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Looking at handaxes from another angle: Assessing the ergonomic and functional importance of edge form in Acheulean bifaces

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ABSTRACT

Edge angle is widely considered to be a morphological attribute that influences the functional performance of lithic technologies. However, the comparative performance capabilities of handaxes that vary in terms of edge angles has never been investigated under experimental conditions. Similarly, detailed accounts of Acheulean handaxe angle variation from archaeological examples have not been reported in the literature. Consequently, it has not previously been possible to assess the extent to which Palaeolithic individuals adhered to specific edge angle ranges during handaxe production or whether resultant artifactual properties may have been in response to varying rates of utility. Here, using a substantial experimental program (n = 500 handaxes), we investigate the impact that edge angle variation has on the cutting efficiency of handaxes at a "whole tool" and "edge-point localized" level. We then examine edge angles in a temporally and geographically wide range of handaxes (n = 643) and assess the extent to which hominins were likely altering tool production choices in response to functional pressures. Our experimental results demonstrate that, up to a certain value, higher edge angles in handaxes can actually increase functional performance. Furthermore, results indicate that edges in the proximal portion of handaxes have the greatest influence over efficiency rates. Combined with examination of archaeological specimens, these results suggest that hominins actively pursued the production of more obtuse edges in the proximal (butt) portion of handaxes in order to increase ergonomic features that facilitated greater efficiency during use. Edge angle values in the proximal portion of the archaeological handaxes were, however, consistently found to be below an efficiency threshold identified at ~70 degrees, above which, an edge's ability to effectively be applied to cutting tasks decreases markedly. This further suggests that the proximal edges of handaxes, at least occasionally, were required as a functional working edge.

1. Introduction

Large bifacially flaked stone tools, generally referred to as "handaxes," were a prominent component of the archaeological record across the Old World for over one million years (Lycett and Gowlett, 2008). Originating in sub-Saharan Africa at least ~1.75 MYA (Beyene et al., 2013; Lepre et al., 2011; Diez-Martín et al., 2015), they were subsequently produced at sites ranging geographically from South Africa to the Levant, and from western Europe to as far east as Korea (e.g., Leakey, 1971; Isaac and Curtis, 1974; Gowlett and Crompton, 1994; Goren-Inbar and Saragusti, 1996; Norton et al., 2006; Santonja and Villa, 2006; Petraglia and Shipton, 2008; Chauhan, 2009; Hosfield, 2011; Pappu et al., 2011; de la Torre, 2011; Bae et al., 2012; Wang et al., 2014). Fundamentally, handaxes represent a means by which individuals were able to modify aspects of the physical environment around them, principally by cutting, splitting, or otherwise deforming organic materials. Indeed, a number of lines of evidence indicate their widespread use during butchery activities and plant modification behaviors (e.g., Keeley and Toth, 1981; Shipman et al., 1981; Domínguez-Rodrigo et al., 2001; Shea, 2007; Rabinovich et al., 2008; Solodenko et al., 2015). This is not to automatically rule out additional roles for handaxes within hominin behavioral strategies (e.g., Pope et al., 2006), but rather, that across their broad temporal and geographic expanse, handaxes were principally produced as functional objects that were modified to undertake

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task-orientated activities—i.e., they were "tools" (*sensu* Shumaker et al., 2011).

Given their practical role, it has been hypothesized that a majority of handaxes made during the Palaeolithic would have been made within functionally viable ranges of variation (Crompton and Gowlett, 1993; Vaughan, 2001; Simão, 2002; Gowlett, 2009; Lycett et al., 2016), a statement that has recently found support through experiments designed to assess the functional effectiveness of handaxes that varied widely in terms of their size and shape (Key and Lycett, 2016b). Notably, however, handaxe edge angles were not examined in that experimental study (Key and Lycett, 2016b). Indeed, while handaxe edge form has often been theoretically linked with varying functional performance capabilities (e.g., Posnansky, 1959; Kleindienst, 1962; Kleindienst and Keller, 1976; Jones, 1980; Mitchell, 1995; Phillipson, 1997; Gowlett, 2006; Machin et al., 2007; Toth and Schick, 2009; Galán and Domínguez-Rodrigo, 2014; Key and Lycett, 2016a), edge angle data are not typically reported for Acheulean handaxes recovered archaeologically. Moreover, the issue of variation in the angles of Acheulean handaxes has never been directly compared with functional experimental data. While previous research has discussed the necessary role of a handaxe's edge morphology in determining its functional performance capabilities, even suggesting that certain forms may have been preferentially sought (e.g., Posnansky, 1959; Kleindienst and Keller, 1976; Gowlett, 2006), detailed mechanical models and explicit experimental procedures designed to test any hypothesized relationships between varying handaxe edge forms and functional performance characteristics are lacking. Indeed, current suggestions are limited to subjective comments or those made within the context of research pertaining to other matters (e.g., Posnansky, 1959; Kleindienst, 1962; Jones, 1980, 1994; Mitchell, 1995; McCall, 2005; Machin et al., 2007; Toth and Schick, 2009; Merritt, 2012; Iovita, 2014; Key and Lycett, 2016a).

This situation is potentially critical given the fundamental role that the form of a stone tool's working edge is known to have on its functional performance capabilities. Indeed, it has long been understood that the angle, relative straightness, length, and uniformity of a flake tool's cutting edge is of potential consequence to its efficiency when undertaking cutting tasks (Wilmsen, 1968; Crabtree, 1977; Walker, 1978; Jones, 1980; Jobson, 1986). This has recently been further emphasized in experimental and morphological investigations examining the varying functional potential of flake cutting tools in respect to their edge morphology (Collins, 2008; Borel et al., 2013; Key and Lycett, 2011, 2015; Romagnoli et al., 2015; Eren and Lycett, 2016; Key, 2016). In specific respect to the issue of edge angles, Key and Lycett (2015) recently demonstrated that for flakes, an automatic relationship between more acute cutting edges and increased functional efficiency (in terms of time) cannot be automatically assumed, and that while relatively small flakes tend to display such a relationship, larger tools facilitate increased working loads that are able to counteract the increased resistance caused by more obtuse working edges.

Ultimately, any influence that the edge angle of a handaxe has on its functional performance is caused by either an alteration to the cutting mechanics experienced between the working edge of the tool and material being cut, or the ergonomic relationship between the tool user and edge points in contact with the hand (Key, 2016). Indeed, the angle on the working edge of a cutting tool is known to directly influence the cutting stress enacted on a worked material, with more obtuse edges decreasing the stress created (Ackerly, 1978; Atkins, 2009; McCarthy et al., 2010; Key, 2016). Hence, if angles on a tool's cutting edge increase, then individuals must increase variables that contribute to the "slice-push ratio," which describes cutting stress, if cutting effectiveness is to be maintained. That is, they must either increase the working load (force) applied and/or the speed with which the cut is performed in order to maintain similar material deformation rates (Atkins et al., 2004; Atkins, 2006). A further noted feature of handaxes is that they incorporate a "handle" that provides both support and forward extension to the working edge as it is held in the hand (Gowlett, 2006). Outside of archaeology, research has been undertaken into the design theory of tool–handle ergonomic "optimization" in relation to modern tools (e.g., Hall, 1997; Edgren et al., 2004; Seo and Armstrong, 2008). Understandably, however, there has been little research into how sharp-edged "handles" interact with the palm of the hand or fingers in the existing ergonomics literature, which might be more relevant in the case of at least some prehistoric handaxes. Indeed, the production of a sharp edge at the point of contact between a hand and a handaxe appears ergonomically flawed given that the hand is at an obvious risk of lacerations/cuts. As has been made clear through previous experimental research, however, despite the presence of sharp edges in the proximal (butt) portion of some handaxes, they can still be effectively used as cutting tools (Jones, 1980, 1994; Pitts and Roberts, 1997: 223–231; Machin et al., 2007; Galán and Domínguez-Rodrigo, 2014). Nevertheless, further work that examines the relationship between edge angle and efficiency in handaxes appears desirable given the direct interaction of this variable with the hand during use.

It is clear that the angles present along the edge of a handaxe might influence the efficiency with which it can be used as a hand-held cutting tool, be this via its relationship with the tool-user's hand or the material being worked. To date, however, the extent and nature of any such influence is unknown and has not been tested via experimental procedures. Furthermore, the degree of edge angle variation within and between various Acheulean handaxe assemblages has not been recorded. Hence, it is not currently possible to assess whether hominins controlled for and/or imposed specific edge angle ranges on handaxes during the Lower Palaeolithic in respect to these factors. Accordingly, the present study had two aims. Our primary aim was to experimentally assess the impact that variable edge angles have on a handaxe's functional performance during cutting. Our secondary aim was to examine edge angle variation in a sample of Acheulean (archaeological) examples in the light of our experimental data, in order to determine the implications of our experiments for hominin behavioral patterns with respect to handaxe manufacture and use.

2. Materials and methods

2.1. Experimental determination of the functional consequences of edge angle variation

Experiments are an important tool for archaeologists interested in addressing a range of questions relating to Palaeolithic technologies (Eren et al., 2016). This includes questions regarding their use, and experiments facilitate a means to examine the extent to which functional factors might have influenced stone tool variation in the archaeological record (e.g., Jones, 1980; Jobson, 1986; McCall, 2005; Machin et al., 2007; Collins, 2008; Sisk and Shea, 2009; Key and Lycett, 2014, 2015, 2016a). Indeed, understanding the comparative functional performance characteristics of variable stone tool morphologies is vital to interpreting what influences practical matters may have imposed on prehistoric tool production behaviors.

2.2. Experimental assemblage

Given the main research goals of this study, it was necessary to generate a large, replica-handaxe assemblage displaying variable