The convex–concave rule and the lever law

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1. Introduction

The convex–concave rule is considered an important theory during treatment decision-making (Kirby et al., 2007). According to this rule (Fig. 1) the therapist moves a bone with a convex joint surface opposite to the direction of restricted movement of the distal aspect of the bone (e.g. the head of humerus inferiorly for restricted shoulder abduction). However, a concave joint surface is mobilized in the same direction as the direction of the restricted bone movement (e.g. the tibia condyles anteriorly for restricted knee extension) (Kaltenborn, 2002: p 34).

Recent studies are questioning this principle. On 3D reconstructions of helical CT data of 3 asymptomatic shoulders Baeyens et al. (2000) for example observed a posterior translation of humeral head during external rotation in 90° abduction. However, the convex–concave rule predicts an anterior glide for external rotation. This observation could also be made in 3 symptomatic shoulders with minor instability (Baeyens et al., 2001). The same method of 3D reconstructions of helical CT data was used in the analyses of pro- and supination of the forearm (Baeyens et al., 2006). It was found for example a posterior translation of the radial head during supination in the proximal radio-ulnar joint, while the convex–concave rule predicts anterior gliding of the radial head’s joint surface on the radial notch of ulna.

Cattrysse et al. (2005) used an electromagnetic tracking device to study coupled motions of the acromioclavicular, glenohumeral and humero-ulnar joints on cadavers. With mathematical calculations they deduced intra-articular kinematics which were not according to the convex–concave principle. Brandt et al. (2007) found in their literature review inconsistent evidence, poor methodological quality, and heterogeneity of the studies, so that no clear conclusion could be drawn on the direction of translation of the humeral head.

Johnson et al. (2007) evaluated the effect of the gliding mobilization in 20 patients with adhesive capsulitis (frozen shoulder). Half of the patients were mobilized anteriorly and the other half posteriorly. They found pain alleviation in both groups, but the posterior mobilization group had better results in range of motion – although the convex–concave rule predicts anterior gliding of the humeral head during external rotation.

The aim of this paper is to explain the mechanics of the convex–concave rule and then to discuss possible misinterpretations in the above mentioned studies.

2. Mechanics of the convex–concave rule

During the movement of a bone around an axis (= osteokinematics), its joint surface is doing complex movements described by arthrokinematics (Williams et al., 1989: p 478). The form of the joint surface has been considered to induce its gliding/
sliding movement: a female (=concave) joint surface glides in the same direction as the bone movement, while a male (=convex) surface is gliding in the opposite direction of the bone movement (MacConaill and Basmajian, 1977: p 36 and 37; Williams et al., 1989: 483). Kaltenborn (2002: p 34) has described these mechanics in terms of the convex–concave rule.

The mechanical basis of the convex–concave rule is the lever law. A lever is a body (mostly a bar) which can be moved around an axis (Brockhaus, 1993). The bones of the locomotor system represent such levers which are moved by muscles or weight forces around the axis of a joint. There are levers with two arms, where weight and force are acting both sides of the axis (e.g. a seesaw: Fig. 2 a), and levers with one arm, where weight and force are acting on the same side of the axis (e.g. a wheelbarrow and a shovel: Fig. 2 b and c).

Movement of a bone with a convex joint surface like the scapula, the lever system is a lever with only one arm (Fig. 3b). The axis of motion remains in roughly the middle of humeral head. One lever arm is the shaft of humerus moving cranially during abduction. The other lever arm is between the axis and the joint surface of humeral head and is moving caudally during abduction.

When moving a bone with a concave joint surface like the humerus represents movement of a lever with two arms (Fig. 3a). The axis is roughly in the middle of humeral head. One lever arm is the shaft of humerus moving cranially during abduction. The other lever arm is between the axis and the joint surface of humeral head and is moving caudally during abduction.

The convex–concave rule is a simplification of these mechanics describing the movements of the joint surfaces using their form. However, there are variations of joint surfaces where this simplification is no longer useful. For example during a cadaver study, Lazennec et al. (1994) found in 150 proximal tibiofibular joints the malleolus moves posteriorly during dorsal flexion in the ankle, the head of fibula is moving anteriorly and the other way round (Lazennec et al., 1994).

3. Discussion: movements of the centre of the humeral and radial head or of the joint surface

Having the lever law as a mechanical basis, the convex–concave rule can hardly be contradicted. So why is it questioned in different studies?

The explanation is a misunderstanding! Baeyens et al. (2000, 2001) described the translation of the centre of the humeral head during external rotation in 90° abduction. Fig. 4a shows a similar movement – horizontal abduction – which is easier to represent graphically. The humerus moves physiologically as a lever with two arms and therefore its joint surface is gliding anteriorly while the bone shaft is moving posteriorly – according to the convex rule.

When gliding is restricted, rolling predominates (Kaltenborn, 2002: p 27). Rolling shifts the axis of motion towards the contact point of the joint surfaces. For simplification this is exaggerated in Fig. 4b. This transforms the humerus nearly into a lever with one arm. In this case the joint surface of the humerus is mostly rolling posteriorly and its anterior gliding is restricted. The centre of the head of humerus is now moving posteriorly. The observation of Baeyens et al. (2000, 2001) is, therefore, correct, but they do not describe the movement of the joint surface as does the convex–concave rule.

The described shift of the axis of motion happens especially in stiff joints and it has been known for a long time (Fig. 5; Jordan, 1963: p 22).
The same explanation applies to the study of pro- and supination of Baeyens et al. (2006). In supination the radial head rotates on its axis. This is a two arm lever system. During supination the lateral aspect of the radial head moves posteriorly, while its medial aspect – the articular surface – moves anteriorly on the radial notch of ulna. This is according to the convex–concave rule! However, rolling of the joint surface causes posterior displacement of the centre of the radial head, which was the correct observation of Baeyens et al. (2006).

The simplification of the convex–concave rule describes only the gliding of the joint surface of the moving bone. It should be noted that human joints surfaces not only glide but simultaneously roll upon the opposite joint surface (Williams et al., 1989: p 483), which is never fully congruent to the other one (MacConaill and Basmajian, 1977: p 33). In the reasoning model of the convex–concave rule the axis of motion is considered stationary for simplification. However, the rolling component in human joints shifts the axis. This is responsible for the displacement of the centre of the humeral head observed by Baeyens et al. (2000, 2001, 2006).

Stiff joints are thought to have restricted gliding and predominant rolling between the joint surfaces (Kaltenborn, 2002: p 27). The cause of this gliding restriction is unclear and may be an increased articular pressure as a consequence of shortening of the joint capsule or increased tension in periarticular muscles. Other causes are possible such as an altered synovial fluid or loosening of periarticular ligaments or insufficiency of periarticular muscles as in hypermobile joints. Shortening of the joint capsule and muscles is also mentioned by Brandt et al. (2007) as a factor having an influence on arthrokinematic movements. These authors confuse, like Baeyens et al. (2000, 2001, 2006), the displacement of the centre of the humeral head with the movement of the joint surface described by the convex–concave rule (Schomacher, 2008).

The increased external rotation after posterior gliding mobilization in the shoulder joint (Johnson et al., 2007) might be explained by the frequently observed anterior positional fault of the humeral head in relation to the acromion (Schomacher, 2007; Bryde et al., 2005). There was no significant difference between anterior and posterior gliding mobilization regarding pain (Johnson et al., 2007). This indicates, that respecting mechanical principles is seen mainly in mechanical parameters like range of motion, while for pain relief many techniques might be done – even ignoring joint mechanics!

Finally, it should be mentioned, that the convex–concave rule describes gliding in physiological joints. It is valid also in pathological ones in which the physiological gliding becomes restricted. However, the physiotherapist should not mobilize a pathological joint according to a rule, but treat pathological clinical findings, which are in correlation with the patient’s complaints.

Fig. 4. The lever system applied to horizontal abduction in the shoulder with physiologic and restricted gliding of the humeral joint surface. (a) Horizontal abduction in a horizontal section: in a physiological joint a lever with two arms exists and the humeral joint surface is gliding anteriorly according to the convex rule. (b) Shift of the axis of motion towards the contact point of the joint surfaces because of restricted gliding. Humerus is becoming a lever with one arm and the centre of head of humerus is moving posteriorly. Note the absence of gliding in this extreme example.

Fig. 5. Extension of the knee with physiological gliding and with restricted gliding due to adhesions. Note the shift of axis of motion (after Jordan 1963: 22).
4. Conclusion

The convex–concave rule, introduced by Kaltenborn into manual therapy, is a didactic simplification of the lever law, during rotatory movements of the joints. Movement of a convex bone corresponds to movement of a lever with two arms (¼ convex rule) and movement of a concave bone to a movement of a lever with one arm (¼ concave rule).

The convex–concave rule describes the movement of a pair of mating joint surfaces (arthrokinematics) and not the movement of the bone e.g. the centre of humeral head (osteo kinematics), which is often analyzed in biomechanical research.

In practice it is important not to transfer the gliding direction from physiological joints to pathological ones for mobilization without a prior examination. Restricted gliding and the associated dysfunctions may have different causes. They must be assessed individually in an examination and the findings must be interpreted in a thorough clinical reasoning process.

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References


