Consistency of sternal percussion performed manually and with mechanical thumper

A.B. Bohadana, S.S. Kraman

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ABSTRACT: Auscultatory percussion is a technique that is potentially useful to study the acoustic behaviour of the chest. However, finger percussion, as used in this technique, has not been previously assessed for consistency.

We calculated the intrasubject variability and short-term reproducibility of this technique in 10 healthy subjects. We examined several indices of the output sound of two series of sternal percussion manoeuvres performed one hour apart by the same examiner. The results were compared to those obtained during sternal percussion performed by a mechanical thumper.

Consistency for both finger and thumper percussion varied from 4.8–20.6 (coefficients of variation) for various acoustic indices. For thumper percussion, the average results were not significantly different from those of finger percussion.

We conclude that finger percussion of the sternum is sufficiently consistent to be used as a tool to investigate the acoustic behaviour of the chest.


Sternal percussion performed with the distal phalanx of a finger forms the basis of a clinical method that has been called auscultatory percussion [1]. It has been claimed that this method can be of use to detect the presence of intrapulmonary lesions. Since it is inexpensive, non-invasive, and easy to perform, this manoeuvre appears attractive as a tool to investigate the acoustic behaviour of the chest, provided that its consistency could be demonstrated. We could find no information on this matter in the literature and so decided to measure the intrasubject variability and short-term reproducibility of sternal percussion by recording the output sound of two series of sternal percussion manoeuvres performed one hour apart by the same examiner. We then compared the results to those obtained by percussing the sternum of the same subjects with a mechanical thumper, designed especially for this study.

Subjects and materials

We studied 10 healthy men, physicians and laboratory technicians, 22–46 yrs of age. Nine were lifetime nonsmokers and one was an occasional smoker, who was asked to refrain from smoking on the day of the study. Chest sounds were detected using an electret microphone that was placed on the right posterior hemithorax, 5 cm below the inferior margin of the scapula. The microphone was encased in a vacuum type chest piece with two concentric chambers. The inner chamber 14 mm diameter and 3 mm depth, acted as a seal between the active element of the microphone and the skin. The outer chamber served to attach the applicator to the chest by creating a partial vacuum inside it using a catheter attached to a rubber bulb. This arrangement permitted rapid and convenient attachment of the microphone to the skin.

Methods

Sound measurements were performed during quiet breathing in the upright posture. Each experiment was performed twice, one hour apart. For five of the subjects, finger percussion was performed first. For the other five, the mechanical thumper was used first. Percussion was performed at the same location at the manubrium sterni that was marked with indelible ink.

Percussion methods

Finger percussion (FP) was always performed by the same examiner (A.B.B.). This was done by tapping gently, but firmly, over the manubrium sterni with the
distal phalanx of the right middle finger. Care was taken to tap as uniformly as possible in an attempt to generate input sounds of constant amplitude.

Thumper percussion (TP) was done using the electropneumatic device shown schematically in figure 1. This device was developed for this study by the Biomedical Engineering Department of the University of Kentucky. It consisted of a supporting structure, represented by a metallic frame containing two horizontal bars, and an active element, represented by a rubber-tipped cylinder, (A) attached to the lowermost horizontal bar. The cylinder was connected to a solenoid valve (B) that, in turn, was connected to a source of compressed air (C). In the open position, the solenoid valve allowed the compressed air to throw the cylinder forward. In the closed position, the cylinder was pulled back by a spring. An electric device generated an adjustable signal that determined, for each cycle, the percentage of time of opening of the solenoid valve. This controlled both the tapping frequency and time of contact between the tip of the cylinder and the site of percussion. At the beginning of each experiment the horizontal bars were adjusted according to the subject's height. The upper bar held a molded plastic support on which the subject rested his chin, whereas the lower bar held, apart from the cylinder, two small laterally adjustable padded supports that allowed the subject to rest his chest anteriorly. These three points of contact between the subject and the thumper were intended to provide both comfort and stability during the experiments. The lower bar's position was considered to be optimal when the level of the tip of the cylinder matched that of the percussing site. Further horizontal adjustment of the cylinder was performed by micrometer.

With the subject in place, the cylinder tapping was begun at a frequency of about 20 taps·min⁻¹. Finally, the tapping force was adjusted until it was felt by the subject to be similar to that experienced during finger percussion. The same procedure was repeated for the second group of experiments.

To determine whether our results were peculiar to the examiner, some additional experiments were performed in which two series of 10 consecutive sternal percussion manoeuvres were performed by an inexperienced examiner, according to the same protocol as described above. The same equipment was used to record and analyse the output sounds over the posterior chest wall. These percussion manoeuvres were the first ever performed by this examiner, a laboratory technician.

Sound recordings were made using the equipment and techniques described previously. Briefly, the preamplified audio signal from the microphone was recorded by a frequency modulation (FM) tape recorder (Hewlett-Packard model 3964 A). Later, the tape was played back and the signal was digitized at 2,000 Hz using a digital waveform analyser (Data Precision Model 6000). Ten consecutive tap waveforms were stored in computer memory in 256 ms long records. No antialiasing filter was used because little energy in excess of 200 Hz was present in the output. Analysis in the time domain was carried out by computing the maximum peak-to-peak amplitude (PKPK AMPL) measured in volts.

Each record was then submitted to a 512-point Fast Fourier Transformation (FFT). The resulting power (squared amplitude) vs frequency plot allowed the calculation of the peak frequency (PF), which corresponded to the frequency observed at maximum power. The power vs frequency plot was then integrated with respect to time, yielding the total power (PWR). To determine stability of frequency, the mid-power frequency (QF2), corresponding to the frequency at the half power point, was then calculated.

For each acoustic index, we calculated the mean (x) and standard deviation (s) of the 10 successive measurements and their coefficient of variation (CV):

\[
CV = \left( \frac{s}{\bar{x}} \right) \times 100.
\]

Short-term reproducibility was assessed by taking the unsigned difference (Δm%) between the mean value of the first (m1) and second (m2) examinations expressed as a percentage of their average:

\[
\Delta m\% = 2 \times (m1 - m2) \times 100 / (m1 + m2).
\]

Statistical analysis was carried out using standard regression analysis and the Student's paired or unpaired "t" tests, where appropriate.
Results

The individual waveforms of the output signals recorded during the first experiment are shown in figure 2; for each subject, the ten waveforms are superimposed. The waveforms of the signals obtained by the two percussion methods were similar to one another. However, the signal produced by mechanical percussion was richer in high frequency components than that obtained by finger percussion.

For both methods, the shape of the waveforms did not change significantly among subjects, usually being composed of a negative followed by a positive deflection. The exceptions to this were subjects Nos 9 and 10 in whom a positive deflection preceded the negative one. The average values of all indices observed in the two examinations are presented for both percussion methods in table 1. For both methods, the differences observed between the two examinations were very small. For the two sets of examinations, the values derived from the TP and FP experiments were similar. The ranges of individual coefficients of variation and their average are shown in Table 2. For both percussion methods the best results were seen for QF2, the average values of which were practically always <5%. For all acoustic indices, the variability observed in the first examination was not significantly different from that of the second examination, regardless of the percussion method. The variability of PKPK AMPL, PWR and PF, tended to be higher with TP than FP but these differences were not statistically significant. However, the variability of QF2 was significantly higher for finger percussion.

Table 2. - Intrusubject variability of two methods of sternal percussion

<table>
<thead>
<tr>
<th>Index</th>
<th>Finger percussion</th>
<th>Thumper percussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>PKPK</td>
<td>Exam 1</td>
<td>Exam 2</td>
</tr>
<tr>
<td>AMPL</td>
<td>(2.7-13.5)</td>
<td>(2.9-12.9)</td>
</tr>
<tr>
<td>PWR</td>
<td>(9.0-24.5)</td>
<td>(5.4-21.2)</td>
</tr>
<tr>
<td>PF</td>
<td>(3.5-70.1)</td>
<td>(0.0-49.1)</td>
</tr>
<tr>
<td>QF2</td>
<td>(0.09-9.9)</td>
<td>(0.0-8.1)</td>
</tr>
</tbody>
</table>

Values are mean CV (coefficient of variation); figures in parentheses represent the range. *: value significantly different from the corresponding one obtained with thumper percussion (p<0.05). For abbreviations see legend to table 1.

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Table 1. - Consistency of sternal percussion

<table>
<thead>
<tr>
<th>Exam</th>
<th>Finger percussion</th>
<th>Thumper percussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>PKPK AMPL</td>
<td>PWR</td>
<td>PF</td>
</tr>
<tr>
<td>Mean 1</td>
<td>6.05</td>
<td>0.343</td>
</tr>
<tr>
<td>Mean 2</td>
<td>5.96</td>
<td>0.330</td>
</tr>
<tr>
<td>Mean 2</td>
<td>5.96</td>
<td>0.330</td>
</tr>
</tbody>
</table>

PKPK AMPL and PWR are expressed in arbitrary amplitude units. Exam: examination; sd: standard deviation; PKPK AMPL: peak-to-peak amplitude; PWR: total power; PF: peak frequency; QF2: mid-power frequency.
As shown in table 3, for both percussion methods, the best values of reproducibility were seen for QF2. In general, the reproducibility of all indices obtained with finger percussion tended to be better than those seen for thumper percussion. However, only the QF2 differences were statistically significant.

Reproducibility in individual subjects was assessed by comparing the first and second examinations by least squares linear regression. For finger percussion, the results were excellent for PKPK AMPL, PWR and QF2 ($r=0.94$, $0.96$ and $0.86$ respectively) but poor for PF ($r=0.32$). For thumper percussion, the correlations were good for PKPK AMPL and PWR ($r=0.77$ and $0.77$, respectively) but not for PF and QF2 ($r=0.09$ and $0.23$, respectively). The results of this series performed

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### Table 3. Reproducibility of two methods of sternal percussion

<table>
<thead>
<tr>
<th>Method</th>
<th>PKPK AMPL</th>
<th>PWR</th>
<th>PF</th>
<th>QF2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finger</td>
<td>12.6 (0-48)</td>
<td>21.2 (2.8-83)</td>
<td>14.1 (0.7-52.2)</td>
<td>4.7 (0-12.4)</td>
</tr>
<tr>
<td>Thumper</td>
<td>14.0 (0.2-55.0)</td>
<td>35.3 (3.1-78.3)</td>
<td>24.1 (3.0-75.5)</td>
<td>12.9 (3.0-25.0)</td>
</tr>
<tr>
<td>p*</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>&lt;0.005</td>
</tr>
</tbody>
</table>

Values are mean $\Delta m\%$ (unsigned difference); figures in parentheses represent the range. *: by unpaired t-test. NS: non-significant. For further abbreviations see legend to table 1.

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### Table 4. Variability and reproducibility of sternum percussion performed by an inexperienced examiner

<table>
<thead>
<tr>
<th>Variability</th>
<th>Reproducibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>PKPK AMPL</td>
<td>11.7 16.1</td>
</tr>
<tr>
<td>PWR</td>
<td>20.1 32.0</td>
</tr>
<tr>
<td>PF</td>
<td>8.0 6.3</td>
</tr>
<tr>
<td>QF2</td>
<td>3.3 3.0</td>
</tr>
</tbody>
</table>

Variability values are CV (coefficient of variation) of 10 consecutive taps. Reproducibility values are mean of $\Delta m\%$ (unsigned difference) of the two examinations performed one hour apart. For abbreviations see legend to Table 1.

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### Discussion

The four acoustic indices adopted for this study were selected because of their ability to express in different ways the two main physical characteristics of sound, its energy and frequency content. Whereas PKPK AMPL is an index of maximum, instantaneous sound energy, PWR defines the total amount of sound energy present in the impulse. Two sounds may have the same PKPK AMPL and yet contain different amounts of total sound energy. PF is used as an index of the frequency spectra of sounds of various natures. However, as indicated by KRAMAN [3], PF can...
be easily influenced by spurious peaks of amplitude, whereas, QF2 weighs all of the components of the spectrum and is less affected by peaks. This fact could be the reason for the greater variability and poorer reproducibility of PF for both percussion methods (tables 2 and 3).

The two main findings of this study were the high degree of consistency of finger percussion and the failure of the mechanical thumper to improve on it. Since the mechanical thumper was built to percuss with a constant force, we had anticipated that it would perform better than our examiner.

In contrast, our experiments demonstrated little significant difference between them. The thumper performance may have been degraded by small chest movements during the experiments. Such movements, due to respiration or the subject’s inability to remain in a perfectly static condition, may have produced small variations in the distance from the tip of the cylinder to the site of percussion, leading to variable tapping force. Since finger percussion was carried out under similar conditions, it appears that the human examiner was able to cope with this problem by adjusting the percussion force to the amplitude and direction of the chest motion.

In conclusion, this study demonstrates that sternal percussion can be consistently achieved using finger percussion and there appears to be little to gain from the use of mechanical mechanisms. We have also shown that consistent sternal percussion can be achieved by an inexperienced examiner. Finally, this study provides indirect evidence that the consistency of conventional percussion as practised by physicians is probably high.

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References