THE MANIPULATIVE CRACK

FREQUENCY ANALYSIS

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Abstract:

Objectives - This research was designed to analyse the frequency spectra of joint crack sounds produced during spinal manipulative therapy applied to the upper cervical spine of 50 volunteers and to determine if the spectra differed between the sexes and or for those with a history of previous neck trauma compared with those without a history of trauma.

Design - Randomised experimental study.

Setting - Macquarie University, Centre for Chiropractic, Summer Hill, New South Wales.

Subjects - Fifty asymptomatic subjects were recruited from the students and staff of the above college.

Intervention - Single, unilateral "diversified", high velocity, low amplitude, rotatory thrust technique applied to the region of the C3/4 zygapophyseal joints.

Main Outcome Measures - Joint crack sound wave analysis of Digital Audio Tape (DAT) recordings, taken from two skin mounted microphones positioned on either side of the cervical spine and later analysed by the use of a computer equipped with professional quality frequency spectrum analysis software.

Results - All fifty manipulations resulted in at least one audible joint crack sound and in total the fifty subjects combined produced 123 individual joint cracks. Only 9 subjects (18%) produced a single joint crack, the majority of the subjects (82%) produced either two (22 subjects) or three (10 subjects) distinct joint crack signals, while seven subjects produced four and two subjects five separate joint crack signals. Frequency analysis was performed on a total of 122 individual wave forms. Peak frequencies for all analysed crack signals ranged from 1,830 Hz to 86 Hz with an mean of 333 Hz (95% C.I., 285-380 Hz), a mode of 215 Hz and a median of 215 Hz. Statistical analysis for recorded signals revealed 95% Confidence Interval for the mean of 285-380 Hz. No statistically significant differences were found for peak frequencies between the sexes or for a previous history of trauma and no trauma and for pre-manipulative and manipulative joint cracks.

Key Indexing Terms: Chiropractic, zygapophyseal joints, cervical spine, joint crack, joint cavitation, manipulation, frequency analysis, spectra, sound recording.

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INTRODUCTION

Noises emanating from the joints, whether it be from fingers, jaw, knees or ankles etc. would be familiar to most people. These joint sounds may take the form of a grating, a clicking, a cracking, or a popping noise and may be broadly categorised into sounds that are produced during normal physiological joint movement or through joint manipulation. When audible to the unaided ear these joint sounds or vibrations may be termed acoustic frequency vibrations, however joints may also produce vibrations that are not heard but felt, which are termed subsonic vibrations, and are clinically described as crepitus(1).

The origin and clinical significance of these vibration emissions have intrigued clinicians and researchers alike, and over the last 100 years this intrigue has resulted in many studies into this phenomenon. Particular emphasis has been placed on joint sounds produced during normal joint movement and ranges of motion. A substantial amount of research on this type of joint noise has been undertaken by the dental profession(2,3,4), with respect to temporomandibular joint noises, whilst orthopaedic researchers have tended to concentrate their efforts on joints sounds emanating from the hip and knee joints(5,6,7).

The cracking noise produced by the manual manipulation of a joint is a common sound to practitioners of manual therapy, such as chiropractors, osteopaths and some physiotherapists. Indeed, it is regarded by some within those disciplines as being the sign of a successful manipulation (8,9,10). The exact mechanism responsible for this audible cracking sound has been investigated by several researchers,(8,11,12) and the "accepted" theory relates to the cavitation of an intra-articular gas bubble. Unsworth, Dowson and Wright(11), in 1971, published the cavitation theory of joint cracking. In their study they imposed a distractive force to the third metacarpophalangeal (MCP) joint, and demonstrated the formation of a gas bubble, predominantly of carbon dioxide. As the traction force increased across the joint, the joint volume increased and the joint fluid partial pressure decreased, causing the intra-articular gases to be drawn out of solution, creating the gas bubble. A subsequent net flow of fluid into this low pressure region collapsed the gas bubble, producing the audible cracking sound. More recently Cassidy et al(8) confirmed this theory by the use of a series of radiographs taken prior to and post manipulation of the third MCP joint. A radiographically visible gas arthrogram was present in 39 of the 42 joints that produced an audible crack, when distracted. Studies by Cassidy (8) and others have suggested that after joint cavitation a demonstrable increase in the passive range of motion of the manipulated joint is achieved(8,10).

With specific reference to spinal manipulation or spinal manipulative therapy (SMT) the cavitation model is also thought to be the mechanism responsible for the audible cracking sound produced by the manipulation process. However, there is a paucity of research in this field and these disciplines have contributed very little to the understanding of this phenomenon. Practitioners of SMT, in particular the chiropractic profession, have only of recent times began to investigate the cracking sound produced by manual manipulation of the spinal apophyseal joints with the majority of this research focusing on the time and amplitude domains(13,14,15).

Within other disciplines the recording and analysis of joint sounds has, over the years, become more and more sophisticated, particularly with the advent of the micro-computer which has allowed researchers to analyse recorded sounds in real time, not only in the time and amplitude domains, but also for frequency composition.

The purpose of this study was to establish if there is a relationship between the frequency spectra, resulting from the cracking sound produced by the application of SMT to the same vertebral level, for different individuals. Further, whether this relationship differs between the sexes and or a previous history of trauma.

MATERIALS AND METHODS

In an earlier experiment conducted by the author(15), fifty-one volunteers were recruited from the students and staff at the Macquarie University of New South Wales, Centre for Chiropractic. Each volunteer was instructed to complete a medical history questionnaire which was designed to screen for the possibility of vertebro-basilar insufficiency, other contra-indications for cervical SMT, and for a history of previous neck trauma. Each volunteer then underwent a physical examination which included, bilateral upper limb blood pressure measurements, testing for nerve root and or spinal cord compromise and for vertebro-basilar insufficiency. Volunteers whose previous history or physical examination revealed any contra - indication to SMT were excluded from the study. One volunteer was excluded from the study due to clinical evidence of cervical radiculopathy.

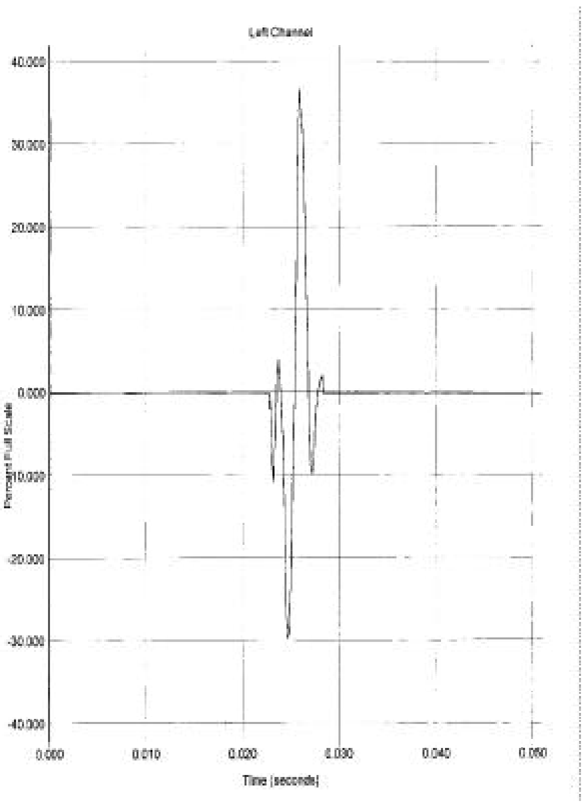
The age of the subjects ranged from eighteen to forty-six years with the mean being twenty-five years. The sex distribution was thirty-six males and fifteen females. From this volunteer group a total of fifty subjects were included in the trial and were randomly allocated, by the use of computer, into two groups. Group A(n=24) received a single “diversified” rotatory manipulation, notionally, to the right C3/4 zygapophyseal joint, and Group B(n=26) a single “diversified” rotatory manipulation, notionally, to the left C3/4 zygapophyseal joint.

Prior to manipulation, each subject had affixed to either side of their neck a Realistic Electrec Condenser omnidirectional microphone, with a frequency response of 50-15000 Hz (Tandy Electronics, Chadstone, Victoria.) The microphones had been previously calibrated by an acoustic engineer and were found to have a decibel differential of less than 0.3 dB. Each microphone was tagged with a right or left marker, corresponding to the left and right channels of the recorder. Each microphone was then supported in a modified plastic syringe cylinder, 2mm from the contact end, so as to avoid direct contact of the microphone with the skin. Each cylinder was vented with two 1mm holes drilled on opposite sides of the cylinder midway between the skin contact surface and the lower surface of the microphone insert. The assembly was then positioned slightly anterior to the transverse process of the C2, and affixed to the skin using adhesive tape. The microphones were then connected to a Sony TCD-D7 DAT Walkman recorder with a frequency range of 20 - 20,000 Hz (1.0 dB) at a frequency response of 44.1kHz and with a dynamic range of 87 dB (Sony (Australia) Pty. Ltd. Surrey Hills, Victoria). The subject number and corresponding side of rotation, together with the side of contact or thrust was verbally recorded, as well as the verbal identification of the left or right microphone. The resultant joint crack or cracks from the manipulation were recorded for later analysis.

RECORDING AND WAVE FORM ANALYSIS

The sounds of the joint crack or cracks were digitally recorded in stereo with a Sony TCD-D7 DAT Walkman and then directly down loaded on to the hard disk of a computer (486 DX IBM compatible computer), which was equipped with a Montecarlo Sound Card (Mainly Multitrac, Dingley, Victoria) and a Spectra Plus Version 3.0, analysis program (ME Technologies, Dyers Crossing, NSW).

Prior to spectral analysis the recorded signals were analysed in the time and amplitude domains (figure 1). As the recording process utilised two microphones only the wave form possessing the highest amplitude was analysed for its spectral characteristics thereby minimising the effect of any overlying soft tissue. Each wave form was analysed at 16 Bits, giving a dynamic range of 65,000+ levels, and at a frequency of 44.1 kHz. Fast Fourier Transform (FFT) analysis was initially performed with a frequency range of 0 - 22,050 Hz with an FFT size of 2048 points, with a 50% overlap and a spectral resolution of 21.533 Hz. Analysis of the sample spectra showed that peak frequency/amplitude measurements were all below 2000Hz and the final analysis was then performed on the wave forms between 0 -2000Hz. using a uniform smoothing window.

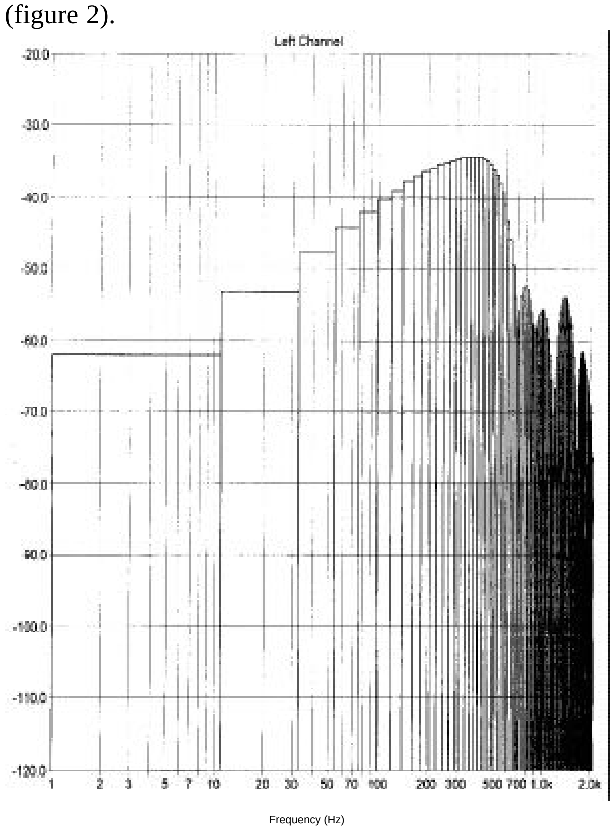


RESULTS

All fifty manipulations resulted in at least one audible joint crack sound and in total the fifty subjects combined produced 123 individual joint cracks. A joint crack was said to occur when it was both audible and produced a corresponding wave form, which on analysis could be cross matched to the audible noise. Although often difficult to discern audibly, analysis of the recorded sound wave patterns revealed that in only 9 subjects (18%) a single joint crack was produced. The majority of the subjects (82%) produced either two (22 subjects) or three (10 subjects) distinct joint crack signals, while seven subjects produced four and two subjects five separate joint crack signals. One of these audibly discernible joint cracks, on analysis, was contaminated and was therefore not included in the final results. Thus, frequency analysis was performed on a total of 122 individual wave forms (table 1). (These results differ slightly from those reported in the previous research(15) due to the more sophisticated analysis system used in the current study).

Six subjects exhibited joint cracking while the joint was being tensioned, during the set-up procedure, and prior to the manipulative thrust, with one subject producing three separate pre-manipulative crack signals. However, in all six subjects further joint cracks were produced when the thrust was applied.

As the recording process was not conducted in an anechoic chamber and that extraneous noise and that created by skin friction from the microphone assembly could not be filtered out, full spectral analysis, although performed, was of little value. Instead the measurements reported here represent only the frequency component corresponding to the peak amplitude of each crack signal (figure 2).



Peak frequencies for all analysed crack signals ranged from 1,830 Hz to 86 Hz with an mean of 333 Hz (95% C.I., 285-380 Hz), a mode of 215 Hz and a median of 215 Hz (figure 3). The mean differs substantially from the median of 215 Hz due to a positively skewed standard distribution. Analyses for differences between sex, a previous history of trauma and no trauma and for pre-manipulative and manipulative joint cracks showed no statistically significant differences. Of the 41 subjects who exhibited multiple joint crack signals 12 (28.6%) displayed at least two signals with the same peak frequency.

DISCUSSION

Frequency analysis of joint sounds by disciplines other than practitioners of SMT has yielded some interesting and worthwhile results, principally due to the non-

Figure 3. Frequency Hz Distribution

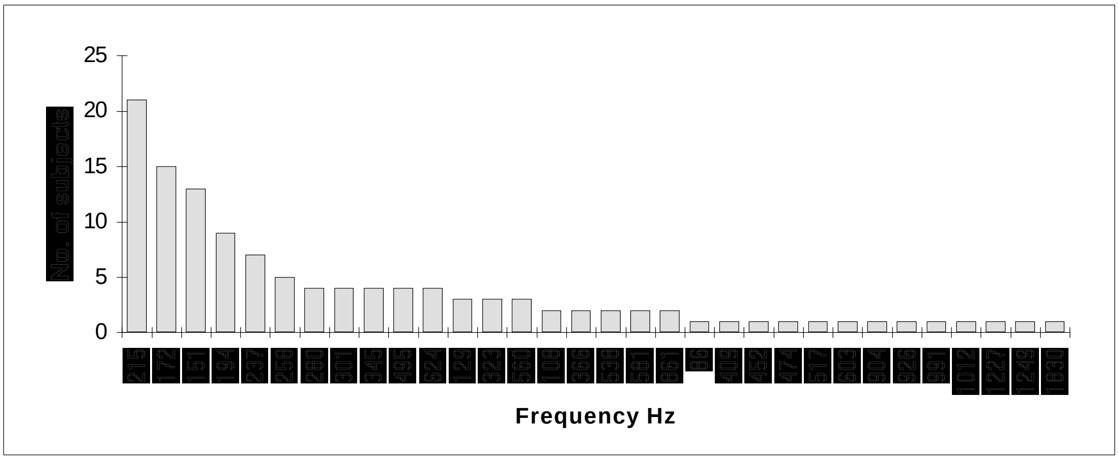


Table 1.

Subject Number	MALE FEMALE	AGE	History Of Trauma	Crack 1 Frequency Hz	Crack 2 Frequency Hz	Crack 3 Frequency Hz	Crack 4 Frequency Hz	Crack 5 Frequency Hz
1	F	46	NO	624	624	172		
2	F	23	NO	172	345	581		
3	M	22	YES	151				
4	M	38	YES	215	861	215	129	
5	F	23	NO	172				
6	M	22	YES	1249	345			
7	F	24	NO	151	603	151		
8	M	35	NO	366	237			
9	M	24	YES	560	129			
10	M	23	YES	194	215	926	1012	
11	M	23	YES	#215	323	581	215	
12	M	22	NO	172	215	1830	151	495
13	M	29	NO	560				
14	M	24	NO	991	495			
15	M	24	YES	172	345			
16	M	27	NO	1227				
17	F	22	YES	409	280	517		
18	M	23	YES	151	108	215		
19	F	22	YES	194	194			
20	F	22	NO	624	237			
21	M	23	YES	#194	301			
22	F	24	YES	624				
23	M	25	NO	194	560			
24	M	22	NO	215	280			
25	M	24	NO	452	301	345	Fault	
26	F	24	YES	215				
27	M	31	YES	#151	151	215		
28	M	22	NO	151	151	172		
29	M	23	NO	538	172			
30	M	24	NO	151				
31	M	25	NO	#215	#194	#86	215	151
32	M	21	NO	237	215			
33	F	22	NO	237	258			
34	F	35	NO	172	215			
35	F	39	NO	538	280			
36	M	26	NO	172	237			
37	M	18	NO	129	301			
38	M	22	NO	474	366			
39	M	24	YES	151	172			
40	M	22	NO	904	151	194		
41	M	22	NO	172	194	194	258	
42	F	21	NO	215	323	215		
43	M	20	NO	#215	172	237		
44	M	30	NO	237				
45	M	21	NO	#108	172	172		
46	M	22	NO	258	215			
47	M	24	NO	323	495	280	301	
48	F	22	NO	172	215	258		
49	M	20	NO	215	215	861	258	
50	M	32	NO	495				

# Denotes pre-manipulative joint crack

invasive nature of the technique.

Within the orthopaedic fraternity the emphasis has been on the recording and analysis of joint sounds emanating from the hip and knee. Kernohan et al(16) using piezoelectric accelerometers suggest that it is possible, via frequency analysis, to differentiate between the normal articular "click" of a neonate hip and that of the "clunking" sound associated with congenital dislocation of the hip. McCoy et al(6) also using accelerometers state that it is possible, from the frequency spectra, to differentiate between a number of normal and pathological knee joint sounds, including patella "clicks" and meniscal pathology with an 86% accuracy.

Many authors(6,7,16) favour the use of accelerometers over that of microphones to record joint sounds as the accelerometer possesses a greater frequency range sensitivity and is not subject to contamination of the recorded signal from extraneous and contact noise. However, the use of accelerometers is not without its own limitations, particularly with respect to effective skin mounting procedures(17).

Watson et al(18) in their study of the cracking sounds produced by manipulation of the metacarpophalangeal joint stated, that although their was considerable variability of peak frequency measurements between individual subjects, that a consistent mean peak value was evident within subjects, suggesting that each joint may possess its own unique characteristic peak frequency.

The only study to examine the frequency spectra of the cracking sounds produced by SMT was by Woods and West(2). In their study they used an Electret microphone connected to a modified stethoscope bell, connected to a professional quality cassette recorder, to capture the sounds produced by SMT applied to the cervical, thoracic and lumbar spines. The signals were then displayed on an oscilloscope connected to a chart recorder and the mean frequency range calculated from the wave pattern. The authors determined that the mean frequencies for the cracking sounds produced by SMT were cervical spine (75.57 Hz 8.69), thoracic spine (66.84 Hz 8.18) and lumbar spine (91.03 Hz 9.54).

The described technique raises some important questions with regard to the validity and reliability of the study. The sound produced by SMT is not composed of pure tones, but rather many different frequency components and as such simple wave form analysis is not an adequate or reliable measure of the frequency spectra. As this research was not conducted in an anechoic chamber the presence of extraneous noise was not taken into consideration and may have therefore confounded the results. Finally, no mention is made of the vertebral level at which the SMT was applied. One would assume that different joints, due to their anatomical variation, would produce different frequency spectra and therefore if the SMT was not directed to the same joint level the resultant data may be invalid.

In the author's clinical experience and as suggested by the current research it is not uncommon for one manipulative thrust to produce two or more distinctive joint crack signals. The question of whether these multiple cracks emanate from the same joint or different joints is yet to answered. A recent paper(19) citing the work of Chen and Israelachvili(20) hypothesises that more than one gas bubble may be produced during the joint distraction process. Further, the authors found that the separation velocity of the opposing surfaces influences the formation of the cavities as well as does the smoothness of the opposing surfaces and the cohesion of the liquid itself and that of the opposing surfaces.

It is generally accepted that for an audible release to be achieved during SMT, the thrust must be administered with a certain velocity, however, during this research five subjects exhibited joint cracking sounds during the set-up procedure and in the author's own clinical experience this phenomenon is not uncommon. The fact that frequency analysis of both these crack sounds and those produced during the SMT process showed no statistically significant difference poses some questions with respect to the mechanism responsible for generating these sounds.

Finally, the rather large difference between the lowest and highest peak frequencies recorded may indicate that different mechanisms may be responsible for the production of the sound and this conjecture warrants further investigation.

CONCLUSION

The chiropractic profession has only of recent times begun to investigate in depth the spinal joint crack phenomenon but falls well behind other professions in their research into sounds emanating from other synovial joints. This research, although not conclusive, should form the foundation for more detailed investigations into the joint sounds resulting from SMT, with the promise of complete noise mapping for all spinal regions. Further, with accurate frequency analysis it may be possible to differentiate between sounds produced by normal joints from those produced by diseased spinal joints.

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