly improve their accuracy. Since the difference between the mean error in the present and prior studies was 0.16 spinal levels, while the height of a lumbar spinal level is about 4cm[34], the difference in the mean errors reported in our prior and present studies was a mere 6.4mm.

There may be better strategies for identifying lumbar levels. Kim[11] suggested using the PSISs as a landmark for identifying spinal levels. Since the second sacral tubercle is very dependably situated between the posterior superior iliac spines[1, 11, 35], enumerating lower thoracic and lumbopelvic levels based on this landmark association might be more accurate. To our knowledge, using this sacral base method alone to identify lumbar spinal levels has not been validated. Jung *et al.*[4] suggested, but did not validate, that using the tenth rib line (an imaginary line that joins the lowest points of the rib cage on the flanks) could serve as an anatomical landmark for identifying lumbar vertebral levels. These authors argued this method was preferable to using the iliac crests, because the tenth rib method would be immune to the errors using the crest method that are due to subcutaneous fat. Borghi *et al.*[36] compared two methods for locating the L4-5 interspace in order to perform a lumbar plexus block, including using the iliac crest method as well using the soft-tissue skin depression at the iliac crest prominence ("Borghi's approach") as an anatomical landmark. Their argument was that using the skin depression at the iliac crest prominence method is more reliable in a population of obese patients or those with larger amounts of subcutaneous fat. We are not aware of any follow-ups to this study that would support or reject the method described.

Some authors have suggested using a combination of methods to accurately enumerate lumbar spinal levels. Ambulkar *et al*.[37] compared the accuracy of manual palpation to that of ultrasound in identifying spinal levels, using MRI as a reference standard. The manual palpation method deployed three spinal landmark rules: the vertebra prominens was said to correspond to the SP of C7, the inferior tips of the scapulae to the SP of T7, and the iliac crests to the SP of L4. However, each of the landmark rules upon which the Ambulkar study depended has been questioned: the vertebra prominens is at the C7 SP only about 70% of the time[38], the spinal level of the inferior tip of the scapula is quite variable but closest to the T8 SP[39], and the palpated (as opposed to imaged) iliac crests are on average closest to the L3-4 interspace[2]. Snider *et al*.[17] studied the accuracy of identifying the L1-L4 SPs using a combination of five different anatomical landmarks: T12 (smaller SP), twelfth rib (attaches to T12), iliac crests (vertebral body of L4), sacral base (body of L5), and the L5 SP (smaller size). Faculty examiners were on average 74% accurate, whereas the residents were 51% accurate. Level identification did not significantly vary among the four lumbar levels examined. Using this combination of landmarks, especially among more experienced examiners, appears to have increased accuracy by more than could be achieved by depending solely on a revised iliac crest landmark role, which we found hypothetically capable of achieving only 48.9% accuracy. Merz *et al*.[30] also used a combination of landmarks to identify the SP of L5: the examiner used either a single landmark – the iliac crests or the inferior aspect of the PSISs – or a combination of one of these landmarks with motion palpation. The highest accuracy recorded was obtained using PSIS identification plus motion palpation, achieving 61% accuracy. This was somewhat lower than the rate achieved by Snider's combined landmark method, but still higher than the hypothetical accuracy rate in our study based on a revised iliac crest landmark rule.

Although none of these combined landmark studies are definitive, there is some evidence suggesting the advantage of using multiple anatomical landmarks to improve spinal identification accuracy. That stated, manual therapists had best accept the reality that there will be errors made using the usual manual methods for lumbopelvic spinal enumeration. This need not be very troubling, in that the importance of abject specificity to ensuring good clinical outcomes has never been established.[40] Moreover, spinal interventions are inherently multi-segmental, directly impacting both a cephalad and a cadual motion segment, thereby spanning three vertebrae.[27, 41] It remains to be seen whether some clinicians would decide the need for greater accuracy warrants the use of an imaging procedure, such as diagnostic ultrasound.[42] The most important scenario in manual therapy likely requiring a high degree of segmental specificity is spinal intervention based on imaging or nerve conduction studies. In anesthesiology, much more is at stake in numerating spinal levels very accurately, which necessarily impacts the effectiveness and safety of the procedure.

Errors in either spinal level identification or enumeration pose several issues for the manual therapist:

- So long as the practitioner in fact directly treats the segment identified by manual examination as the optimal site for intervention, the clinical outcome need not necessarily be impacted by enumeration errors.
- That stated, enumeration errors will necessarily lead to charting errors.
- Charting errors may lead to sub-optimal or inappropriate interventions in multi-practitioner clinic settings or if the patient were to seek care in a different professional setting, when other practitioners must rely on chart notes that might be in error.
- If selecting an intended spinal site of care depends on a non-manual assessment procedure, such as imaging or neurological evaluation, errors in manual spinal level identification may lead to inappropriate interventions.
- In a research setting, errors in either spinal level identification or enumeration can confound reliability and validity studies.

Errors in identifying or numerating lumbopelvic spinal levels pose greater problems for anesthetists and other health care professionals, for whom errors in segmental specificity inherently involve more risk. Since spine patients are generally injected between vertebrae, anesthetists focus on numerating interspinous spaces. Accuracy in identifying and numerating spinal levels is essential to the practice of anesthesiology, both to ensure effective and safe anesthesia.[43] Injecting lumbar interspaces above the L3-4 interspace increases the risk of neurological injury, since the conus medullaris may extend as low as the upper body of L3.[16]

Limitations

We excluded five studies[24,26-28,31] that reported data in ways that precluded the calculation of the magnitude and direction of errors; the results may have been different if the findings of these studies could have been included. These five excluded studies included a total of 198 subjects. This study did not concern the possibility of improving lumbar spinal level identification in specialized patient populations, such as pregnant women, morbidly obese patients, or pediatric patients. The patient populations used in the included studies differed in various demographic and clinical factors, suggesting caution in applying the results of this review to patients in different clinical settings. The particular lumbopelvic and lower thoracic segments that examiners were asked to find were not evenly dispersed throughout the lumbopelvic region included, there having been a preponderance of studies addressing the L4 level. The data from studies using full-level and those using half-level increments were combined for data analysis, which may have impacted the results.

Conclusions

The results of our exploratory study are consistent with Chakraverty's suggestion[1] that deploying a revised landmark rule for the spinal level identified by iliac crest palpation would almost certainly increase accuracy in lumbopelvic spinal level identification: a heuristic calculation suggested accuracy would increase from 26.3% to 46.9%. Moreover, palpation based on the revised rule eliminated the systematic bias toward cephalad errors, such that the frequency of caudal and cephalad errors (29.3% and 23.8% respectively) very evenly distributed. However, random errors due to patient variability and stochastic examiner mistakes would still be very common, occurring about half the time.

Future research might best explore alternatives to using the iliac crests alone as a landmark for spinal level enumeration, such as using a different single landmark (such as the S2 tubercle) or a combination of manual methods. Even were a more accurate spinal level enumeration method found, it would still be necessary to determine if clinicians could be reliably trained to use that method. Future research might also investigate to what extent clinical outcomes depend on specificity in level enumeration, both in manual therapy and especially anesthesiology settings.

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