Weapon and tool use during the Nordic Bronze Age

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ABSTRACT
Wear analyses of 100 bladed objects including swords, spears, daggers, and knives dating to the Nordic Bronze Age was conducted focusing on Northern Germany. These analyses indicate changing patterns for tip and edge wear, the relationship of curvatures, fractures, and cracks, and for different traces of repairs. Comparing these results to published wear analyses suggests changing patterns across object forms and time. It can be hypothesized that there is a trend towards accommodating fighting style preferences with diverging object designs. This started at the end of the Late Neolithic with the change from halberds to swords/daggers and spears.

The changing patterns were interpreted as indications of shifts in the use of swords, spears, and daggers following changes in the design of these objects. Swords and spears were used in increasingly more specialised motions over time, i.e. swords in slashing/cutting and spears more often for thrusting. Daggers may have shifted away from a role as combat weapons to multipurpose tools more in line with period III knives. This was interpreted as evidence for the existence of a technological network in which changes in design and use of bladed objects inform each other. The results provide the base for future research into object design, specialization, and social significance that can test the hypotheses put forward in this paper.

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Introduction

Early Nordic Bronze Age metalwork is essential for the study of Bronze Age technology, practices, and social organization in this region. Archaeologists often investigate bronze objects within the scope of the study of economic processes using methods including contextual, trace elemental, and isotopic analysis (Earle, 2002; Earle et al., 2015; Kristiansen, 2016; Larsson, 1989; Ling et al., 2013; Ling et al., 2014). Early use-wear studies used within this framework substantiated hypotheses on the economy of metal supply and management (Kristiansen, 1979, 1984). Kristiansen saw the re-sharpening and reduction in the general shape of swords as indicative of a prolonged use-life as a consequence of supply shortages. This was an important contribution towards understanding the socio-economic dynamics of the Bronze Age in Scandinavia. However, a more detailed analysis can inform us about the use and significance of the objects themselves.

In his later work, Kristiansen included other damage, which he termed "scars" (Kristiansen, 2002). However, these "scars" have different forms, each of which could be caused through considerably different activities, actions or processes. A more detailed study of wear marks and their position can enrich our knowledge about these bladed objects. Dolfini and Crellin (2016) have argued that a stricter protocol is necessary in order to fully understand the use of weaponry. Such an approach has been used to argue the fighting styles using swords or spears during period I of the Nordic Bronze Age (1700-1500 BC) followed similar patterns. This may have facilitated the adoption of innovations in weapon technology (Horn, 2013, 2014a). Building on this prior work, our aim is to give a more detailed account of Nordic Bronze Age weaponry by extending the chronological framework and including the results of new wear analyses.

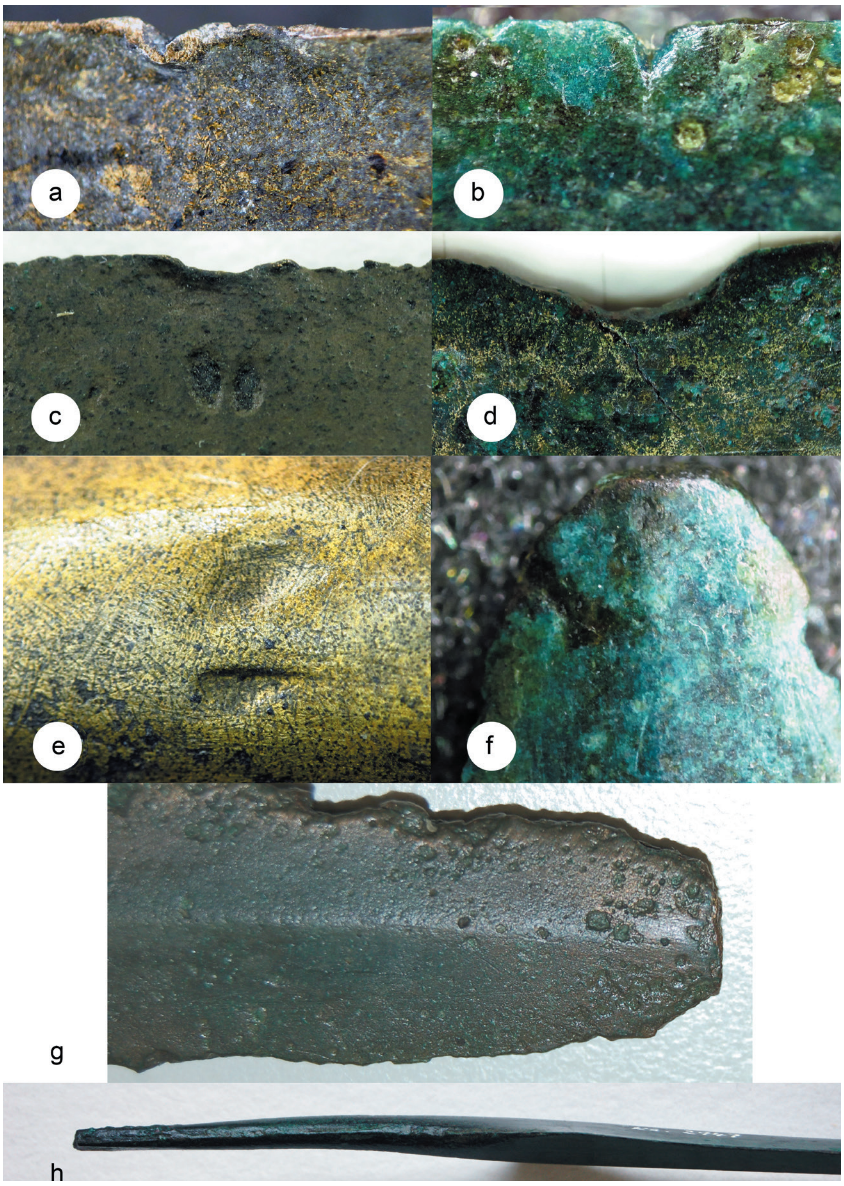

Fig. 1: a. Notch with displaced material (x150, LMSH KS923);
b. Notch with micro-fissure at the central point (x150, LMSH KS8017a);
c. Indentation with material displacement (x60, LMSH KS1204);
d. Indentation with a fissure (x60, LMSH KS7367);
e. Two blowmarks (x60, LMSH KS11145.2);
f. Pressured tip (x60, LMSH KS2948);
g. Tip broken and lost (MUFB Im1155);
h. Hilt with curved deformation (LMSH KS2947).

Method

To enable detailed observations, it was necessary to classify several wear categories, building upon earlier work (Bridgford, 1997; 2000; Dolfini, 2011; Horn, 2013; Molloy, 2008; Molloy et al., 2016; Contributions in Uckelmann and Mödlinger, 2011). The formation of damage depends upon complex processes involving material properties (for example hardness, toughness, malleability, tensile strength, etc.), surface shape of both objects, speed and strength of the impact, dimensions of the involved objects, the relational trajectories of the objects, and potential prior damage such as hair-line cracks. To be archaeologically visible the force of the impact has to surpass the material properties of the metal to leave a trace, the damage has to occur on a preserved part of the weapon – e.g. not the wooden shaft, and the wear has to be mostly unaffected by corrosion (Horn and Holstein, 2017).

Wear marks can be classified based on their morphology (Horn, 2013, 2014a) which will be outlined in the following. Other nomenclatures have been proposed (Bridgford, 2000; Gentile and van Gijn, 2019; Molloy, 2006), however, to keep comparability with earlier papers in the region we keep the definitions put forward in Horn's previous publications (Horn, 2013, 2014a, 2017). *Notches* are v-shaped intrusions (Figure 1a-b) and *indentations* have more rounded u-shapes (Figure 1c-d). Both occur along the cutting edge of bladed objects. *Blow marks* are similar in form to notches and indentations but are located on the weapon's body (Figure 1e). *Pressured tips* are recognisable by a flattening of areas on top of the tip (Figure 1f). This does not preserve a mark that is indicative of the shape of the object that the subject impacted against. *Fractures* propagate through the entire object and commonly break it into several pieces that could be lost (Figure 1g). This is an obvious problem because these lost pieces could carry damage that becomes unobservable using archaeological analyses. Cracks are a preliminary stage of fractures because they do not propagate through the entire object, and do not break it apart. Fractures and cracks can a direct outcome of blows that also cause notches, indentations, and blow marks (Figure 1b, e). *Curvatures* can occur on a scale from faint to extreme forms and on several different axes (Figure 1h). Subtle curvatures that extend across the entire object can be caused by earth pressure when the artefact is buried in the ground. Small, slightly broken or chipped material that is still attached to the main body of the object and that is directly associated to an impact has been termed *material displacement*.

Wear formation is complex, but the mechanics of deformation of metal can cause wear that forms through different actions to look very similar. That can happen when the surfaces impacting against each other have a similar morphology (Horn and Holstein, 2017). For example, pressured tips may have the same shape regardless of whether the tip hits bone, metal, or a rock on the ground. The same is true for damage caused by thrusting or throwing. Furthermore, curvatures from sudden impacts or prolonged high pressure can also be very similar. Therefore, the only remedy is a comparative approach to the different wear marks on an individual weapon, the distribution of wear patterns across a single weapon category, and the similarities and differences of wear across different weapon categories. Additionally, the morphology of the objects should be taken as an indicator of the intended use of an object. Nevertheless, it should be kept in mind that objects can be used in a variety of ways which were not anticipated when they were produced. It is, therefore, important to compare the described damage categories to damage produced by independent experiments conducted by various researchers (Anderson, 2011; Dolfini and Crellin, 2016; Gentile and van Gijn, 2019; Molloy, 2006; O'Flaherty, 2007; O'Flaherty et al., 2008).

Cracks are more susceptible to corrosion which propagates along those features leading to internal stress which could be relieved through the formation of fractures (Horn, 2013; Horn and Holstein, 2017; Hunt Ortiz, 2003; Orfanou and Rehren, 2015; Sáez and Lerma, 2015; Shreir, 2010). Corrosion can preserve traces of wear, for example striations in fine grained patina. Conversely, aggressive patina affects thinner parts more strongly, especially when weakened through damage, such as at cutting edges. That means that areas which are interesting for wear analysis can be obscured or dissolved first (c.f. Horn and Holstein, 2017). However, detailed observation of corrosion processes can provide information about damage, contexts, and the position of metalwork within such contexts (Högberg et al., 2016). The change in the material properties through the forces of an impact (for example, in density) can cause different colourings and rates of corrosion to occur around the impact. This may, for example, help in differentiating the character of indentations, especially those affected by repair or corrosion. The impact causing an indentation affects the material differently than a casting flaw leading to a different coloration of the patina. This can sometime be observed as a kind of corona around the previously damaged part (Horn, 2013; Horn and Holstein, 2017). This should ideally coincide with other indicators. For example, an indentation would, if observable, have a more or less flat bottom while a casting flaw like a sinkhole would extend convexly towards the body of the weapon. Thus, it may be possible to observe damage through the discoloration of patina.

Attention was also paid to *striations, hammer marks, material reduction*, and *asymmetries* as possible indicators of *repair*. Repair results from the curation of weapons, performed to keep them in a usable state. Therefore, while repairs are an indicator for the use of an object, they also obscure the specifics of the damage which had originally been there. However, re-damaging of repaired sections opens a window to a new dimension in which it is possible to investigate the complexity of object biographies (Molloy, 2011, 2018). It is a window into ongoing use, as is, for example, the stratigraphy of a pit that has been filled and re-cut repeatedly (Horn, 2013).

Material

Wear analysis was conducted on a sample of 100 bladed objects (Table 1). The sample contained

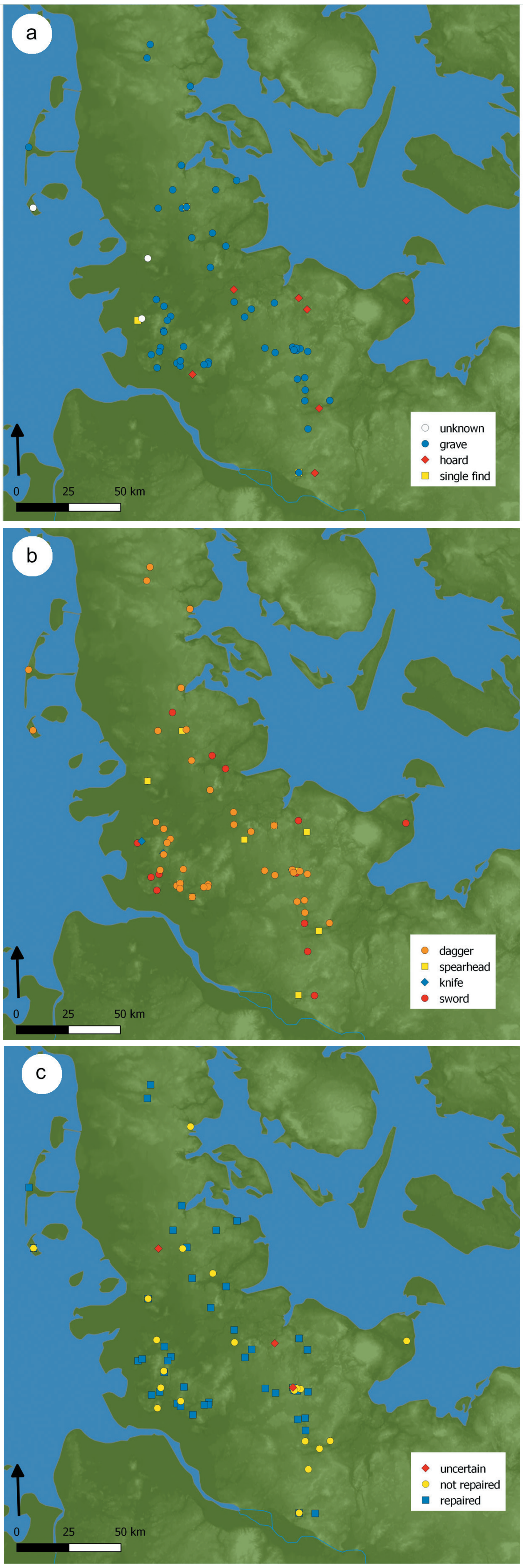

Figure 2. Distribution of analysed artefacts:
a. Context;
b. Object category;
c. Repaired vs. not repaired.

swords (23) and spearheads (18) which are traditionally seen as weapons, although spears could also have been used for hunting or fishing. The daggers analysed (49) are traditionally seen as being multifunctional objects. Additionally, ten Bronze Age knives were studied as a sample of objects commonly identified as being a 'tool'.

Of importance for this discussion, one earlier study concentrated on the wear of weaponry dating to period I of the Nordic Bronze Age (Horn, 2013, 2014a) and another focused on Late Neolithic copper-alloy halberds (Horn, 2017). The material for this study is more varied, mainly deriving from later periods to enable us to compare and to expand the relevance of the results of previous studies. However, the geographic focus is narrower as all objects analysed were discovered in the region of Schleswig-Holstein in the north of Germany (Figure 2). Of the swords, six belong to period II (1500-1300 BC), eight to period III (1300-1100 BC), five date either to period II or to period III. Six belong to the Late Bronze Age in period IV (1100-900 BC) or V (900-700 BC). Eight daggers may be dated to period I, thirty-one to period II, and seven to period III. One dagger comes from a context at the transition of period I to II and another cannot be assigned to any specific period within the Early Bronze Age. Of the spearheads, nine belong to period II, only two to period III and five to the Late Bronze Age. Two additional spears from period I were analysed. Apart from one knife dating to the Late Bronze Age, the remaining nine were discovered in period III contexts. If the material is broken up by object type and chronology, the numbers become very low which makes the interpretation tentative. Full metal hilts were present on twelve daggers and on one sword. These numbers are too small to justify further detailed discussion. Given the structure of the sample, the focus will be on the different categories of artefacts: knives, swords, daggers, and spears.

For source criticism, the different contexts of discovery for the material will be outlined (Horn and Holstein, 2017). Most finds were discovered in graves and the number of single finds is negligible (Figure 3a). Spears are almost equal in proportions from hoards and graves (Figure 3a). Swords were deposited more often in graves, however, seven were discovered in hoards (Figure 3a). Only two daggers come from hoards while forty-two are finds from

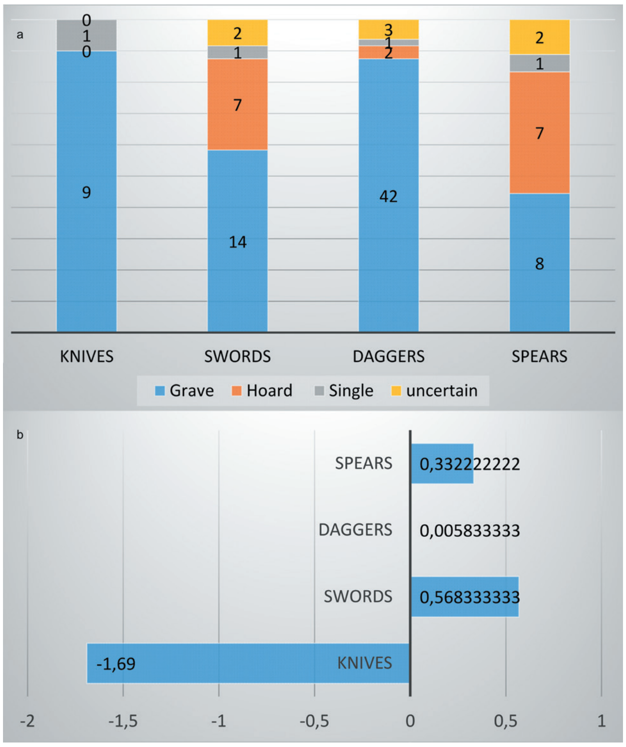

Figure 3. a. Relative quantities of the contexts of the object categories;
b. Deviation of the object categories from the damage average.

mortuary contexts better (Figure 3a). This is significant, because burial finds are more often affected by heavy, dissolving corrosion which affects the visibility of wear marks negatively (Horn and Holstein, 2017; Sáez and Lerma, 2015). Therefore, wear marks may be underrepresented in the sample.

Analysis I – Damage

It was possible to document 292 direct indicators of use and 114 potential traces of repair (Table 1). That means overall, that the average of direct evidence for wear was 2.89 per object. Swords (3.46) and spears (3.22) deviate in the positive from this average (+0.57 and +0.33) meaning they have over three indicators of use on average (Figure 3b). Conversely, knives deviate in the negative with only 1.2 wear marks on average (-1.69). Daggers represent the average well. The average for repair traces is 1.13 per object. Here the deviation per object gives a different impression. Knives, swords, and spearheads deviate in the negative with 0.8 to 0.94 repair traces on average. Only daggers diverge in the positive with an average of 1.4 traces (Figure3b).

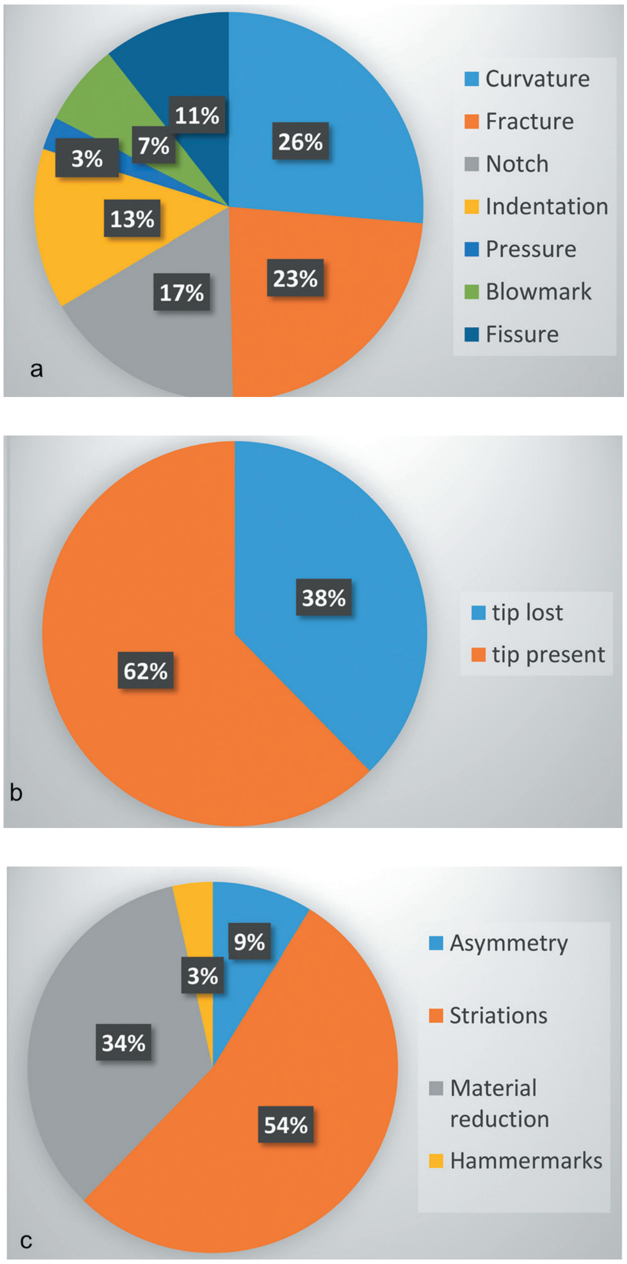

Figure 4. a. relative share of damage categories in the sample; b. Lost tips compared to preserved tips; c. relative share of repair trace categories in the sample;

Curvatures of various degrees represent most wear with 26 % (77; Figure 4a). Together with fractures (23 %, 68) curvatures account for ca. half of the observed indicators of use. Notches are the third most frequent damage with 17 % (49) followed by indentations (13 %, 39) and cracks (11 %, 31). Blow marks only account for 7 % (20) of the visible damage. Pressured tips were observed in only nine cases (3 %, 9).

It seems that pressured tips only rarely occur. However, Horn has argued that this observation may be misleading, since fractures often disturb tips, and the loss of tips makes any investigation impossi-

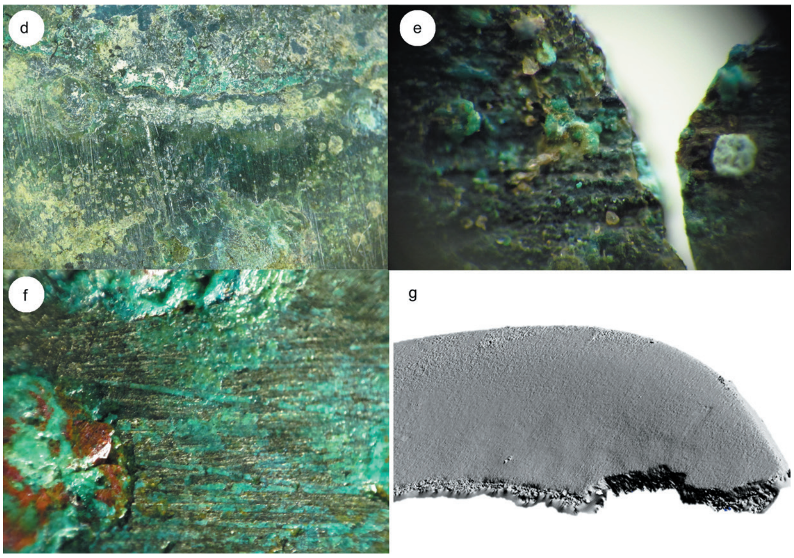

Figure 4. d. striations stopping in front of a discoloration that indicates the area covered by the hilt of a sword (x60, LMSH KS8020a);
e. grinding striations under patina, disrupted by a fracture (x300, LMSH KSB26a);
f. grinding striations partially covered by patina (x150, LMSH KSB150m);
g. hammer marks visible on a 3D model produced from x60 images (LMSH KS11440b).

ble (Figure 1h) (Horn, 2013). Tips are lost in over one third (38 %) of the analysed cases (Figure 4b). Therefore, the number of pressured tips could be much higher. While other damage indicators can occur more than once on a single object because they can be located on a different section of the cutting edge, pressure can only occur in two places. Swords and daggers with a hafting plate offer the opportunity for the occurrence of pressure not only on the tip, but also on the edge of the hafting plate. However, the force that creates pressure must be so strong that it travels through the entire object to push the hafting plate hard enough into the handle to compress the metal. Yet, forces diminish as they travel through the metal. Additionally, the hafting plate is pushed into the softer wood which serves to cushion the blow. This gives rise to forces that may be strong enough to lead to pressured tips but be too weak to travel through the object and damage the hafting plates.

Indicators of repair are often varied and overlaying striation patterns that occur on different parts of the object (Figure 4d-f). They account for over half of the traces (54 %, 61; Figure 4c). This is followed by the material reduction in thickness, width, and length on a third of the objects (34 %, 39). Asymmetries on objects that may be caused by repair processes are a specific form of material reduction. A separate category was created based on the difference in form. Asymmetries were observed on 9 % (10) of the objects. The least frequent were unambiguous hammer marks (3 %, 4). The problem here is that hammer marks are often subtle. The reasons for this could be careful and minimal cold working that does not risk damaging the blade. Alternatively, hammering could be smoothed over by grinding or polishing. Another problem might be that hammer marks, although faint, cover larger areas. This means a microscope is needed to recognise hammer marks, but the hammer marks are too large to fit in the frame making their observation difficult. The hammer marks on a knife from Bornhöved (LMSH KS 11440b) were discovered only later when a 3D model was reconstructed from photos taken with 60-times magnification allowing the observation of a larger surface at a microscopic scale (Figure 4g).

Analysis II – Objects

If the focus is shifted to the damage and repair categories on the individual object types (Figure 5a-b), it turns out that spears exhibit the most frequent instances of direct impact damage, i.e. notches, indentations, blow marks, and pressured tips. This accounts for over 50 % of the damage documented on all spears and on swords combined. A slight difference exists between rates of damage seen on swords and spears. Spears are more likely to have pressured tips and blow marks, while swords have higher instances of notches. Spears were more frequently affected by curvatures. Curvatures also outweigh cracks and fractures on swords, but when combined, the latter are more frequent.

Damage patterns of knives are different to swords and spears (Figure 5a). Curvatures, fractures, and cracks outweigh other damage. In fact, indentations, pressure on tips, and blow marks are absent.

Although notches were observed in only three cases, the relative proportions make them almost as important on knives as they are on swords.

In the overall damage distribution, daggers represent a mixed artefact category between knives on one side and spears and swords on the other (Figure 5a). Notches, indentations, blow marks, and pressured tips are present, but compared to other damage these categories occur less often than on spears and swords. Curvatures, fractures, and cracks are much more frequent which resembles the pattern found for knives. The relative distribution of these categories, however, is different.

Comparing only the relative proportions of curvatures, fractures, and cracks, it turns out that daggers are much closer to swords (Figure 5b). Fractures and cracks occur more often than curvatures, with fractures being slightly more frequent on daggers (Figure 5b). Knives and spears both have curvatures as their most frequent category of damage in this comparison (Figure 5b). Looking at the relative proportions of notches, indentations, pressure on tips and blow marks, knives are the outlier (Figure 5a). Compared to the knives, the other artefact categories are much more similar. Spears, however, deviate to a small degree, as pressured tips and indentations are more pronounced (Figure 5a).

The traces of repair processes on daggers and spears are more similar than the damage patterns. For both object categories, asymmetries occur more or less pronounced (Figure 5c). No hammer marks could be recognised on spears and only on one dagger (Figure 5c). Conversely, on knives and swords hammer marks occur in several cases. Strong asymmetries could not be observed on swords. Knives are produced asymmetrically, which prevents assessment.

Summarising the traces of use (damage and repair) on tips, swords and spears appear to be rather similar again with 62 % (15) and 61 % (11) of the tips affected by damage and/or repair (Figure 5d). Only 40 % (19) of daggers possessed tips with evidence of use (Figure 5d). This category of damage could not be observed on knives at all.

Analysis III – Through time

The following analysis is very fragmented and the sample size for each category can be small. Therefore, the remarks will be kept short due to their tentative nature. Knives were excluded because all except one dated to period III of the Nordic Bronze Age. The Early Bronze Age finds are in 80 % of cases retrieved from burials, therefore, the patterns described in the following cannot be attributed to a difference in depositional patterns. The Late Bronze Age finds have primarily been discovered in hoards (58 %). It is of course possible that the patterns described in the following are a result of different deposition practices, i.e. there could be contexts in which largely unused objects were deposited. However, this seems in this case unlikely to be a general rule since wear can be observed on objects from all contexts.

Figure 5. a. Impact damage amounts per object category; b. Plastic deformation amounts per object category; c. Repair indicators per object category; d. Contexts per object category.

Changes in the damage pattern for daggers occur from period I to period III. The most obvious is that the relative amount of curvatures increases. This is perhaps related to the decrease in fractures and fissures (Figure 6a). This goes along with an increase in edge related damage, i.e. notches and indentations with a simultaneous decrease in instances of tip damage (Figure 6b). Another interesting observation is that unambiguous material reductions

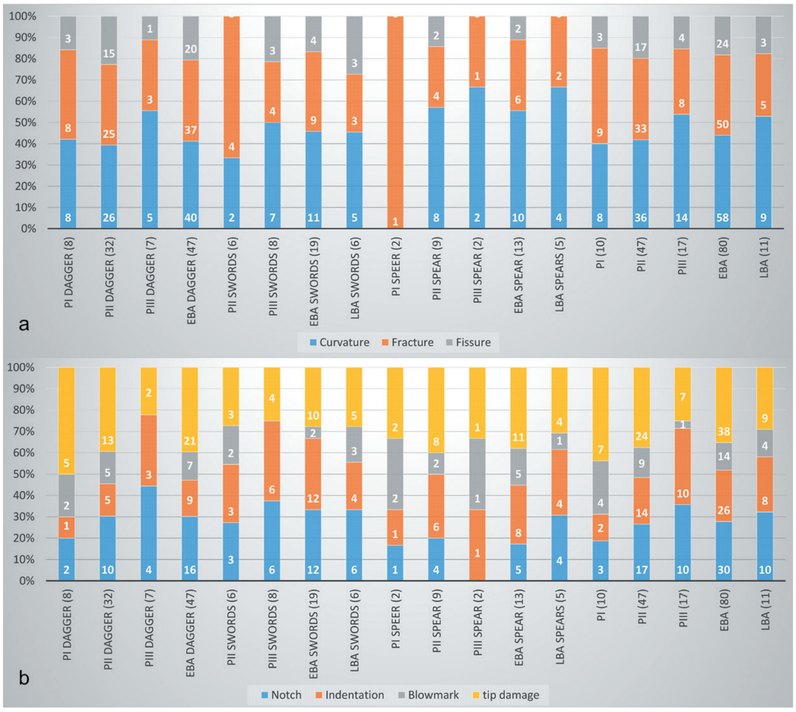

Figure 6. a. distribution of amounts of plastic deformation chronologically sorted; b. impact and tip damage chronologically sorted.

are more common on later daggers than earlier ones. Throughout the Early Bronze Age hammer marks may become more prevalent (Figure 7a). When we compare instances of damage traces and repair traces, the latter become more pronounced in their size or extent over time (Figure 7b).

Swords exhibit curvatures in period III more often than in period II. This coincides with a strong decrease in fractures (Figure 6a). Spearheads show an increase in curvatures, but only two spearheads dating to period III have been analysed. Compared to daggers, notches increase. This relative increase could be misleading because it is caused by the absence of blow marks (Figure 6b). Indentations are more frequent in period III. The relative amount of striations remains stable on swords from period II to period III. Hammer marks only occur in period III (Figure 7a). Swords and daggers display a relative increase in repair traces (Figure 7b).

Comparing Early Bronze Age swords and spears to Late Bronze Age specimens shows several differences. In terms of damage, the categories for swords remain relatively even. However, the sample from period III shows that the relative quantity of curvatures is lower again (Figure 6a). The Late Bronze Age swords have a more even distribution of notches, indentations, and blow marks (Figure 6b). Notches and indentations increase on Late Bronze Age spears (Figure 6b) and so do curvatures when plastic deformations are compared (Figure 6a), but blow marks and tip damage rates decrease (Figure 6b). On Late Bronze Age swords, traces of repair are more frequent than on their Early Bronze Age counterparts (Figure 7b). This trend is reversed on spearheads where they show a faint increase. During the Late Bronze Age, striations occur somewhat more often compared to material reductions on both weapon forms. Horn and von Holstein (2017) point out that use wear is better preserved overall on objects from hoards. The raised amounts of observable use wear during the Late Bronze Age could, therefore, be a result of the higher amount of finds from hoards.

Discussion - Comparison with published material

In the following, the data will be discussed including the published results of wear analyses on Nordic Late Neolithic and Bronze Age metalwork (Horn, 2013, 2017). For this discussion, cracks were merged with fractures as they were not separated in the older publications. The separation between swords and daggers dating to the Nordic Bronze Age is another problem. Despite few longer specimens, for example, in Torupgårde, Denmark, early blades of the Sögel-Wholde complex and the Apa-derived blades can be very short, more akin to daggers. In the older publications, these were termed swords because

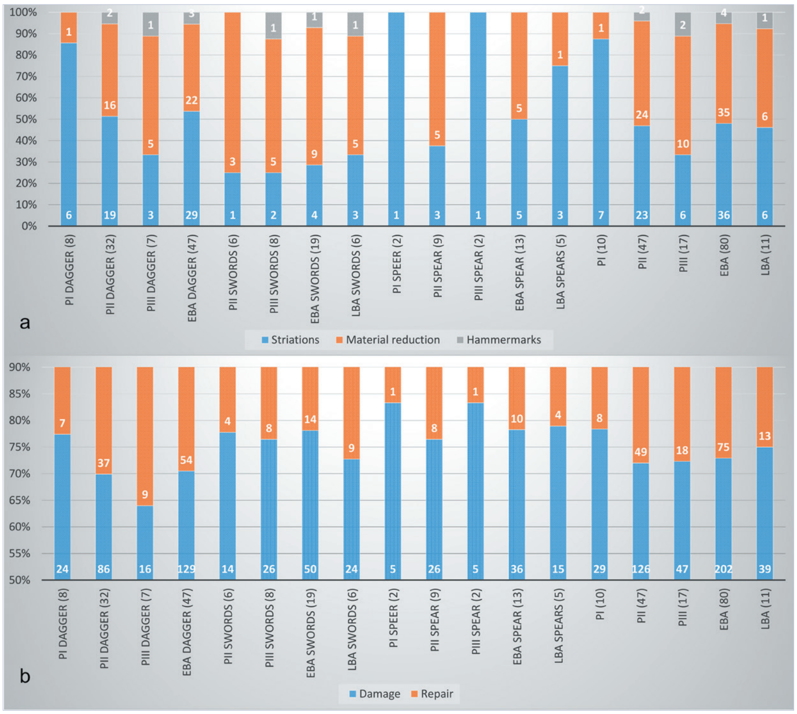

Figure 7. a. repair indicators chronologically sorted;
b. comparison of damage versus repair indicators chronologically sorted.

the sample only contained period I material. Judging by the relative size of contemporary blades they fulfilled the role of swords. To complicate matters even more swords can be shortened to dagger-length through use and repair (Horn, 2013; Kristiansen, 1984, 2002). In this work, we will include period I blades into the category daggers, but also compare them to the swords. The published sample included 156 spears and 50 daggers (swords) dating to period I or the Nordic Bronze Age and 15 halberds dating to the Late Neolithic. This material was discovered in Northern Germany, Denmark, Sweden, and Norway (Horn, 2013, 2017).

From the Late Neolithic halberds to period II daggers and swords, curvatures decrease relative to fractures, which means that later weapons fractured more frequently. Curvatures again increase in period III. However, they do not eclipse the sum of curvatures on halberds (Figure 8a). This is likely the result of higher impacting forces through the longer lever arm. This may have been counteracted by producing them with stronger mid-ribs than period I and II daggers and swords (Horn, 2014b; Liversage and Liversage, 1989; Vandkilde, 1996). This, and perhaps differences in fighting style, made fractures perhaps less likely. Therefore, the different morphology of these weapons could explain the different damage patterns. However, period III daggers do not have thicker cross-sections than period II specimens, yet curvatures increase. Therefore, the observed changes could be related to a significant change in use. Spearheads of period I and II have high levels of curvature like halberds (Figure 8a). Given the narrow cutting edges and the strong sockets reinforced by being a composite construction of bronze with a wooden shaft, high impact forces were necessary to fracture these weapons. This means that stress caused by impacts is more likely to be relieved in curvatures. Throughout the Bronze Age, spears were constructed with increasing sturdiness (Jacob-Friesen, 1967) which may explain the increase in instances of curvatures during the Late Bronze Age. Curvatures on swords and daggers decrease in frequency in the transition from period I to period II, while the patterns observed on spears remains more stable.

Notches, indentations, and blow marks below the tip section are testimony to the use of cutting or slashing actions in combat because such actions expose these sections of the blade to potential damage. Conversely, stabbing and thrusting exposes the tip because it hits resistance first. To bring the differences between cutting/slashing and stabbing/thrusting into sharper focus, notches, indentations, and blow marks below the tip and tip damage have been summarised. Each weapon may occur more than once in the statistic because a single weapon can obtain both edge and tip damage.

Dagger use may be mostly unchanged from period I to II with a slight increase in evidence for stabbing/thrusting. A significant change occurs during

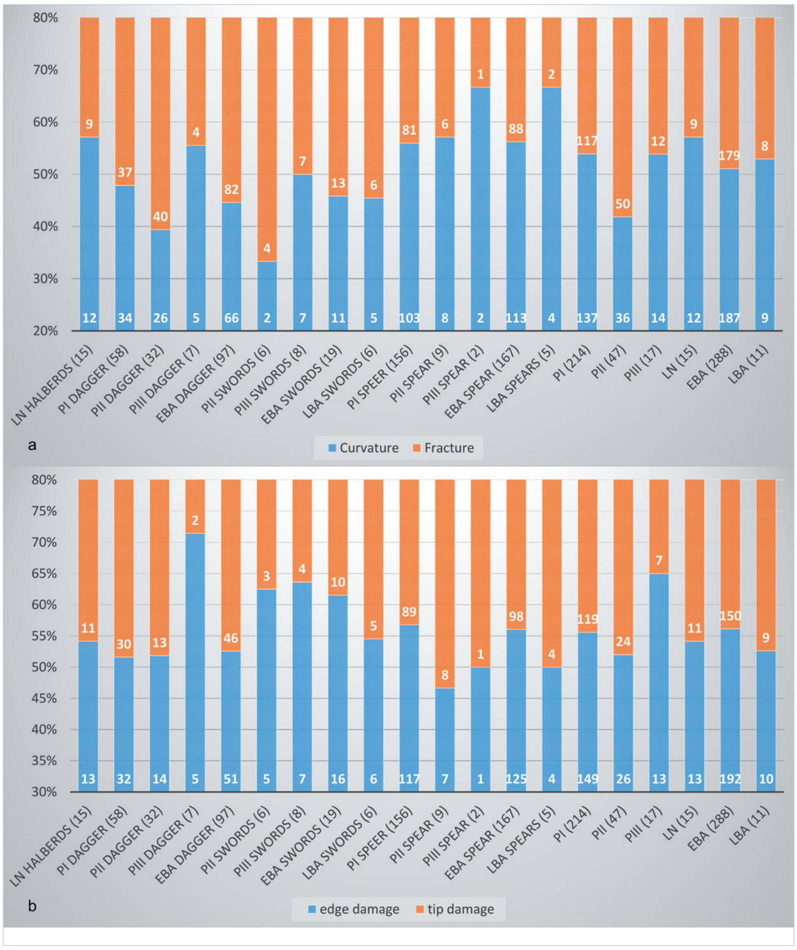

Figure 8. a. Plastic deformation comparison with published samples;
b. edge and tip damage comparison with published samples.

period III with a shift to cutting/slashing. The traces begin to resemble the damage pattern seen for knives (Figure 8b). The data for spears experiences a significant shift from period I to period II, in that rates of damage to the tip increases (Figure 8b). Late Bronze Age spears show a similar trend when compared with the Early Bronze Age specimen. The data for period I swords (here re-classified as daggers) shows a significant shift when compared to period II swords. Conversely for spearheads, documented instances of edge damage becomes more pronounced (Figure 8b). During the Late Bronze Age rates of edge and tip damage seem to be on the same level again (Figure 8b).

Interpretation

Based on a comparison of the quantities of copper objects and the degradation of swords through use, various authors have argued that period II is the phase of the most significant influx of metal into the Nordic sphere (Earle et al., 2015; Kristiansen, 1979; Ling et al., 2013; Ling et al., 2014). This is congruent with an increase in the dimensions of swords and spears (Aner and Kersten, 1973-2014; Kristiansen, 1984, 2002; Oldeberg, 1974, 1976) which confirms a better availability of copper and tin. One effect is that swords and daggers become more distinct in form. The increase in thickness especially makes the objects sturdier, so that they are less likely to fracture. Therefore, the increase in curvatures from period I to period II could be based on technological change facilitated by a better availability of raw copper and tin which may have worked in concert with other changing factors like the display of status and prestige.

Regardless of the maximum thickness and other dimensions, the cutting edges are always thin to allow for effective cutting. In the same sense, tips are often the part of the weapon that is most prone to damage because they are narrow and thin. This means that cutting edges and tips can theoretically withstand a similar amount of damage independent of the overall dimensions of the object. Therefore, the relative distribution of damage on cutting edges, including blow marks, and tips is more likely to inform us about the use of bladed objects than curvatures and fractures. This means that we can use the data on edge and tip wear presented above to interpret the functionality and the changes in use patterns for different categories of objects (Dolfini and Crellin, 2016; Horn, 2013, 2014a).

Edge and tip wear are about even on halberds in the Nordic sphere. Therefore, they could be interpreted as an all-purpose weapon used for slashing and for stabbing and thrusting. Local, temporal, and morphological differences exist on European halberds indicating differences in the frequency and the specific modes of use. However, overall, halberds appear to be a well-rounded weapon form suited for use combining several different attacks and defences throughout Europe (Brandherm, 2011; Dolfini, 2011; Horn, 2013, 2014a, 2017; O'Flaherty et al., 2008).

Period I spears and daggers/swords in the Nordic sphere continue this trend. The detailed study of their wear showed no significant deviation in their pattern. This result was used to argue that period I daggers/swords and spears were used in a similar all-around style including thrusting, cutting, and slashing motions (Horn, 2014a). Contrary to notions put forward in older literature (Fontijn, 2005; Harding, 2007; Mercer, 2006; Tarot, 2000), these results show that early weaponry was efficient in combat, and that spears were not only used as a throwing weapon or that swords were only for thrusting. Molloy (most recently 2017) argued the same point for the Irish swords and spears. Considering the earlier results, diverging edge and tip wear patterns of swords and spears dating to period II may indicate a shift to more specialized combat roles. The increase in tip damage on period II spears may indicate that they were more frequently thrusted or thrown. However, edge damage is still present and could point to a continued use of spears for slashing or blocking motions in combat (see also Anderson, 2011). This means spears were still not thrown, but became a specialized thrusting and stabbing weapon.

Conversely, the higher quantity of edge damage on swords may point to more frequent slashing and cutting in combat in period II. If the small sample can be trusted, the trend of using spears more often for thrusting movements in combat continues during the Late Bronze Age while sword use was more balanced again. The diverging use of swords and spears during period II could be caused by changes in weapon design, but could also promote such changes. Such a development may have been the increase in sword length.

As also observed in the Irish material, for example, the size range of spearheads widens around 1500 BC (Molloy, 2017) although in Scandinavia this may happen somewhat earlier during the 16th century BC (Vandkilde, 1996). While there is some deviation in the use-wear between longer and shorter spears during period I that indicates some tendencies and preferences in the combat style depending of weapon form, it cannot be argued that a specialization or strong divergence took place (Horn, 2018). Since the edge wear rates seem to remain considerable throughout the Early Bronze Age, slashing may remain an important combat move using spears. Which means that, unlike the Irish spears, there seems to be no process in Scandinavia towards a fighting in more close ranks which culminates in the development of Hoplite warfare in Greece (Molloy, 2017; van Wees, 2004). This means that fighting stays more individualized at least until 1100 BC when the Early Nordic Bronze Age ends. This may be in line with the suggested contemporary social model of a decentralized power structure (Kristiansen, 2007).

In the following, we will suggest that the specialised roles of swords and spears in combat may have contributed to a shift in the use of daggers. The increase of edge damage by over 15% on period III daggers compared to the previous period could be interpreted analogously to swords. Daggers could have been used more often for cutting and slashing in combat. However, edge damage is likely cause through dynamic, high impact edge on edge action (Gentile and van Gijn, 2019). Considering the shortness of daggers this seems to involve a high risk of injury to the fighters themselves. Perhaps this means that the period III daggers do not exhibit combat damage. Bearing in mind the observation that the damage and repair pattern of daggers and knives start resembling each other, another interpretation may be put forward. The parallel use-wear patterns could indicate the possibility that daggers were less often used in combat altogether. Instead they may have become a tool without, or with a diminished role in combat. This is supported by the morphology of daggers dating to period III. These daggers do not have the thick mid-ribs of their predecessors (Oldeberg, 1974). This does not preclude a combat use per se but it will make these blades more prone to fractures and cracks if use for high velocity thrusting. Instead we see a rise in curvatures parallel to the levels of knives. These are caused by frontal forces leading pressure that is not high enough to exceed the strength of bronze and is subsequently not relieved in breakage but in deformation. That may mean that work using the tip was still carried out such as piercing something or cutting by pushing the tip downward. These are tasks that would also have been performed using knives which could be an explanation for the similarity in their damage pattern. Perhaps later daggers were not intended to be used for high stress tasks such as combat. A hypothesis could be that the specialisation tendencies of spears and swords for combat may have left the space for daggers to develop into tools with a greater emphasis on domestic functions. However, this should be tested in the future with a greater sample of knives to compare.

Overall, our results indicate that from the Late Neolithic through to period III of the Nordic Bronze Age, the use of bladed metal objects diversified their morphology from halberds to spears, swords, daggers and finally adding knives. A specialisation in use begins with the morphological shift, albeit with a delay. This process may have led to a decline in the importance of daggers as a major fighting implement. These changes are interlocking shifts that form a tight network in which changes in object design and use affect and influence each other even across object categories. Development and change seem to happen in increments and not through a sudden "revolution".

The approach of analysing bladed objects of different forms and across longer time-spans was fruitful. It was possible to investigate trends in the use of weaponry in the Nordic sphere. Future studies analysing more bladed objects with a wider geographic and chronological extent should test and correct these observations and interpretations.

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Supplement

Table 1 (next page). Data overview (LMSH: Landesmuseum Schleswig-Holstein Schloss Gottorf; MUF B: Museum für Ur- und Frühgeschichte Berlin).

Inventory number	Museum	Context	Object	Period (Nordic Bronze Age)	Fissure (corrosion)	Fracture (corrosion)	Curvature	Fracture	Repair	Notch	Indentation	Pressure	Blow-mark	Fissure	Damage to blade tip	Decoration	Damage to hafting plate	Comments
1869	LMSH	grave	Full hilted dagger	II	x			x	x	x			x	x	x	x		Worn down sword
3783	LMSH	?grave	Full hilted dagger	II				x	x							x		
6027	LMSH	grave	Dagger	II			x	x	x	x				x	x			Inhumation
6958	LMSH	grave	Dagger	I			x	x	x	x			x	x	x	x		Inhumation
8742	LMSH	grave	Full hilted dagger	II			x	x	x				x			x		
8745	LMSH	grave	Dagger	I			x	x	x									Heavily corroded
11881	LMSH	grave	Dagger	I			x	x	x						x	x		Inhumation
12141	LMSH	?grave	Full hilted dagger	II			x	x							x			Strongly reconstructed, no cutting edge damage observable
12587	LMSH	grave	Dagger	I			x	x	x					x	x	x	x	Inhumation
13619	LMSH	?grave	Dagger	I			x	x	x						x	x		Casting error frontal third
14149	LMSH	grave	Dagger	II			x	x	x					x				Inhumation
16272	LMSH	single	Dagger	II			x	x	x	x				x	x		x	
10221a	LMSH	grave	Dagger	II			x	x	x	x	x			x			x	Sheath remains; inhumation
10454 a	LMSH	grave	Full hilted dagger	II			x	x	x		x				x	x		Casting error central part of the blade; inhumation
10803d	LMSH	grave	Dagger	I			x	x	x									Strong modern grinding; inhumation

Inventory number	Museum	Context	Object	Period (Nordic Bronze Age)	Fissure (corrosion)	Fracture (corrosion)	Curvature	Fracture	Repair	Notch	Indentation	Pressure	Blow-mark	Fissure	Damage to blade tip	Decoration	Damage to hafting plate	Comments
11405b	LMSH	grave	Dagger	I			x	x	x					x	x	x	x	Casting error on mid rib; inhumation
12008a	LMSH	grave	Full hilted dagger	II	x		x	x	x					x		x	x	Heavily corroded; inhumation
12058 III a	LMSH	grave	Dagger	II			x	x	x					x			x	Inhumation
12122b	LMSH	grave	Dagger	II			x	x										Inhumation
13707b	LMSH	grave	Full hilted dagger	II				x					x			x		Inhumation
14147y	LMSH	hoard	Dagger	II			x	x	x					x	x			
18214b	LMSH	grave	Full hilted dagger	II			x	x	x				x	x		x		Inhumation
19982e	LMSH	grave	Dagger	II			x	x	x						x	x		
5104b	LMSH	grave	Full hilted dagger	II			x	x	x		x			x		x		
6050a	LMSH	grave	Full hilted dagger	II	x		x	x	x						x	x		Inhumation
6240c	LMSH	grave	Dagger	II				x		x				x	x			Inhumation
8790.4a	LMSH	grave	Dagger	II			x	x	x					x				Inhumation
B 101.1	LMSH	grave	Dagger	II	x	x	x	x									x	Urn
B 120.2a	LMSH	grave	Dagger	II			x	x	x	x								Heavily corroded; inhumation
B 382.2	LMSH	grave	Dagger	II			x	x	x									Heavily corroded; inhumation
B163e	LMSH	grave	Dagger	EBA			x	x	x					x	x	x		Casting error on blade; inhumation
B166a	LMSH	grave	Full hilted dagger	II	x			x	x					x	x	x		Inhumation

Inventory number	Museum	Context	Object	Period (Nordic Bronze Age)	Fissure (corrosion)	Fracture (corrosion)	Curvature	Fracture	Repair	Notch	Indentation	Pressure	Blow-mark	Fissure	Damage to blade tip	Decoration	Damage to hafting plate	Comments
B171b	LMSH	grave	Dagger	I/II			x		x									Inhumation
B413	LMSH	grave	Full hilted dagger	II				x	x		x			x	x	x		Heavily corroded; inhumation
KS 11145_1 (k)	LMSH	hoard	Spear	II	x		x	x	x		x							
KS 11145_2 (l/e)	LMSH	hoard	Spear	II			x	x	x		x		x					
KS 11145i	LMSH	hoard	Spear	II			?		x	x	x				x	x		
KS 11186a	LMSH	?grave	Sword	EBA	x	x	x			x	x				x	x		
KS 11311	LMSH	grave	Sword	III	x	x	x			x	x					x	x	Sheath remains; heavily corroded
KS 11440a	LMSH	grave	Sword	III	x	x	x			x	x			x	x	x	x	
KS 11440b	LMSH	grave	Knife	III		x	x		x							x		Cremation
KS 11522	LMSH	grave	Spear	LBA	x	x	x	x	x							x		Urn
KS 11814a	LMSH	grave	Sword	II	x	x		x			x				x		x	Sheath and other organic remains
KS 11814c	LMSH	grave	Dagger	II	x	x	x	x							x			Heavily corroded
KS 1204	LMSH	single	Sword	II			x	x	x	x	x	x			x		x	Bog
KS 12288 c	LMSH	hoard	Sword	V	x		x	x	x	x	x			x	x		x	
KS 12288a	LMSH	hoard	Sword	V		x	x	x	x	x			x		x	x	x	Casting seam
KS 12288b	LMSH	hoard	Sword	V			x	x	x	x	x		x	x				Casting seam
KS 12292 g	LMSH	grave	Dagger	II	x	x	x	x	x	x	x				x			
KS 12307	LMSH	grave	Spear	III		x	x								x			Shaft remains
KS 13071a	LMSH	grave	Sword	III		x	x		x						x	x	x	
KS 13071e	LMSH	grave	Knife	III	x	x	x			x					x			
KS 13479	LMSH	grave	Dagger	III	x	x	x	x							x	x		
KS 14373	LMSH	single	Spear	LBA	x	x	x		x	x	x	x			x	x		
KS 19666b	LMSH	hoard	Sword	V	x	x	x	x		x	x		x	x	x	x		
KS 19982c	LMSH	grave	Spear	II		x	x		x	x	x			x	x	x		
KS 22297	LMSH	grave	Dagger	I		x	x	x	x	x	x		x				x	
KS 22913	LMSH	?grave	Sword	EBA							x							

Inventory number	Museum	Context	Object	Period (Nordic Bronze Age)	Fissure (corrosion)	Fracture (corrosion)	Curvature	Fracture	Repair	Notch	Indentation	Pressure	Blow-mark	Fissure	Damage to blade tip	Decoration	Damage to hafting plate	Comments
KS 2947	LMSH	hoard	Sword	V			x		x	x	x	x	x		x	x	x	Sinkhole frontal third; Casting seam hammered
KS 2948	LMSH	hoard	Sword	V			x		x	x	x			x	x		x	sinkholes
KS 3017	LMSH	grave	Spear	II			x						x		x	x		Wooden remains
KS 4983a	LMSH	grave	Dagger	III			x			x					x		x	Sheath remains
KS 4983c	LMSH	grave	Dagger	III		x	x		x	x							x	Organic remains
KS 5104	LMSH	grave	Spear	II	x	x	x	x		x	x					x		Shaft remains
KS 6240	LMSH	grave	Spear	II	x	x	x			x	x			x	x	x		
KS 6343_1	LMSH	hoard	Spear	II	x	x	x		x									
KS 6343_2	LMSH	hoard	Dagger	II		x	x	x	x	x			x					
KS 6414b	LMSH	grave	Spear	LBA			x		x	x	x				x	x		
KS 7367 a-f	LMSH	grave	Dagger	III	x	x	x	x	x	x	x			x				Organic remains
KS 8015f	LMSH	grave	Knife	III		x	x	x	x							x		
KS 8016a	LMSH	grave	Sword	III		x	x	x	x	x	x				x		x	
KS 8016c	LMSH	grave	Knife	III	x	x			x	x								
KS 8017a	LMSH	grave	Sword	III	x	x	x	x		x				x	x	x	x	Wooden remains
KS 8017f	LMSH	grave	Knife	III		x	x		x									
KS 8018a	LMSH	grave	Sword	III		x			x	x	x				x		x	Organic remains
KS 8018b	LMSH	grave	Knife	III		x			x	x								
KS 8019a	LMSH	grave	Sword	III	x	x	x	x	x	x	x			x	x		x	Wooden re-mains; heavily corroded
KS 8020a	LMSH	grave	Sword	EBA	x	x				x	x			x	x	x	x	
KS 8020d	LMSH	grave	Knife	III		x	x		x							x		
KS 8754b	LMSH	grave	Knife	V										x		x		Urn
KS 923	LMSH	hoard	Spear	LBA			x	x		x	x	x			x			Bog
KS 924	LMSH	unkown	Spear	II			x	x	x			x				x		
KS B 150 c	LMSH	grave	Dagger	II	x	x	x	x	x	x				x		x		
KS B 150 m	LMSH	grave	Dagger	II	x	x	x	x	x									

Inventory number	Museum	Context	Object	Period (Nordic Bronze Age)	Fissure (corrosion)	Fracture (corrosion)	Curvature	Fracture	Repair	Notch	Indentation	Pressure	Blowmark	Fissure	Damage to blade tip	Decoration	Damage to hafting plate	Comments
KS B 330	LMSH	grave	Spear	LBA			x		x	x	x	x	x		x			
KS B 559	LMSH	unkown	Spear	III		x	x	x	x		x	x	x		x			Organic remains
KS B26a	LMSH	grave	Dagger	III	x	x		x	x	x						x		Sheath remains
LA 46	LMSH	grave	Sword	II-III	x	x	x	x	x	x	x							Sheath remains
ll 2658	MUF B	grave	Sword	II				x	x	x								
ll 2660	MUF B	grave	Dagger	II		x	x			x		x					x	
ll 2697	MUF B	grave	Sword	II						x					x	x		
ll 9514	MUF B	single	Knife	III				x	x							x		
ll 9608	MUF B	grave	Sword	II				x								x		Heavily corroded
lm 1152	MUF B	hoard	Spear	I				x	x		x		x		x			
lm 1153	MUF B	hoard	Spear	I						x			x		x	x		
lm 1155	MUF B	hoard	Sword	EBA			x	x	x	x					x	x		
lm 2072a	MUF B	grave	Dagger	III				x	x		x							Cremation
lm 2159	MUF B	grave	Full hilted dagger	II			x	x	x		x		x			x		Heavily corroded
lm 2399	MUF B	grave	Dagger	III			x	x	x									Heavily corroded; urn
lm 2402b	MUF B	grave	Knife	III			x		x									Inhumation