Review

An evidence-based review on the validity of the Kaltenborn rule as applied to the glenohumeral joint

Corlia Brandt\textsuperscript{a,}\textsuperscript{*}, Gisela Sole\textsuperscript{b}, Maria W. Krause\textsuperscript{a}, Mariette Nel\textsuperscript{c}

\textsuperscript{a}Department of Physiotherapy, Faculty of Health Sciences, University of the Free State, South Africa
\textsuperscript{b}Musculoskeletal and Sports Physiotherapy, School of Physiotherapy, University of Otago, New Zealand
\textsuperscript{c}Department of Biostatistics, Faculty of Health Sciences, University of the Free State, South Africa

Received 25 January 2005; received in revised form 26 January 2006; accepted 15 February 2006

Abstract

Kaltenborn’s convex–concave rule is a familiar concept in joint treatment techniques and arthrokinematics. Recent investigations on the glenohumeral joint appear to question this rule and thus accepted practice guidelines. An evidence-based systematic review was conducted to summarize and interpret the evidence on the direction of the accessory gliding movement of the head of the humerus (HOH) on the glenoid during physiological shoulder movement. Five hundred and eighty-one citations were screened. Data from 30 studies were summarized in five evidence tables with good inter-extractor agreement. The quality of the clinical trials rated a mean score of 51.27% according to the Physiotherapy Evidence Database scale (inter-rater agreement: $\kappa = -0.6111$). Heterogeneity among studies precluded a quantitative meta-analysis. Weighting of the evidence according to Elwood’s classification and the Agency for Health Care Policy and Research classification guidelines indicated that evidence was weak and limited. Poor methodological quality, weak evidence, heterogeneity and inconsistent findings among the reviewed studies regarding the direction of translation of the HOH on the glenoid, precluded the drawing of any firm conclusions from this review. Evidence, however, indicated that not only the passive, but also the active and control subsystems of the shoulder may need to be considered when determining the direction of the translational gliding of the HOH. The indirect method, using Kaltenborn’s convex–concave rule as applied to the glenohumeral joint, may therefore need to be reconsidered.

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Keywords: Glenohumeral; Translational glide; Evidence-based; Kaltenborn

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\textsuperscript{*}Corresponding author. P.O. Box 339 (G30), Bloemfontein 9300, South Africa. Tel: +51 4013297; fax: +51 4013290.
\textit{E-mail address:} gnfteb.md@mail.uovs.ac.za (C. Brandt).

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1. Introduction/background

Dysfunction of the shoulder girdle is one of the most common musculoskeletal conditions to be treated in primary care. Thirty-four per cent of the general population may suffer from shoulder pain at least once in their lifetime (Green et al., 2002). In addition to the high incidence rate, shoulder dysfunction is often persistent and recurrent (Winters et al., 1999).

Physiotherapy for shoulder dysfunction may include manual therapy joint techniques to treat pain or stiffness. Various approaches to treatment have been proposed, such as the Maitland approach (Maitland, 1998), movement with mobilization (Mulligan, 1999), and the application of passive mobilization techniques following the convex–concave rule (Kaltenborn and Evjenth, 1989).

The latter approach is based on direct and indirect assessment of translational glides. Using the direct method, the passive translational gliding movements are performed by the therapist to the patient’s painful and/or stiff joint to determine which direction may be limited (Kaltenborn and Evjenth, 1989). Joint mobilizations would then be performed as a treatment method in the decreased direction to restore normal movement. The indirect method of determining the direction of translational glide was termed the “Kaltenborn convex–concave rule” (Kaltenborn and Evjenth, 1989). This rule was first described by MacConaill (1953). Following this method, the therapist examines active and passive physiological movements such as flexion, extension, abduction and lateral rotation (Kaltenborn and Evjenth, 1989). The direction of the glide would then be determined by considering the geometry of the moving articular surfaces. In the glenohumeral joint, the glenoid fossa (concave surface) was considered to be stable (fixed) while the humeral head (convex surface) would be moved (mobilized) during a physiological shoulder movement. According to the convex–concave rule, the convex surface (humeral head) would glide in the opposite direction to the bone movement. Thus, during abduction of the arm, the humeral head would glide caudally. Kaltenborn and Evjenth (1989) proposed that for restricted shoulder extension and lateral rotation, the humeral head should be glided ventrally (anteriorly), and for restricted flexion and medial rotation, the humeral head should be glided dorsally (posteriorly).

Kaltenborn and Evjenth (1989) thus based the clinical reasoning of appropriate direction of translational glide mainly on the anatomy of the osseous articulating surfaces. More recently it has been suggested that other factors, such as the concept of functional stability (Panjabi, 1992), may also need to be considered in the assessment of the arthrokinematics of the glenohumeral joint (Hess, 2000). The question thus arose whether the convex–concave rule is valid in the clinical reasoning of the most appropriate direction of translational glide applied in the assessment and treatment of shoulder dysfunction.

The aim of this study was to investigate the evidence on the arthrokinematics of the glenohumeral joint supporting or negating the validity of the MacConaill and Kaltenborn rule and theory.

2. Methodology

2.1. The search strategy and data selection

An academic, computerized search was conducted. CINAHL, MEDLINE, The Cochrane Controlled trials register of randomized controlled trials, Kovsiedex, South African Studies and Sport Discussion were searched from 1966 to October 2003. The search was limited to English and human studies. Keywords such as shoulder, glenohumeral, kinematics, arthrokinematics, mechanics, translation(al), roll(-ing) and/or glide(-ing), accessory movement, and Kaltenborn were optimally combined. The search was continued over a period of ten months (Hoepfll, 2002).

The titles and the abstracts of the retrieved citations were screened for relevance by the primary investigator. The reference lists of the relevant articles were checked by one reviewer to identify additional publications. Five clinical experts in the field of shoulder orthopaedics were also contacted in order to retrieve data (Oxman et al., 1994; Mays and Pope, 1999; Green et al., 2002; Tugwell et al., 2003).

The second screening consisted of the blinded assessment of the full papers’ Method and Results sections by two independent reviewers. The reports were numbered at random and the authors’ names and affiliations, the name of the journal, the date of publication, and the acknowledgements were erased to ensure blinded assessment. All types of study designs were included in the systematic
review to increase its clinical value (Mays and Pope, 1999; Elwood, 2002; Hoepfl, 2002; Fritz and Cleland, 2003). In vivo and in vitro studies were assessed. The investigated population had to be human (male and/or female), a mean age of 15 years or older, with or without shoulder pathology. The study had to investigate a variable factor regarding glenohumeral joint translation and had to measure the direction of translation of the humeral head on the glenoid fossa during normal or simulated, active or passive physiological shoulder movement. The reviewers decided upon inclusion by means of consensus (Oxman et al., 1994; Jadad et al., 1996).

Data were extracted from the included reports and summarized on a standardized data collection form by two independent, masked reviewers. The form provided for the gathering of information on the study design, subgroups, exposure or intervention, study population, research methodology, data analysis, main results, hypotheses, and any other relevant data (Oxman et al., 1994; Elwood, 2002; Scholten-Peeters et al., 2003; Tugwell et al., 2003). The data were recorded (by means of consensus) as stated in the report. Where data were unclear and biased recording a possibility, it was clearly indicated (Scholten-Peeters et al., 2003).

2.2. Quality assessment of the clinical trials

The quality of the clinical trials were assessed by means of the 11-item Physiotherapy Evidence Database (PEDro) scale which was developed by the Centre for evidence-based Physiotherapy, University of Sydney. The PEDro scale measures the internal validity and the sufficiency of the statistical information provided by a clinical trial. The scale assesses criteria such as random allocation, concealment of allocation, comparability of groups at baseline, blinding of patients, therapists and assessors, analysis by intention to treat, adequacy of follow-up, between group statistical comparisons, report of point estimates, and measures of variability. Though the PEDro scale does not provide for the gathering of information on the study design, subgroups, exposure or intervention, study population, research methodology, data analysis, main results, hypotheses, and any other relevant data (Oxman et al., 1994; Elwood, 2002; Scholten-Peeters et al., 2003; Tugwell et al., 2003). The data were recorded (by means of consensus) as stated in the report. Where data were unclear and biased recording a possibility, it was clearly indicated (Scholten-Peeters et al., 2003).

Clinical trials were considered for meta-analysis regardless of their quality score in order to reduce bias (Guyatt et al., 1995; Woolf, 2000). The following study characteristics were compared by two independent reviewers in order to identify the possibility of statistical pooling of results: (i) the study populations, (ii) the interventions, (iii) the sample sizes, (iv) the availability and format of the results, (v) the statistical methodology used for analysis, and (vi) the hypotheses tested (Dickersin and Berline, 1997).

2.4. Weighting of the evidence

The strength of the scientific evidence was rated by two analysts according to two classification systems (Moher et al., 1996; Elwood, 2002; Mays and Pope, 2002) namely, (i) a hierarchy of evidence (Table 1) relevant to human health studies (Elwood, 2002) and (ii) the modified classification of the Agency for Health Care Policy and Research (AHCPR) guidelines (Table 2) on acute low back problems in adults (Ejnisman et al., 2002).

3. Results

3.1. Study characteristics

Fig. 1 depicts the results yielded by the search and selection process. Eighteen clinical trials, seven comparative, and five descriptive studies were included in the review. Summary of the data indicated major methodological heterogeneity. Researchers used various protocols and measuring instruments such as magnetic tracking devices or position sensors (n = 11), three-dimensional magnetic resonance imaging (n = 4), computertomography (n = 3), ultrasonic devices (n = 2), potentiometers (n = 3), radiographs (n = 6), and arthroscopy (n = 1) for investigation. Eleven studies were conducted in vivo and in vitro. Movements were either done passively (n = 15) or actively (n = 14); simulated, static or continuous, while the plane of motion also varied. Data were gathered on eight different physiological movements performed through a variety of ranges of motion. The movements of active flexion, active extension, and passive horizontal extension were not included in any investigation.

The literature indicated six main factors to explain the translational behaviour of the humeral head namely, the influence of (i) the capsulo-ligamentous structures (n = 17), (ii) neuromuscular control (n = 17),
(iii) articular geometry/congruency/conformity \((n = 8)\),
(iv) negative intra-articular pressure \((n = 4)\), (v) rigidi-
fication of musculature \((n = 1)\), and (vi) gravity \((n = 1)\).

Agreement between the reviewers were 100% for the
data extracted on the sample and methodological
characteristics. Disagreement occurred only on the
study design in two of the studies which was resolved
by means of consensus.

3.2. Methodological quality

The mean PEDro score of the clinical trials equalled
51.27%. Table 3 summarizes the individual results. The
inter-rater agreement for quality assessment was poor
\((k = -0.611)\). This was confirmed by the 95% con-
fidence level of \([-0.8661 ;-0.3562]\).

3.3. Meta-analysis

Heterogeneity among studies, insufficient reported
data, and poor study quality precluded statistical
pooling of results.

3.4. Level of the evidence

Twenty-five of the reviewed studies were analysed
qualitatively. Five studies were excluded due insufficient
information provided for classification purposes.

According to Elwood’s classification (Table 1), one
study fulfilled the criteria for level 2s evidence, five
for level 3 and 19 studies for level 4 evidence. The
level 2s evidence found (i) translation to be in the
opposite direction during active physiological move-
ment in pathological joints and (ii) the humeral
head to remain centered during active physiologi-
cal movement in normal joints (Paletta et al., 1997).
For all other stratified movement planes, only levels
3 and 4 evidence were found. Table 4 summar-
izes the amount and level of evidence found on the
direction of the translational movement of the humeral
head.

According to the AHCPR rating system (Table 2),
level C evidence is contradictory on the direction of
translation during active and passive lateral rotation in
90° of elevation in normal and reconstructed joints
(Karduna et al., 1997; Williams et al., 2001). Only
inconsistent, level D evidence could be found on the
translation occurring during physiological movements
in other planes.

Inclusion of only higher quality clinical trials (quality
score \(\geq 54.5\%\)) in the weighting of the evidence indu-
ced the following changes: according to Elwood’s
classification, only level 4 evidence was now available,
while the level of evidence according to the AHCPR
rating system, remained unchanged.
4. Discussion

4.1. Methodological quality of the clinical trials

Analysis of the methodology used by some of the included studies lead to serious concerns regarding the biomechanical and neurophysiological validity of their results (to be discussed in the next section). According to the PEDro scale, methodological shortcomings of the clinical trials concerned mostly the insufficient reporting of random allocation, insufficient reporting of concealment of allocation, and insufficient or unclear description of blinding of therapists and assessors. This may indicate that many of the clinical trials were, in fact, not
randomized, which may raise some concern regarding the appropriateness of the PEDro scale for assessing these trials (Verhagen et al., 1998). It should be noted, though, that poor reporting does not necessarily imply that the criteria were not satisfied during the execution of the trial (Elwood, 2002).

A quality score of 50–60% have been suggested as a cut-off to distinguish between good and poor quality studies (Maher et al., 2003; Scholten-Peeters et al., 2003). The mean quality score of 51.27% together with the poor inter-rater agreement (k = −0.611) necessitated careful consideration regarding the methodological quality of the included clinical trials (Oxman et al., 1994; Elwood, 2002; Scholten-Peeters et al., 2003).

The best approach when comparing the agreement between two raters is to calculate the \( k \) statistic. Similar to other methods, such as McNemar’s test which was also calculated (0.3103), small frequency tables (in this study \( n = 30 \)) present difficulties associated with the use and interpretation of kappa (Altman, 1996; Elwood, 2002). The problem most cited is that the value of \( k \) depends upon the proportion of subjects in each category. Landis and Koch (1977), as well as Elwood (2002), have characterized ranges of values for kappa with respect to the degree of agreement they suggest. Values greater than 0.75 may be taken to represent excellent agreement beyond chance, values below 0.40 may be taken to represent poor agreement beyond chance, and values between 0.40 and 0.75 may be taken to represent fair to good agreement beyond chance.

### 4.2. The evidence on the arthrokinematics of the glenohumeral joint

The best evidence (level 2s), as well as many of the selected studies (\( n = 17 \)), supported the hypotheses of

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Table 3
Summary of the quality scores of clinical trials

<table>
<thead>
<tr>
<th>Study</th>
<th>Mean quality scores (out of 11)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level 2s evidence</strong></td>
<td></td>
</tr>
<tr>
<td>Paletta et al. 1997</td>
<td>5</td>
</tr>
<tr>
<td>Karduna et al. (1997)</td>
<td>7</td>
</tr>
<tr>
<td>Freeman et al. (1992)</td>
<td>6</td>
</tr>
<tr>
<td>Freeman et al. (1990)</td>
<td>6</td>
</tr>
<tr>
<td>McMahon et al. (1995)</td>
<td>4.5</td>
</tr>
<tr>
<td>Gohlke et al. (1994)</td>
<td>3</td>
</tr>
<tr>
<td>Vasek et al. (1997)</td>
<td>5</td>
</tr>
<tr>
<td>Novotny et al. (1998)</td>
<td>4.5</td>
</tr>
<tr>
<td>Williams et al. (2001)</td>
<td>6.5</td>
</tr>
<tr>
<td>Apreleva et al. (1998)</td>
<td>6</td>
</tr>
<tr>
<td>Wueker et al. (1994)</td>
<td>6</td>
</tr>
<tr>
<td>Loehr et al. (1994)</td>
<td>5</td>
</tr>
<tr>
<td>Karduna et al. (1996)</td>
<td>6</td>
</tr>
<tr>
<td>Thompson et al. (1996)</td>
<td>5</td>
</tr>
<tr>
<td>Helig et al. (1993)</td>
<td>6</td>
</tr>
<tr>
<td>Wueker et al. (1998)</td>
<td>6</td>
</tr>
<tr>
<td>Debski et al. (1995)</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total mean score</strong></td>
<td>5.64</td>
</tr>
</tbody>
</table>

Table 4
Levels of evidence

<table>
<thead>
<tr>
<th>Physiological movement</th>
<th>Direction of translation of humeral head</th>
<th>Centered</th>
<th>Non-uniform</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active: normal joints</strong></td>
<td>Same</td>
<td>Opposite</td>
<td>Centered</td>
</tr>
<tr>
<td>( n = 8 )</td>
<td>3 (n = 1)</td>
<td>2 (n = 1)</td>
<td>5 (n = 1)</td>
</tr>
<tr>
<td>( n = 7 )</td>
<td>4 (n = 7)</td>
<td>4 (n = 1)</td>
<td>2s (n = 1)</td>
</tr>
<tr>
<td><strong>Level: C</strong></td>
<td><strong>Level: C</strong></td>
<td><strong>Level: D</strong></td>
<td><strong>Level: D</strong></td>
</tr>
<tr>
<td><strong>Active: pathological joints</strong></td>
<td>Same</td>
<td>Opposite</td>
<td>Centered</td>
</tr>
<tr>
<td>( n = 7 )</td>
<td>3 (n = 1)</td>
<td>3 (n = 1)</td>
<td>2 (n = 1)</td>
</tr>
<tr>
<td>( n = 6 )</td>
<td>4 (n = 6)</td>
<td>3 (n = 1)</td>
<td>4 (n = 1)</td>
</tr>
<tr>
<td><strong>Level: C</strong></td>
<td><strong>Level: C</strong></td>
<td><strong>Level: D</strong></td>
<td><strong>Level: D</strong></td>
</tr>
<tr>
<td><strong>Passive: normal joints</strong></td>
<td>Same</td>
<td>Opposite</td>
<td>Centered</td>
</tr>
<tr>
<td>( n = 6 )</td>
<td>3 (n = 1)</td>
<td>2 (n = 1)</td>
<td>1 (n = 1)</td>
</tr>
<tr>
<td>( n = 5 )</td>
<td>4 (n = 5)</td>
<td>4 (n = 1)</td>
<td>4 (n = 1)</td>
</tr>
<tr>
<td><strong>Level: C</strong></td>
<td><strong>Level: C</strong></td>
<td><strong>Level: D</strong></td>
<td><strong>Level: D</strong></td>
</tr>
<tr>
<td><strong>Passive: pathological joints</strong></td>
<td>Same</td>
<td>Opposite</td>
<td>Centered</td>
</tr>
<tr>
<td>( n = 7 )</td>
<td>3 (n = 1)</td>
<td>3 (n = 1)</td>
<td>1 (n = 1)</td>
</tr>
<tr>
<td>( n = 6 )</td>
<td>4 (n = 6)</td>
<td>4 (n = 3)</td>
<td>4 (n = 1)</td>
</tr>
<tr>
<td><strong>Level: C</strong></td>
<td><strong>Level: C</strong></td>
<td><strong>Level: D</strong></td>
<td><strong>Level: D</strong></td>
</tr>
</tbody>
</table>

Levels of evidence are indicated according to Elwood’s classification system (normal print) and according to the AHCPR’s guidelines (in italics). —, No evidence; \( n = \) amount of studies.
capsulo-ligamentous structures and neuromuscular control influencing the translation of the head of the humerus (HOH). The capsulo-ligamentous structures may be responsible for an obligatory translation of the humeral head at the end range of motion when the capsule and/or ligaments are tensioned. This was especially observed during passive motion in the absence of rotator cuff activity (Howell et al., 1988; Harryman et al., 1990, 1992; Gohlke et al., 1994; Debski et al., 1995; Karduna et al., 1996, 1997; Paletta et al., 1997; Novotny et al., 1998; Rhoad et al., 1998; Baeyens et al., 2000; Williams et al., 2001). During active movement the stabilizing effect of the rotator cuff on the humeral head causes a centring motion (Poppen and Walker, 1976; Howell et al., 1988; Gohlke et al., 1994; Wuelker et al., 1994, 1998; Debski et al., 1995; Karduna et al., 1996; Thompson et al., 1996; Karduna et al., 1997; Paletta et al., 1997; Apreleva et al., 1998; Rhoad et al., 1998; Graichen et al., 2000, 2001; Williams et al., 2001; Von Eisenhart-Rothe et al., 2002). Any loss of or defect in the stabilizing mechanism of the shoulder joint may increase or disrupt normal translational patterns, depending on the involved structure and its role in the gliding of the humeral head (Poppen and Walker, 1976, 1978; McGlynn and Caspari, 1984; Howell et al., 1988; Ozaki, 1989; Harryman et al., 1990; Helms et al., 1993; Loehr et al., 1994; Debski et al., 1995; McMahon et al., 1995; Deutsch et al., 1996; Thompson et al., 1996; Karduna et al., 1997; Paletta et al., 1997; Apreleva et al., 1998; Novotny et al., 1998; Wuelker et al., 1998; Baeyens et al., 2000, 2001; Graichen et al., 2000, 2001; Von Eisenhart-Rothe et al., 2002). Pain, muscle spasm, and loss of proprioception associated with shoulder dysfunction may lead to neuromuscular responses. Imbalance/incoordination of the shoulder musculature may influence the translation of the humeral head (Poppen and Walker, 1976; Wuelker et al., 1994, 1998; Bertoft, 1999; Graichen et al., 2000; Von Eisenhart-Rothe et al., 2002).

In correlation with the original theory of MacConaill and Kaltenborn, some studies did report that geometrical factors, such as the size of the humeral head, may determine translation. Increased head size seems to distension the capsule and thus reduce translation (Vaesel et al., 1997; Rhoad et al., 1998).

To relate the findings of this review on the translational direction of the humeral head to the Kaltenborn rule, the best evidence will be considered (Elwood, 2002). The level 2 evidence found in 50% of cases was found to be consistent with the opposite direction during active horizontal extension with lateral rotation and in the same direction during active abduction in anterior unstable joints and joints with rotator cuff tears. The humeral head remained centred during active abduction in normal shoulder joints (Paletta et al., 1997). According to the AHCPR classification, level C evidence (n = 2, quality scores > 50%) were contradicting regarding the translational direction during active and passive lateral rotation in 90° of elevation in normal and reconstructed joints (Karduna et al., 1997; Williams et al., 2001).

Considering Table 4, interpretations with regards to the convex–concave rule need to be made with caution due to the following limitations: (i) the table is not representative of all physiological movements since certain motion planes were not investigated by any of the studies; (ii) findings regarding the direction of translation were inconsistent for different physiological motion planes, and (iii) heterogeneous shoulder pathologies were grouped together, although these may affect translation in different manners (Burkhardt, 1994; Meister, 2000).

4.3. Relating the findings to Kaltenborn’s rule and theory

Kaltenborn and MacConaill based their hypotheses of normal and abnormal intra-articular dynamics on the geometry of the articulating surfaces and location of the movement axis alone (MacConaill, 1953; Kaltenborn and Evjenth, 1989). The evidence indicates (i) different arthrokinematic behaviour for normal and dysfunctional joints and (ii) that not only the passive subsystem, but also the active and control subsystems may determine intra-articular gliding motion.

It appears that Kaltenborn’s rule for the treatment of restricted joint motion may be valid if the intention of the treatment is to stretch a tight capsulo-ligamentous structure causing limitation of the physiological joint motion. By gliding the humeral head in the opposite direction of the restricted physiological bone movement, the restricting capsulo-ligamentous structure may be stretched. According to the evidence, however, this motion performed by the therapist may not necessarily mimic the true gliding taking place due to the tight structure.

4.4. Implications and recommendations

Clinically authors postulate that the validity of the Kaltenborn rule might not be accepted dogmatically. The arthrokinematics of each patient might need to be considered in the context of existing neuro-musculoskeletal and biopsychosocial dysfunction which requires the process of clinical reasoning. Scientifically such a recommendation still lacks evidence.

Methodologically sound, randomized, clinically controlled, in vivo, and homogeneous primary studies are needed on this subject. As such studies emerge, this review should be updated and reproduced. To ensure a meta-analysis in future reviews, the following criteria need to be considered: (i) movement should be classified as active or passive, (ii) the plane and the range of motion investigated should be similar, (iii) homogeneous pathologies should be grouped, and (iv) measuring
instruments, exposures or interventions, as well as the hypotheses tested, should be similar.

4.5. Limitations of this review

Bias needs to be considered. Only one reviewer was involved in the initial screening of the 555 citations. A few articles could not be retrieved internationally and attempts to retrieve unpublished literature yielded no results.

Working with such considerable amounts of evidence could not exclude the possibility of including multiple publications from the same large trial. Careful inspection, though, did not reveal any such errors. Information from papers concerning the same variables or cohorts, may influence the quality rating of similar papers later on. Earlier papers can provide the reviewers with additional information on validity.

This review lacks statistical strength due to the preclusion of a meta-analysis and the poor kappa value calculated for inter-rater agreement. The findings should be interpreted with caution due to the limitations of a qualitative/categorical analysis.

5. Conclusion

Inconsistent evidence, poor methodological quality and heterogeneity among the reviewed studies precluded the drawing of any firm conclusions regarding the direction of translation of the humeral head on the glenoid. The indirect method using Kaltenborn's convex–concave rule, as applied to the glenohumeral joint, need to be investigated appropriately by primary studies to determine its validity. It can only be postulated that not only the passive subsystem, as proposed by Kaltenborn, but also the active and control subsystems may need to be considered when determining the direction of the translational gliding movement of the humeral head. It is suggested that clinical decisions of appropriate gliding directions in the assessment and treatment of a patient with shoulder dysfunction should be considered carefully at this stage.

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