ACCELERATIONS RECORDED FROM THE SPINOUS PROCESSES DURING SPINAL MANIPULATIVE TREATMENTS OF THE THORACIC SPINE

DR. WALTER HERZOG Ph.D.*
DR. ESTHER SUTER Ph.D.
DR. PHILIP J. CONWAY D.C.

Abstract: The purpose of this study was to identify the frequency components of accelerations measured on the spinous processes of vertebrae caused by chiropractic treatments, and to speculate as to the origin of the various components. We found distinct acceleration signals in the range of 0-50 Hz and above 200 Hz. The low frequency components were convincingly matched to the displacements caused by the manipulative forces; the high frequency components were found to be similar in duration and shape to confirmed cavitations in synovial joints, thus they were speculated to originate from the spinal facet joints.

Key Indexing Terms: Chiropractic, biomechanics, spine, conservative treatments, frequency analysis.

INTRODUCTION

Spinal manipulative treatments (SMTs) are typically associated with a cracking sound or an audible release. These cracking sounds have been described qualitatively by Sandoz (1969)(1), and quantitatively by a number of scientists for manipulations on metacarpophalangeal (2-4) and spinal joints (5-7). Two basic methods have been employed to record joint cracking: (1) microphones (2,7) and (2) accelerometers (5,6). Microphones have the advantage that they are easy to set up; however, they are prone to picking up environmental noise, such as the sounds produced by muscle contractions (8), and the signals recorded by the microphone have to go through musculoskeletal tissues before they can be monitored. The sounds produced by muscular contraction may interfere with the sounds of the joint produced during SMT (9) and musculoskeletal tissues act as a low pass filter for sounds, and thus cracking sounds recorded with a microphone may be distorted (Figures 1a,b).

Accelerometers have the advantage that they can be placed directly over the target site, therefore the cracking sounds can be obtained without many of the distortions associated with microphone recordings; however, they have the disadvantage that they pick up the local deformations caused by the spinal manipulative treatments (Figure 2). Therefore, it is not always obvious which part of the recorded signal corresponds to the cracking sound and which part is caused by local deformations of the treatment.

Figures 1a,b: Representative acceleration-time and sound-time histories obtained from cavitations of metacarpophalangeal joints. a) and b) represent two different recordings.
The frequency content of the acceleration-time data were obtained using a fast Fourier transformation. After it had become obvious that the acceleration-time data had two distinct frequency components, one below 50 Hz, the other above 200 Hz, the data were filtered using a high-pass (200 Hz) and a low-pass (50 Hz) filter. After having applied the high-pass filter (which just retained the high frequency component of the original acceleration-time data plus some noise), the remaining signal was compared to the signal obtained from confirmed cavitations of metacarpophalangeal joints obtained earlier. After having applied the low-pass filter (which just retained the low frequency component of the original acceleration-time signal), the remaining signal was compared to the second time derivative of the force-time data. The second time derivative was chosen for comparison because it was assumed that the magnitude of the treatment force would be directly related to the displacements of the spinal bodies; therefore the second time derivative should represent the acceleration of the spinal bodies as measured experimentally. Comparisons between the low-pass filtered acceleration signals and the processed force-time data were made after normalizing the force signal (which was measured in Newtons) in such a way that its peak value corresponded to the peak value of the acceleration signal (which was recorded in arbitrary units).

RESULTS

The results obtained from the patients and the asymptomatic subjects were the same, and thus, are not further distinguished. Furthermore, the results of interest to this study were conceptually the same for all treatments on different spinal levels; thus, the findings are presented for a representative (not best - not worst) case.

Frequency analysis of the acceleration-time data revealed that most of the signal power was contained in the range of 0-50 Hz, but there was a further distinct signal centred at around 200-300 Hz. Using the low-pass filter (50 Hz), the original signal was reduced to a smooth, triphasic acceleration-time record (Figure 3b). Using the high-pass filter (200 Hz), the triphasic signal seen in Figure 3(b) was virtually eliminated, and the original signal was reduced to a large spike (Figure 4, arrow) and some noise. When differentiating the original force-time curve twice with respect to time, and normalizing it in the way described in the Methods section, the processed signal was always triphasic and was similar to the corresponding low-pass filtered acceleration-time curve (Figure 5). When expanding the high-frequency component of the acceleration-time signal on the time axis, it was found to be a triphasic signal in most cases (Figure 6), although biphasic and quadrophasic signals were also observed. The duration of the high-frequency signals were typically about 5-20 ms.
DISCUSSION

It was found that the acceleration-time signals obtained from a thoracic vertebra during SMTs had a low-frequency (0-50 Hz) and a high-frequency (greater than 200 Hz) component. The high-frequency component was typically triphasic and lasted for about 5-20 ms (Figure 6) which corresponded well to confirmed cavitation signals obtained from metacarpophalangeal joints (Figure 1). The high-frequency component of the acceleration-time curves from the thoracic vertebrae were also consistent with the signals found by Méal and Scott (1986) for confirmed cavitations of the metacarpophalangeal joints; however, the duration of the sound wave in the study by Méal and Scott (1986), as well as the durations reported by Sandoz (1969)(1) were considerably longer (25-75 ms) than those found here. This discrepancy may be explained by the distortion of sound signals which are introduced when using microphones and mechanical pen recorders.

Figure 5: Normalized force-time and acceleration-time (VMG) histories for the treatment shown in Figure 2. The low-pass filtered acceleration-time history (VMG) agrees well with the second derivative of the force-time (Force) history, indicating that the accelerations produced by the treatment force cause the low frequency component of the acceleration signal.
match identically (Figure 5) suggests that the low-frequency component of the recorded acceleration signal is caused by the treatment forces, and that the treatment forces are not perfectly proportional to the corresponding displacements. A non-perfect proportionality between force and displacement appears quite feasible because the vertebral motion segments may become stiffer (i.e., more force is required to cause a given displacement) as spinal deformation increases with increasing treatment forces.

Summarizing, the results of this study confirmed that SMTs causing joint cracks give acceleration-time curves with a distinct low-frequency and a distinct high-frequency component. The high-frequency component has a similar shape and duration as acceleration signals obtained from confirmed cavitations of metacarpophalangeal joints. Based on these observations, we suggest that the high-frequency component is associated with cavitations of the spinal facet joints occurring during SMTs. The low-frequency component was similar in shape and duration to the second time-derivatives of the treatment force-time histories. From this result, we suggest that the low-frequency component of the acceleration-time signals is primarily caused by the displacements associated with the treatment thrust.

If we assume that SMTs cause spinal facet joints to cavitate, as suggested by the results of this study, it would be of great interest to develop a technique that allows the identification of the joint that cavitated. We have attempted (in pilot experiments with four accelerometers) to quantify the origin of the cracking sound associated with SMTs, but despite a time resolution of better than one-twentieth of a millisecond, we were unable to determine the exact origin of the cavitation signals.

ACKNOWLEDGMENTS

We would like to acknowledge the financial support for this study from the College of Chiropractors of Alberta, the Chiropractic Foundation for Spinal Research, and the Canadian Chiropractic Association (through the Centennial Research Award).

REFERENCES

1. Sandoz R. The significance of the manipulative crack and of other articular noises. Ann Swiss Chiro Assoc 1969; 4: 47-68.
2. Méal GM, Scott RA. Analysis of the joint crack by simultaneous recording of sound and tension. J Manip Physiol Therap 1986; 9: 189-95.
3. Miereau D, Cassidy JD, Bowen V, Dupuis P, Noftall F. Manipulation and mobilization of the third metacarpophalangeal joint. Manual Med 1988; 3: 135-50.
4. Cassidy JD, Kirkaldy-Willis WH. Manipulation. In: Kirkaldy-Willis WH, ed. Managing Low Back Pain. New York: Churchill Livingston, 1988: 287-96.
5. Conway PJW, Herzog W, Zhang Y, Hasler EM, Ladly K. Forces required to cause cavitation during spinal manipulation of the thoracic spine. Clin Biomech 1993; 8: 210-4.
6. Herzog W, Zhang YT, Conway PJ, Kawchuk GN. Cavitation sounds during spinal manipulative treatments. J Manip Physiol Therap 1993a; 16: 523-6.
7. Reggars JW. The manipulative crack-frequency analysis. Aust Chiro & Osteo 1996; 5: 39-44.
8. Vaz MA, Zhang YT, Herzog W, Guimaraes ACS, MacIntosh BR. The behavior of rectus femoris and vastus lateralis during fatigue and recovery: an electromyographic and vibromyographic study. Electromyrogr clin Neurophysiol 1996; 36: 221-30.
9. Zhang YT, Frank CB, Rangayyan RM, Bell GD. A comparative study of simultaneous vibromyography and electromyography with active human quadriceps. IEEE Trans Biomed Eng 1992; 39: 1045-52.
10. Herzog W, Conway PJ, Kawchuk GN, Zhang Y, Hasler EM. Forces exerted during spinal manipulative therapy. Spine 1993b; 18: 1206-12.
11. Hessel BW, Herzog W, Conway PJW, McEwen MC. Experimental measurement of the force exerted during spinal manipulation using the Thompson technique. J Manip Physiol Therap 1990; 13: 448-53.
12. Herzog W. Biomechanical studies of spinal manipulative therapy (invited review paper). The Journal of the CCA 1991; 35: 156-64.