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Modern stone tool users from northern Kenya emphasize mass and edge length in the selection of cutting tools

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The production and use of informal flake cutting tools played an essential role in foraging across human history. While much is known about the production of these tools, the attributes that facilitate their selection and use remain underexplored. This is because there remain few opportunities for the use of such tools in a traditional setting. The Daasanach of East Turkana, Kenya, maintain a tradition of stone tool production and use, affording the opportunity to investigate tool selection in a natural setting. Through interview and video documentation, we observed eight expert toolmakers complete butchery tasks, allowing us to link traditional technological knowledge governing cutting tool selection with measurable lithic attributes. Our findings reveal that factors such as edge angle, mass and grip significantly influence tool selection and cutting efficiency. These insights provide new perspectives on the functional relevance of informal cutting tools that are largely understood through experimentation. The outcomes of this study provide a venue for interpreting lithic variability in ancient contexts from the perspectives of traditional expert tool users. This research underscores the utility of detailed ethnographic studies to complement archaeological findings, enhancing our understanding of early human technological evolution.

1. Introduction

Since the Pliocene, hominins have been producing and using informal cutting tools to effectively extract tissue from animal carcasses [1]. This ability is linked to increased meat consumption, thus contributing to broader dietary change in the hominin lineage [2,3]. The behaviour requires the knowledge and skill to select materials and tools with task-appropriate properties [4,5]. However, our understanding of this topic has primarily focused on the selection of materials most suitable for tool production [5–8]. The capacity to select suitable cutting tools is equally important, as it influences one's ability to complete a given task. For example, hominins often accessed animal carcasses in areas with high predation pressure, where choosing the most suitable tool probably increased the chances of successfully acquiring meat [9].

Much of what is currently known on the issue is derived from variably controlled experiments that examine relationships between flake attributes and their ability to cut through various substrates effectively [10]. These studies show that edge angle, edge length, mass and thickness all serve to influence the cutting utility of a given tool [11]. More acute or narrower edge angles have greater cutting-edge efficiency in smaller flakes [12]. However, Key *et al.* [12] show that once the mass of a tool increases beyond a specific threshold (14.9 g), the influence of edge angle diminishes because flakes with more mass can impose greater force loads during cutting. Ergonomics also plays an important role in the utility of a flake, as one's ability to apply the necessary force during cutting relies on how well the tool can be gripped [10,11]. Individuals often risk cutting their hands or experience discomfort when gripping tools with a continuous lateral edge [13,14]. Whereas, thicker tools or those with a cortical surface provide surfaces that are easier to grip during use [15].

Although experimental studies are critical for identifying the morpho-functional characteristics that make cutting tools effective, whether tool users actively consider these attributes in the selection process remains understudied. Understanding how informal cutting tool attributes influence tool selection preferences would allow researchers to associate lithic variability with the functional needs and technical knowledge of the tool user. Existing ethnographic accounts of stone tool-making populations provide crucial insights as they focus on individuals who possess traditional knowledge about stone tools gained through the accumulated experience of using stone tools throughout their everyday lives. General observations from Australia and Papua New Guinea stress how tool selection is often dictated by the task at hand, with considerable flexibility in using any suitable edge. These summary observations emphasize how task requirements intersect with raw material properties, ergonomics, size and shape to influence selection choices [16,17]. Observations also explore how aspects like working edge angle and size influence selection for specific tool classes and how they influence blank selection/rejection [18–22]. A range of socio-ecological factors, including age [23], distance to source and acquisition costs [24], and personal preference [22], also contribute to the process of stone tool production, selection and use.

Despite the value of these studies, there remains a disconnect between ethnographic classifications and attributes commonly used to describe stone tools, illustrating the need for more explicit connections between the traditional knowledge of modern tool makers and stone tools [25]. The majority of ethnographically documented stone tool-using populations no longer retain use of the technology at present, except for a few specialist activities [23,26,27]. Few studies to date explore the relationship between the attributes of informal cutting tools that guide tool selection and the attributes of those that are used in task activities. As pointed out by Gould [28], the knowledge guiding selection can be easily lost if stone tool attributes are studied on their own.

Here, we present a rare study of the production and selection of informal cutting tools by the Daasanach of East Turkana in Kenya and Ethiopia, who actively maintain a tradition of using stone tools for a range of cutting tasks from animal butchery to woodworking [29]. Through four separate demonstrations, we asked eight expert volunteers with extensive experience to make and use stone tools to butcher medium-sized goats. By doing so, we observed the process through which stone was procured and lithics were produced and selected in order to complete a common task. By combining observation with structured interviews and lithic analysis, we characterized the production, selection and use of informal cutting tools, allowing us to link traditional ecological knowledge surrounding stone tool use with lithic variability. Subsequently, this allowed us to link techno-functional attributes known to influence cutting-edge efficiency with the process of cutting tool selection. The insights gained through this study of modern tool users provide new insights to assist in the interpretation of lithic variability in ancient contexts.

2. Materials

(a) Study population

The Daasanach are an ethnic group of pastoralists who live in a remote desert region of northern Kenya along the eastern shore of Lake Turkana [30]. While the Daasanach are not isolated from Kenya's broader economic system, herding and the maintenance of livestock are the primary subsistence practices of this community. As a result, a large proportion of the Daasanach community continues to maintain traditional practices associated with the pastoralist lifestyle, including the use of stone tools. Specifically, community members utilize informal core and flake technology to produce sharp cutting edges for a range of tasks, including butchery, woodworking and hidescraping. The use of stone tools has declined within the population due to increased access to metal over the last 30 years; however, herders continue to engage in the practice when they are grazing livestock in remote pastures and access to knives is scarce, especially for younger community members. As a result, the butchery of animals, particularly goats and sheep, using stone tools, remains a common practice among experienced herders. During production, community members do not shape their tools, nor do they create flakes on an as-needed basis. Instead, they produce many cutting tools in a single episode of production, which they then evaluate and select for use. Observing this process provides a rare opportunity to understand the relationship between task activities and the attributes of informal cutting tools influencing selection choices as seen from the perspective of experts.

(b) Tool use and butchery demonstrations

We conducted four separate actualistic observations of a common task, where pairs of two experienced tool users were asked to acquire, produce and use stone tools to butcher a medium-sized goat. All participants were Daasanach male herders who, through interviews, were determined to have extensive knowledge and experience associated with the production and use of stone tools. During the demonstration, we did not instruct the participants on how to make, use or select the tools. Instead, each participant was simply asked to make and use stone tools to complete the task according to their own knowledge and experience.

Following the recommendation of the participants, the demonstrations were conducted in a remote location along the bank of the Loborana River to ensure access to suitable stone materials and minimize interference with the daily operations of homesteads (figure 1A,B). The demonstrations were broken down into four sequential phases: acquisition, production, selection and use. Each participant was separated during the first two phases to ensure that the acquisition, production and selection of lithic materials were not influenced by the presence of the other participant. During the acquisition phase, participants were asked to collect raw materials in the surrounding area that they would use to create the tools for the butchery. Participants could collect as much or as little material as needed and were not limited in how long they could spend searching.

During production and selection, participants were asked to create and select the cutting tools that they would use during the butchery. Participants were not restricted in how many cutting tools they could make or select. During the use phase, the participants would work together to butcher a single medium-sized goat (figure 1D–F). The only instruction that was given was that they would only use the tools they had produced themselves. Beyond that, the participants were free to carry out the task as they preferred. All demonstrations were recorded using two Sony Alpha 7 HD video cameras.

(c) Interview structure

Each participant was asked 18 questions to assess their experience producing/using stone tools and their understanding throughout the phases of the demonstration. All background questions were asked before the start of the demonstration. Conveniently, the phases of acquisition, production, selection and use created natural stopping points to interview participants about each phase, which allowed us to minimize interview fatigue from asking too many questions at once. The participants were asked questions separately so that they would not influence each other's answers. The materials and/or stone tools produced were present, so specific features of the objects could be referred to when necessary.

The interviews were administered in Daasanach with the aid of two translators at the site of the demonstration. Both translators were fluent in both English and Daasanach to mitigate any issues associated with language barriers. The translators had been working with the authors on documenting, observing and discussing stone tool production among the Daasanach for multiple years. As a result, the translators were experienced with the concepts of stone tool use that we were trying to study. This ensured that all the concepts covered in the interview were accurately conveyed to the participants. Institutional approvals for interviews were obtained from the University of Nebraska–Lincoln before data collection began, and informed consent was gained from all community members who participated.

(d) Observation of lithics and collection after use

All created lithics were collected and assigned to the participant who produced them. Continuous observation from start to finish allowed us to assign each tool to one of four distinct selection stages (figure 2): (1) artefacts discarded and not considered further after production; (2) detached products that were set aside during and after production for further inspection, but not selected for use by the participant; (3) those identified from the initial selection as tools they would use; and (4) those that were ultimately used in the goat butchery and associated activities. To ensure that lithics could be confidently associated with a specific stage of selection, lithics from each stage were collected as soon as it was clear that they were no longer considered for future use. Lithics belonging to stages 1 and 2 were assigned after each participant had finished selecting the cutting tools that he intended to use. Stage 2 lithics could be differentiated from stage 1 because participants often handled or set them aside for further inspection, whereas stage 1 lithics were not touched after their production. Stage 3 lithics were easily identified because participants actively identified them as pieces they wanted to use. Each stage 3 lithic was labelled with a unique identifier (UID) in a bright-coloured metallic marker to facilitate identification throughout the butchery (figure 1C). Every time a tool was picked up for use, the time, the participant, the UID and what it was being used for were recorded in a field notebook, and these instances were likewise documented via video recording. This allowed us to track the use of each tool throughout the demonstration. Following the demonstration, all the used lithics were placed into individual plastic bags and assigned a barcode number so that each lithic and all associated information would be entered into a database.

3. Methods

(a) Lithic analysis

To establish connections between lithic attributes and the tool selection process, we analysed the 309 lithics that possessed a cutting edge of 1 cm or greater following standard archaeological methods (see electronic supplementary material). Each lithic was classified as an angular fragment, complete flake, broken flake, core or core fragment. Lithics were also characterized using common archaeological measures associated with the functional efficiency of cutting tools, including raw material type, mass, cutting edge angle, cutting edge length, proportion of cortex and maximum thickness. Mass serves as an important variable in understanding tool selection, as it has been shown that cutting efficiency is directly influenced by the amount of force that can be applied during use [12,31].

Cutting-edge angle is also considered an important variable that influences the ability of tools to complete tasks, as it is often used as a proxy for sharpness [12]. Acute angles have been shown to improve cutting-edge efficiency in small tools [11], yet overly acute edges have been demonstrated to break under stress [32]. Conversely, the force required for effective cutting increases as the edge angle becomes more obtuse [33]. For each of the lithics in this study, the area of the viable cutting edge was

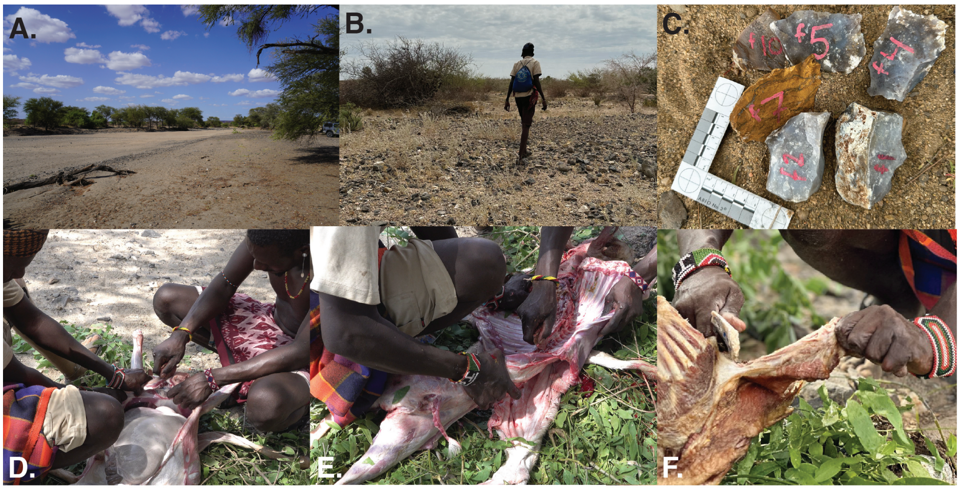

Figure 1. A montage of photos showing context. (A) The dried river bed where the demonstrations took place. (B) A participant searching for raw material. (C) Examples of lithics selected for use and labelled for identification throughout the butchery. (D–F) Documentation of the use of core and flake technology during the butchery task.

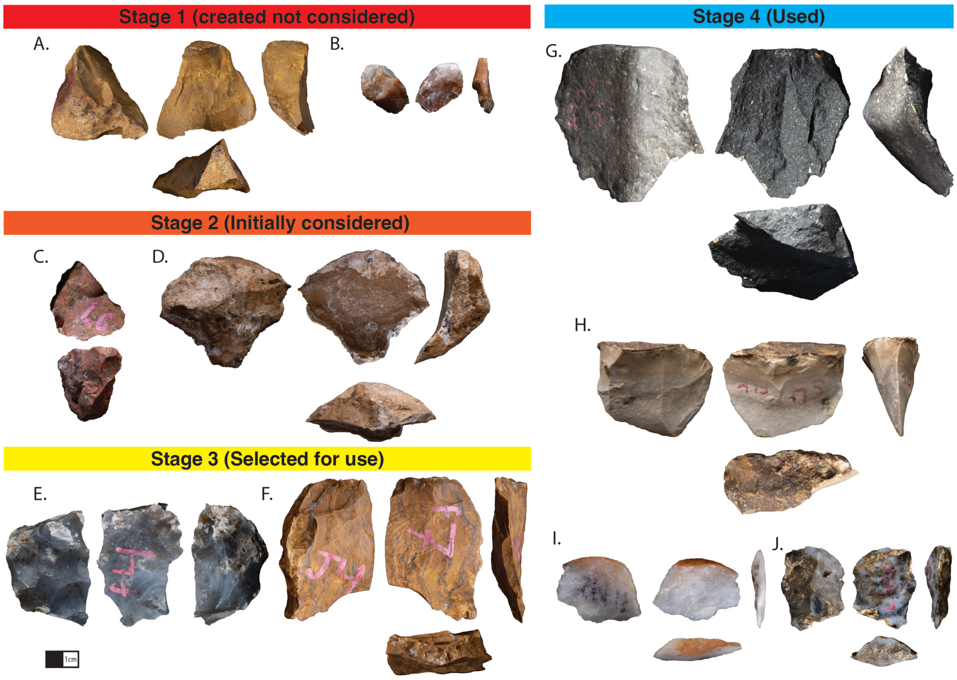

Figure 2. Examples of lithics from different stages of selection and use. (A) Chert flake produced but not considered after initial production. (B) Quartz angular fragment not considered after initial production. (C) Chert core that received only initial consideration. (D) Chert flake set aside for further consideration. (E) Chalcedony core selected for use. (F) Chert flake selected for use. (G) Basalt flake used for disarticulation and chopping through bone. (H) Quartzite flake used for the entire butchery task. (I) Quartz flake used for almost the entire butchery task. (J) Chalcedony flake used for skinning and organ processing.

identified based on the presence of an edge angle of 90 degrees or less. The Dibble caliper method [34] was used to record edge angles at 1 cm intervals across the length of the cutting edge. The average edge angle was then calculated by taking the mean of all recorded angles. This method also provided the basis for estimating the cutting-edge length of each lithic.

Cutting-edge length is positively correlated with increased cutting efficiency [10]. This is because longer cutting edges increase the total amount of edge that can be drawn over the substrate with each stroke, while also enabling greater velocity of the cutting stroke. The cutting-edge length of a lithic was defined as the total centimetre length of edges that formed a 90-degree angle or less. Given that edge angle measurements were taken at 1 cm intervals along the cutting edge, the total length of the cutting edge was calculated by summing the total number of edge angle measurements recorded for each lithic.

Cortex is the rough, weathered exterior of the stone [31]. While cortex itself has not yet been linked to any direct improvement in cutting efficiency, it is an important variable from an ergonomic perspective [11]. The smooth, blunt surface provided by the cortex can be easily gripped, permitting the optimal application of force from the hand to the lithic's cutting edge. Thus, the presence of cortex may influence the selection of any given tool. The representation of cortex is coded as a proportion of the total surface area. This is visually estimated by the analyst at five intervals: 0%, 25%, 50%, 75% and 100%.

Maximum thickness was recorded in millimetres at the midpoint of the artefact along the axis perpendicular to both the length and width measurements. Although the maximum thickness of a tool will scale with mass, the thickness of a tool is important for maximizing grip and the application of cutting stress [11]. While thin objects may be useful for precision cutting, thicker objects likely provide a greater amount of material that can be gripped.

(b) Statistical analysis

We used a Bayesian generalized linear model with an ordered logit error structure and a cumulative logit-link function to determine the influence of specific lithic attributes on participant selection choices [35]. An ordinal model allows us to express the response variable as a series of ordered categories, such as those that characterize the selection stage. Specifically, the model estimates the cumulative proportion of lithics within each selection stage and the influence of the predictor variables on this proportion. For example, if tool mass positively affects whether a tool will be used (stage 4), then increasing mass will increase the proportion of tools selected for use.

In the model, the selection stage was the response variable, with cutting-edge length, mass, maximum thickness and cortex defined as predictor variables. We only included lithics that possessed a cutting edge length greater than zero ($n = 307$). We standardized mass by taking its cube root, given that it varies in three dimensions, whereas linear measurements, such as length, can only vary in one dimension. This is common practice in archaeological research examining the relationship between linear dimensions and mass [36]. Given previous literature on the relationship between mass and cutting-edge attributes, an interaction term between mass and edge length and mass was included in the model. Given the lack of understanding between these variables and selection, uniform, regularizing priors were used for each predictor variable.

To investigate the influence of the individual participants on selection choices, we developed a second model with the same structure as model 1 but also included the participant ID as a varying intercept as a predictor variable. This allowed us to investigate if the patterns elucidated in model 1 were driven by any single individual or were reflective of group-level preferences. The participant variable was included as an index variable with uniform regularizing priors. The priors were designed (see electronic supplementary material) to allow the effect of the participant variable to vary according to each individual. The details of the individual model can be found in the supplementary online material.

The model was designed, coded and implemented in R (v4.3.2) using the Rethinking package [35,37]. Each model was run with four Markov chains for 10 000 iterations each. Diagnostic analyses examining model convergence were used to investigate whether the Markov chain effectively sampled the distribution. No issues were detected. Trace plots, Rhat values, the number of effective samples and tables of marginal distributions summarizing the marginal distributions of each model are provided in the electronic supplementary material and available online.

4. Results

During the material acquisition phase, the participants selected five distinct rock types: basalt, quartz, chalcedony, fossilized wood and quartzite. The types of rock chosen varied between individuals, and not every participant chose the same range of material types (electronic supplementary material, table S1). As a result, the influence of raw material type on selection could not be assessed. During production, the participants created a total of 445 lithics. The number of pieces created varied considerably between participants, ranging from as few as nine to as many as 137 (electronic supplementary material, table S1). Of those initially created (stage 1), only 220 lithics were considered beyond their initial production. One hundred and sixteen of these lithics were set aside for further inspection (stage 2). Only 66 of the pieces that reached stage 2 were chosen as tools that would be used to complete the butchery task (stage 3). During the interview, participants would distinguish between lithics in stage 3 that would be useful for specific tasks, such as skinning, slaughter, ligament cutting, quartering and cutting between joints. Across the eight participants, only 32 stone tools were actually used to complete the butchery task (stage 4). Participants varied in the number of pieces they considered at each stage and selected for use (electronic supplementary material, table S2). Despite making functional distinctions, participants showed a tendency to use the same tool instead of switching between them. Three of the eight participants used a single tool for the majority of the butchery possess. In all other cases, switching between tools was infrequent but often corresponded with specific phases of the butchery process requiring specific functional attributes of the stone (discussed below).

The participants produced a range of archaeological types, including angular fragments, broken flakes, complete flakes, cores and core fragments. The participants did not distinguish between these various archaeological types, and as a result, participants selected and used tools representing the full range of typological categories included in this study. Nevertheless, there was a clear preference for complete and broken flakes for use. While these two categories comprise approximately 50% of all lithics produced, they represent more than 95% of all objects selected as suitable for use (stage 3). Complete flakes represent the vast majority (85%) of the lithics that were used during the butchery task (stage 4; figure 3). On average, complete flakes tended to possess more cutting-edge length than angular fragments, broken flakes and core fragments. Cores only possessed 0.5 cm more cutting edge than complete flake but were also substantially greater in mass (electronic supplementary material, table S1).

When the lithics were compared according to their selection stage, substantial overlap in their morpho-functional attributes is observed (figure 4; electronic supplementary material, figure S1). This indicates that there are substantial similarities in the lithics found between each group. This range of overlap is partially because the participants almost always produced far more material than they used. In fact, only one of the eight participants used every tool that he created. In some cases, participants even remarked that they had not picked up every single adequate tool and could go back to the lithics they had not considered for use to collect more suitable pieces if needed.

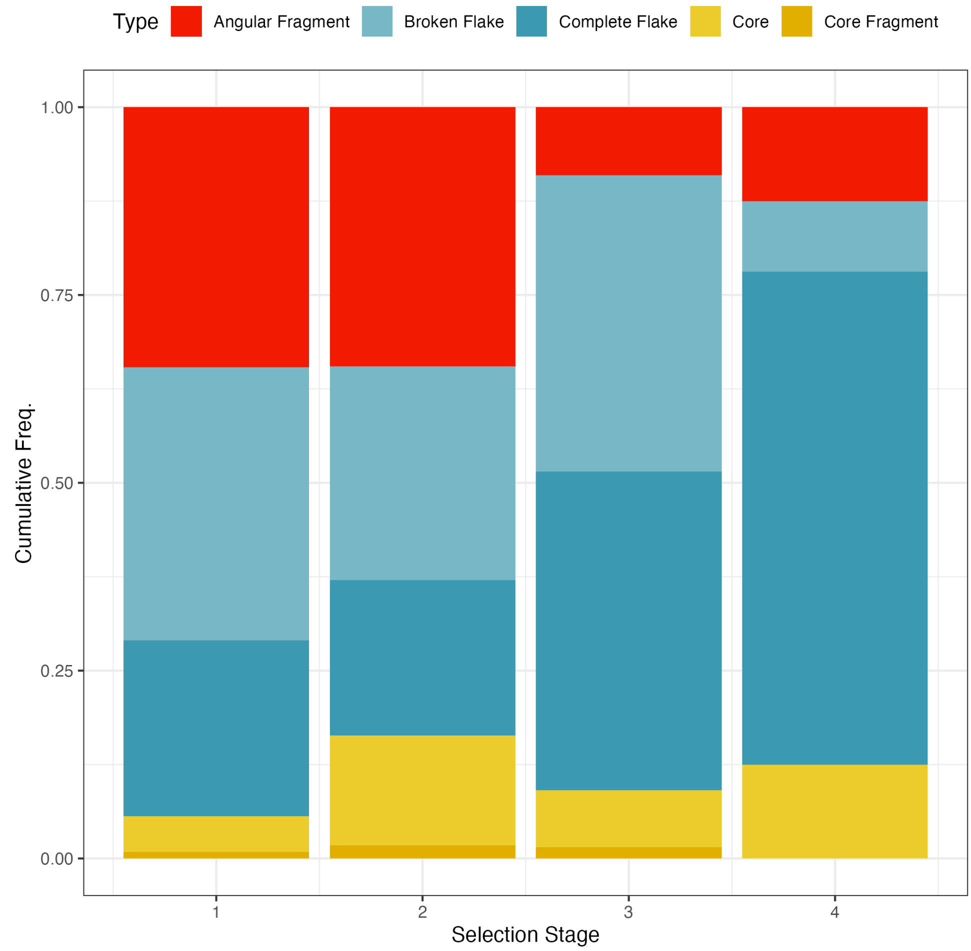

Figure 3. Cumulative frequencies of archaeological types according to selection stage. (1) Produced but not considered. (2) Set aside for further consideration. (3) Selected for use during the butchery task. (4) Used during butchery tasks.

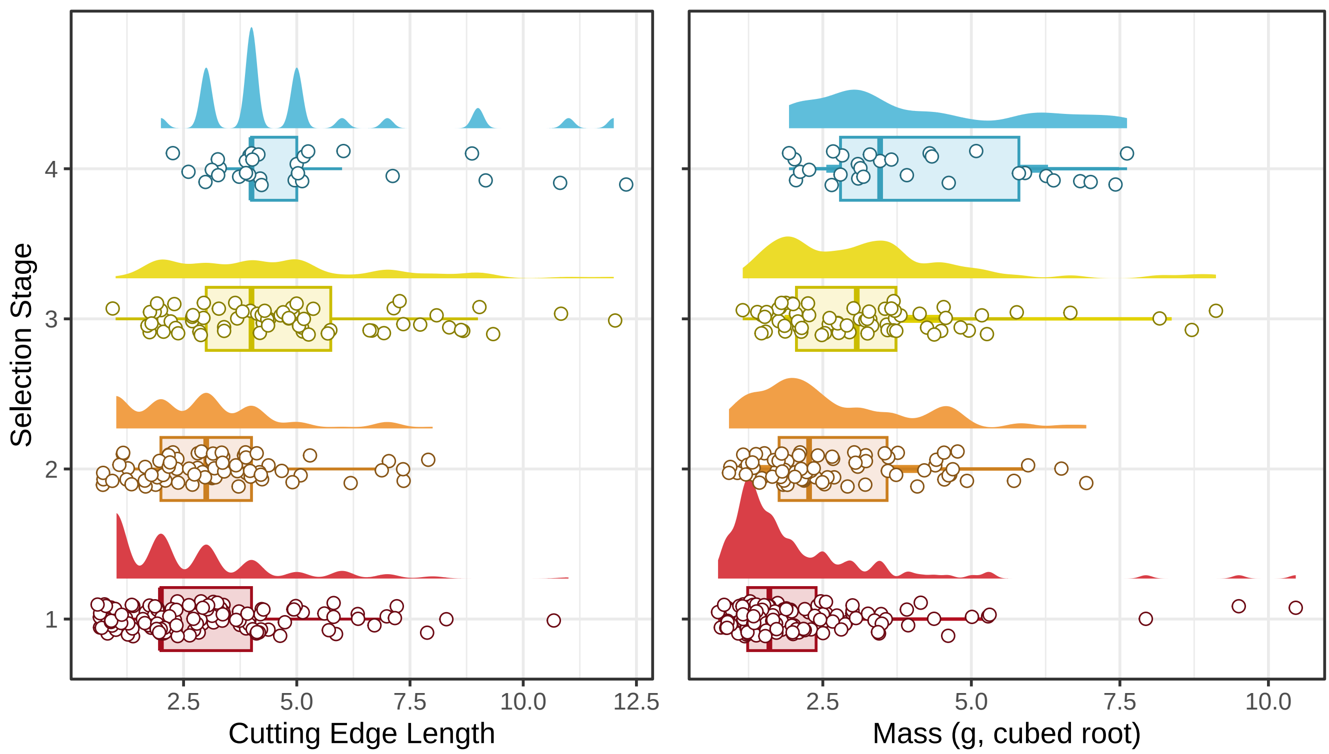

Figure 4. Rain cloud plots showing the distribution of cutting edge length (left) and (right) mass values for each stage of selection. In both cases, there is selection against the lithics with the shortest cutting edge and least mass at each selection stage.

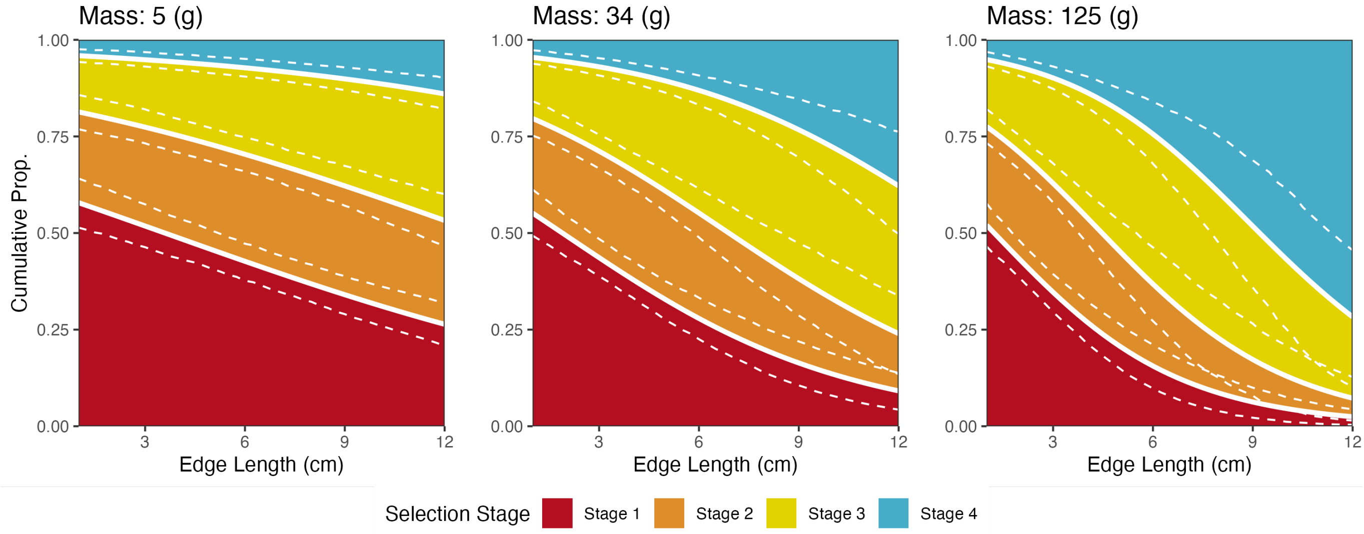

Figure 5. Posterior predictive distributions showing the interacting influence of mass and cutting-edge length on tool selection. Each colour represents the predicted proportion of tools present in each stage for any given value of edge length along the *y*-axis. The white lines represent the predicted boundaries or cut-points for each stage of selection, and the dashed lines represent 95% compatibility intervals for each of these cut-points. When mass is 5 g, the proportion of lithics in stage 4 (used) and stage 3 (suitable for use) is small, regardless of edge length. However, as mass increases, the influence of cutting-edge length on the likelihood that a tool is used becomes stronger. These three values were chosen to emphasize how the chances of a lithic being chosen change from when it is very small to when it is the median mass of a lithic in stages 3 and 4, to when its mass is on the upper end of those chosen.

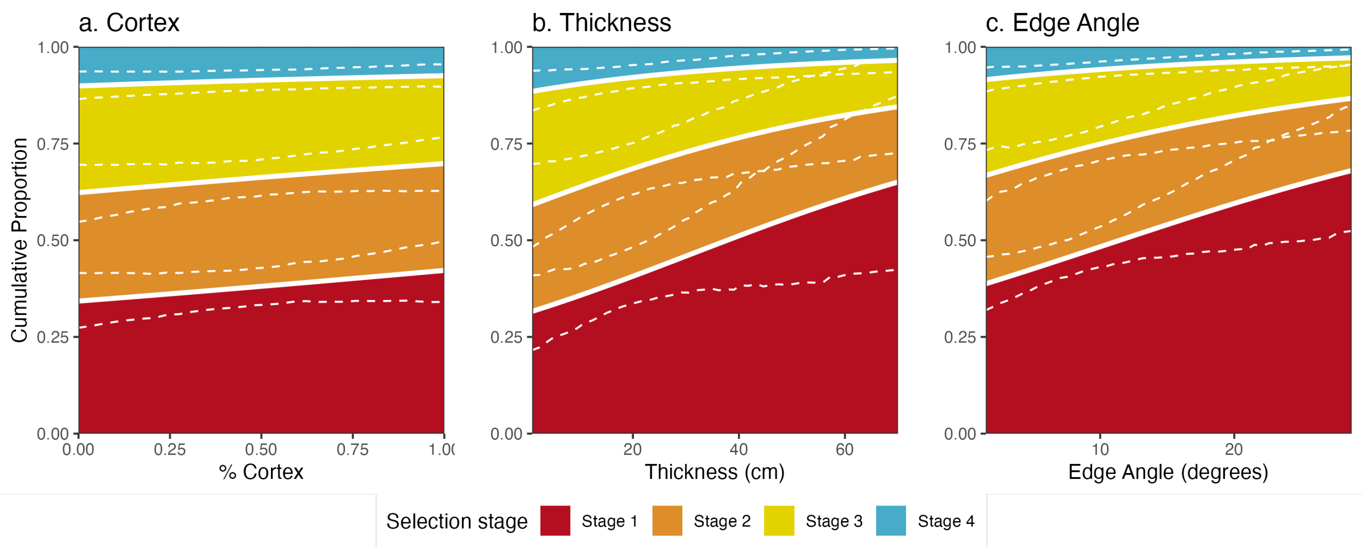

Figure 6. Posterior predictive distributions for the influence of cortex, thickness and edge angle on the selection stage.

Although participants selected lithics that varied widely in their morpho-functional attributes, the ordinal regression model revealed consistency in the attributes that influenced tool selection choices. Of all the variables considered, mass and cutting-edge length had the greatest influence on selection. 50% of the lithics that were not considered for use beyond their initial production (i.e. stage 1) are pieces with a mass of less than 5 g and a cutting-edge length of 2 cm or less (figure 4). Although some lithics bearing these attributes were set aside for further consideration (stage 2), there was a preference for lithics with greater-edge lengths at each stage (figure 4). In comparison with stages 1 and 2 (median mass: 6.1 g), tools that were used during the task (stage 4) were greater in mass (median: 41.6 g). Moreover, cutting-edge lengths of tools selected for use (stage 3) ranged from 2 cm to 11 cm (median mass: 28.9 g). Only a single tool with a cutting edge less than 4 cm in length was used during the butchery task (stage 4; median mass: 45.2 g).

Our analysis also revealed that considerations of cutting edge and mass were not independent of each other but instead formed a strong interaction (figure 5). Tools with smaller amounts of mass were less likely to be considered, selected, or used, regardless of the length of their cutting edge. As shown in figure 5, the ordinal model shows that when the mass of a tool is below 40 g, cutting edge length only increases the likelihood of selection for use (stage 3) or the ultimate use of an artefact (stage 4) by a maximum of 10% to 15%. As the mass of the tool increases to 34 g (the median mass of tools in stage 4) and greater, increasing the cutting-edge length also has a larger influence on the likelihood that a tool will be selected (by up to 65%, figure 5.). Interviews with the participants indicated that longer cutting edges were important for specific aspects of the butchery, such as slaughter and cutting through ligaments during the disarticulation of various joints. While there was only one reference to the size of the tools (see below), participants consistently explained that the tools they selected had 'strong edges' and would fit well in the hand during use.

Moreover, tools with a mass greater than 300g and a cutting-edge length greater than 7 cm have a 75% chance of being used during the butchery task. Objects of the same mass but with a cutting-edge length of 10 cm or greater have a 90% chance of being selected for use. Although tools with such attributes were infrequently created, observations of the butchery tasks showed that preference for larger tools with longer cutting edges corresponds to specific phases during the butchery that required heavy-duty chopping to cut through cartilage and bones, such as the sternum and pelvis during disarticulation. Participants also considered the angle of the cutting edge when selecting tools. Edge angle has often been used as a proxy for edge sharpness, and some have argued that more obtuse edge angles are less efficient [12]. In line with this notion, lithics with more acute average edge angles had an increased likelihood of being considered (stage 2) and selected for use (stage 3) by up to 25%. However, once selected as a usable tool (stage 3), the mean edge angle has little influence on whether a tool that was selected for use was ultimately used (figure 6c). This pattern of selection and use is surprising given that participants were frequently observed visually and tactilely inspecting the edges of created tools during the selection process.

Although participants discussed the fit of these tools in their hands during selection, attributes related to ergonomics had little influence on selection. Even though cortex provides a smooth exterior surface that can be comfortably gripped during use [11], none of the participants exhibited any preference for objects with or without cortex. This observation is reflected in the ordinal model, which shows that the amount of cortex has little influence on the likelihood a piece will reach a specific stage of selection (figure 6a). Similarly, while thicker stone tools have more volume that can be used to obtain a better grip [11], the results of the model reveal that thinner tools were more likely to be considered and/or selected for use. However, as with edge angle, the thickness of the tool had little influence on whether it was actually used. These results are consistent with observations where participants were observed using pieces with a wide range of thicknesses (stage 4; min: 0.4 cm, max: 4.7 cm). However, the model also reveals that there is a wide range of uncertainty surrounding the influence of thickness on selection, which increases as lithics become thicker (figure 6b).

5. Discussion

Stone tools serve as one of the primary lines of evidence used to understand the behaviours of past people. While much is known about aspects related to the production and efficiency of cutting edges, research on selection has largely focused on evaluating raw material properties that influence fracture predictably [12], with less focus on understanding the attributes that influence artefact performance characteristics. Of the studies exploring the relationship between lithic attributes and task performance, ethnographic examples are scarce and the majority of experimental studies are conducted by modern researchers and participants from industrial societies [12].

Working with the Daasanach offers a unique opportunity to link the selection preferences of traditional stone tool makers with the tools they produced and used. The fact that informants produce an abundance of sharp cutting edges from which to select a subset for use, with yet a smaller subset used, provides a uniquely detailed perspective from which to evaluate the selection of informal cutting edges by modern stone tool users. The wide range in variability of the attributes and raw materials of the lithics selected for and used highlights a wide range of tools that can be used to complete butchery tasks. Such diversity highlights the functional flexibility of informal cutting tools.

Some of this diversity is probably explained by the individual preferences and skills of the participants. One individual mentioned that his near-exclusive selection and use of quartz was because he had developed a preference for that material. However, the diversity of materials selected and variations in the number of lithics produced made it difficult to investigate the role of individual preferences with only eight participants. Nevertheless, there was a great deal of consistency between the participants that allowed us to explore the link between lithic attribute variability and the process of artefact selection and use.

Limited participant sample size is a common issue in ethnographic [15] and experimental studies [38]. Such small samples can be seen as limiting the capacity of our results to generalize beyond the participants included. Continued study of stone tool selection within the Daasanach community will further shed light on the diversity of individual preferences while increasing the overall robustness of the identified trends revealed by our analysis. Nevertheless, there is a fair degree of consistency in the selection patterns observed by each participant, which appears to relate to the functional suitability of the tools for specific phases of the butchery process.

Although participants, during the interview, identified lithics that would be useful for specific functional tasks (e.g. disarticulation and skinning), there was a tendency for participants to use a single tool instead of switching between multiple tools. This could be explained by the substantial overlap between lithics of various selection stages, indicating that there is a wide range of lithics that are suitable for butchery. This is emphasized by the fact that some of the participants stated that suitable tools could probably be selected from those that they had not considered (stages 1 and 2). Thus, the incentive to change tools throughout the butchery was low as it was likely that the stone that was already being used was sufficient to complete the task.

Thus, while knowledgeable stone tool users can identify lithics that are more suitable than others for specific tasks, it does not necessarily imply that such tools will be used in that manner. Moreover, such observations could also highlight differences between verbalized knowledge and how it is applied in practice [39]. The participants of the study began using stone tools for cutting tasks as children. As a result, their selection criteria developed through years of experience and require a consideration of a range of attributes simultaneously. While lithics useful for specific cutting tasks may be easily recognized, their selection preferences may not be so easily broken down into a list of traits or attributes.

This could explain the discrepancies between the interviews, ergonomics and lithic attribute data documented in the study. Participants visually and tactilely inspected individual pieces before use but also discussed how the fit between the hand and the tool was important for tool selection. However, the ordinal model revealed that the proportion of cortex and thickness did not influence the selection process. This may indicate that individuals did not consider specific attributes when assessing the ergonomics of the tool. This is particularly the case when it is possible to modify the tool to achieve better grips during use. One participant was observed blunting the sharp edge of a tool to prevent it from cutting his hand during use. Moreover, given that increasing the mass of the tool can also increase the amount of volume available to grip, it may be that the ergonomic advantages of selected tools are derived solely from their mass. However, the ergonomics of stone tools are probably more complex than can be understood through single lithic attributes such as cortex and thickness. For example, although the Daasanach do not distinguish between typological categories used to describe the archaeological record, they exhibited a preference to select (stage 3) complete and broken flakes and predominantly use complete flakes during butchery (stage 4). Archaeological research suggests that complete flakes possess more cutting-edge than other typological categories [40]. While the complete flakes produced tended to possess more cutting-edge length than most other technological categories, there is a considerable amount of overlap in cutting-edge lengths across technological categories. It is thus likely that this preference is not solely driven by edge length, and there may be some ergonomic benefit to the morphology of flakes over other archaeological types that was not captured in the attributes considered in this study.

Nevertheless, the results of the statistical analysis reveal consistencies in the morpho-functional attributes of the lithics chosen by Daasanach toolmakers. The fact that participants selected longer cutting edges (>4 cm) and with narrow edge angles demonstrates that edge characteristics play an important role in the selection process. These results are consistent with experimental research that shows that edge length allows tool users to cut more substrate per stroke while also increasing the velocity of the stroke [11]. Narrow edge angles form a sharper edge and allow for more precision while requiring less force during cutting [12].

Moreover, the interaction between edge length and mass shows that mass, in addition to cutting edge characteristics, plays an important role in decisions about artefact selection. The fact that this interaction has a substantially stronger influence on the selection of tools than the average edge angle indicates that mass is a more important characteristic. From a functional perspective, mass increases cutting efficiency simply because more force can be applied to larger tools with less risk of the tool's edge breaking [12]. The preference for mass over edge angle is probably related to the fact that acute edge angles only improve cutting efficiency when cutting tools are relatively small [11]. However, once lithics increase beyond an average mass of 14.9 g [11], the capacity to apply greater force loads diminishes the influence of edge angle on cutting efficiency. Most of the tools selected and used by the participants are greater than this size threshold reported by Key *et al.* [12]. In this light, the strong interaction between mass and edge length indicates that the utility of a cutting tool is not simply based on edge characteristics, but on one's capacity to apply force to it during use. The prioritization of mass over edge angle, therefore, allows Daasanach toolmakers to use tools that are less likely to break without compromising cutting efficiency. This pattern of selection proved to be particularly important at specific stages of the butchery, such as cutting through the pelvis and sternum, where a combination of force and cutting capacity is required.

(a) Archaeological implications

Modern toolmakers like the Daasanach cannot stand in as a direct analogue for past toolmakers across human evolutionary history. Nevertheless, the relationship between commonly studied archaeological attributes and the selection patterns revealed by this study provides a new avenue of discussion regarding the links between behaviour, archaeological patterns and broader evolutionary trends. Specifically, our results are particularly relevant to the Plio-Pleistocene, where most of the record consists of informal core and flake technology. The fact that the Daasanach used only 10% of the total number of lithics produced is consistent with observations on post-production selection among stone tool-using populations in Australia [15,41]. How modern stone tool populations produce and select informal cutting tools thus challenges the long-standing perception of how ancient toolmakers made cutting tools [42]. Considering modern tool users, it becomes equally plausible that hominins were producing many tools that were then selected from, as opposed to producing the 'ideal' flake as needed. Given this possibility, understanding the production and selection strategies of ancient hominins becomes all the more important, as the low proportion of lithics used by the Dasaanach and other ethnographic examples [41] implies that a substantial portion of the recovered stone tool archaeological record was never actually used.

The patterns of selection revealed through this study allow an examination of the behavioural significance of archaeological patterns from a functional context [43]. Overall, the diversity of morpho-functional attributes exhibited by tools chosen for use indicates that there is a wide range of lithic variability that is acceptable for butchery. While this variability indicates that there may be a wide range of archaeological forms that are associated with a single task [44], it also emphasizes the functional flexibility associated with informal core and flake technology [45]. This flexibility is further emphasized by the fact that some individuals did not need to switch between tools during the completion of the task. This flexibility may have allowed hominin toolmakers to efficiently produce tools to use in a vast range of contexts to access and process animal tissues [46,47]. This may have been an important factor that allowed core and flake technology to become as prolific as it did in the Plio-Pleistocene hominin repertoire [48].

The Plio-Pleistocene record is characterized by a preponderance of small flakes that are argued to have played an important role in the foraging behaviours of hominin tool makers [46,49,50]. However, it is argued that meat consumption during this time was limited to the scavenging of previously consumed carcasses [9,51], which would have been facilitated by small cutting tools ranging from 5 g to 50 g [52]. However, the participants' prioritization of tools with longer cutting edges and greater mass, in our study, contrasts with this idea. Moreover, while smaller tools would have been efficient for lighter duty tasks, such tools may have been limited in their capacity to cut through bone. If hominins produced and selected lithics in the same fashion as the Daasanach, then it could be that larger flakers were selected out from the abundance of small flakes that were also created. If this is the case, then it would imply that a proportion of the small flakes found in the Plio-Pleistocene record may be simply the byproduct as opposed to the intended end-product. However, it is important to keep in mind that the need to prioritize cutting tools with specific attributes is undoubtedly task dependent. While our study focused on butchering an entire goat carcass, Oldowan tool makers are thought to have often scavenged for meat [51]. It is, thus, unclear if hominins at this time would have needed larger flakes to process whole carcasses as humans do. In addition, Oldowan tool makers probably engaged in woodworking and plant processing with cutting tools [53–56]. Therefore, it would be important to investigate how these selection criteria change under varying cutting tasks with different substrates.

Nevertheless, the strong selection for larger tools with longer cutting edges observed in this study provides an interesting point of discussion for technological change in the early Stone Age. The appearance of large flake production around 1.76 Ma is often associated with shifts in technological strategies associated with the production of large cutting tools [57,58]. Moreover, large flakes also benefit hominin tool users, given that they possess more cutting edge and can be maintained for longer durations [45]. However, their importance for specific cutting tasks during whole carcass processing, such as splitting the rib cage and pelvis during butchery, highlights the functional relevance of larger flakes. In this light, the emergence of larger cutting tools may have also served to accommodate increased emphasis on the processing of larger, more complete carcasses that are associated with the increases in carnivory and earlier access to animal carcasses documented at this time [59].

Within the context of economization, hominins are argued to balance the trade-off between the functional needs of lithic technology and the amount of stone that is available for utilization. While archaeologists often emphasize the need to maximize the amount of cutting edge per unit of raw material, there is also a great deal of variation in how hominins economize stone. The preference for more cutting-edge but also more mass indicates that the most efficient utilization of stone may not have been the most suitable from the perspective of the Daasanach tool selection. This may indicate that the functional needs of the tool user may have sometimes been at odds with the most efficient economization of stone. However, the Daasanach live in a region where stone suitable for use is abundant, which may reduce their need to consider trade-offs between tool economization and tool selection. As a result, there is little incentive to economize stone efficiently given that there is always an opportunity to retrieve more [60,61]. Therefore, the variation that is observed in how much cutting-edge is generated through stone tool production across human evolution may also relate to different environmental contexts.

6. Conclusion

The Daasanach are one of the few remaining stone tool-using populations on earth and thus represent an unheralded opportunity to gain further insights from a living population of experienced stone tool users. Their unique practices and perspectives have an authenticity and ecological relevance that extends beyond the confines of archaeological analyses and controlled experiments. As such, they provide a useful basis with which to evaluate common archaeological assumptions at the heart of lithics research. This study provides valuable insights into the complex relationship between lithic attributes and tool selection among traditional tool users, shedding light on the functional flexibility and task-specific requirements associated with the use of informal core and flake technology for animal butchery. While these findings underscore the wide variability in tools chosen for use, they also reveal a clear selection preference for specific morpho-functional attributes. From an evolutionary perspective, the study offers insights into the potential implications for understanding lithic variability in ancient tool assemblages. Daasanach selection preferences challenge conventional notions of maximizing cutting-edge per unit mass, suggesting that functional requirements and environmental contexts may have driven variability in stone tool economization across human history.

Ethics. All participants gave their consent to be included in this research. This work was conducted in compliance with regulations outlined by the University of Nebraska-Lincoln Institutional Review Board (IRB Number: 20180518256EP) as well as those outlined by the National Museum of Kenya in accordance with guidance outlined in research permit NACOSTI/P/25/4174504.

Data accessibility. An archived release of the code for the analysis and creation of figures included in the paper and supplementary material is available on Zenodo and the author's github page [62].

Supplementary material is available online [63].

Declaration of AI use. We have not used AI-assisted technologies in creating this article.

Authors’ contributions. J.S.R.: conceptualization, data curation, formal analysis, investigation, methodology, software, validation, visualization, writing—original draft, writing—review and editing; M.J.D.: conceptualization, funding acquisition, investigation, methodology, project administration, resources, supervision, writing—review and editing; C.E.H.: data curation, formal analysis, investigation, methodology, writing—review and editing; E.K.N.: conceptualization, investigation, methodology, project administration, resources, supervision, writing—review and editing; L.V.L.: conceptualization, funding acquisition, investigation, methodology, project administration, resources, supervision, writing—review and editing.

All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Conflict of interest declaration. We declare we have no competing interests.

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References

1. Thompson JC, Carvalho S, Marean CW, Alemseged Z. 2019 Origins of the human predatory pattern: the transition to large-animal exploitation by early hominins. *Curr. Anthropol*. **60**, 1–23. (doi:10.1086/701477)
2. Aiello LC, Wheeler P. 1995 The expensive-tissue hypothesis: the brain and the digestive system in human and primate evolution. *Curr. Anthropol*. **36**, 199–221. (doi:10.1086/204350)
3. Patterson DB *et al*. 2019 Comparative isotopic evidence from East Turkana supports a dietary shift within the genus *Homo*. *Nat. Ecol. Evol*. **3**, 1048–1056. (doi:10.1038/s41559-019-0916-0)
4. Inizan ML, Reduron-Ballinger M, Roche H, Tixier J, Féblot-Augustins J (eds). 1999 *Technology and terminology of knapped stone: followed by a multilingual vocabulary—Arabic, English, French, German,Greek, Italian, Portuguese, Spanish*. Nanterre, France: CREP.
5. Stout D, Hecht E, Khreisheh N, Bradley B, Chaminade T. 2015 Cognitive demands of lower paleolithic toolmaking. *PLoS One* **10**, e0121804. (doi:10.1371/journal.pone.0121804)
6. Stout D, Quade J, Semaw S, Rogers MJ, Levin NE. 2005 Raw material selectivity of the earliest stone toolmakers at Gona, Afar, Ethiopia. *J. Hum. Evol*. **48**, 365–380. (doi:10.1016/j.jhevol.2004.10.006)
7. Braun DR, Ditchfield P, Ferraro JV, Maina D, Bishop LC, Potts R. 2008 Oldowan behavior and raw material transport: perspectives from the Kanjera formation. *J. Archaeol. Sci.* **35**, 2329–2345. (doi:10.1016/j.jas.2008.03.004)
8. Braun DR, Plummer TW, Ferraro JV, Ditchfield P, Bishop LC. 2009 Raw material quality and oldowan hominin toolstone preferences: evidence from Kanjera South, Kenya. *J. Archaeol. Sci*. **36**, 1605–1614. (doi:10.1016/j.jas.2009.03.025)
9. Blumenschine RJ. 1991 Hominid carnivory and foraging strategies, and the socio-economic function of early archaeological sites. *Phil. Trans. R. Soc. Lond. B* **334**, 211–219. (doi:10.1098/rstb.1991.0110)
10. Key AJM. 2016 Integrating mechanical and ergonomic research within functional and morphological analyses of lithic cutting technology: key principles and future experimental directions. *Ethnoarchaeology* **8**, 69–89. (doi:10.1080/19442890.2016.1150626)
11. Key A, Lycett S. 2023 The ergonomics of stone tool use and production. In *The Oxford handbook of cognitive archaeology* (eds T Wynn, KA Overmann, FL Coolidge). Oxford, UK: Oxford University Press. (doi:10.1093/oxfordhb/9780192895950.013.29)
12. Key AJM, Lycett SJ. 2015 Edge angle as a variably influential factor in flake cutting efficiency: an experimental investigation of its relationship with tool size and loading. *Archaeometry* **57**, 911–927. (doi:10.1111/arcm.12140)
13. Key AJM, Lycett SJ. 2017 Reassessing the production of handaxes versus flakes from a functional perspective. *Archaeol. Anthropol. Sci*. **9**, 737–753. (doi:10.1007/s12520-015-0300-1)
14. Whittaker JC, McCall G. 2001 Handaxe-hurling hominids: an unlikely story. *Curr. Anthropol*. **42**, 566–572. (doi:10.1086/322547)
15. Hayden B. 2015 Insights into early lithic technologies from ethnography. *Phil. Trans. R. Soc. B* **370**, 20140356. (doi:10.1098/rstb.2014.0356)
16. Gould RA. 1968 Living archaeology: the Ngatatjara of Western Australia. *Southwest. J. Anthropol*. **24**, 101–122. (doi:10.1086/soutjanth.24.2.3629417)
17. White JP. 1968 Ston naip bilong tumbuna: the living stone age in New Guinea. In *La préhistoire: problèmes et tendances* (eds F Bordes, D de Sonneville Bordes), pp. 511–516. Paris, France: Editions du CNRS.
18. Gould RA, Koster DA, Sontz AHL. 1971 The lithic assemblage of the Western Desert aborigines of Australia. *Am. Antiq*. **36**, 149–169. (doi:10.2307/278668)
19. Gallagher JP. 1977 Contemporary stone tools in Ethiopia: implications for archaeology. *J. Field Archaeol*. **4**, 407–414. (doi:10.1179/009346977791490131)
20. Roth WE. 1904 *Domestic implements, arts, and manufactures*. Brisbane, Australia: Government Printer, Department of Public Lands.
21. Spencer B, Gillen FJ. 1912 *Across australia, vol. 2*. Cambridge, UK: Cambridge University Press. (doi:10.1017/CBO9780511751172)
22. Hiscock P. 2004 Slippery and billy: intention, selection and equifinality in lithic artefacts. *Camb. Archaeol. J*. **14**, 71–77. (doi:10.1017/s0959774304230050)
23. Weedman KJ. 2006 An ethnoarchaeological study of hafting and stone tool diversity among the gamo of Ethiopia. *J. Archaeol. Method Theory* **13**, 188–237. (doi:10.1007/s10816-006-9010-4)
24. Sahle Y, Negash A, Braun DR. 2012 Variability in ethnographic hidescraper use among the Hadiya of Ethiopia: implications for reduction analysis. *Afr. Archaeol. Rev*. **29**, 383–397. (doi:10.1007/s10437-012-9114-z)
25. White JP, Thomas DH. 1972 What mean these stones? Ethno-taxonomic models and archaeological interpretations in the New Guinea highlands. In *Models in archaeology* (ed. D Clarke), pp. 275–308. London, UK: Routledge.
26. Stout D. 2002 Skill and cognition in stone tool production: an ethnographic case study from Irian Jaya. *Curr. Anthropol.* **43**, 693–722. (doi:10.1086/342638)
27. Sahle Y *et al*. 2025 Ethnographic toolstone heat treatment reveals distinctive motives and patterns of material transformation. *Sci. Rep*. **15**, 12854. (doi:10.1038/s41598-025-97207-9)
28. Gould RA. 1980 *Living archaeology*. Cambridge, UK: Cambridge University Press.
29. Toth N. 1982 The stone technologies of early hominids at Koobi Fora, Kenya: an experimental approach. Doctoral dissertation, University of California, Berkeley, CA.
30. Ford LB *et al*. 2023 Water insecurity, water borrowing and psychosocial stress among Daasanach pastoralists in northern Kenya. *Water International* **48**, 63–86.
31. Andrefsky W. 2005 *Lithics: macroscopic approaches to analysis*, 2nd edn. Cambridge, UK: Cambridge University Press. (doi:10.1017/CBO9780511810244)
32. Eren MI, Lycett SJ, Patten RJ, Buchanan B, Pargeter J, O'Brien MJ. 2016 Test, model, and method validation: the role of experimental stone artifact replication in hypothesis-driven archaeology. *Ethnoarchaeology* **8**, 103–136. (doi:10.1080/19442890.2016.1213972)
33. McCarthy CT, Annaidh AN, Gilchrist MD. 2010 On the sharpness of straight edge blades in cutting soft solids, part II: analysis of blade geometry. *Eng. Fract. Mech*. **77**, 437–451. (doi:10.1016/j.engfracmech.2009.10.003)
34. Dibble HL, Bernard MC. 1980 A comparative study of basic edge angle measurement techniques. *Am. Antiq*. **45**, 857–865. (doi:10.2307/280156)
35. McElreath R. 2020 *Statistical rethinking: a bayesian course with examples in R and Stan*. New York, NY: Chapman and Hall/CRC.

36. Braun DR, Harris JWK. 2003 Technological developments in the oldowan of Koobi Fora: innovative techniques of artifact analysis. In *Oldowan: rather more than smashing stones* (eds J Moreno, RM Torcal, I de la Torre), p. 29. Bellaterra, Spain: Treballs D'Aqueologia.
37. R Core Team2023 R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. See https://www.R-project.org/.
38. Eren MI *et al*. 2024 Experimental bison butchery using replica hafted Clovis fluted points and large handheld flakes. *J. Archaeol. Sci*. **55**, 104480. (doi:10.1016/j.jasrep.2024.104480)
39. Suwa M. 2008 A cognitive model of acquiring embodied expertise through meta-cognitive verbalization. *Information and Media Technologies* **3**, 399–408. (doi:10.11185/imt.3.399)
40. Muller A, Clarkson C. 2016 Identifying major transitions in the evolution of lithic cutting edge production rates. *PLoS One* **11**, e0167244. (doi:10.1371/journal.pone.0167244)
41. Holdaway S, Douglass M. 2012 A twenty-first century archaeology of stone artifacts. *J. Archaeol. Method Theory* **19**, 101–131. (doi:10.1007/s10816-011-9103-6)
42. Roche H, Blumenschine RJ, Shea JJ. 2009 Origins and adaptations of early *Homo*: what archeology tells us. In *The first humans: origin and early evolution of the genus* Homo (eds F Grine, JG Fleagle, RE Leakey), pp. 135–147. Dordrecht, The Netherlands: Springer. (doi:10.1007/978-1-4020-9980-9_12)
43. Iovita R. 2024 A return to function as the basis of lithic classification. Zenodo. (doi:10.5281/zenodo.7734147)
44. Isaac GL. 1977 Squeezing blood from stones. In *Stone tools as cultural markers: change, evolution, and complexity* (ed. RVS Wright), pp. 5–12. Canberra, Australia: Humanities Press.
45. Rezek Z, Dibble HL, McPherron SP, Braun DR, Lin SC. 2018 Two million years of flaking stone and the evolutionary efficiency of stone tool technology. *Nat. Ecol. Evol*. **2**, 628–633. (doi:10.1038/s41559-018-0488-4)
46. Gallotti R. 2018 Before the acheulean in East Africa: an overview of the oldowan lithic assemblages. In *The emergence of the acheulean in East Africa and beyond* (eds R Gallotti, M Mussi), pp. 13–32. Cham, Switzerland: Springer International Publishing. (doi:10.1007/978-3-319-75985-2_2)
47. Plummer TW, Finestone EM. 2018 Archeological sites from 2.6–2.0 Ma: toward a deeper understanding of the early oldowan. In *Rethinking human evolution* (ed. JH Schwartz). Cambridge, MA: MIT Press. (doi:10.7551/mitpress/11032.003.0015)
48. Braun DR, Harris JWK. 2009 Plio-Pleistocene technological variation: a view from the KBS MBR. Koobi Kora formation. In *The cutting edge: new approaches to the archaeology of human origins* (eds K Schick, N Toth), pp. 17–32. Bloomington, IN: Stone Age Institute Press.
49. Schick KD, Toth NP. 1994 *Making silent stones speak: human evolution and the dawn of technology*. Phoenix, AZ: Simon and Schuster.
50. Caro DD, Kuhn M, Thompson N, Panagopoulou E, Harvati K, Tourloukis V. 2025 Small flakes for sharp needs: technological behaviour in the Lower Palaeolithic site of Marathousa 1, Greece. *PLoS One* **20**, e0324958. (doi:10.1371/journal.pone.0324958)
51. Pobiner BL. 2020 The zooarchaeology and paleoecology of early hominin scavenging. *Evol. Anthropol*. **29**, 68–82. (doi:10.1002/evan.21824)
52. Plummer T. 2004 Flaked stones and old bones: biological and cultural evolution at the dawn of technology. *Am. J. Phys. Anthropol.* **47**, 118–164. (doi:10.1002/ajpa.20157)
53. Keeley LH, Toth N. 1981 Microwear polishes on early stone tools from Koobi Fora, Kenya. *Nature* **293**, 464–465. (doi:10.1038/293464a0)
54. Lemorini C, Bishop LC, Plummer TW, Braun DR, Ditchfield PW, Oliver JS. 2019 Old stones' song—second verse: use-wear analysis of rhyolite and fenetized andesite artifacts from the oldowan lithic industry of Kanjera South, Kenya. *Archaeol. Anthropol. Sci*. **11**, 4729–4754. (doi:10.1007/s12520-019-00800-z)
55. Lemorini C *et al*. 2014 Old stones' song: use-wear experiments and analysis of the oldowan quartz and quartzite assemblage from Kanjera South (Kenya). *J. Hum. Evol*. **72**, 10–25. (doi:10.1016/j.jhevol.2014.03.002)
56. Plummer TW *et al*. 2023 Expanded geographic distribution and dietary strategies of the earliest Oldowan hominins and *Paranthropus*. *Science* **379**, 561–566. (doi:10.1126/science.abo7452)
57. Lepre CJ, Roche H, Kent DV, Harmand S, Quinn RL, Brugal JP, Texier PJ, Lenoble A, Feibel CS. 2011 An earlier origin for the Acheulian. *Nature* **477**, 82–85. (doi:10.1038/nature10372)
58. Beyene Y *et al*. 2013 The characteristics and chronology of the earliest acheulean at Konso, Ethiopia. *Proc. Natl Acad. Sci. USA* **110**, 1584–1591. (doi:10.1073/pnas.1221285110)
59. Pante M. 2010 The larger mammal fossil assemblages from beds III and IV, Olduvai Gorge, Tanzania: implications for the feeding behavior of *Homo erectus*. Doctoral dissertation, Rutgers University, NJ.
60. Andrefsky W. 2008 Raw-material availability and the organization of technology. *Am. Antiq*. **59**, 21–34. (doi:10.2307/3085499)
61. Andrefsky W. 2009 The analysis of stone tool procurement, production, and maintenance. *J. Archaeol. Res*. **17**, 65–103. (doi:10.1007/s10814-008-9026-2)
62. reevesj191. 2025 reevesj191/Cutting_Edge_Butchery: Publication: Modern stone tool users from Northern Kenya emphasize mass and edge length in the selection of cutting tools (Proof). Zenodo (doi:10.5281/zenodo.17885520)
63. Reeves JS, Douglass MJ, Haney CE, Ndiema EK, Luncz LV. 2026 Supplementary material from: Modern stone tool users, from Northern Kenya, emphasize mass and edge length in the selection of cutting tools. Figshare. (doi:10.6084/m9.figshare.c.8239338)