The attached document was submitted in support of an entry into the SCA Arts & Sciences competition known as “Ice Dragon” held April 13, 2019, in the Barony of the Rhydderich Hael (see http://www.ice-dragon.info/).

Many thanks to the individuals who judged this and all entries and provided feedback on them, as well as to those who organized and staffed the event.

 The author may be contacted at kps1@cornell.edu with questions, comments, etc.



# Ice Dragon 2019

submission in category

# ApR1: Applied Research

“Extremely well researched items too simple or modest to compete fairly in a more traditional category. The score would be split between the research paper and the item, with the paper being worth more than half of the points.”

This paper was submitted February 28; the associated “item” is a set of four pairs of skates and seven wooden poles for display on site on the day of the competition (and illustrated herein).

# Experiments with Bone Ice Skates and Their Associated Poles

A study of archaeological finds, medieval textual references, and illustrations from books and maps, reveals certain information about bone ice skates, whose blades typically come from horses or cows, as well as the poles used with them during the Middle Ages. However, many details remain unclear as to which types of bones and pole tips may perform better than others. This paper conveys the results of some practical experiments intended to elucidate basic and finer points of the skates' and poles' characteristics, construction, and use.

Three on-ice testing sessions were held in order to learn about the properties of different types of skates and the poles used in propulsion when wearing them. Bone skates cannot be used to push the skater forward like modern metal-bladed ones because the bones have no edges with which to bite the ice and brace against it. Instead, a wooden pole is rammed down into the ice between the legs and used as leverage to gain forward momentum.

All three skating sessions were observed, photographed, and filmed by various assistants and interested parties. Links to YouTube videos may be found at the end of this report.

Further, the same pair of turnshoes was used in all three sessions on all skates in order to achieve consistent results. The shoes were made by the author and have a 9-10 oz. vegetable-tanned sole. A felted insole and thick socks were worn inside the shoes each time.

*The shoes used throughout these experiments, here mounted on deer bones with leather laces.*

**Experimental skating session #1**
My initial experimental skating session took place at a full-sized, indoor hockey rink where I tried skating with cow and white-tailed deer bones for blades. I pushed myself with a wooden stick that had a pointed end covered with a thin metal pastry cone. During that time on the ice, I propelled myself around the rink a couple of times. However, the metal cone tip quickly bent and became blunt, greatly increasing the difficulty involved in pushing against the ice because it frequently slipped instead of digging in. This test demonstrated the feasibility of the skates and their pole as a way to slide across the ice. Two main questions arose from this session: 1) what kind of pole tip would work better; 2) would horse or cow bones work better than deer (the latter two types are much more prevalent in the archaeological record).

**Experimental skating session #2**
My second skating session was held on an outdoor pond with an ice surface ranging from totally clear and smooth along the edges to rather bumpy and snow-covered in the center. I tried deer, horse, and cow bones for skate blades. I also brought seven different poles, each with a slightly different tip construction / configuration. After the second round of testing, it became clear which poles worked best, but a couple of questions still remained about skates: 1) were the horse bones too big and could they be improved by further smoothing; 2) would the application of pig grease help them slide (see historical references below regarding the application of grease).

**Experimental skating session #3**
In the third ice session, a few finer points and outstanding questions were addressed. These tests took place at the same ice rink as session #1 and I re-tried cow and horse bones after minor adjustments and the application of pig grease. Further, a pair of wooden skates were tested for comparison to bone.

# Medieval References to Skating

We have two medieval accounts - one illustrated - of people on bone skates using poles to push themselves across the ice:

*When the great marsh that washes the Northern walls of the city is frozen, dense throngs of youths go forth to disport themselves upon the ice. Some gathering speed by a run, glide along, with feet set well apart, over a vast space of ice.*

*Others make themselves seats of ice like millstones, and are dragged along by a number who run before them holding hands. Sometimes they slip owing to the greatness of their speed and fall, every one of them upon their faces.*

*Others there are, more skilled to sport upon the ice, who fit to their feet the shin-bones of beasts, lashing them beneath their ankles, and with **iron-shod poles** in their hands they strike ever and anon against the ice and are borne along swift as a bird in flight or a bolt shot from mangonel.*

*But sometimes two by agreement run one against the other from a great distance, and, raising their poles, strike one another. One or both fall, not without bodily harm, since on falling they are borne a long way in opposite directions by the force of their own motion; and wherever the ice touches the head, it scrapes and skins it entirely.*

*Often he that falls breaks arm or shin, if he fall upon it. But youth is an age greedy of renown, yearning for victory, and exercises itself in mimic battles that it may bear itself more boldly in true combats.*

- William FitzStephen, *ca.* 1173, *A Description of the Most Noble City of London*. (Translated from Latin by L. Gourde.)

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See Alsford (2016) for a different translation as well as notes about different surviving versions:

*When the great marsh that laps up against the northern walls of the city is frozen, large numbers of the younger crowd go there to play about on the ice.*

*Some, after building up speed with a run, facing sideways and their feet placed apart, slide along for a long distance. Others make seats for themselves out of ice-slabs almost as large as millstones, and are dragged along by several others who hold their hands and run in front. Moving so quickly, the feet of some slip out from under them and inevitably they fall down flat.*

*Others are more skilled at frolicking on the ice: they equip each of their feet with an animal's shin-bone, attaching it to the underside of their footwear; using* ***hand-held poles reinforced with metal tips****, which they periodically thrust against the ice, they propel themselves along as swiftly as a bird in flight or a bolt shot from a crossbow.*

*But sometimes two, by accord, beginning far apart, charge each other from opposite directions and, raising their poles, strike each other with them. One or both are knocked down, not without injury, since after falling their impetus carries them off some distance and any part of their head that touches the ice is badly scratched and scraped.*

*Often someone breaks a leg or an arm, if he falls onto it. But youth are driven to show off and demonstrate their superiority, so they are inclined to these mock battles, to steel themselves for real combat.*

A transcription of the Latin by Riley (1860):

*XXIII. De Ludentihus super glaciem.*

*Cum est congelata palus ilia magna quae moenia urbis Aquilonalia alluit, exeunt lusum super glaciem densae juvenum turmae. Hii, ex cursu motu captato citatiore, distantia pedum posita, magnum spatium, latere altero praetenso, perlabuntur. Alii quasi magnos lapides molares de glacie sedes sibi faciunt; sessorem unum trahunt plurimi praecurrentes, manibus se tenentes. In tanta citatione motus aliquando pedibus lapsi cadunt omnes proni. Sunt alii super glaciem Ludere doctiores, singuli pedibus suis aptantes, et subtalaribus suis alligantes, ossa, tibias scilicet animalium; et palos,* ***ferro acuto supposito****, tenentes in manibus, quos aliquando glaciei illidunt, tanta rapacitate feruntur quanta avis volans, vel pilum balistse. Interdum autem, magna procul distantia, ex condicto, duo aliqui ita ab oppositis veniunt, Curritur, palos erigunt, se invicem percutiunt; vel alter vel ambo cadunt, non sine laesione corporali, cum post casum etiam vi motus feruntur ab invicem procul; et qua parte glacies caput tangit, totum radit, totum decorticat, Plerumque tibia cadentis, vel brachium, si super illud ceciderit, confringitur: sed aetas avida gloriae juventus, cupida victoriae; ut in veris proeliis fortius se habeat, ita in simulatis exercetur.* [Search Google for the phrase “ferro acuto supposito” for a Google book with more information.]

*The other kind of men are those who attach to the soles of their feet piece of flat, polished iron, a foot long, or the flat bones of deer or oxen, the shin bones, that is. These are slippery by nature because they have an inherent greasiness and achieve a very great speed,* ***though only on smooth ice****, and continue shooting forward without pause as long as the ice remains level.*

*Among this sort too there are found everywhere men who take pleasure in racing for a prize. Their race-course over* ***frozen lakes as smooth as a mirror*** *is fixed at eight to twelve Italian miles from one end to the other, or it can be less. The prizes are silver spoons, copper pots, swords, new clothes, and young horses, but more often the last.*

*The rest are outrun by those competitors in the race who attach to the soles of their feet the shin-bones of deer* ***thoroughly smoothed and greased with pork fat****, since, when the cold drops of water rise as it were through the pores of the ice during fierce cold, the bones smeared in this way cannot be hampered or kept in check, as iron can however much it is polished or greased.*

*For no greasing suits iron as much as it does the shin·bones of deer or bullocks, which have an innate slipperiness of their own. In this way, whenever the ice, two or three fingers thick, is clear and bared of snow, these shows are performed easily and with little fear of danger; but this is by no means the case at other times, for you are never in greater peril or nearer to death than when you set off skating while the ice is covered with even the thinnest layer of snow.*

*For rivers or brooks, silently and swiftly entering the lake from its shores, wear away the ice by their constant movement so that it cannot grow thick and firm, unless the streams themselves are held in check by a very hard frost. But sometimes rash skaters, ignorant of or scorning the properties of ice and racing with more temerity than caution, are drowned, their bodies lamentably left under the ice and on top of it their heads, which have been sliced off by the sharp edge of the ice as if by an axe.*

- Olaus Magnus, 1555, *Description of the Northern Peoples*, Book I, Chapter 25. (Translated from Latin by P. Fisher and H. Higgens.) The illustrations are chapter vignettes from Book 1:25, Book 20:17, and Book 11:36, respectively, from top to bottom.


Two ice skaters on Section F of *Carta Marina*, by O. Magnus, 1539. Note that Magnus did not himself illustrate his works. He commissioned their images to be drawn by Italian artists while he was in exiled from Sweden in Rome (i.e., the artists have likely never seen skates themselves).

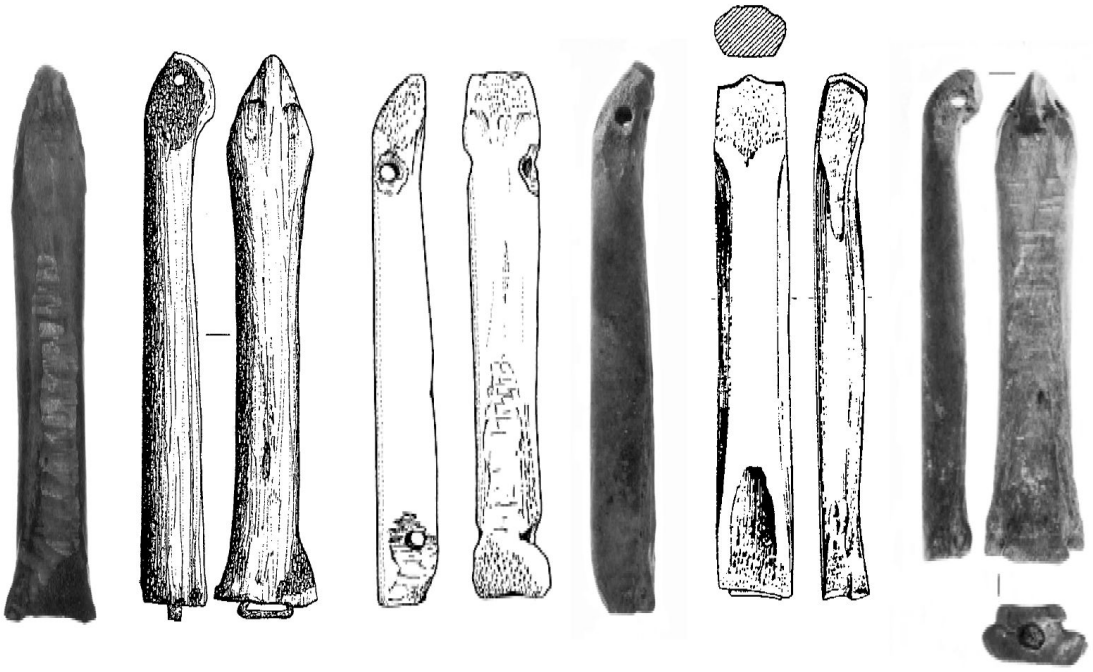
# Types and Characteristics of Bones Used as Skates

Bone ice skates date back thousands of years in Scandinavia, the British Isles, and throughout Europe where weather allows their use, serving people until at least the late 1800s in Iceland (Balfour, 1898: 29) and even into the 1930s in Estonia (Edberg and Karlsson, 2016:13). The vast majority of bones found archaeologically come from cows and horses, with perhaps 45% of each making up most of the corpus, with almost 10% being deer, and the remainder assorted other animals of smaller size (and likely meant for the use of children). In nearly all cases these are metatarsal or metacarpal (shin) bones, however sometimes other leg bones or even ribs seem to have been used (Küchelmann and Zidarov, 2005: 2).

My first ice session used relatively fresh white-tailed deer bones and a pair of dried cow bones. Since then, however, I acquired a pair of horse bones from a friend, and a local butcher provided me with two pairs of cow legs, from which I boiled out the bones. Those deer, horse, and cow bones were used in session two. The third session incorporated the original dried cow bones, the horse bones, and a pair of wooden skates made from a sapling (added as a point of comparison for curiosity's sake).

In the archaeological record, bones used as ice skates are distinguishable from others because they have been worked to more or less extent in any combination of ways, including:

- A hole drilled through the front perpendicular to the length of the bone side-to-side
- Angling the front upward from base to top
- Angling on each side of the front to form a point
- A hole drilled into the back of the bone toward the front to hold a wooden peg
- Flattening of top and/or bottom of the bone
- Roughening of the surface on which the skater stood to better grip the shoe sole



*A selection of bone skates showing common modifications such as shaping and roughening of the top surface. (After Küchelmann and Zidarov, 2005: 5.)*

For my experiments, I used a hatchet to flatten and shape all the bones along their length, but primarily at both ends. I roughed the top surface to facilitate the shoe leather gripping the bone. I angled the front upward and inward from both sides. I drilled a cross-wise hole in the front of the deer bones, and a longitudinal hole in the rear, and attached laces by looping a leather thong up over the instep, around the ankle and down under a wooden peg in the rear then back up to the instep and around the ankle to tie in the front. I also drilled holes in the first pair of dried cow bones and added a rear peg but did not add laces to them. The fresh cow bones and horse bones had no holes drilled into them.

*The deer bones before and after shaping, drilling, and roughening. The cow and horse bones were also shaped with the hatchet to flatten them, angle their front ends, and add texture to their top surfaces.*

It should be noted that many skates have no holes, and at least one post-medieval reference indicates that laces were used only by children and novice skaters; experienced skaters simply stood on the bones (MacGregor, 1976: 65). In my sessions, I found that laces made little difference to keeping the bones in position, but it's possible that my particular choice of lacing pattern was suboptimal. Certainly simply standing on them works well enough.

*The three types of bones used (from left to right): horse, deer, cow.*

*Wooden skates. Left: roughened top surface, Right: planed bottom surface.*

It took me some 30-60 minutes to prepare each pair of bones. Chopping with the hatchet removes slivers or chunks of bone depending on the angle of impact, the force applied, and the part of the bone struck. I definitely erred on the side of caution because of my limited supply of bones and inexperience with the hatchet. Despite that, one pair of dried deer bones cracked substantially so I abandoned them. In the interest of time, I used a modern drill to make the holes, rather than a medieval tool. Based on some archaeological finds, it appears that occasionally people made holes with a knife tip rather than a drill (Lauwerier and R. Van Heeringen, 1998: 124).

# Experiments with Bones

Various aspects affect the bones' performance characteristics. These include their length, their width, their mass, and their smoothness. Each type tested varies in these four factors. See the photos above for an idea of relative sizes and Table 1 below for a listing of lengths and weights.

Some bones are easier to stand on: the massive horse bones are the most comfortable simply because they offer more area to support the foot, extending past the shoe sole in both the front and the rear. However, their larger surface area greatly expands the area of friction and increases inertia making it harder to get going when standing on them. Countering that, however, is the larger area able to take force from the pole as transmitted down through the body and the feet.

The deer bones, being the narrowest, felt the most like modern skates. In my experience they offered the most directional control, but the least stability, with the lowest ice-contact profile and the least support for the foot. Given their lack in the archaeological record, perhaps there were not as readily available, or people simply preferred more substantial bones for skating.

In the middle I place the cow bones: too short for comfort and least controllable for direction. I found myself spinning quickly and easily while attempting to use them in many cases. They were not great to stand on because of their bumpy ends under my sole. For children, however, I suspect they are more comfortable.

*Video stills showing trials with cow, horse, and deer bones (left to right).*

All of these factors will be felt differently by people with different sizes of feet and body weights, and perhaps different senses of agility or control. It's certainly possible that adults, youth, and children preferred different types of bones based on their shoe size and experience with skates.

One particularly interesting point of speculation arose during testing: how do the sizes of the modern animals' bones compare to those found archaeologically, especially for horses. The size of animals, both now and in the past, can vary according to their breed, environment, health, diet, age, living conditions, care and treatment, etc. We assumed that the modern horse bone's length and mass would greatly surpass those of medieval horses, often thought to be more like modern ponies. Perhaps many medieval horses were diminutive, and perhaps their bones were sometimes made into skates. However, according to Küchelmann and Zidarov (2005: 6) who illustrates several horse bone skates dated to the 9th/10th centuries, the size of the one I tested does not differ significantly from the medieval ones.

During the experimental process, it occurred to me that a simple wooden skate should also be tried for comparison. Accordingly, I cut two spans of a hardwood sapling to fit within the size range of the bones being tested, both in length and diameter. I used a plane to flatten one side of each to a width of about 1" (2.5cm) to form the top, and the opposite side to be about .75" (2cm) wide as the bottom. I roughened the top surface with a hatchet as with the bones. I used a saw to angle the front tips upward and inward, and left them undrilled. On the very slippery ice, they worked well, but perhaps not quite as well as bones. It will be interesting to try a pair made from dried, plain seasoned wood as well as greased.

With regard to trying different animals' bones, as well as bones of different conditions, for me in my trials, deer work the best, cow offers the least control, and horse bones need especially smooth ice. Fresh bones seem to work better than dry ones, but applying pig grease to dry bones by rubbing with a cloth appears to freshen them up quite a bit. More testing is needed to confirm these observations, and to observe whether other people have different experiences.

*Table 1: Summary of skate characteristics.*

| Skate Type | Deer* Bone | Horse Bone | Cow Bone | Wood |
|---|---|---|---|---|
| **Length** | 9.75” (24.5cm) | 13.5” (34cm) | 8.25” (21cm) | 10.5” (26.5cm) |
| **Width** | .75-1.25” (2-3.5cm) | 2-3.5” (5-9 cm) | 1.5-2.5” (4-7cm) | 1.5” (4cm) |
| **Weight (pair)** | 8.65 oz. (245g) | 52.7 oz. (1494g) | 19.7 oz. (560g) | 12.9 oz. (366g) |
| **Comments** | Most directional control, least friction | Most comfortable, most friction | Least directional control | Moderate in all ratings, perhaps not quite as fast as bone |

* white-tailed deer, rather than red deer as found in archaeological deposits.

*The author on cow bones poling along, as in the manuscript images above.*

# Experiments with Poles

After the first session's thin metal pole tip failed, it became clear that a more robust solution was needed. Various people suggested one thing or another, and I had some ideas of my own to try, resulting in this list:

- Slab of metal inserted into a slot in the pole, then cross-braced with metal shanks
- Thicker metal for the cone
- Tapered nail or spike driven into the pole, with the head then cut off and ground to a point
- Simple fire-hardening

Some of these solutions require more work than others. In the end, I made and tested seven different poles during the second ice session. Details of each follow. In sum, all of them worked far better than the original thin metal cone.

*Tip #1: metal slab inserted into a slot in the pole, braced with transverse shanks through the pole*
Master Bedwyr Danwyn thought of this approach and graciously hosted me in his workshop, guiding me through the process of creating a substantial metal point and anchoring it in place within the pole. In summary, we cut a piece of spring steel into a tapering point in two dimensions then ground a more rounded tip.

I cut a slot in the pole, drilled holes through the wood and the metal, then secured it in place with a nail that I peened over hand-cut rivets made from sheet metal. Master Bedwyr helped me through the process of heating the metal to make it soft, then tempering it to make it hard. I learned a great deal about working metal in this process and ended up with a substantial pole tip.

*Crafting the custom blade: cutting from found spring steel; cut, gound, polished, and drilled ready to mount; mounting in progress; successfully mounted.*

*Tip #2: Thicker metal cone*
Such hardware can be purchased from various online replica weapon storefronts in different dimensions where they are labelled as spear butt caps. I chose a substantial one of 2mm-thick mild steel, with a length of 6.25”/16cm. The cone is simply a curved piece of metal with two unsealed butted edges. I carved and sanded a pole end to fit well within the cone and simply jammed it onto the pole (i.e., neither glue nor mounting hardware was used to secure it).

*Tip #3: Fire-hardened wood*
I carved and sanded a point onto a green pole. I repeatedly inserted and slowly turned the tip of the pole into a bed of glowing coals in a home wood-burning stove until it started to turn a bit brown and smoke a little. A thermometer on the stove read about 400 degrees F., but no doubt the bed of coals was substantially hotter. This process took about 10 minutes. I have never attempted this before, and proceeded after researching the topic online, with results of numerous methodologies being promoted. The one I chose seemed simplest. After the pole cooled down I found it to be noticeably harder than before the heat treatment.

*Tips #4-6: Tapered metal nails driven into the pole then beheaded and ground to a point*
I obtained three different sizes of square metal nails, first finding a very small, short one (1”/2.5cm), then a medium one (2”/5cm), then a large, long one (4.5”/11.4cm). These all appear to be hand-forged iron and were easily cut with a standard hacksaw. I drove the nails into the pole with a hammer, then ground points on the beheaded end with a modern grinding wheel.

*Tip #7: Hard metal spike inserted into pole*
While shopping in a used-hardware store, I came across a metal object of unknown purpose, but which had a long metal spike on one end. Trying to cut it to suitable length resulted in a broken hacksaw blade, but a Sawzall reciprocating blade made short work of it, ending up with a spike 5.7”/14.5cm long. I drilled a hole into the pole about 3”/7.6cm deep, then inserted the metal spike down into it. It fit very snugly within its hole and I pounded it against a cement floor to ensure it was solidly mounted. I then touched up the point with a stone grinding wheel.



*Spike and nails before and after beheading, along with the spear butt cap.*

*The complete set of seven pole tips. From left to right: large nail, custom mounted blade, medium nail, fire-hardened wood, hardened metal spike, spear butt cap, small nail.*

As previously mentioned, all of these tips worked much better than the first session's thin metal cone.

However, some of these tips worked better than others:

-The spear butt cap and hard metal spike worked best.

-The smallest and the largest nails bent after only a few minutes' use (the middle one was therefore not tried).

-The pointed metal slab worked if properly oriented, otherwise it sliced the ice. (That is, if parallel to the push it didn't set well; if perpendicular it did.)

-The fire-hardened tip worked much better than expected, but occasionally slipped. It became somewhat dulled.

At this point I believe we have no further question about the tips, so long as metal was available. Embedding the nails further into the pole so that they barely protrude might suffice to keep them from bending, and thus do well with minimal metal work and metal investment. A good cone or hard-metal

spike work the best for the least amount of work for someone putting together a push-pole, but of course they would need access to a metal worker or funds to acquire the metal.

All the poles used in this experiment were made from small hardwood saplings cut green about 4-6 weeks before they were used on the ice. They vary from 1-1.5 inches (2.5-3.8cm) diameter along their approximately six-foot (1.8m) length with the thicker end at the bottom.

It should be noted that using the poles resulted in many spots of chipped-out ice, thus destroying the smooth surface needed by the bone skates. It seems that too much poling in one area would roughen it quickly and ruin it for other skaters.

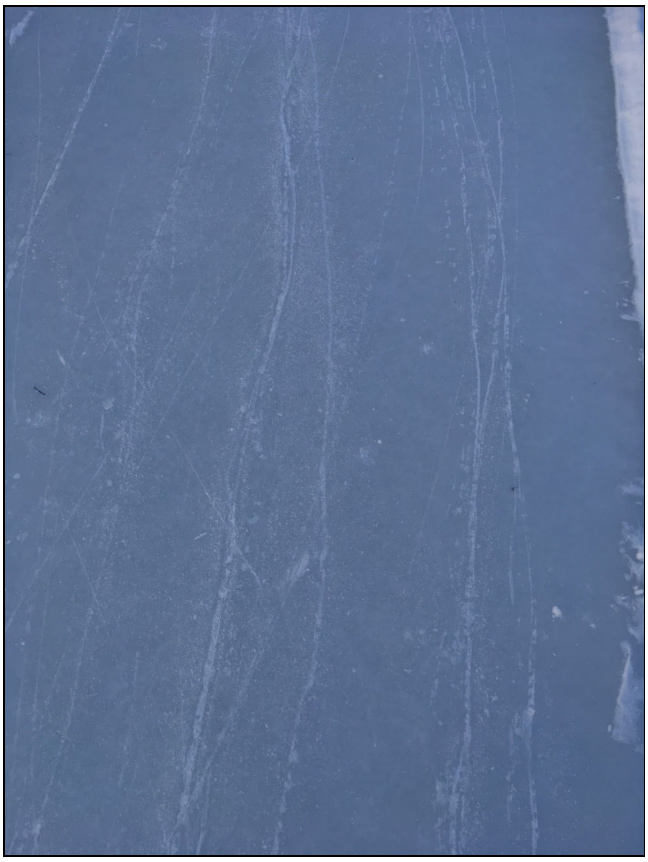
# Concerning Ice

As mentioned, sessions #1 and #3 took place in an indoor ice rink, while session #2 took place on an outdoor pond. Unfortunately, the condition of the ice in session #1 was not particularly noted, however it's most likely that it had been roughened somewhat by previous skaters. During session #3, however, the ice rink had apparently been newly resurfaced: it was glassy and extremely slippery (even to the point where I was able to push myself wearing only my shoes, albeit not as well as on skates).

The pond varied from rather bumpy and lumpy in its middle to somewhat smooth to very smooth on its perimeter along its shore edge. No doubt this reflects different conditions during its freezing, transitioning quickly in the shallowest areas and then more slowly in the middle, with the incorporation of snow and/or slush or wind-driven water slopping over the edges during freezing.

The pond session revealed that smooth ice is essential. At one point I was pushing along and decided to try going into a rougher zone. In that test, I kept going and the skates did not, and I was happy that the bones had no laces. The polished ice of the third session revealed how well all of the skates could work, with pig grease increasing the slipperiness even further.

Presumably ice-forming conditions in Europe favored the production of smooth ice often enough to make skating a feasible activity. Indeed, I would argue that the very presence of bone skates serves as evidence that such ice formed then and people took advantage of it often, whether for sport or transportation or both.



*Above: bone skate tracks on pond ice. Right: horse bones and spear butt pole ready for trial.*

# Conclusions

After three sessions on the ice with various kinds of skates and pole tips, I have reached several conclusions so far, and pose some points for consideration.

**First, and most important, the smoothness of the ice makes a significant difference to the performance of the skates.** In my experience, any but the glassiest of ice will work against the skates and make them difficult if not impossible to use. Using a metal-tip pole quickly creates a surface hostile to the skates because of the divots they make (this can be seen in the videos linked below, especially the outdoor ones). Thus, people using the skates will desire a large surface of smooth ice.

**Second, many solutions of pole tips suffice.** Thus, one might expect most poles to have had a minimal amount of metal in order to reduce any associated cost. Indeed, it may be the case that many skates were used without any metal at all, especially as bone skates from the Bronze Age survive. It's difficult to believe that rare metal would have been used for trivial pastimes such as recreational skating. On the other hand, if one has a spear (bronze, iron, steel) readily available for hunting or weaponry, one can simply flip it around and use it for propulsion across the ice.

**Third, all of the kinds of bones tested work, and can be used without laces.** Greasing them does appear to improve their speed at least for a while. Perhaps more interestingly, the wooden skates worked nearly as well as the bone ones, and took only minutes to make. One wonders how many wooden skates once existed alongside their enduring bone cousins. Even if they survived archaeologically, they might not be recognized as skates. Of course, when they wore out or broke, they would be used for firewood.

**Fourth, they are fun to use.** When asked whether skates were used for transport or entertainment, or both, I would hypothesize more for fun than for travel. After all, we do have two medieval texts that describe their use during leisure time, and ethnographic reports of kids enjoying them into the 1930s (Edberg and Karlsson, 2016:13), but there are also reports of people using them for travel, hunting, and fishing (MacGregor, 1976: 65-66). With more practice and a willing partner, as well as protective gear, I would like to *run one against the other from a great distance, and, raising [our] poles, strike one another.*

**Fifth, It's quite clear that using a pole to push forward requires arm and upper-body strength for pushing and much agility and leg strength to stay atop the skates.** If one wants to go any serious distance, endurance will be necessary as well. In my short trials, I found that once at speed it was easier to stay at speed, and it was impossible to change course in any intentional manner. Even though skating requires significant effort, the energy expended may fall below that expended trying to traverse an alternative route on land (Formenti and Minetti, 2007, 2008).

**Sixth, I found that one needs to wear appropriate clothing.** I had to hitch up my knee-length tunic into my belt in order to get it out of the way of the pole. Obviously past skaters would need to do that too, or wear something more suitable to the activity in the first place. Note that in the 16th-century manuscript images, the skaters appear to be wearing tight-fitting clothes all over. Perhaps the drawing accurately depicts actual skaters of the time, although that seems unlikely because the art was created in Italy.

No doubt with more practice people can become much better at moving in the direction they wish to go with less energy devoted not only to pole-pusing but also to maintaining an upright relaxed position. Trying to skate this way with a backpack or pulling a sledge, as one might if traveling with purpose, seems to be a tough way to move material. On the other hand, if the terrain and weather conditions favor it, and one has the choice to go over ice to save time or distance and can carry a couple of bones and a stick, it's likely worth the minimal effort to have them available during a trek to pay a visit, attend gatherings, or just enjoy the outdoors.

# Further Experiments

At some point it will be interesting to hold further trials that consider various other aspects of the skates, including these:

- Invite children to wear them and compare their results to mine.
- Use them more extensively to determine how the bones wear.
- Try longer sessions with pig grease to learn how long it lasts.
- Attempt to use two poles instead of one.
- Hold up a cloth or piece of leather stretched between sticks as a sail.
- Simply practice with them to gain comfort and control.
- Try tilting against someone else using them.

# Acknowledgements

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Research facilitation: the staff of the Interlibrary Loan dept. at the Cornell University library.

# Sources, References, and Related Reading

I read all of these works to the extent possible (some having only English summaries). If you wish to prioritize your use of them, start with MacGregor (1976) and Küchelmann and Zidarov (2005).


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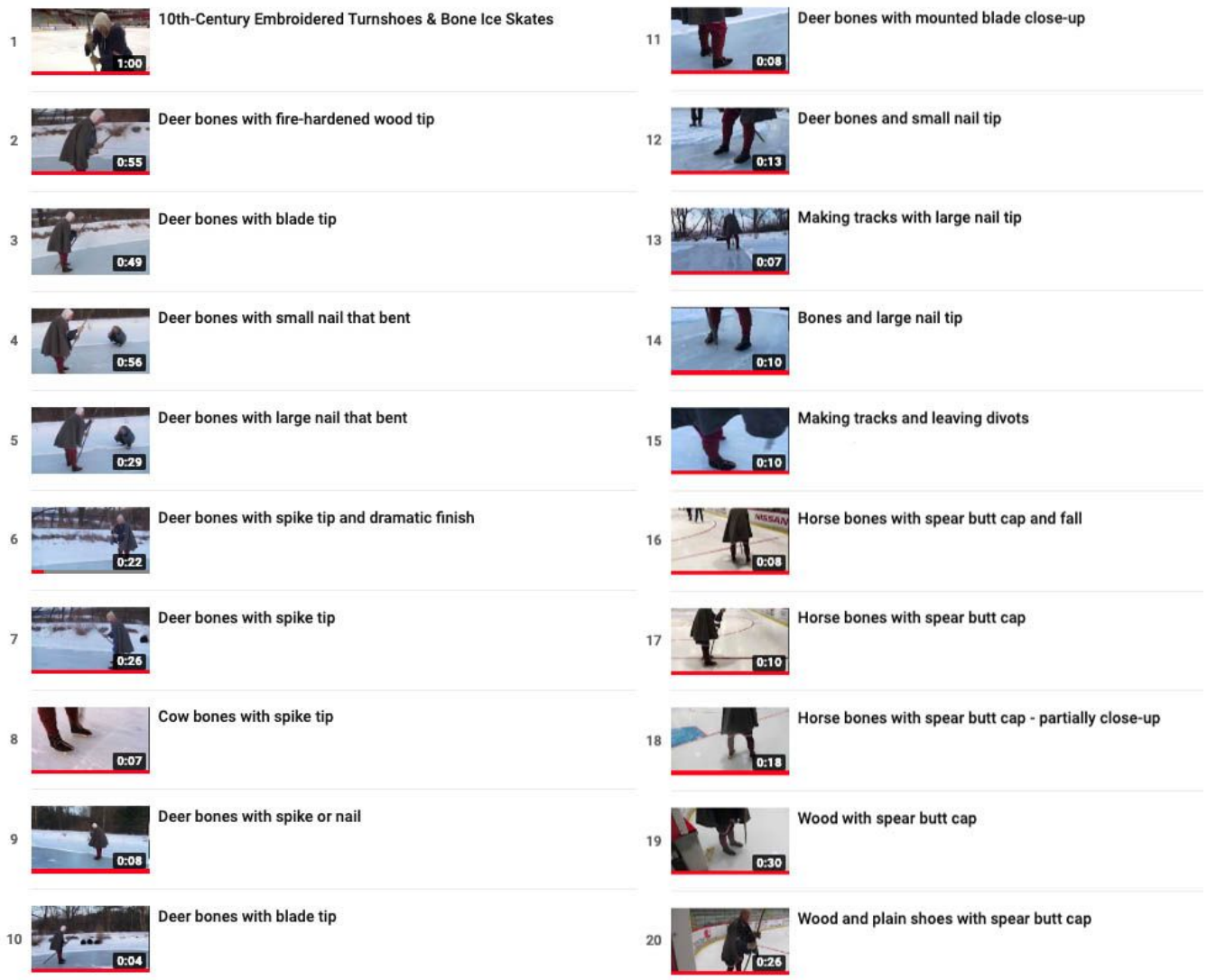
**Videos made during trial sessions can be viewed on a YouTube playlist at this URL:**
**http://tinyurl.com/yy6flg6w**



*Most archaeological presentations end with a sunset photo. This one is by Elska á Fjárfelli.*