How accurate was Viking Age weighing in Sweden?
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How accurate was Viking Age weighing in Sweden?

By Erik Sperber


From the dimensions of a few of the many Viking Age balances found in Sweden, mostly in a fragmentary state, their sensitivity at different loads could be calculated. For three balances the calculations could be experimentally corroborated. The most common type, having a balance beam of about 100—120 mm, was shown to give 1 mm deflexion of the needle tip for a differential load of 0.2—0.4 g at nearly zero total load. At a load of 35 g on each pan this deviation was caused by an extra load of 0.8—1.2 g, i.e. 2—3% of the unilateral load. Twenty-four weights from the Bandlunde, Gotland, found weighing about 1.5 g were shown to have been manufactured with ±0.08 g standard deviation from the average value. A balance fragment from the same find had a sensitivity of 0.2 g per 1 mm deflexion. The precision of the weights and the balance thus correspond well.

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The presence of a large number of Viking Age balances and weights in Sweden raises the question, how accurate was weighing in the commerce of this period.

The balances, in particular, lend themselves to a much more penetrating study than has been made earlier. A few of them are still functioning. As to the weights, corrosion has added a great deal to the variance of the weight sets. Yet the recent very well preserved find at Bandlunde, Gotland, gives us new possibilities. Its study has merely begun.

Trade in Sweden, of course, was always part of trade in Europe. Some preliminary studies of the weighing accuracy in ancient times therefore have been included in the present article.

The balances found in Sweden.
The balances found in Sweden are mostly of the collapsible type. They are very similar, if not identical, in construction and could well derive from a common "factory" or handicraft center. Similar collapsible beam balances are known to have existed in the late Roman and Byzantine Empires and have also come to light from contemporary Egypt (Kisch 1966).

Berg and Ottosson (1984) listed 115 balances, mostly in a fragmentary state, found in Sweden. It is widely accepted that these balances were used for weighing the silver, and sometimes gold, coins and pieces that often appear together with the balances in contemporary hoards. In the times in question, it was necessary to weigh not only the silver pieces, but also the coins, which often differed widely in weight. The standard of the mints was so low that coins intended to represent the same value sometimes differed in weight by a factor of four even for new coins.

A few of the balances are so well preserved that they can still be used for their original purpose. Three of them are kept in the Museum of National antiquities in Stockholm, others are on exhibition in other museums or in private hands.

Earlier weighing experiments
Weighing experiments to estimate the sensitivity or — as it turned out — the lack of sensitivity of Viking Age balances have previously been carried out by the Finnish physicist G. G. Häggström (1841) and the Swedish archaeologist T. J. Arne (1918).

Häggström put all the ancient weights avail-
able to him on the pans of his balance and found out that it could not discriminate between 100.3 and 102.1 g (diff. 1.8%). He also indicated the feature of the balance responsible for the lack of sensitivity. Hällström’s results will be further discussed later in this article.

Arne tested the balance from Vårdinge which is available also to the present author. He used another method. With no other load, he put milligram weights on one of the pans until a deflexion could be observed. He had to add 0.45 to 0.50 g to reach this point. (Arne did not specify the total load. My measurements, however, clearly show that it must have been close to zero. In addition, Arne would probably have specified any other load.)

Experimental estimation of the sensitivity of a functioning balance

Three balances from the Viking Age were available for the estimation of their sensitivity, the sensitivity being defined as the overweight on one of the pans which causes a deflexion of the needle’s tip by 1 mm from zero. Obviously the value 1 mm may be discussed. A smaller deviation still could be used. On the other hand, the rest point of the needle is obscured by the holder of the balance and in most cases can not be easily observed.

In our experiments no attempt was made to reach exactly 1 mm. Instead, a number of overweights were used and the corresponding tip deviations measured in mm. The measurements were transformed into the tangent of the angle of the deviation from the horizontal and then plotted. (Fig. 1.) From the set of straight lines obtained, the relation $\tan \alpha$/gram overweight could be calculated. The zero point of the balance could be calculated too, but is of minor interest for the present investigation. The results of measurements of the three balances and a nineteenth century balance are given in Table 1.

The sensitivity of all the three ancient balances at zero load turns out to be 0.2 to 0.4 g for 1 mm deflexion. At higher loads the sensitivity decreases and for very high loads, up to 50 to 100 g on each pan, the difference between the two pans must be 2 to 3% to be able to be detected.
Table 1. The sensitivity of balances: calculated and found. — Vågarnas känslighet: beräknad resp. funnen.

1:1 Balances in working order. — Användbara vågar.

<table>
<thead>
<tr>
<th>Balance number</th>
<th>Load, g</th>
<th>g/tg α calculated</th>
<th>g/tg α found</th>
<th>g/l mm deflexion calculated</th>
<th>g/l mm deflexion found</th>
<th>% of load calculated</th>
<th>% of load found</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHM 15115</td>
<td>0</td>
<td>12.2</td>
<td>12.7</td>
<td>0.4</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Sö, Värdfinge</td>
<td>2 x 20</td>
<td>19.8</td>
<td>21.4</td>
<td>0.7</td>
<td>3.4</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 x 50</td>
<td>31.8</td>
<td>33.2</td>
<td>1.1</td>
<td>2.2</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>SHM 26039</td>
<td>0</td>
<td>13.3</td>
<td>12.2</td>
<td>0.3</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Up, Hållnäs</td>
<td>2 x 22</td>
<td>20.1</td>
<td>9.3</td>
<td>0.4</td>
<td>1.8</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 x 42</td>
<td>27.8</td>
<td>22.8</td>
<td>0.7</td>
<td>1.7</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>SHM 6819</td>
<td>0</td>
<td>5.2</td>
<td>3.8</td>
<td>0.2</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>ÖP</td>
<td>2 x 20</td>
<td>12.1</td>
<td>7.8</td>
<td>0.5</td>
<td>2.4</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 x 40</td>
<td>18.2</td>
<td>14.4</td>
<td>0.8</td>
<td>2.0</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>19th century</td>
<td>0</td>
<td>0.99</td>
<td>1.19</td>
<td>0.03</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 x 17</td>
<td>2.65</td>
<td>2.47</td>
<td>0.07</td>
<td>0.4</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 x 35</td>
<td>4.42</td>
<td>4.95</td>
<td>0.15</td>
<td>0.4</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 x 50</td>
<td>5.93</td>
<td>6.48</td>
<td>0.18</td>
<td>0.4</td>
<td>0.4</td>
<td></td>
</tr>
</tbody>
</table>

1:2 Balances and fragments not in working order. — Ej användbara vågar och fragment.

<table>
<thead>
<tr>
<th>Balance number</th>
<th>Load, g</th>
<th>g/tg α calculated</th>
<th>g/l mm deflexion calculated</th>
<th>% of load calculated</th>
<th>% of load found</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHM 6104</td>
<td>0</td>
<td>4.3</td>
<td>0.2</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Gö, Visby</td>
<td>2 x 13</td>
<td>8.5</td>
<td>0.4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2 x 35</td>
<td>16</td>
<td>0.8</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>SHM 1304</td>
<td>0</td>
<td>19</td>
<td>0.3</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>ÖP</td>
<td>2 x 35</td>
<td>27</td>
<td>0.5</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>2 x 100</td>
<td>43</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>2 x 500</td>
<td>140</td>
<td>2</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>SHM 12960</td>
<td>0</td>
<td>5</td>
<td>0.2</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Gö, Hellvi</td>
<td>2 x 13</td>
<td>9</td>
<td>0.3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>2 x 35</td>
<td>15</td>
<td>0.5</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Bandlunde</td>
<td>0</td>
<td>4</td>
<td>0.2</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Gö, Burs</td>
<td>2 x 13</td>
<td>8</td>
<td>0.3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>2 x 35</td>
<td>15</td>
<td>0.6</td>
<td>1.6</td>
<td>1.6</td>
</tr>
</tbody>
</table>

The calculation of the sensitivity of a balance

The sensitivity of a symmetrical two arm balance like those used above can also be calculated from its main dimensions. These characteristic dimensions are explained in the legend of Fig. 2, which does not show the pans.

The basic equation for a balance at equilibrium, using the symbols of Fig. 2 is:

\[ T_1 \cdot l_1 = T_2 \cdot l_2 \]  \hspace{1cm} \text{Eq. (1)}

\( T_1 \) and \( T_2 \) = weight of each pan, load included. \( l_1 \) and \( l_2 \) = length of the balance arms, i.e. the distance between the points c and e and f and c.
respectively. If both arms are equal, the equation tells us that the loads are equal too. If the arms are not equal, useful results may still be obtained by exchanging the right and the left load. The (geometric) average of the two weighings will give the true weight.

Of the balances measured, including those in fragments, the arms of each proved to be equal within one percent or so. Thus, inequality does not seem to have been a major problem.

If there is an overweight on one of the pans, the above equation does not fit. The balance will remain in a new equilibrium position at an angle \( \alpha \) from the horizontal. The problem is illustrated in Fig. 3, with the additional assumption is made that the two suspension points of the pans and the support point of the beam are all situated on the same straight line.

This condition is met with by all balances used for chemical analysis since about A.D. 1800. Its importance was stressed e.g., by Gahn and Berzelius in Lärobok i kemien (Berzelius 1818). The overweight, in this case, will be counterbalanced by the weight of the beam:

\[
d' \sin \alpha = q \cos \alpha \\Rightarrow q = \frac{l' \cos \alpha}{d' \sin \alpha}
\]

or \( \tan \alpha = \frac{q}{l'} \).

In other words, the deflexion is greater when the beam is longer, and smaller if the beam is heavy or if the center of gravity is further away.

With the Viking Age balances the three suspension and support points were never situated on a straight line, thus meeting this important condition for an analytical balance. For our calculations, this means that the distance \( d' \) (Fig. 2) was different from zero and in fact considerable, mostly 6 to 10 mm. When this \( d' \) term is taken into consideration, our formula becomes, after a slight rearrangement:

\[
\frac{p}{l} = \frac{d' q + d' \cdot T}{d' \sin \alpha} \quad \Rightarrow \quad \tan \alpha = \frac{q}{l'} + \frac{T}{d' \sin \alpha}
\]

The points, weights and distances of this formula can be measured on most balances, in some cases with some difficulty. The center of gravity, for instance, is indistinct and its site has to be approximated. Despite the error introduced here, it will be possible to estimate the sensitivity of the balances to the nearest 10—20 %, an accuracy sufficient for our purpose of attaining a momentary picture of weighing.

The balances used for the weighing experiments

Table 2 gives the main features of the balances and fragments included in the present study. Some further facts are given below.

**Balance SHM 15115, Värdinge parish, Södermanland.** It is complete with balance beam, pans with chains, the pointer and the supporting yoke. It was used by Arne (1918) in his experiment mentioned above. Attached to the chains are five small pieces of sheet bronze, three on one side, two on the other. These pieces greatly puzzled Arne, who believed that they were meant to repair some deficiency, not defined, attributed to the balance. As a matter of fact, they were almost certainly intended for zero point correction.

**Balance SHM 26039, Hållnäs parish, Uppland.** The balance beam and its support were intact. One of the pans and its chains were heavily corroded. Missing
Table 2. Balances studied. — De studerade vågarna.

<table>
<thead>
<tr>
<th>Balance number</th>
<th>Beam length (mm)</th>
<th>Beam weight (g)</th>
<th>Pointer length (mm)</th>
<th>Support point distance (cm)</th>
<th>Pans weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHM 15115 Sö</td>
<td>94</td>
<td>11.8</td>
<td>31</td>
<td>6.5</td>
<td>9</td>
</tr>
<tr>
<td>SHM 26039 Hällnäsv, Up</td>
<td>139</td>
<td>33</td>
<td>33</td>
<td>8.8</td>
<td>11.8</td>
</tr>
<tr>
<td>6819:536 Öi?</td>
<td>82.5</td>
<td>6.3</td>
<td>19</td>
<td>4.7</td>
<td>6.7</td>
</tr>
<tr>
<td>19th century</td>
<td>119</td>
<td>12.8</td>
<td>33</td>
<td>1.8</td>
<td>3.0</td>
</tr>
<tr>
<td>SHM 6104 Visby, Go</td>
<td>100</td>
<td>14.3</td>
<td>20</td>
<td>6</td>
<td>8.5</td>
</tr>
<tr>
<td>SHM 1304</td>
<td>242</td>
<td>c. 90</td>
<td>(60?)</td>
<td>9.5</td>
<td>14.5</td>
</tr>
<tr>
<td>SHM 12960 Helvi, Go</td>
<td>124</td>
<td>23</td>
<td>31.5</td>
<td>6.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Bandlunde Burs, Go</td>
<td>122</td>
<td>12</td>
<td>25</td>
<td>6.5</td>
<td>9</td>
</tr>
</tbody>
</table>

Figures which could not be measured are in brackets. — Siffror inom parentes är uppskattade.

parts had been replaced by pieces of plastic and stainless steel wire. As a result the corroded pan was about 5 g too light, net. An appropriate weight was added to restore the equilibrium.

Balance SHM 6819 probably stems from Öland. It was bought from a private collector some 150 years ago. It is a complete balance beam with its pointer, the supporting yoke and the pans. The pans have been fitted with new chains in modern times.

The “19th century balance” was bought in an antique shop together with a few weights. It is assumed to be a coin balance and had gallow ends. According to Kisch (1966) such balances were common in Central Europe from the 18th century and onwards. The weights, if Swedish, probably belonged to one of the systems in use before 1855. The balance was contained in a wooden box marked “Made in Germany” which casts some doubt on the above dating. The balance, not being an archaeological artefact, could be disassembled and reassembled at will, which was of great help.

The center of gravity, the only point not easily found was approximated as follows: Imagine that the beam is a short cylinder, Ø c. 5 mm, attached to two slightly conical identical arms, giving a total length of 100 mm. The center of the cylinder is also its center of gravity. Suppose that the beam weighs 10 g and that it is fitted with a conical pointer, 30 mm in length, weighing 1 g. The gravity center will then move about 1.1 mm towards the pointer’s tip. During the measurement this figure was kept in mind. Nevertheless the random error in estimating tended to be high. For the 19th century balance this problem did not exist. The beam, devoid of all accessories, was allowed to hang freely. The center of gravity, by definition, found its place on the vertical line from the point of suspension. Practical problems also arose when the weights of the different parts of the balances were to be determined. Nor could they be wholly solved. The part to be weighed was placed on the pan of a digital scale. All other parts were assembled in the palm. An attempt was then made to reach a point where the parts in the palm influenced the weight shown on the scale as little as possible. The task proved easier and its results less inaccurate than had been expected. Errors in excess of ±1 g were few. Again, the 19th century balance was very useful when judging the errors to be expected.

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The experiments illustrated in Table 1 together with all data for the functioning balances except \( d_1 \) and \( d_2 \), can be used for a “backward calculation” of \( d_1 \) and \( d_2 \). The sets of data for zero load and for the highest load tested were used. The results are presented in Table 3. The values for \( d_1 \) and \( d_2 \) measured directly or through weighing coincide well within the experimental errors caused by the primitive measuring equipment and the caution necessary when handling the ancient artefacts.

The figures of Table 2 show very clearly that the weighing properties of a balance can be calculated from its main dimensions.

It should be stressed that the sensitivity as measured or calculated here is not of statistical origin, but a constructional parameter, similar to e.g. the swinging time of the balance or the weight of its beam.

The dimensions of many of the fragments of balances, kept in the museum still retain most of their dimensions. They can often be used to answer the original question regarding the precision of Viking Age weighing. Four such balance beams, lacking useful pans and with other defects are listed in Table 2. For the calculation the sets of data are complemented by making plausible assumptions, above all regarding the weight of the pans etc. This approach is generally regarded with some suspicion by scientists. To archaeologists it is often necessary and has frequently yielded important results.

As was to be expected, the incomplete balances do not differ appreciably from those in working order.

**The zero adjustment of the Vårdinge balance**

The five small pieces of bronze hanging over the pans of the Vårdinge balance greatly puzzled Arne who in fact found no credible explanation for them.

They may simply have been detachable weight pieces that were kept in a convenient way. If so, it remains to be discovered why there were three pieces on one side and two on the other and that, using this arrangement, the needle of the balance happened to point at zero.

By far the most probable explanation for their presence at the balance is that they were intended for zero adjustment. For proper weighing any well defined place for the needle-point may, in fact, be chosen but for a suspicious customer, constantly afraid of being cheated by a shily merchant, only the supporting yoke would be the acceptable zero point. A well adjusted zero point would be an important “confidence creating measure”. One might therefore hope that the spacing between the

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**Table 3. Estimation of the distances from the support point of the beam to the center of gravity of the beam, and to the line joining the two suspension points of the pans. — Bestämning av avståndet från balkens understödspunkt till dess tyngdpunkt och till den linje som förenar de två vägskålamens upphängningspunkter.**

<table>
<thead>
<tr>
<th>Measuring method</th>
<th>The center of gravity</th>
<th>The line of suspension</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>direct</td>
<td>by weighing</td>
</tr>
<tr>
<td>SHM 15115 Vårdinge, Sö</td>
<td>6.1</td>
<td>6.5</td>
</tr>
<tr>
<td>SHM 26039 Hällnäs, Up</td>
<td>6.0</td>
<td>8.8</td>
</tr>
<tr>
<td>6819:536 Öl?</td>
<td>2.4</td>
<td>4.7</td>
</tr>
<tr>
<td>19th century</td>
<td>2.7</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Mean — Medeltalet

Standard error of mean — Medeltalets medelfel

\[ \pm 1.0 \]
weight of bronze pieces would give some information regarding the use of the balance in addition to the evidence reported above.

Consequently, the pieces were measured, their volume calculated and multiplied with a supposed density of 8.5. The weights proved to be:

First side: 0.64, 0.44 and 0.59 g. Sum 1.67 g
Sec. side: 0.32, 0.43 0.75 g

The differences between the pieces mainly depend upon differences in thickness, 0.32 to 0.64 mm. Evidently the pieces were not cut from the same sheet. The weights are crude multiples of 0.15 g. By simple rearrangement of the pieces without omitting any one of them it is possible to obtain the overweights 0.92 (the present figure) 0.90, 0.68, 0.48, 0.38, 0.36, 0.33 and 0.03 g. If we keep to the five pieces — they may have special value for the owner or are partly intended to be a decoration of the balance — we find that the above series covers every 0.2 to 0.3 gram interval between 0.0 and 0.9 g or if right and left are reversed — 0.9 — 0 — +0.9 g.

To summarize: The bronze pieces allow a zero adjustment of the Vårdinge balance to the nearest 0.2—0.3 g. This figure is slightly better than the actual sensitivity of the balance estimated by weighing or calculation, 0.4 g. The two sets of data for the sensitivity thus largely support each other.

The accuracy of the weight system of Bandlunde, Gotland

No balance can be better than the set of weights used. Therefore, the weights constitute another important source of information regarding the accuracy of ancient weighing. The main obstacle is, of course, the corrosion which changes the weights to an unpredictable extent. The statistically calculated variance will therefore give a blurred picture of the situation a thousand years ago.

Twenty-one weights of the Bandlunde find belonged to a group which have been intended to weigh about 1.4 to 1.5 g each when new. After stabilization, they weighed 1.26 to 1.56 g. The group was well separated from adjacent weights and showed normal distribution around its mean value.

When found, this sample weighed 1.487 ±0.087 g; after the stabilization the weight was 1.429 ±0.078 g. The weights had lost 0.058 g each without any significant change in the variance. This shows that the dirt and corrosion products removed did not contribute significantly to the random deviations present in the samples. Apart from the corrossions removed, large amounts of rather non-reactive corrosion adhere to the weights. In many cases it still covers undamaged parts of the original decoration of the weights.

The standard error obtained, ± 0.08 g, implies that deviations from the average weight by more than approximately 0.2 g occur only about once in 25 estimations. In addition it compares well with the insensitivity limits observed for the balance found together with these weights, cf. above.

The Bandlunde find also contains several globular weights in various states of preservation. These weights have been examined by the present author (Sperber 1986). Measurement of the weights which had suffered the least from corrosion yielded values up to five times more accurate than those found by direct weighing. A common denominator was found among the 12 weights in question, viz. that they were all multiples of 4.2 g σ = ±0.08 g i.e. ±2 %. This figure means that the weights in their present state may sometimes deviate ±4 % from the average.

There are numerous finds of weights from this period, but complete or nearly complete sets are rare. As a rule only one or two weights are found together. The preferred sizes are 11 to 13 g and 31 to 33 g. In the Bandlunde find approximately 1.5 g is also very frequent. Even if subtractive use of the weights was common, a set consisting of only two or three weights would have been very difficult indeed to work with. It would be necessary to work with provisional weights and, in addition, to try some taring technique.

Single weights were valuable for another purpose. They could be used to control the weight sets owned by a trading partner. It seems possible that this was the main reason for the many single weights found.

The Bandlunde find also contains a frag-
mentary balance. It has been described in some detail by Koivunen and Derestorp (1987). The main dimensions of this balance could be measured or approximated. It is included in Table 2. Its sensitivity could be calculated with a rather high degree of accuracy. It was found to be about 0.2 g/1 mm deflexion at zero load. At a load of 2 x 35 g, the sensitivity was about 2% per 1 mm deflexion.

The similarity between the two figures, the deviation 2σ = ±0.16 g for the small weights and 0.2 g/1 mm deflexion for the balance, are striking. With this balance it could be attested that 95% of the weights differ no more than 0.2 g from the intended value of 1.49 g. Before corrosion even stricter requirements could probably be encountered.

Regarding the globular weights with flat polar surfaces it also seems safe to assume that the balance is a little better than the weights in their present state. Here too, it must be inferred that the weights were better a thousand years ago. The balance, on the other hand, has retained its original characteristic dimensions.

To sum up, the weights and the balance from Bandlunde form a well poised system, where the balance and the weights match each other very nicely.

Discussion
The most important steps in the development of the two-armed balance were:

— Recognition of the advantage of using balances with equal arms and development of the theory which allowed work alternatively with unequal arms.

— Recognition that the sensitivity of a balance depends to a very great extent on the rather short distance between the supporting point of the beam and its center of gravity.

— The almost total elimination of the influence of the total load, including the weight of the pans on the sensitivity. This is accomplished if the two suspension points of the pans and the supporting point of the beam are all situated on a straight line.

The first point was largely clarified in Classical times by famous Greek scientists such as Pythagoras, Archimedes, Menelaos and others.

The second point was probably solved by the Romans but written sources seem meagre probably because the problem was not properly recognized and expressed. There are many finds of antique balances. Unfortunately, to most
archaeologists, the importance of the short distance between the support point of the beam and its center of gravity is far from obvious. This distance is therefore not included in the published descriptions of balance finds.

The third point was solved at the latest c. 1800 by the Swedish scientist Gahn after the problem had been properly recognized. It may have been evident to others too, even earlier, but the final practical solution was presented by Gahn.

The Viking Age balance type and some far more sensitive balances were evidently in use simultaneously though in different countries and probably for different purposes. It remains to be explained why they were so popular in Sweden or at least among foreigners visiting Sweden. The answer may be that there was no urgent need for very accurate and hence more expensive balances in Swedish market-places. The need for handiness was much more evident. The balances had a very beautiful appearance, shining from brass or bronze, giving a status value to the owner despite their probably modest price, made possible by large-scale production.

References
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Hur noggrant kunde vikingarna väga?
Under vikingatiden var hopfällbara, likarmade vågar med därtill hörande vikter vanliga i Sverige. De användes inom viktsområdet 1 till 100 gram. Man har utgått från att guld och silver var de enda varor i dåtidens handel tillräckligt dyrbara för att påkalla noggrann vägning inom detta område och att vågarna därför användes vid köp av dessa ämnen. År 1984 fanns 115 vågar eller fragment i svenska museer (Berg och Ottosson 1984) tillsammans med flera hundra vikter.

Känsligheten hos en balansväg beror på dess konstruktion. Särskilt viktigt är det lilla avståndet, vanligen under 10 mm, mellan vågbalkens stödpunkt (eggen) och dess tyngdpunkt. Denna relation har föga eller inte alls uppmärksammat av arkeologerna och avståndet i fråga anses därför inte i publicerade rapporter om fynden.

Däremot tycks relationen ha varit mer eller mindre väl känt bland romerska och arabiska vägfabrikanter, som av återfunna mynt och viktsatser att döma kunde tillverka vågar med känslighet ner i milligramområdet. Svensken Gahn som levde 1745—1818, gavs av Berzelius äran för att teoretsiskt ha utrett och praktiskt ha löst problemet samt att ha spritt sitt vetande till den vetenskapliga världen.

Författaren har genom tillämpning av enkel vågteori, genom praktiska vägningsförsök och genom uppmätning av dimensioner och övriga data hos sju vikingatida vågar och vågfragment kunnat visa att den ursprungliga känsligheten kan beräknas för t. o. m illa medfarna vägfynd.
Härför måste först ej tillgängliga data ersättas med sannolika siffror (exempelvis vikten hos felande vågskålar o. dyl.).

Känsligheten hos samtliga sju vågar visade sig ligga mellan 0,2 och 0,4 g för 1 mm utslag på visaren vid nära noll grams total belastning. Vid hög belastning sjunker känsligheten. Vid vägning av ca 50 g vara ligger noggrannheten av vägningen omkring 2 %, vilket bekräftas av ett vägningsförsök från 1842, utfört av den utmärkte finske fysikern G. G. Hällström år 1842. Hans våg kunde inte skilja 100,3 g från 102,1 g.

Även om de gamla vågarna inte var särskilt känsliga var de av en enkel och praktisk konstruktion. Säkerligen gjorde den stora produktionen priset överkomligt och de var vackra att se på. De fyllde därför en stor uppgift i handeln med silver och guld. Omfattningen av denna handel visas bland annat av de många fynden av silverskatter från denna tid.

Noggrannheten hos de vikter som användes till vågarna var väl anpassad till vågarnas känslighet. Hos ett fynd från Gotland, Burs sn, Häffinds var spridningen mellan ett tjugotal kubooktaedriska vikter som vägde omkring 1,5 g, ±0,08, vilket innebär att avvikelser från medelvärdet med ±0,2 g (=vågens känslighet) var ovanliga.