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Audible sounds associated with spinal manipulation – a snap-shot summary report (Nov 2012)

- **Key messages**
- **There is some evidence to suggest that the audible sound during a manipulation is needed to have a local effect on short-latency stretch reflex.**
- **The audible sound may not be needed to reduce pain immediately following a manipulation.**
- **There is still much research needed to establish the significance of the audible sound in the treatment outcomes and physiological effects of joint manipulation.**
- **Five main theories arise from the literature:**
- Release of trapped intra-articular material such as synovial folds or meniscoids.
- Relaxation of hypertonic muscle by sudden stretching, the mechanoreceptor-pain gate or reflexogenic theory.
- Disruption of the articular or periarticular adhesions.
- Unbuckling of motion segments that have undergone disproportionate displacements.
- Pressure reduction in the joint results in the formation of gas cavities. When the vapour phase of these cavities collapse, energy is released in the form of sound. Gas is a consequence of the 'crack' rather than the cause.

Context

Spinal manipulation is just one of many techniques employed within osteopathic practice. This aspect of practice remains the most commonly researched and has been shown to be well used in practice[1]. Various theories exist concerning what actually occurs to cause the cracking sound associated with joint manipulation or cavitation. The evidence for these theories is discussed in this article.

Early investigative work

Investigation of the phenomenon of joint cracking was first cited in the literature in 1911 in the work by Fick[2]. Subsequent authors including Dittmar and Nordheim also investigated this phenomenon[3,4]. They observed bubbles in joints and were interested in them "as a means of obtaining radiographs of fibrocartilage in the knee without using a contrasting medium". Roston and Wheeler-Haines[6] conducted the earliest detailed study in this area but focussed on metacarpophalangeal (MCP) joints.

Sandoz reviewed the work of the earlier authors cited and stated that "We must frankly admit that, for the manipulator, the crack represents an important, although not an absolute nor a sufficient criterion for a good manipulation" [7,8]. Mierau *et al*[9] went further stating that the joint crack is integral to the manipulative process and is what separates manipulation in general from mobilisation. Cassidy *et al* supported this view, but it is refuted by Flynn *et al*[10,11 12].

Wolff[13] published the first graphic recording of articular cracking, and Unsworth *et al*[5] continued the work of Roston and Wheeler-Haines[6] by constructing a machine that could study the effects of loading on the separation of the metacarpohalangeal joints in man. Unsworth *et al*[5] used a selection of splints to ensure correct alignment of the fingers to the loading mechanism; the fingers rested on an X-Ray plate that could be loaded laterally and loads of up to 16kg were applied. If cracking occurred a trace was marked at the point of cracking. Gas analysis was also carried out on the synovial fluid of a selection of patients, one of whom had a traumatic effusion and others who had rheumatoid arthritis. The research team also constructed a model of the MCP joint using the data from their initial findings on loading and separation of the human joint to continue their studies.

Unsworth *et al*[5] used the term cavitation to describe "the formation of vapour and gas bubbles within fluid through local reduction in pressure. When vapour collapses on moving into a region of very high pressure, very high impact pressures can be generated". They also stated that "if large pressure reduction takes place, the fluid is converted into vapour bubbles in these low pressure regions forming gas cavities". Gas analysis of the synovial fluid was 15% by volume, and over 80% carbon dioxide. Unsworth *et al*[5] proposed from their work that the audible crack heard during manipulation of a joint was due to the formation of gas cavities from multiple bubbles. The pressure in the bubble is very low while the pressure in the surrounding fluid is nearer to ambient conditions. As joint separation occurs at a high rate, there is a net flow of fluid into the low pressure regions. The resulting collapse of the vapour phase of the cavities allows the release of energy as noise in the form of a "crack". The gas removed during the period of low pressure returns to ambient pressure but is not reabsorbed for 20-30 minutes. A second crack is unlikely to be achieved within this time. The gas is, therefore, a consequence of the "crack" and not the cause of the cracking.

Méal and Scott[14] attempted to develop the work of Sandoz by analysing the simultaneous recordings of joint tension and sounds which occurred during manipulation. They employed a tension transducer and an ultraviolet trace to this end. They found the tensions required to produce a "cracking" sensation varied considerably between 3 and 23kg. The drop in tension during the joint crack was of amplitude of 1/16 to 4/16 of an inch using the measurement of the time. The authors found that when subjects in the study were more tense, it was more difficult to produce a crack. The weather was also reported to affect the quality of the "crack"; joints would crack more easily when a low pressure system was present producing less tension and making less noise. Herzog[15] duplicated this work using a small skin-mounted accelerometer affixed to the spinous process of T3 to record the joint crack signal produced by manipulation applied at the transverse process of T3.

Watson and Mollan[16] investigated the process of joint cracking using cineradiography using the third MCP joint. A single subject was examined using a frame rate of 120 frames per second. They found that the joint separation after the crack was approximately four times larger than the resting joint separation. Full separation of the joint was reached within two frames at 16.6msec: the bubble generated during joint separation occurred between two frames in less than 8.3ms12. Reggars and Pollard[17] undertook a considerable amount of work investigating whether there is a relationship between the side of head rotation and the side of joint cracking during "diversified" rotator manipulation of the cervical spine. The diversified rotatory technique* was first described by Gitelman and Fligg[18] and is the most frequently used technique by North American chiropractors. Reggars and Pollard[17] concluded from their study that using the diversified rotator technique, joint cracking occurs on the ipsilateral side to head rotation and the opposite side of the thrust. They also suggested that there is some evidence that previous neck trauma may have an influence on the side of the joint crack[19,20]. Later work by Reggars attempted to analyse the frequency of joint crack sounds to see if there was a difference between sexes and when previous trauma was present[21,22,23].

Effects of habitual joint cracking

Some individuals habitually crack their joints with the knuckle being the most favoured joint. Little work has been undertaken looking at the long term effects of joint cracking. It has been suggested by some authors that habitual knuckle cracking can have a direct effect on the soft tissues of the hand: in one case radiographic change has been reported[24]. There is, however, insufficient evidence to make any definitive conclusions on the long term effects of knuckle cracking. Swezey and Swezey[25] compared the incidence of osteoarthritis in nursing home residents with histories of habitual joint cracking and those without. No statistically significant difference was identified to correlate knuckle cracking with the incidence of osteoarthritis.

Castellanos and Axelrod[26] continued this work looking at 300 patients aged 45 and over. Only 26% of this population was found to use knuckle cracking and this had no correlation on the incidence of osteoarthritis of the hand joints. Grip strength and hand swelling were also examined and 75% of the knuckle crackers had less grip strength and a higher incidence of hand swelling indicating a greater effect on soft tissues than on bone and cartilage. Watson[27] investigated the possibility of cartilaginous damage from cavitation by examining a microcavitation effect. Ultrasound was used to generate microcavitation and it found that this process could damage articular cartilage for exposure greater than 10 seconds. It has been estimated that the energy from cavitation during a single joint crack is 0.07mJ/mm at the articular surface[28,14]. The energy produced by Watson during his experiment was 3.75W/mm[29,27]. It would be necessary to produce joint cracking every 30 seconds for 24 hours to create the equivalent energy that Watson suggested produced articular damage[30].

Chen and Israelachvili[31] developed this topic further but proposed that damage occurs during the formation of a cavity. Using a model resembling the architecture of an articular joint, they found cavitation occurred above a minimum velocity. As the velocity of separation during cavitation increased, instead of a smooth separation, the surfaces "snapped back" and a fracture occurred in the viscous fluid forming a vapour cavity. Examination of the joint surfaces showed that damage occurred in the area of "snap-back" and not where vapour had collapsed. They suggest that the cracking sound occurs at the snap-back stage. This theory is also supported by classic descriptions on cavitation[32,33,28,34].

Chen and Israelachvili[31] tried to apply this concept to joint manipulation. Their joint model had four distinct components:

- Cartilage
- Subchondral bone
- Joint capsule (including mensicoids and synovial folds)
- Synovial fluid

The model was examined at different stages during the manipulation cycle:

Resting stage: Opposing joint surfaces are in contact separated by a thin layer of synovial fluid. A small amount of tension applied to the joint separates the cartilage surfaces but the gap is filled with synovial fluid from the joint margins. The volume of the joint is thought to remain constant and achieves this by invaginating, lengthening and increasing the stress on the articular ligament as the joint is separated.

Further separation of the joint places too great a stress on the capsular ligament to allow the joint capsule to invaginate further.

Chen and Israelachvili[31] suggest that when the force on the joint capsule exceeds a certain level, the energy built up in the capsular ligament causes elastic recoil so that the capsule snaps back from the synovial fluid, causing cavitation to occur at the capsular/synovial fluid interface. At the same time the volume of the joint increases and the internal joint pressure decreases. Dissolved gasses are released within the synovial fluid near the ligament/fluid interface; within a fraction of a second the gasses coalesce to form a single bubble within the joint capsule.

Elastic recoil stage: The authors propose several ideas for what occurs during the elastic recoil:

- The ligament snaps away and the strain and tension across the capsule drops.
- The forces across the joint cause the bones to separate. The distraction of the joint is limited by the anatomical limits of the capsular ligament. The abrupt halt of the joint separation causes the strain on the ligament and periarticular connective tissue to dramatically increase.

Final stage: At this point, the joint has distended by a significant difference and the joint cavity now contains a gas bubble within the synovial fluid. The external force is equal to the tension on the ligaments and the new lower pressure within the joint capsule.

More recently, Clark *et al*[37] compared 10 patients with chronic LBP and 10 healthy individuals when investigating the neurophysiologic effects of spinal manipulation (SM). They observed a significant decrease in the short-latency stretch reflex in patients who experience an audible sound during the SM. They concluded that SM resulting in an audible pop down-regulates the sensitivity of muscle spindles and/or other segmental sites of the Ia stretch reflex pathway.

Sillevis *et al*[38] were also interested in the significance of the 'pop' sound in SM and measured pupil diameter change to assess the effect of SM on the central nervous system. They also measured pain levels before and after SM using the Visual Analogue Scale (VAS). Sillevis *et al*[38] found no significant pain reduction in the subjects who experienced an audible sound compared with the subjects who received the SM and the sound was absent. However, the group to receive SM, irrespective of an associated sound, had a significant reduction in pain compared to the group who received spinal mobilisation only.

Summary:

Research into this area has been conducted over a considerable period of time. Four main theories concerning the cause of audible sounds on manipulation emerge from a review of the literature and are summarised below[35,36]:

- Release of trapped intra-articular material such as synovial folds or meniscoids
- Relaxation of hypertonic muscle by sudden stretching, the mechanoreceptor-pain gate or reflexogenic theory
- Disruption of the articular or periarticular adhesions

- Unbuckling of motion segments that have undergone disproportionate displacements.

The audible cracking sound is only one effect produced during spinal manipulation; a variety of other effects have also been documented. These will be considered at greater length in another article.

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