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Clinical examination tools for lateropulsion or pusher syndrome following stroke: a systematic review of the literature

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Objective: To examine the clinimetric properties and clinical applicability of published tools for ‘quantifying’ the degree of lateropulsion or pusher syndrome following stroke.

Data sources: Search through electronic databases (MEDLINE, EMBASE, CINAHL, Science Citation Index) with the terms lateropulsion, pushing, pusher syndrome, validity, reliability, internal consistency, responsiveness, sensitivity, specificity, posture and stroke. Databases were searched from their inception to October 2008.

Review methods: Abstracts were selected by one author. A panel of experts then determined which should be included in this review. Five abstracts were reviewed and the panel agreed to omit one abstract because those authors did not write a full manuscript. The panel critiqued manuscripts according to predetermined criteria about clinical and clinimetric properties.

Results: Four manuscripts referencing three tools for examining lateropulsion were found. Validity and reliability data support the clinical use of the Scale for Contraversive Pushing, the Modified Scale for Contraversive Pushing and the Burke Lateropulsion Scale. The Scale for Contraversive Pushing has the most extensive testing of clinimetric properties. The other tools show promising preliminary evidence of clinical and research utility. More testing is needed with larger, more diverse samples.

Reviewers’ conclusions: The Scale for Contraversive Pushing, the Modified Scale for Contraversive Pushing and the Burke Lateropulsion Scale are reliable and valid measures with good clinical applicability. Larger, more varied samples should be used to better delineate responsiveness and other clinimetric properties of these examination tools.

Introduction

Lateropulsion following stroke, or ‘pusher syndrome’, is characterized by patients pushing toward their paretic sides during functional activities and strong resistance to passive correction of the altered posture back to the vertical upright position.1
Pe´rennou et al.2 recently found that patients with hemispheric stroke and lateropulsion have an alteration of their sense of verticality. They actively align the longitudinal axis of their bodies with a perceived vertical which is biased to the contralesional side (i.e. tilted toward the paretic side). The neural mechanisms underlying lateropulsion are not fully understood but alteration of subjective postural vertical sensation suggests that patients with lateropulsion use an egocentric reference system for vertical that does not parallel earth vertical.2

The focus of intervention for lateropulsion is amelioration of pushing so that upright activities, transfers and walking can be safe and functional. Therapists currently work on balance correction through motor control training1,3–5 but these patients have longer recovery times than typical patients with stroke.6,7 Designing and validating time-efficient rehabilitation programmes that reduce lateropulsion implies using tools to objectively quantify the degree of lateropulsion and the patient’s course of recovery. Objective examination tools will help therapists detect and monitor patients with lateropulsion who may benefit from specific rehabilitation exercises. Rehabilitation efficacy could then be determined using these tools as the main judgement criteria.

Recently developed measurement tools are based either on ordinal scales8,9 or on measurements of the trunk or limb tilt in a laboratory setting2,10–12 Ordinal scales do not require specific testing apparatus. They are applicable to all patients, regardless of their postural capacities and the treatment setting. Although several scales are now available to document the degree of lateropulsion, the prevalence of lateropulsion after stroke is still poorly estimated, ranging from 10% to 60%.6,7 We postulated a lack of agreement in the definition of lateropulsion and/or a pushing behaviour, great variations in the selection of items used to construct the scales, and differences in their scoring and threshold for the diagnosis. Time since the onset of the patient’s stroke may also influence examiners’ ability to use a particular tool effectively. We conducted one of the first critical reviews of this emerging literature in order to facilitate clinician decision-making, and to promote researchers’ thinking on this topic. This systematic review examines the relevance, practical aspects and clinimetric properties of published scales to assess lateropulsion.

Methods

The following databases were searched: MEDLINE, EMBASE, the Cumulative Index of Nursing and Allied Health Literature (CINAHL), Science Citation Index (ISI Web of Knowledge, Web of Science) as well as reference lists from manuscripts dealing with diagnosis or treatment of lateropulsion. Each database was searched from its inception to October 2008. Keywords for the search included: lateropulsion, pushing, pusher syndrome, validity, reliability, internal consistency, responsiveness, sensitivity, specificity, posture and stroke. One reviewer (SRB) independently conducted the electronic search by reviewing titles and abstracts. A sample search strategy is described in the Appendix. This reviewer also examined reference lists of manuscripts which referred to intervention for lateropulsion or pusher syndrome following stroke. Inclusion required that the abstracts: (1) referenced scales for measuring lateropulsion or pushing toward the weak side following hemisphere stroke (contralesional lateropulsion); (2) addressed at least one clinimetric property of that scale; (3) were published in English; and (4) corresponded to a full manuscript. Abstracts that referenced lateropulsion to the strong side, as in Wallenberg syndrome (ipsilesional lateropulsion), were excluded. Abstracts that mentioned measurement tools requiring specialized equipment were also excluded.

Five abstracts met the inclusion criteria; these were sent to the review panel which includes experts in lateropulsion following stroke (RB, DP, MR) and measurement and statistics (MGEP). The panel agreed by consensus to omit review of one abstract about the Melbourne Pusher Scale13 because it did not have a full manuscript associated with it.

Data were extracted from the manuscripts by one reviewer (SRB) then all panel members analyzed manuscripts for the quality of clinimetric properties of the scales according to the following predetermined criteria. Face validity was
considered appropriate if the scale was based on Davies’ definition of lateropulsion with the components of pushing to the weak side and resistance to passive correction to a neutral alignment. Some authors also considered use of the uninvolved extremities to push toward the weak side as a determining factor in lateropulsion. We judged the content validity according to the criteria suggested by Domholdt: (1) the appropriateness of the sample; (2) whether the scale contained most aspects of the phenomenon; (3) whether appropriate emphasis was placed on key items; and (4) whether the key items were relevant to clinical examination of the patient. Concurrent validity compares the scale with a known standard measure. We evaluated the appropriateness of the standard selected, the timeliness of performing both tests and the appropriateness of the sample. We set a criterion sample size as 100 subjects as a guideline for judging validity studies, acknowledging that clinical samples are often samples of convenience and that appropriate sample size will be dependent on characteristics of the measurement tool and the effect size. We looked at the selection criteria for samples in the studies to ensure that the researchers selected patients with a wide range of symptoms and severity.

Intertester and intratester reliability, comparing consecutive measures from different or the same examiner, respectively, was judged for the appropriate statistic chosen, the heterogeneity of the sample tested, and the characteristics of the examiners.

Sensitivity and specificity were judged by the sample size, spectrum of patients tested and the selection of the ‘gold standard’ to which the scale is compared for accuracy in making the same conclusions. An aspect of reliability, internal consistency of items within the scale, was analysed for agreement in scores from different parts of the scale and the total score. Scores higher than 0.90 may indicate areas of redundancy in the scale. Responsiveness estimates the ability of a measure to detect change over time.

All panel members then commented about the clinical utility and ease of use of the scale. They considered the practicality of the ordinal grading scale, how the scale reflects function, and how it assists with decision-making for the patients with lateropulsion following stroke. Items included in this review were approved by consensus among all panel members. There was an a priori decision that the majority opinion would be considered the opinion of the panel. Reliability of the panel members was not formally assessed.

Results

Our search yielded four manuscripts which described and/or analysed three scales for detecting and tracking lateropulsion following stroke.

We provide brief descriptions of the measurement scales, a description and analysis of the clinimetric properties and clinical practicality of each, based on the criteria noted above. Table 1 describes attributes of the scales and the research studies. Table 2 summarizes findings for the clinimetric properties of the Scale for Contraversive Pushing, the Modified Scale for Contraversive Pushing, and the Burke Lateropulsion Scale.

Scale for Contraversive Pushing

Description

Karnath et al. based the clinical assessment Scale for Contraversive Pushing on three components of Davies’ criteria: (1) degree of symmetry of the posture; (2) the presence of abduction or extension of the uninvolved extremities to increase the area of contact with the supporting surface; and (3) the degree of resistance to passive postural correction. Each component is tested in sitting and standing yielding a maximum component score of 2. Patients are considered to show pushing if each component is present and each component score is 1 or greater. The Scale for Contraversive Pushing indicates degree of postural symmetry (component 1) and the attitude of the involved extremities (component 2) with decimal values.

Clinimetric properties

Baccini et al. limited their sample to patients with stroke and postural asymmetry although the age range, gender mix and functional status were consistent with a sample of patients with stroke (Table 1). One examiner diagnosed 17 of these patients with lateropulsion by clinical
Table 1 Comparison of attributes of the measurement scales and of research methods

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Scale for Contraversive Pushing\textsuperscript{17,18}</th>
<th>Modified Scale for Contraversive Pushing\textsuperscript{15}</th>
<th>Burke Lateropulsion Scale\textsuperscript{9}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinal scale characteristics</td>
<td>3 components scored in sitting and standing: spontaneous body posture (0, 0.25, 0.75, 1 = severe tilt); extension/abduction of uninvolved extremities (0, 0.5, 1 = performed spontaneously at rest); resistance to passive correction (0, 1 = resistance occurs).\textsuperscript{14,17,18} Total score not used by originator of the SCP\textsuperscript{14}</td>
<td>4 testing positions: sitting, standing, sitting transfer, standing transfer. Each scored 0–2 = pushes continuously with force enough to fall if not supported, abducts uninvolved arm and/or leg spontaneously, even at rest. Total maximum = 8</td>
<td>5 testing positions: supine rolling, sitting, transferring, standing, walking. Scoring based on degree and point of onset of resistance to passive correction (sit, stand) or degree of pushing evident (supine, transfer, walking). 0–3 scale except for standing (0–4). Total maximum = 17</td>
</tr>
<tr>
<td>Indicator of latero-pulsion/pusher syndrome</td>
<td>Score on each component &gt;1\textsuperscript{14,17,18}</td>
<td>3 points or more</td>
<td>2 points or more</td>
</tr>
<tr>
<td>Face validity based on Davies’ criteria\textsuperscript{1}</td>
<td>Includes 3 aspects</td>
<td>Includes 2 aspects</td>
<td>Includes 2 aspects</td>
</tr>
<tr>
<td>Content validity Sample</td>
<td>Limited by sampling Patients with stroke with presence of postural asymmetry in sitting and standing: n = 26 (right brain lesion n = 17, left brain lesion n = 9)\textsuperscript{17} Patients with first stroke, unilateral motor deficits and balance problems: n = 105 from 2 inpatient rehabilitation centres\textsuperscript{18}</td>
<td>Limited by sampling Patients with stroke exhibiting probable pushing: n = 19 for validity study; n = 17 for intertester reliability study</td>
<td>Adequate Patients with stroke: n = 85</td>
</tr>
<tr>
<td>Heterogeneous sample</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of raters</td>
<td>1 physician and 3 physiotherapists including one expert</td>
<td>5 physiotherapists</td>
<td>1 study physical therapist and 6 physical therapists</td>
</tr>
<tr>
<td>Mean number of days post onset of CVA when initial testing occurred</td>
<td>19.0 ± 7.8 (SD) days\textsuperscript{17} 17.3 ± 6.2 (SD) days\textsuperscript{18}</td>
<td>4–8 days, no mean specified</td>
<td>19.0 ± 2 (SEM) days</td>
</tr>
</tbody>
</table>

SD, standard deviation; SEM, standard error of the mean; CVA, cerebrovascular accident.
<table>
<thead>
<tr>
<th>Clinimetric property</th>
<th>Scale for Contraversive Pushing\textsuperscript{17,18}</th>
<th>Modified Scale for Contraversive Pushing\textsuperscript{15}</th>
<th>Burke Lateropulsion Scale\textsuperscript{9}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Validity</td>
<td>Agreement with expert who diagnosed lateropulsion varied with cut-off criterion (see text)\textsuperscript{17,18}</td>
<td>Concurrent validity with Berg Balance Scale ($r_s = -0.52$) and Swedish Physiotherapy Clinical Outcome Variables ($r_s = -0.43$)</td>
<td>Concurrent validity with Fugl-Meyer Balance score ($r_s = -0.57$), with admission FIM motor subscore ($r_s = -0.58$) and length of rehabilitation stay ($r_s = 0.60$)</td>
</tr>
<tr>
<td></td>
<td>Construct validity of total SCP with Barthel Index ($r_s = -0.632$), balance score of the Fugl-Meyer Assessment ($r_s = -0.866$), and mobility section of the Lindmark and Hamrin motor assessment chart ($r_s = -0.595$)\textsuperscript{18}</td>
<td>Posture component and total SCP: $r_s$ ranged from $-0.595$ to $-0.704$ with each of the above tests. Use of extension and the resistance components: $r_s$ ranged from $-0.345$ to $-0.447$ with each of the above tests\textsuperscript{18}</td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td>Inter-rater reliability: ICC $&gt;0.929$ for all subscores and total score\textsuperscript{17}</td>
<td>Inter-rater agreement: kappa $= 0.51$ at initial evaluation (IE) and kappa $= 0.73$ at discharge (DC) of patient. Inter-rater correlation $r_s = 0.82$ at IE and $r_s = 0.94$ at DC</td>
<td>Inter-rater reliability with an expert ($r = 0.94$); Intra-rater reliability ($r = 0.93$)</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>64.7% with original criterion (all subscores &gt;1); 100% with modified criterion (all subscores &gt;0)\textsuperscript{18}</td>
<td>Not examined</td>
<td>Not examined</td>
</tr>
<tr>
<td>Specificity</td>
<td>100% with original criterion; 97.7% with modified criterion\textsuperscript{18}</td>
<td>Not examined</td>
<td>Not examined</td>
</tr>
<tr>
<td>Internal Consistency</td>
<td>Cronbach’s alpha $= 0.919$.\textsuperscript{17}</td>
<td>Component scores correlated with each other and with the total score ($r$ ranged from 0.711 to 0.956 ($P &lt; 0.001$))</td>
<td>Not examined</td>
</tr>
<tr>
<td>Responsiveness</td>
<td>Not examined</td>
<td>Not examined</td>
<td>Not examined</td>
</tr>
</tbody>
</table>

$r_s$, Spearman rank order correlation coefficient; $r$, Pearson product-moment correlation coefficient.
examination. This sample was biased toward patients with right-sided brain lesions but this is not atypical of samples of patients with postural problems. Four examiners were paired and performed consecutive testing within minutes of each other. Validity was established using a kappa coefficient to test agreement of the diagnosis of lateropulsion using the Scale for Contraversive Pushing with the clinical diagnosis made by an expert (Table 2) who followed criteria similar to those used to create the scale. Care must be taken in interpreting this as validity because it is a measure of intertester agreement. Using the original criterion for diagnosing lateropulsion (score for each component $>1$), testers had moderate agreement with the clinical evaluation of the expert ($\kappa = 0.497$, SE $= 0.099$). Changing the criterion to a score greater than 0 for each component, improved agreement between the expert making the clinical diagnosis and the examiners using the Scale for Contraversive Pushing ($\kappa = 0.917$, SE $= 0.057$).

Better inferences can be made from a later study by Baccini et al. because they selected a larger, more heterogeneous sample of patients with first stroke who had unilateral involvement and documented motor and balance deficits (Table 1). They used the Cohen kappa coefficient ($\kappa$) to show degree of agreement with the clinical diagnosis made by one member of the research team and Scale for Contraversive Pushing scores performed by another member of the team. Results depended on the cut-off criterion: if total Scale for Contraversive Pushing $>0$, $\kappa = 0.212$; if Scale for Contraversive Pushing on each component $>1$, $\kappa = 0.754$; and, if Scale for Contraversive Pushing on each component $>0$, $\kappa = 0.933$.

Construct validity (Table 2) was estimated using Spearman rank correlation coefficients of Scale for Contraversive Pushing component and total scores with the Barthel Index (a functional assessment), the balance subscore of the Fugl-Meyer Assessment Scale, and ‘the subscore of the mobility section of the motor assessment chart developed by Lindmark and Hamrin’ (ref. 18, p. 954). Although labelled construct validity, Baccini et al. compared the Scale for Contraversive Pushing to related constructs of balance and function, not the construct of lateropulsion.

Baccini et al. established reliability for each subscore and a total score using an intraclass correlation coefficient (ICC) for single measures. They randomly paired examiners ($n = 3$) who tested patients within minutes of each other. Typical criteria for the use of ICC include continuous data with a normal distribution. Given the small sample size and the lack of a clear description of the ordinal data distribution, one must question the use of the ICC statistic. However, their use of the kappa coefficient as a measure of agreement between examiners confirmed the ICC results (Table 2). The authors attribute this degree of reliability to the limited range of values on the Scale for Contraversive Pushing.

Baccini et al. again used the clinical examination of an expert as the criterion reference for sensitivity and specificity analyses. With the larger sample, Baccini et al. established that sensitivity and positive predictive values were greatest if each component score was greater than zero (Table 2). Specificity was strong, regardless of cut-off criterion selected. Baccini et al. attributed this to the rule that all signs (components) must be present in order to make the diagnosis.

Internal consistency measures were based on Scale for Contraversive Pushing scores of one examiner using Cronbach’s alpha and Pearson coefficients (Table 2) to compare component scores and the total score. Internal consistency was high for component scores and the total score. Cronbach’s alpha exceeded the standard cut-off of 0.90 indicating that some redundancy may exist in the scale. Strong correlations existed among component scores and the total score. The part of the Scale for Contraversive Pushing relating to the degree to which patients thrust their uninvolved extremities had the lowest correlations with other parts of the test. Internal consistency appears possible for the Scale for Contraversive Pushing but studies involving more subjects and examiners are warranted.

**Clinical practicality**

Some questions arise regarding the practical aspects of the Scale for Contraversive Pushing because it was published without any guide for the instructions to be given to patients, and with
different levels of decimal scaling throughout the items. Karnath and Brötz\(^{19}\) later clarified how to test the degree of extension or abduction of the uninvolved extremities.

The clinimetric properties of the Scale for Contraversive Pushing were not tested until after the scale was introduced into the literature. The findings of Baccini \textit{et al.}\(^{17,18}\) suggest that an \textit{a posteriori} change in the criterion for diagnosis of lateropulsion might be appropriate. The criterion where each component score must exceed 0 consistently enhanced clinimetric properties. Baccini \textit{et al.}\(^{17,18}\) also used a total score which was not part of the original scale but it may be useful in the clinical setting. Further analyses of the responsiveness of the Scale for Contraversive Pushing with more examiners and patients are also required.

\textbf{Modified Scale for Contraversive Pushing (M-SCP)}

\textit{Description}

Lagerqvist and Skargren\(^{15}\) developed a modified version of the Scale for Contraversive Pushing for giving a composite score which quantifies pushing/lateropulsion. The scoring criteria of the Modified Scale were based on the definition of pusher syndrome by Davies\(^{1}\) and Karnath’s original scale.\(^{14}\) The scoring sheet includes these test conditions: (1) static sitting at the bedside with the feet on the floor; (2) static standing with a full erect posture; (3) transferring from bed to a chair or wheelchair (with armrests) while maintaining hip flexion; and (4) transferring from bed to chair or wheelchair by coming to a full standing position and stepping or pivoting 90 degrees.\(^{15}\)

\textbf{Clinimetrics}

Face validity of the Modified Scale was established by the correspondence of the grading criteria and the functional positions chosen for testing. Use of a guideline to define testing positions and scoring strengthens face validity. The ultimate sample size was small and all patients exhibited signs of lateropulsion\(^{15}\) (Table 1). Lagerqvist and Skargren\(^{15}\) had an adequate mix of patients with left and right hemiplegia and an age range that was representative of the general stroke population. They appear to have included patients with very poor balance as well as those whose lateropulsion resolved by the time of discharge.\(^{15}\) More details about the sample characteristics such as motor and sensory status would have been desirable.

Low to moderate relationships were found for concurrent validity using the Berg Balance Scale (balance) and the Swedish Physiotherapy Clinical Outcome Variables (functional ability) as the criteria references (Table 2).\(^{15}\) Intertester reliability was tested with pairs from a pool of five physical therapists simultaneously scoring patients within eight days of onset of stroke and again at discharge from acute rehabilitation. One tester examined the majority of the cases while the second tester varied. The consistency of this one examiner may have accounted for higher values than if the two testers were randomly assigned. Sensitivity/specificity data, internal consistency and responsiveness are not available for this scale.\(^{15}\)

\textbf{Clinical practicality}

The M-SCP has face validity with a standardized scoring system which adequately reflects the gradient of lateropulsion that occurs during recovery. Use of whole numbers on the M-SCP versus decimals on the Scale for Contraversive Pushing makes the M-SCP more similar to typical ordinal scales used in rehabilitation. The similarity of scoring scale for each of the four components makes use of a total score more meaningful. Adding transfers and using specific scoring criteria help examiners of patients whose lateropulsion tends to become manifest with dynamic balance activities. Patients who are pushing when they transfer with their hips flexed will most likely push when standing erect and scoring instructions allow for this possibility.\(^{15}\) Progress may be noted if the patient ceases pushing when transferring with the hips flexed using armrests and only pushes when the centre of gravity is higher while in standing. This ability to show progress is consistent with the natural history of lateropulsion whereby it becomes less manifest in static, more supported positions. Lagerqvist and Skargren suggest that a change of 2 points or more is needed in the total to document a true change in the degree of lateropulsion.\(^{15}\) This allows for fluctuation of neurological symptoms during the acute phase after stroke.
Burke Lateropulsion Scale

Description

The Burke Lateropulsion Scale rates the action/reaction of patients required to keep or change position. For testing sitting and standing the patient is passively tilted 30° (15–20° for standing) towards his/her paretic side (contralesional tilt) then brought back to vertical alignment. Scores are then based on any voluntary or reflex movements noted in trunks, arms or legs according to the angle from true vertical where resistance starts. For example, the sitting scores are: 0 = no resistance; 1 = resistance starts at 5° tilt before full vertical; 2 = resistance starts at 10° tilt before full vertical; and 3 is scored if they sense true vertical between 30° and 10°. Scores for supine rolling, transferring and walking are based on the severity of pushing sensed by the examiner (0, 1 = mild, 2 = moderate or 3 = severe).

Clinimetrics

D’Aquila et al. tested the reliability and validity of the Burke Lateropulsion Scale (Table 2) with 85 patients with stroke, 31 of whom had lateropulsion scores greater than 0. The sample had an adequate mix of patients with left- and right-sided weakness, with and without hemianopsia or visual neglect. They also included patients with brainstem lesions and ‘other combinations of locations’ (ref. 9, p. 104) of lesions. Most of the patients with lateropulsion had Burke Lateropulsion Scale scores between 2 and 8 although several had scores between 12 and 16. This range of severity appears adequate for validity testing.

Face validity of the Burke Lateropulsion Scale is inherent in the scoring where resistance to passive correction of the posture or the presence of pushing during rolling, transferring or walking are assessed. Abduction and extension of the extremities are not specifically scored. This scale provides the examiner with a sense of how lateropulsion will affect functional activities. The scoring criteria are explicit although they differ by position of the patient. There is a greater emphasis on standing scores (0–4) as compared to the 0–3 scale for all other items. This weighting was done to accommodate predominant clinical features of lateropulsion. D’Aquila et al. justified content validity because the scale’s development evolved over several years with input from many practitioners. They included several dimensions of the clinical presentation of the patient with lateropulsion in the scale.

D’Aquila et al. used the correlation between Functional Independence Measure motor scores and the balance subscore of the Fugl-Meyer Assessment of Motor Performance Following Stroke to establish concurrent validity (Table 2). The moderate correlations show that the construct of lateropulsion measured in the Burke Lateropulsion Scale is related to but is distinct from measurements of the constructs of balance (Fugl-Meyer Assessment balance subscore) and functional status (motor Functional Independence Measure).

Intertester reliability (Table 2) was established for measures by two examiners and an expert examiner (from a pool of six examiners) taken up to two days apart. Similar results established intratester reliability of measures done two days apart. D’Aquila et al. used Mann–Whitney tests to confirm that patients did not exhibit a significant change in their status between subsequent test dates. They acknowledged that the slight change in mean Burke Lateropulsion Scale scores that occurred in patients with each subsequent test may have been due to patient–therapist familiarity or due to slight improvement in the patients’ degree of lateropulsion. They did not test patients longitudinally to determine responsiveness. They did not formally assess sensitivity/specificity or internal consistency.

Clinical practicality

As with the Scale for Contraversive Pushing and Modified Scale for Contraversive Pushing, examiners may exhibit subjective biases in scoring the degree of resistance felt when passively moving the patient during testing with the Burke Lateropulsion Scale. D’Aquila et al. included a wide range of patients with and without lateropulsion yet the examiners had excellent reliability. They did not appear to have difficulty interpreting the 5- or 10-degree increments from true vertical for marking resistance to passive correction to the vertical upright position.
The Burke Lateropulsion Scale has a precise guide for instructions and notation, and satisfactory clinimetric properties. It yields a total score as a way to quantify lateropulsion/pushing which is a crucial point for longitudinal tracking of patients, both in clinical practice and in clinical trials. Sit-to-stand transfers and walking are two motor tasks initially described as able to reveal lateropulsion/pushing\cite{1}; these tasks are examined in the Burke Lateropulsion Scale. One may question why the authors incorporated supine rolling into a scale addressing an upright postural problem. Patients with severe lateropulsion apparently resist postural change while rolling\cite{1}. Incorporating supine rolling, transfers and walking allows caretakers to plan for adequate help when working with patients with strong lateropulsion. The Burke Lateropulsion Scale reflects the progress most patients make when lateropulsion is no longer present in supine and sitting but exists in walking as the total scores go from higher to lower values.

Discussion

The Scale of Contraversive Pushing, the Modified Scale of Contraversive Pushing and the Burke Lateropulsion Scale have good to excellent clinimetric properties and clinical applicability. The Scale for Contraversive Pushing had the most rigorous testing of clinimetric properties. When clinicians and researchers are interested in tracking patients with lateropulsion or are looking for small changes in their status, scales with wider metric ranges such as the Modified Scale of Contraversive Pushing and the Burke Lateropulsion Scale may be more useful than the Scale for Contraversive Pushing. Non-parametric statistics should be considered for these ordinal rating scales for lateropulsion following stroke because of the low number of ranking items and the possibility that a non-Gaussian distribution will represent the sample being studied. Future studies should also report confidence intervals associated with the clinimetric properties\cite{16}.

We feel our search strategy was adequate because we selected the major search engines and were current until October 2008. A reference within another manuscript\cite{17} noted the Melbourne Pusher Scale\cite{13} but communication with the authors showed that this scale did not undergo rigorous clinimetric testing. Other scales may exist that were described and published in languages other than English. We did not search for scales to score lateropulsion which may be part of a larger motor or perceptual assessment tool. Our study has limitations because only one reviewer searched the databases and extracted relevant items.

Lateropulsion following stroke is, by its nature, difficult to study. Patients generally decrease the degree of pushing as they progress and tracking validity and reliability presents logistical problems to researchers. Generalizations we make in this review assume that patients included in the studies were representative of a typical stroke population. Motor, sensory and perceptual status of the subjects in these studies was not presented. The age range appeared to correspond to that of the typical stroke population in all of the studies. Average duration from stroke onset until the date of assessment for purposes of these research studies ranged from approximately 6 days\cite{15} to 19 days\cite{9,17,18}. The reader should be mindful of this discrepancy when considering generalizations made in this review.

Only Baccini and associates\cite{18} used a sample size of 100 or more. Only D’Aquila et al\cite{9} and Baccini et al\cite{18} documented a sample that appeared heterogeneous across the spectrum of degree of lateropulsion.

Each of the scales for lateropulsion had face validity by reflecting two or more of the criteria suggested by Davies\cite{3} to distinguish patients with lateropulsion according to their postural lean toward the weak side and their resistance to passive movement into the correct posture. Each scale could be used at the bedside or clinic. Although sample characteristics were questioned, content validity of the scales as they were constructed appears sound. All scales measure the patient in sitting and standing. The Burke Lateropulsion Scale and the Modified Scale for Contraversive Pushing address lateropulsion with transferring. The Burke Lateropulsion Scale is the only scale to incorporate lateropulsion assessment during supine rolling and walking. This latter aspect may make it more useful in acute hospitals where patients are more likely to show lateropulsion even in supine.
By the time most patients reach inpatient rehabilitation centres, their lateropulsion may have resolved in supine but they may still show lateropulsion in standing or walking by the time of discharge.

Lack of a standard for comparison for concurrent validity testing was expressed. Attempts to compare the scales to known scales for balance and function yielded only moderate relationships. Balance and function should be related to the degree of lateropulsion but the fact that other factors also influence balance and function may account for the lack of strong associations. Although they labelled it 'construct' or 'concurrent' validity, perhaps these researchers were actually testing 'convergent construct validity' whereby the lateropulsion was a construct that inherently differed from the related constructs of balance and function. This might explain the moderate relationships.

To date, only the total Scale for Contraversive Pushing has been compared to the magnitude of the contralesional tilt of the postural, visual and haptic vertical sensory modalities in the laboratory setting. Formal validation of the scales for lateropulsion by comparing them to laboratory assessments versus expert opinion appears indicated. Perhaps clinical measures of lateropulsion, balance and function should be triangulated with laboratory measurement of postural vertical sensation as a means of validating all the constructs that comprise lateropulsion.

The subjective nature of the judgments required by examiners for all scales was not a barrier to reliability. Some studies used testers who were instrumental in the development of the scale as subjects in the reliability and validity studies. Logistical considerations in busy clinical settings necessitate such a design. Potential bias would have been eliminated if the reliability study was conducted at a different institution or with random assignment from a pool of testers who were not part of the development process.

The Modified Scale for Contraversive Pushing has been proposed to improve the Scale for Contraversive Pushing, however, it faces several limitations. Intertester reliability estimates are promising although more work with a diverse sample is needed. Baccini et al. suggest that the items on the Modified Scale and their scoring system make it a different scale from the original Scale for Contraversive Pushing. They also suggest that future research is needed to define an appropriate cut-off score to define lateropulsion with the Modified Scale.

Baccini et al. raised another issue about cut-off scores to define lateropulsion with the Scale for Contraversive Pushing. Deviating from the original criterion (each component >1) improved validity and sensitivity. Defining lateropulsion by each component score greater than zero improved agreement with an expert as well as improved diagnostic accuracy. Validation of the Scale for Contraversive Pushing against instrumented systems for measuring subjective postural vertical rather than expert opinion might clarify which of the criteria best reflect the patient's perceptual status.

A problem common to all scales is how to examine a patient with lateropulsion who is unable to be tested in standing or walking for reasons that may or may not be concurrent with lateropulsion. If patients have lateropulsion in sitting, then the therapists can make the assumption that they will also exhibit it in standing and record a presump tive score. The problem arises if patients no longer exhibit signs of lateropulsion in sitting but they cannot be tested in standing or walking because of lower extremity weakness or obesity or cardiovascular problems that preclude standing. Should the therapist assume that lateropulsion is not present? Should the therapist change the total point value for the scale, omitting points that could have been scored in standing from the total? This option causes a problem for the statistician analysing longitudinal data with total scores.

Conclusions

This systematic review yielded an internationally created array of scales available to evaluate lateropulsion on a subjective, qualitative level. All scales show face validity because their scoring coincides with the criteria set out by Davies. Validity studies and sensitivity/specificity calculations are limited by a lack of a 'gold standard'. Moderate associations with balance and functional measures have been established.
Despite the subjective nature of the scoring, reliability of all the scales appears good enough to establish their clinical utility. More work is needed with larger, more heterogeneous samples of patients with stroke to confirm validity and establish the value of individual scales as sensitive and specific screening tools. Responsiveness needs to be established for all scales.

Clinical messages

- Three scales exist that measure lateropulsion or pusher syndrome following stroke, each based on the definition of pusher syndrome defined by Davies.
- The Scale for Contraversive Pushing was tested most extensively and has acceptable clinimetric properties.
- The Burke Lateropulsion Scale and the Modified Scale for Contraversive Pushing address more functional positions and have scales which can yield a total that is useful for clinical decision-making and research.

Competing interests

One of the authors of this manuscript (MR) was associated with the development of the Burke Lateropulsion Scale.

Contributors

SRB searched the databases, selected the abstracts, coordinated the review, and wrote the paper. RB, MGEP, DP and MR assisted in interpreting the clinimetric properties and clinical practicality of the measures based on the various studies, made substantial contributions to the manuscript and approved the final version.

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Appendix – Sample search strategy from CINAHL

Entering search terms ‘lateropulsion OR pushing OR pusher syndrome AND validity AND stroke’ yielded 5 abstracts examined by one reviewer (SRB).

The strategy was repeated using the search terms ‘lateropulsion OR pushing OR pusher syndrome AND reliability AND stroke.’ The same abstracts appeared; likewise, when the term ‘reliability’ was substituted for ‘internal consistency,’ ‘responsiveness,’ ‘sensitivity OR specificity.’

Four abstracts met the inclusion criteria. Manuscripts were sent to the panel for further critique.