Koto scales and tuning

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This thesis deals with the koto, a 13-stringed wooden instrument belonging to the zither family and one of the most representative instruments used in Japanese music. The following points are discussed: 1) explanation of the physical construction and nature of the instrument, 2) nomenclature, explanation and analysis of the characteristic koto tunings (or modes, termed in Japanese chōshi), including an analysis of their frequency of use in traditional music and their interrelationships, 3) explanation of the traditional way of setting up or tuning the chōshi, using the most common chōshi (hira jōshi) as an example, 4) analysis of individual performer’s pitch deviations (especially concerning the minor seconds) using this traditional tuning method, and 5) a proposal for a more reliable method of tuning (especially in regards to beginners), based on the results of this research. Included also are data in 4) showing that the minor seconds, in particular, are related to the Pythagorean seconds, and that the tuning over the total range of the koto shows scatter deviations similar to those found in a normally tuned piano.

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1. INTRODUCTION

The koto, Japan’s representative thirteen-string zither, originally was played only in the Imperial gagaku court orchestra, having been imported from Mainland Asia in the 7th century along with the other gagaku instruments. In the 17th century, however, the koto found its way into the popular culture, largely due to the efforts of the blind musician/composer, Yatsuhashi Kengyo.

The koto and its music—both traditional (17th–19th centuries: including solo and ensemble pieces with the shakuhachi bamboo flute and shamisen three-stringed lute) and contemporary (including ensemble works with non-Japanese instruments)—continues to flourish and expand today. All traditional koto music can be categorized into a series of modes or tunings called chōshi. Attaining a correctly tuned chōshi is, of course, one of the most important aspects of koto playing, and it is one of the first things beginning koto students learn. Nonetheless, there is no scientific standardization of chōshi, resulting in a considerable deviation among individual performers in their tuning methods.

This study, by analyzing the chōshi presently used by a number of leading koto performers, aims to clarify the chōshi interval relationships and proposes a more reliable tuning method, especially in regards to the semi-tones.

2. BACKGROUNDS OF SURVEY

2.1 The Instrument

The koto, a zither, appears simply and organically constructed. The overall length is around 182 cm and, shaped long and thin (cf. Fig. 1), is made from paulownia wood. The instrument body is hollow and acts as the sounding board. There are two sound holes on the instrument’s backside, and thirteen strings are strung along the convexly-shaped upper side. Each string is supported by movable bridges called ji.

During performances, the ji must be continually readjusted to keep the instrument in tune. Mechanical vibrations from the strings and certain perform-
The best ji bridges are made from ivory. The recent scarcity of ivory has resulted in the increasing use of plastics, however. Likewise, strings were always made from natural silk, whose tonal resonance is generally recognized as superior to synthetic materials, such as tetron and nylon. Silk is not very durable, however, and must be replaced before each performance (a job for specialists). Most performers alternate between the use of silk and synthetics, according to the nature of their performance.

All thirteen koto strings are of the same standard gauge and are strung at about the same tension. The pitch of each string is therefore determined by how far the movable ji bridge is positioned from the fixed bridge (called ryukaku). Obviously, the farther a ji is placed from the ryukaku, the lower the pitch.

The no. 1 string of the koto is on the opposite side of the player, farthest away from his reach. This string is always tuned first. This pitch is very often set at D\(_3\), but it can be lowered as low as A\(_2\) by using a smaller ji or by loosening the string tension. In the traditional choshi tunings, if the lowest string were pitched at D\(_3\), the highest string would normally be pitched at A\(_2\) (providing two and a half octave range). This upper string can be raised an octave, however, giving an overall range of four octaves (A\(_2\) to A\(_6\)). No traditional choshi utilizes this full four-octave range, however.

The strings are plucked with finger plectra which are made from ivory and leather. They are worn on the thumb, index, and middle fingers of the right hand.

2.2 Koto Scales

With the exception of contemporary pieces, koto music utilizes two basic pentatonic scales, which Japanese musicologists loosely classify as in and yo. Although these scales are neither minor nor major in the sense of Western music, the in scale has a distinct minor flavor while the yo scale retains a sense of the major. Furthermore, within these two scales, there are ten primary koto choshi (or joshi) tunings or modes each of which always retains the same relative pitches, although the absolute pitches can shift up or down.

Figure 2 shows the relative pitch positioning and mutual relationship of these ten tunings. Special note should be made of the relationship between the hira joshi, gaku joshi, and nogi joshi. Although scholars Kikkawa and Kamisango emphasize the relationship between hira joshi and gaku joshi, I believe it is better to associate the hira joshi with the nogi joshi. Although both gaku joshi and nogi joshi are of the major-sounding yo scale, both the hira joshi and nogi joshi begin on the same no. 5 koto string.
The *hira joshi* mode (of the minor-sounding in scale) is oldest (dating back to the 17th century) and most frequently used of all koto tunings. For that reason, most koto players consider the *hira joshi* as the standard koto tuning.

The aforementioned minor-sounding in scale can be expressed on strings 5-6-7-8-9-10 of the *hira joshi* tuning (cf. Fig. 2). In solfege, it would be mi-fa-la-si-do-mi. In the *hira joshi* tuning, string no. 1 and string no. 5 are the same pitch, but string no. 1 can be tuned either at the same pitch or an octave lower than string no. 5. The tuning nomenclature indicates only the relative intervals and not absolute pitches, therefore, the *hira joshi*, or all of the tunings, can be pitched either high or low. The absolute pitch is decided by the player (dependent upon various factors: the aesthetic nature of the piece, performance conditions, vocal ranges of the singers, type of

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**Fig. 3** Mutual relation of all the Ikuta School tunings. This figure shows the interrelationships of the koto tunings and how the tuning name changes as the pitch of certain strings are altered. For example, beginning with *hira joshi*, if string no. 8 is lowered one half step and string no. 9 is raised a step, the tuning changes to *hankumori joshi*, and if string no. 4 on *hankumori* is raised a step, the tuning changes to *shiagari-hankumoi*, etc.
Table 1 Incidence of use of the ten major tunings.

<table>
<thead>
<tr>
<th>Tuning</th>
<th>A. Beginning of song</th>
<th>B. Include modulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percentage</td>
</tr>
<tr>
<td>Hira jōshi</td>
<td>72</td>
<td>40.0%</td>
</tr>
<tr>
<td>Hankumoi jōshi</td>
<td>44</td>
<td>24.4%</td>
</tr>
<tr>
<td>(Honkumoi jōshi)</td>
<td>38</td>
<td>21.1%</td>
</tr>
<tr>
<td>Iwato jōshi</td>
<td>5</td>
<td>2.8%</td>
</tr>
<tr>
<td>Nakazora jōshi</td>
<td>5</td>
<td>2.8%</td>
</tr>
<tr>
<td>Akebono jōshi</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Gaku jōshi</td>
<td>2</td>
<td>1.1%</td>
</tr>
<tr>
<td>Hanakumo jōshi</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Natsuyama jōshi</td>
<td>2</td>
<td>1.1%</td>
</tr>
<tr>
<td>The others</td>
<td>12</td>
<td>6.7%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>180</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

accompanying instrument etc.) when the string no. 1 is tuned.

In addition to the ten tunings of Fig. 2, there are 15 supplementary tunings which occur briefly in the process of modulation or in certain pieces (Fig. 3). The names indicated here are the ones generally used by the Ikuta style of koto playing.

Table 1 shows how often each tuning is actually utilized in a representative cross-section of classical music. The music used in this study was taken from the record set of traditional koto and shamisen music from the 17th to 20th centuries, "Sōkyoku Jiuta Taikei." Of the 220 pieces contained in this set, 180—the ones with koto parts—were used. As can be ascertained from Table 1, the hira jōshi comprises the largest percentage of all the chōshi tunings; 40.0%. Next is hankumoi jōshi at 24.4%, shown in column A. The kumoi jōshi (including honkumoi jōshi) comprises 21.1% of the total tunings. The hankumoi jōshi is really the hira jōshi with string no. 8 lowered one-half step and string no. 9 raised one step, with the lower strings remaining in the hira jōshi tuning. The hankumoi jōshi tuning belongs to the kumoi group. These three tunings: hira, hankumoi, and kumoi jōshi are of the minor sounding in scale and the in scale account for 91.1% of all koto tunings.

Most traditional koto pieces contain one or more modulations, where the tuning changes. Column B of Table 1 shows the incidence of tunings which occur after modulation within a piece. In the majority of these modulations, the tuning changes upwards a fifth. After modulation, it should be noted that the occurrence of the hira jōshi increases by 40 pieces and the nakazora jōshi by 23 pieces. This is due to the fact that, during modulation, the tuning changes from kumoi or hankumoi jōshi to the hira jōshi, or from the hira jōshi to the nakazora jōshi. Oftentimes, however, there is a double modulation of the kumoi or the hankumoi to the nakazora through the hira jōshi.

2.3 Tuning Method

The hira jōshi tuning is the most standard of all koto tunings. This can be ascertained from the name itself; hira means "standard" or "everyday," jōshi means tuning.

Figure 4 shows analyses of tuning process and the relationship in intervals among the strings in the case of the hira jōshi. The figure graphically relates the thirteen strings with ji (bridges) on the sounding board from the performer’s perspective.

After the string no. 1 is set to the determined pitch, the string no. 2 is tuned a perfect fourth above the string no. 1, and the string no. 3 is tuned a perfect fifth above the string no. 1. The string no. 4 is tuned a minor second above the string no. 3, and the string no. 5 is tuned an octave above the string no. 1. The string no. 6 is tuned a minor second above the string no. 5, and the string no. 7 is tuned an octave above the string no. 2. Following the same process, strings no. 8 through no. 13 are each tuned an octave above...
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strings no. 3 through no. 8 respectively; string no. 8 is an octave above no. 3; string no. 9 is an octave above no. 4, etc.

The tuning method for koto strings, as mentioned above, is based on perfect fifths, fourths and eighths. It must be noticed, however, that seconds are determined largely by the individual performer's musical sense. Personal deviation therefore tends to occur in the intervals of second. Therefore, the fourths and fifths (shown by break lines in Fig. 4) would also be affected.

3. ACTUAL TUNING OF THE D-HIRA JÔSHI

The koto is simple and unstable, but its musical charm lies precisely in its simplicity and delicate response. The performer must develop a highly refined sense of pitch and tonal control in order to master the instrument.

A series of pitch measurements were carried out in order to determine and analyze the actual pitches and their variations on kotos tuned by professional performers. The most common of all chôshi tunings, the D-hira jôshi (with the string no. 1 tuned to D3) was used as the example.

3.1 Outline of the Experiment
1) Subjects: Six professional koto players, five of whom are lecturers at the Tokyo National University of Fine Arts and Music.
2) Tuning utilized: D-hira jôshi (with the string no. 1 tuned to D3)
3) Instruments: High quality professional-use instruments.
4) Measuring Equipment:
   - Digital audio tape recorder: TCD-D10 (SONY)
   - XD-Z700 (VICTOR)
   - Digital chromatic auto tuner (pitch detector): 393 (ZEN-ON)
5) Experimental procedure
   After a subject completed tuning, three repeated tones were struck moderately and recorded for each of the thirteen strings. In this manner, two or three recordings for each subject were made one by one on different occasions. Recorded samples were analyzed in the laboratory using a pitch detector.

3.2 Results and Discussion of the Measurements
1) Personal reproducibility
   Figures 5 and 6 show the results of each of the three measurements for two subjects, O and M.

![Fig. 4 The most common method of tuning the hira jôshi.](image)

![Fig. 5 Examples of the actual state of tuning as compared to equal temperament (Subject O, reference tone D3).](image)

![Fig. 6 Examples of the actual state of tuning as compared to equal temperament (Subject M, reference tone D3).](image)
Measured pitches are compared with the equal tempered scale. The deviations are shown for each of 13 strings in cents.

Noticeable deviations amongst all subjects can be observed on the whole, but subject M (Fig. 6) shows a much wider scatter in tuning than subject O (Fig. 5) for example.

Examined in detail, wide scatters are found to be related to incidences of the minor second (semi-tone). It must be mentioned, however, that the aesthetic attitudes of the performer affect the tuning of the semi-tones. As mentioned by M after the series of experiments, the subject purposely altered the semi-tone intervals to provide different nuances to the tuning.

2) Comparison with the equal temperament, especially in regard to the piano

In Fig. 7, the averaged results show clearly the up-and-down characteristics of koto tunings. It is very interesting to compare these relationships with tunings found on the piano.4)

In piano tuning it is well known that there is a typical deviation pattern from the equal tempered scale over a large range of notes, part of which can be seen in this graph. Adjusting the two curves of the piano and koto at D3, they also coincide at certain higher notes, which are the peaks in the up-and-down characteristics. These notes are tuned using perfect fifths and perfect eighths.

On the other hand, the dips in the up-and-down characteristics can be related to the notes based on “musical” semi-tone tuning, except for the first one tuned in perfect fourths.

Those results show clearly that from the view point of fine adjustment of pitch, the koto is quite different from the piano, even though they both tend toward trend of stretched octaves.

3) Deviation among the subjects

The values of the standard deviation are shown in Fig. 8. Larger S.D. values are calculated for the semi-tones. The same pattern appears again in the higher notes being transferred up an octave. It is interesting to observe that the scatter found in the high register remains minimal, whereas the stretching effect is inherent throughout the tuning process.

4) Octave intervals

As mentioned above, the tuning method of the koto for the hira jōshi uses eight perfect eighth transfers. Tuning is undertaken, of course, very carefully. Nonetheless, the averaged results shown...
in Fig. 9 show that the tuned eighths tend to become wider in the higher notes. This kind of widening phenomenon, already explained in Fig. 7, can be related to the phenomena which occurs in the piano tuning.

5) Fifth intervals

One distorted fifth is derived with an interval wider than the others, which are very close to perfect fifth, as shown in Fig. 10. The influence of the semi-tone tuning process on the distorted fifth has become noticeable.

Experts revise the distorted fifth, if needed, during their performance by shifting the ji a little.

6) Fourth intervals

Perfect fourths are introduced in the first stage of the tuning process. Later on, upward transfer by an octave and other tuning processes produce a total of seven fourths among the strings.

Figure 11 shows two remarkably widely scattered fourths, tending toward narrowness, unlike the fifth which tended toward wideness.

7) Semi-tone intervals

The basic koto tuning process requires, in general, two semi-tone direct adjustments respectively as shown in Fig. 4. Besides these, two other semi-tone intervals are introduced an octave above by transfer.

Figure 12 shows results which indicated that, as a whole, the semi-tones of koto music resemble the Pythagorean semi-tone (90 cents), as Shirasuna pointed out in the unpublished results of his own measurements in 1967.

The semi-tone intervals are quite narrow compared with those found in the equal temperament (100 cents) and just intonation (112 cents).

A zigzag pattern indicates that there was a certain difference in the subjects' sense of pitch since the intervals of those two semi-tones differ considerably. This result is not unexpected, however, since the koto players themselves rely only on empirical methods with which to tune these two semi-tones.

8) Thirds and the hira jōshi

As is shown in Fig. 4, neither major nor minor thirds appear among the open strings. Those intervals will be made, if needed, temporarily by increasing tension of a certain string with the left hand, in a typical technique for koto playing called oshide.
9) Comparison with the Pythagorean scale

The results of these measurements suggest that koto tuning is comparable to the Pythagorean scale. Leaving the problem of thirds aside, measured results re-arranged in the way shown in Fig. 13 suggest that it would be possible to replace these koto tunings with a scale tuned by the Pythagorean method, and in addition, the interval stretch towards the higher notes could be introduced using data concerning the piano tuning.

4. APPLICATION OF THE PYTHAGOREAN METHOD

The semi-tone tuning undertaken by a well-trained koto player can be replaced by the Pythagorean semi-tone. The semi-tone intervals tuned by professional koto players are considerably narrower than those of equal temperament which are commonly used in modern Western and Eastern music.

It is not easy for beginners to correctly tune the semi-tone intervals. Therefore, a simple, reasonable method for practical tuning—using only perfect fourths and fifths—would facilitate their studies and improve playing techniques.

In 1985, Shirasuna introduced a modified method for tuning the *hora jōshi*. The method starts from the string no. 1 as usual, however, the string no. 4 is temporarily tuned a perfect fourth above the string no. 2 and in addition, the string no. 5 is also temporarily tuned a perfect fourth above the string no. 4. Then, the string no. 4 is corrected to perfect fifth below the string no. 5, and also the string no. 5 is corrected down to an octave above the string no. 1.

The author of this report would like to propose some changes on Shirasuna’s suggestions from a practical point of view. This alternate method is shown in Fig. 14. The important point is that, instead of the string no. 5, the string no. 6 is temporarily tuned a perfect fourth above the string no. 4. Then, the string no. 4 is corrected to a perfect fifth.
below the string no. 6. Finally, the string no. 6 is lowered a perfect fourth above the corrected string no. 4. The reason for such a change is that the alternate method is similar to the method for tuning the hanakumo jōshi, and is already familiar to most koto players.

5. CONCLUSIONS

One of the characterizing factors of koto music is the interval relationship within the traditional tunings which differs significantly from interval relationships found in the equal-tempered scale. Several factors contribute to this: the construction of the instrument itself, the fundamental tuning methods, and performance techniques which require that the performer makes pitch changes (cf. oshide string pushing technique) and slight tuning adjustments while playing.

This research confirmed, through a survey of 259 representative tuning examples, that the hira jōshi tuning was the most often utilized of all traditional koto tunings. Furthermore, the actual tuning process undertaken by a selective group of professional performers was investigated and documented. It was documented that the koto tunings consist of intervals of the perfect fourth, fifth, and octaves. In addition, there are minor second tunings which vary according to the individual player’s ear. The fourths and fifths are tuned directly while the minor seconds are tuned indirectly, therefore tending toward distortion.

Scatter is a phenomena which appears in the koto tuning process. The semi-tone intervals are usually tuned empirically, they tend to produce greater scatter, especially compared with the other intervals. As a whole, a resemblance to the Pythagorean semitones can be observed.

An interval stretch, coinciding to the interval stretch found in piano tunings, can be observed throughout the total koto range. Based on the results of this research, a more reliable tuning method, especially in regards to the semi-tones, has been proposed. This proposal is particularly intended for beginning and intermediate koto players.

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4) Published data for the tuner’s guide by YAMAHA CORPORATION.