Assessment of the importance of glenohumeral peripheral mechanics by practicing physiotherapists

KENNETH KIRBY Duke University, Durham, North Carolina, USA
CHRISSHOWALTER Maitland Australian Physiotherapy Seminars, Cutchogue, New York, USA
CHAD COOK Division of Physical Therapy, Duke University, Durham, USA

ABSTRACT  Background and Purpose. Physiotherapists develop clinical reasoning theories and applied manual therapy skills through a variety of educational exposures. No studies have assessed the importance of selected theories such as the convex–concave rule, capsular pattern and scapulohumeral rhythm during clinical decision-making by physiotherapists. The present study investigated which variables physiotherapists considered were associated with the importance of these theories during practice and investigated physiotherapists’ perception of translational motion biomechanics of the glenohumeral (GH) joint.  Method. Six hundred and sixty physiotherapists in the USA volunteered to participate in this study. Using ologit regression analyses, the identifier themes and clinical background characteristics were associated with importance of peripheral biomechanics in manual therapy application and reliability/validity of the scapulohumeral rhythm theory in predicting pathological sequences of the shoulder complex. An intraclass correlation coefficient (ICC) was used to determine agreement regarding necessary translation of the GH joint for normal movement.  Results. The majority of physiotherapists indicated that all theories were important or very important during treatment decision-making and reported frequent utilization. Regression models identified that the importance placed on peripheral biomechanics was negatively influenced by academic qualification (bachelors and masters degrees) and gender (men were less likely to report that scapulohumeral rhythm was a reliable/valid predictor of shoulder pathology). ICC values identified excellent agreement among clinicians regarding translational motion.  Conclusions. The importance of biomechanics of the periphery for use, validation and frequency was based heavily on adoption of selected theories of glenohumeral movements despite evidence that suggests the theories lack validity. Copyright © 2007 John Wiley & Sons, Ltd.

Key words: capsular pattern, convex–concave, ologit, peripheral biomechanics, shoulder
INTRODUCTION

Physiotherapists develop clinical reasoning theories and applied manual therapy skills through a variety of educational exposures, including academic degree programmes, clinical residency and fellowship training, continuing education and informal individual mentoring (Boissonnault et al., 2004). In the USA, manual therapy interventions, including mobilization or manipulation for peripheral and spinal joints, are a standard inclusion in physiotherapists’ education curricula according to the Normative Model of Physical Therapist Professional Education (American Physical Therapy Association, 2004) and accreditation criteria for physiotherapist education programmes (Commission on Accreditation in Physiotherapy Education, 2004).

Physiotherapy interventions are based upon measurements from many clinical tests collected during the evaluation process (Riddle, 1992; Kaltenborn, 1993). Passive physiological and accessory motion testing by orthopaedic manual therapists are frequently employed to determine appropriate treatment choices (Kaltenborn, 1993; Rouval et al., 1996). Passive physiological movements are fundamental techniques of clinical judgement in determining joint stiffness and corresponding treatment (Battie et al., 1994) while accessory motions involve the articular movements of roll, spin and glide (Kaltenborn, 1993). Many physiotherapy disciplines base their manual treatment techniques on selected theories of peripheral mechanics, educational models learnt in the classroom and continuing education settings (Boissonnault and Bryan, 2005).

Prevalent theories associated with glenohumeral (GH) movements, germane to selection of treatment interventions of the shoulder include the theory of convex–concave rule of arthrokinematics, Cyriax’s capsular pattern and the scapulohumeral rhythm theory. These theories have been purported as useful in diagnosis and essential for subsequent treatment of musculoskeletal related maladies (Cyriax, 1947; Hoppenfeld, 1976; Kaltenborn, 1980; Cyriax, 1982; Magee, 1987; Corrigan and Maitland, 1988; Reid, 1992; Donatelli, 1997; Neumann, 2002).

MacConaill (1953) was one of the first to investigate intra-articular joint kinematics, based on theoretical movements between articular surfaces. Terminology was introduced to describe a predictable movement pattern based on the contact of the articular surface of the distal (moving) segment on the articular surface of the proximal (stable) segment. Slide, also called ‘glide’, occurred when a single point on one articular surface contacts multiple points on another articular surface. Roll, also called ‘rock’, occurred when multiple points along one rotating articular surface contacted multiple points on another articular surface. Spin occurred when a single point on one articular surface rotates on a single point on another articular surface.

Based on MacConaill’s observations, Kaltenborn (1980) advocated the use of the convex–concave rule to describe intra-articular kinematics during manual therapy. In summary, this rule purports that concave articular surfaces moving on convex surfaces will roll and glide in the same direction, whereas the movement of convex surfaces on concave will result in roll and glide in the opposite directions (Baeyens et al., 2000). In essence, this theory states that the surface geometry of a joint determines the accessory movement pattern during physiological movement. Therefore, examination and treatment are guided by the joint
geometry and variations are considered either abnormal or inappropriate.

Cyriax (1982) established the concept of capsular patterns as an essential element of soft tissue examination. He proposed that all synovial joints demonstrated range of motion loss in proportional plane-based movements when certain pathologies existed, which solely affected the joint capsule. For the GH joint, Cyriax (1982) proposed the following pattern of plane-based loss of range: external rotation limited at a greater rate than abduction, which in turn is limited at a greater rate than internal rotation. He emphasized looking for the capsular pattern during passive range of motion testing because this would help the clinician implicate the structure responsible for the limited movement, namely the joint capsule.

A widely cited study on the kinematics of the shoulder (Inman et al., 1944) stated that GH joint abduction/flexion occurs concurrently with scapular upward rotation, an observation now referred to as ‘scapulo-humeral rhythm’. Inman et al. (1944) also stated that this natural timing or kinematic rhythm was fairly constant throughout most of GH abduction, occurring at a ratio of 2 : 1 (for every 3° of shoulder abduction, 2° occur by GH abduction and 1° occurs by scapular upward rotation). Considering this, a full arc of shoulder abduction (180°) is the result of 120° of GH abduction and 60° of scapular upward rotation.

At present, we know of no studies that have investigated the prevalence and estimated importance of these theories during clinical decision-making by physiotherapists. Because teaching these theories and subsequent manual therapy treatment interventions involves preparation that is enhanced during clinical education experiences (Boissonnault et al., 2004) and is significantly influenced by the assigned clinical instructor (Boissonnault and Bryan, 2005) we felt that practising physiotherapists would most appropriately reflect the current trends of use. Now that recent literature regarding the theories of selected intervention methods is available (Harryman et al., 1990; Brossmann et al., 1996; Winters et al., 1997a; Winters et al., 1997b; Conroy and Hayes, 1998; Bang and Deyle, 2000; Hsu et al., 2002; Lewis et al., 2005) and since considerable differences in how manual intervention is integrated into professional practice exists, we were interested in investigating two primary objectives. First, we planned to investigate which variables physiotherapists consider are associated with the importance of peripheral biomechanics in determination of use, validation and frequency of use during practice. Second, we endeavoured to investigate physiotherapists’ perception of translational motion biomechanics of the GH joint in a non-pathological individual that would identify if clinicians agree on a specific amount of translational motion.

METHOD

Sample

Six hundred and sixty (660) practising bachelors, masters and doctoral-trained physiotherapists participated in this study (Table 1). The physiotherapists were voluntary participants of a continuing education course that focused on peripheral manual therapy techniques. The courses were not part of an organized degree-granting process and primarily addressed Maitland/Australian based methods of assessment and treatment. The course was the first in a series of four manual therapy courses and was the only course that focused solely on peripheral manual therapy methods.
Procedure

Each consecutive course participant was recruited to participate voluntarily in the survey. The data collected were part of information gathered to focus the educational material toward gaps in knowledge from the participants of the course. The survey was administered during the pre-registration period, prior to the initiation of the coursework or discussion of the manual therapy philosophy. Pre-course administration of the survey reduced the potential of bias regarding peripheral biomechanical constructs and allowed subjects to record their responses based on present knowledge of the selected theories of the GH joint. The physiotherapists were provided with written instructions requesting that they answer the questions to the best of their ability. The survey consisted of 15 questions; the first six were ordinal Likert-type questions which included the following:

- How important do you feel the theory of peripheral biomechanics is (e.g. roll, spin and slide) in your application of manual therapy?
- How important do you feel the theory of peripheral biomechanics is (e.g. roll, spin and slide) in validating manual therapy?
- How often do you consider, or use roll, spin and slide during your manual therapy treatment?
- How reliable/valid do you feel the convex–concave theory is in predicting articular motion of the GH joint?
- How much translational motion (in mm) is needed for normal shoulder function in abduction, flexion and extension?
- How reliable/valid do you feel the scapulohumeral rhythm theory is in predicting pathological sequences in the shoulder complex?

The remaining questions were associated with frequency of manual therapy course attendance, manual therapy background or discipline, educational degree, years of practice experience, age and gender. Manual therapy background is exposure or completion of a manual therapy continuing educa-

TABLE 1: Demographic background of survey respondents

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Mean 33.4</th>
<th>Standard deviation 7.1</th>
<th>Range 23–60 (8 missing)</th>
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<tr>
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<tr>
<td>Experience (years)</td>
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<td>6–10</td>
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<td>11–15</td>
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<td>16–20</td>
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<tr>
<td>Physical therapy education</td>
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<tr>
<td>Bachelors</td>
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<td>Masters</td>
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<td>Doctoral</td>
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<td></td>
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<td>Maitland</td>
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<td></td>
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<tr>
<td>McKenzie</td>
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<tr>
<td>Paris</td>
<td>30</td>
<td></td>
<td></td>
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<tr>
<td>Other — not designated</td>
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<td></td>
<td></td>
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<tr>
<td>Osteopathic</td>
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<td></td>
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<tr>
<td>Kaltenborn</td>
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<td></td>
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<td>IAOM*</td>
<td>5</td>
<td></td>
<td></td>
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<tr>
<td>Mulligan</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grimsby</td>
<td>5</td>
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<td></td>
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<tr>
<td>NAIOMT**</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eclectic</td>
<td>267</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

tion group within or outside the USA, which has influenced the participant’s assessment and treatment. Background does not reflect membership within a nationally sponsored organization such as the Association of Chartered Physiotherapists in Orthopaedic Medicine (ACPOM), Society of Orthopaedic Medicine (SOM), or the American Academy of Orthopedic Manual Physical Therapists (AAOMPT).

All data were collected and coded to ensure confidentiality. A blinded data administrator processed the data using SPSS Version 11.0.1 and participated in the statistical analysis. The database was approved by the Duke University Institutional and Ethics Review Board.

Statistical analysis

Using SPSS Version 11.0.1, descriptive and inferential statistical analyses were performed. Descriptive statistics were used to outline the frequencies of manual therapy course attendance, manual therapy background or discipline, gender and educational degrees, and the mean years of practice experience and age of the participants. Two separate ologit regression analyses were performed using the dependent variable question ‘How important do you feel the theory of peripheral biomechanics is (e.g. roll, spin and slide) in your application of manual therapy?’ and the dependent variable question ‘How reliable/valid do you feel the scapulohumeral rhythm theory is in predicting pathological sequences in the shoulder complex?’ An ologit (maximum likelihood ordered logit regression) regression analysis fits ordered logit models of an ordinal (polytomous) dependent variable against the selected independent variable questions. Independent variables can exist using any form of data; those variables that are nominal and ordinal are dummy coded allowing individualized association to the dependent variable. Since the dependent variable question values consist of ranks without order, the actual values taken on by the dependent variable are irrelevant except that larger values are assumed to correspond to probability of changing one lower Likert choice to one ‘higher’ outcome, and vice versa (Field, 2001).

Since the question associated with ‘How much translational motion (in mm) is needed for normal shoulder function in abduction, flexion, and extension?’ involved ratio data, a model 2.1 intraclass correlation coefficient (ICC) was used to determine inter-rater reliability among the respondents. Although no standards exist that determine acceptable reliability, values close to 1.0 represent stronger reliability, whereas values closer to 0.0 represent weak reliability.

RESULTS

Descriptive findings

The majority (81.6%) of the participants indicated that the theory of peripheral biomechanics (e.g. roll, spin and slide) was ‘very important’ or ‘important’ in their application of manual therapy. Only five participants (0.8%) of the 660 identified the theory of peripheral mechanics as ‘not important’. Furthermore, a large proportion (73.1%) of participants indicated that the theory of peripheral biomechanics (e.g. roll, spin and slide) was ‘very important’ or ‘important’ in validating manual therapy, and (88.7%) of the participants reported they ‘frequently’, ‘somewhat frequently’ or ‘sometimes’ consider or use roll, spin and slide during their manual therapy treatment. Slightly over 70% of the participants felt that the convex–concave theory is ‘very reliable’
or ‘somewhat reliable’ in predicting articular motion of the GH joint. Lastly, 77.4% of the participants felt that the scapulohumeral rhythm theory is ‘very reliable’ or ‘somewhat reliable’ in predicting pathological sequences of the shoulder complex.

Inferential finding, ologit regression

The model fit value for the first ologit regression using the dependent variable ‘How important do you feel the theory of peripheral biomechanics is (e.g. roll, spin and slide) in your application of manual therapy?’ was significant ($p \leq 0.0001; \chi^2 = 445.9$). The Nagelkerke pseudo $R^2$ was 0.59, indicating that the goodness of fit within this model was good. The Nagelkerke pseudo $R^2$ measures the explanatory power of the model, a similar concept to the regression coefficient in a linear model (Long, 1997). The first ologit regression yielded four significant results. First, the likelihood that therapists who indicated that peripheral biomechanics was important was influenced by their academic degree. Both bachelor’s and master’s level clinicians were less likely to report the importance of use of roll spin and slide during treatment application than doctor-trained clinicians ($p \leq 0.0001$). Second, those who felt that the theory of peripheral biomechanics was important for validation of manual therapy were also more likely to consider the use of peripheral biomechanics as ‘important’; specifically, those who reported ‘very important’ ($p < 0.0001; \chi^2$ test $= -4.64$) and ‘important’ ($p = 0.004; \chi^2$ test $= -1.86$). Several variables approached but did not meet significance, including ‘How reliable/valid do you feel the convex–concave rule is in the predicting articular motion of the GH joint?’ ($p = 0.053; \chi^2$ test $= 3.84$) and those who reported a North American Institute of Orthopedic Manual Physiotherapy (NAIOMPT) background ($p = 0.059; \chi^2$ test $= 2.42$). Both were positively associated with use. The first ologit regression results are outlined in Table 2.

The model fit value for the second ologit regression was significant ($p \leq 0.0001; \chi^2 = 159.1$). The Nagelkerke pseudo $R^2$ was 0.26, also indicating that the goodness of fit within this model was fair. The second ologit regression using the dependent variable ‘How reliable/valid do you feel the scapulohumeral rhythm theory is in predicting pathological sequences in the shoulder complex?’ yielded two significant results. First, men were less likely to report that scapulohumeral rhythm was a reliable/valid predictor of shoulder pathology ($p = 0.007; \chi^2$ test $= 0.476$). Additionally, those who felt that the

<table>
<thead>
<tr>
<th>Variable</th>
<th>$B$</th>
<th>$SE$</th>
<th>Wald $\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bachelor’s degree</td>
<td>16.44</td>
<td>0.407</td>
<td>1630.1*</td>
</tr>
<tr>
<td>Master’s degree</td>
<td>16.34</td>
<td>0.385</td>
<td>1799.2*</td>
</tr>
<tr>
<td>Importance of peripheral biomechanics in validating manual therapy (‘very important’)</td>
<td>$-4.64$</td>
<td>0.676</td>
<td>47.2*</td>
</tr>
<tr>
<td>Importance of peripheral biomechanics in validating manual therapy (‘important’)</td>
<td>$-1.86$</td>
<td>0.638</td>
<td>8.5**</td>
</tr>
</tbody>
</table>

*Indicates level of significance $p \leq 0.05$; **indicates level of significance $p \leq 0.0001$; only variables that were significant ($p \leq 0.05$) are reported. $B =$ Beta; $SE =$ Standard Error.
theory of peripheral biomechanics was important for validation of manual therapy; while a similar number feel that the convex–concave theory is at least ‘somewhat reliable’ in predicting articular motion of the GH joint. A majority also felt that the scapulohumeral rhythm theory is somewhat or very reliable in predicting pathological sequences of the shoulder complex. Nearly all of the participants claimed they consider, or use roll, spin and slide as least sometimes during their manual therapy treatment. Furthermore, the clinicians demonstrated strong agreement about the quantity of translational motion needed for normal shoulder function.

Our study found that clinicians’ pre-concept of available translation within the GH joint demonstrates excellent agreement. This finding is promising since the GH joint frequently exhibits translatory-only movements during pathology and an understanding of normal available movement is essential to recognize pathological conditions (Howell et al., 1988; Paletta et al., 1997; Matsen et al., 1998; Baeyens et al., 2000). During pathology, it is common for the humerus to translate anteriorly and/or superiorly in the GH joint (Harryman et al., 1990; Brossmann et al., 1996). Harryman et al. (1990) suggested that this phenomenon is associated with asymmetric tightening of the posterior capsule, which results in translation of the humeral head in the opposite direction of the

**DISCUSSION**

The findings of this study indicate that physiotherapists support the importance of key theories associated with peripheral shoulder biomechanics for practice use and validation. The majority of the surveyed participants reported that the theory of peripheral biomechanics associated with the convex–concave rule (e.g. roll, spin and slide) is important or very important in validating manual therapy; while a similar number feel that the convex–concave theory is at least ‘somewhat reliable’ in predicting articular motion of the GH joint. A majority also felt that the scapulohumeral rhythm theory is somewhat or very reliable in predicting pathological sequences of the shoulder complex. Nearly all of the participants claimed they consider, or use roll, spin and slide as least sometimes during their manual therapy treatment. Furthermore, the clinicians demonstrated strong agreement about the quantity of translational motion needed for normal shoulder function.

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**TABLE 3: Ologit regression 2: ‘How reliable/valid do you feel the scapulohumeral rhythm theory is in predicting pathological sequences in the shoulder complex?’**

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>SE</th>
<th>Wald χ²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male gender</td>
<td>0.467</td>
<td>0.176</td>
<td>7.31**</td>
</tr>
<tr>
<td>Importance of peripheral biomechanics in validating manual therapy</td>
<td>−1.72</td>
<td>0.624</td>
<td>7.59**</td>
</tr>
</tbody>
</table>

*Indicates level of significance p ≤ 0.05; ** indicates level of significance p ≤ 0.0001; only variables that were significant (p ≤ 0.05) are reported. B = Beta; SE = Standard Error.

**Importance of glenohumeral peripheral mechanics**


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limited capsule. Because translation is an essential element of accessory mobilizations, and since proper dosage should be considered important during treatment, this finding is promising. We know of no studies that have investigated force dosage or a similar form of quantitative assessment at the shoulder but according to our findings, clinicians should expect to produce similar linear values regarding distance.

Recent information has suggested that evidence to support the convex–concave theory for the GH joint, is poor (Howell et al., 1988; Paletta et al., 1997; Matsen et al., 1998; Baeyens et al., 2000). Although joint mobilization techniques have demonstrated benefit for patients with various shoulder pathologies it is questionable whether these benefits require the specificities of the convex–concave rule. Selected authors have reported that mobilization techniques are preferable to physiological stretching because the movements provide a precise stretch to the restricted aspect of the capsule (when pre-positioned in the restricted position) with less subsequent pain, less force and less compression on painful structures (Johns and Wright, 1962; Lundberg, 1969; Conroy and Hayes, 1998). End range mobilizations, irrespective of the convex–concave rule, have long been advocated for improvement of range of motion (Wadsworth, 1986; Edmond, 1993). End range mobilizations that engage the restricted aspect of the capsule do lead to multi-directional improvements in range of motion for patients with adhesive capsulitis or other conditions associated with range of motion losses (Vermeulen et al., 2000). These findings suggest that selection of manual therapy technique that focuses on a specific direction based solely on the convex–concave rule may not yield values any better than the antagonistic direction at the shoulder.

A methodical evaluation of the existence of a capsular pattern of the shoulder as proposed by Cyriax has not yet been performed; however, several studies have identified variability of a capsular pattern of the shoulder (Warner et al., 1996; Donatelli, 1997; Winters et al., 1997b; Rundquist et al., 2003; Rundquist and Ludewig, 2004). Cyriax (1978) initially proposed that pathology in the shoulder results in range of motion loss in proportional patterns based on a ratio (3 to 2 to 1), external rotation is limited more than abduction that is limited more than internal rotation proportionally. He used this ratio to differentiate between losses of motion secondary to bony, muscle, or capsular changes. Donatelli (1997) described a ‘modified capsular pattern’ where external rotation at 0° was more restricted than external rotation at 90° of shoulder abduction followed by internal rotation at 90° of shoulder abduction. In contrast, Warner et al. (1996) found that external rotation at 0° was more restricted than internal rotation at 90° and than external rotation at 90°. If indeed these considerable variations exist in the proposed capsular pattern, then the ability to differentiate losses of motion secondary to bony, muscle or capsular changes is questionable.

Since the time of Inman’s work in 1944, several studies have examined the kinematics of shoulder abduction with emphasis of motion in the scapular plane (Freedman and Munroe, 1966; Poppen and Walker, 1976; Bagg and Forrest, 1988; Paletta et al, 1997; Mandalidis et al., 1999) and on motion while lifting different loads (McQuade and Schmidt, 1998). These studies reported variations in Inman’s original work. For example, Bagg and Forrest (1988) reported a mean GH to scapular rotation of 3.29:1 between 21° and 82° of abduction, 0.71:1 between 82° and 139° of abduction, and 1.25:1 between 139° and 170° of abduction.
However, Inman’s classic ratio of 2:1 remains a valuable maxim regardless of the differing ratios reported in literature, due to its ease of remembrance and ability to help clinicians visualize the relationship between the humerus and scapula during the full range of shoulder abduction.

**Limitations of the study**

The findings of this survey were drawn from participants of one manual therapy continuing education programme in the USA. This particular approach does not focus heavily on biomechanical theories such as the convex–concave rule or capsular pattern theory during peripheral manual therapy assessment and treatment. The possibility exists, though unlikely according to the level of importance most clinicians placed on the theory of peripheral biomechanics, that the participants of the course selected this particular manual therapy continuing education course based on this reason. Nearly 82% of the survey respondents indicated that the theory of peripheral biomechanics was important in their application of manual therapy, a figure that supports adherence to biomechanical principles. Furthermore, these findings are limited to US clinicians and generalization to non-US clinicians is inappropriate.

Because the majority of clinicians selected the higher Likert-type categories, the chance of meeting significance for each variable was reduced. An ologit regression requires relatively moderate dispersion of selections across all Likert-type categories for improved sensitivity. Consequently, some of the variables that approached or did not meet significance may have been significant if more participants had indicated that biomechanics were not important during their clinical decision-making. Additionally, it is likely that many of the course participants categorized their approach on a background or discipline in which they were not versed or skilled in. Many indicated that their approach did not follow one specific background and selected ‘eclectic’. The possibility exists that one’s exposure to a particular manual therapy model included incorrect or misinformation, thus reducing the purity of the model.

**CONCLUSIONS**

The findings of our study demonstrate the physiotherapists agree on the available translation of motion in the GH joint but make clinical decisions based on selected biomechanical principles that may lack validity. Basing decision solely on biomechanical theories may result in techniques that are not optimal for patient improvement. Because the majority of clinicians identify the use of these principles, the risk of a sub-optimal outcome is disconcerting. Future research should investigate whether clinicians can accurately detect peripheral biomechanics as determined by 3-D motion analysis research. Additionally, future investigation whether peripheral biomechanical findings in the clinic are reflective of preconceived translational motion is worth exploration.

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Address correspondence to: Chad Cook PT, PhD, MBA, OCS, COMT, Assistant Professor, Division of Physical Therapy, Duke University, DUMC 3907, Durham, NC 27710, USA (E-mail: chad.cook@duke.edu).