EXARC JOURNAL 2019/2
23 Articles | Open Access

Reviewed Article:

Skills Shortage: A Critical Evaluation of the Use of Human Participants in Early Spear Experiments

Persistent Identifier: https://exarc.net/ark:/88735/10426

EXARC Journal Issue 2019/2 | **Publication Date:** 2019-05-21

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Hand-delivered spears are the earliest clear hunting technology in the archaeological record, with origins from 400,000 years ago, before the evolution of our own species. Experimental archaeological approaches to early weaponry continue to grow, and both controlled and naturalistic experiments are making significant contributions to interpreting such technologies. Using human participants is often useful and sometimes necessary for such work. This paper argues that greater consideration should be afforded to a number of

aspects of human performance in experimental work - whether naturalistic or controlled - including how proficiency and physiology may affect outcomes.

> As most anthropologists and archaeologists do not lead lives with equivalent levels of physical activity to hunter-gatherers, we must reconsider the accuracy of using researchers to launch weapons in experimental studies. By ignoring the problem of our present day skills shortage we end up with what we might call 'the replicator's conceit'.

Introduction

With exciting new archaeological discoveries of Pleistocene spears (Thieme, 1997; Dobrovolskaya, Richards and Trinkaus, 2011; Nikolskiy and Pitulko, 2013; Schoch, et al., 2015) there has been a significant increase recently in the interest in the performance of these earliest weapons. Multiple experimental studies have used humans to thrust or hand-throw spears, usually to evaluate damage to weapons or prey (Huckell, 1982; Guthrie, 1984; Schmitt, Churchill and Hylander, 2003; Smith, 2003; Lombard, Parsons and van der Ryst, 2004; Parsons and Badenhorst, 2004; Bradfield and Lombard, 2011; Rios-Garaizar, 2016; Gaudzinski-Windheuser, et al., 2018). However, only some of these experiments mention the skill level of the humans involved in these experiments, and none provide data on their physiology or discuss how these factors may affect results. There are only a handful of papers that explicitly discusses the value of using skilled participants in weapon studies (Rots and Plisson, 2014; Whittaker, Pettigrew and Grohsmeyer, 2017) but what specifically constitutes 'expertise' and how this could be compared is not always elaborated upon nor defined.

It is widely understood that weapon performance is determined by skill or expertise more than weapon design. In addition to often-discussed factors such as environment, raw material properties, and prey characteristics, performance is also mediated on a human level. This includes technical skills and learned gestures, experience from real life situations, the physiology of the person behind the weapon, and human decisions and errors (Knecht, 1997; Whittaker and Kamp, 2006). This paper, an expansion of an earlier blog post, takes a critical look at the implications of using human participants in experimental archaeological work relating to hand-delivered spears.

Some key estimates on spear performance come from experimental studies involving untrained participants. As one example, Calvin Howard conducted an experiment (1974) to evaluate spear thrower performance. In that experiment spear thrower darts were also thrown by hand. That paper contributed to estimates provided by Hughes (1998) of hand-thrown spear velocities that have been replicated in controlled experiments (Sano and Oba, 2015; Schoville, et al., 2017). According to Howard (1974, p. 104), 'Thrower "A" is the writer and thrower "B" is his 18 year old son', with no further discussion as to expertise or physical fitness. Steven Churchill, who has contributed significantly to research on spear use over many decades, more or less admits that much about our understanding of hand-delivered spears is based on unskilled use: “There is very little mention of the accuracy of this weapon in the ethnographic literature, although there is ample evidence from experimental research that it is an inaccurate weapon in the hands of anthropologists” (Churchill, 1993, p. 19).

A handful of experimental studies on spears used human participants with training in activities that bear at least some resemblance to use of a spear for hunting, including javelin athletes (See Figure 2) (Rieder, 2001; Smith, 2003; Milks, Parker and Pope, 2019), military personnel (Milks, et al., 2016) or martial arts specialists (See Figure 1) (Gaudzinski-Windheuser, et al., 2018). Perhaps the optimal choice, when available, is to use a participant with skill in using hand-delivered spears for hunting (La Porta, Hosfield and Hurcombe, 2018) although even these participants are likely to have limitations in comparison with prehistoric hunters.

Object-based skills such as flint knapping or metal working can be analysed and measured against archaeological artefacts, and even without the aid of precision measuring tools people can replicate objects with reasonable fidelity (Eerkens, 2000). Perhaps as a result of the fact that it is easier to ‘see’ and compare results in object-based experiments with the archaeological record, there seems to be more discussion and acknowledgement of skill limitations. For example, present-day flint knappers do discuss skill, experience, and social contexts of lithic production (for example, see Stout, et al., 2008; Nami, 2010; Eren, et al., 2016). Such debates need to be had within prehistoric weapon studies. It is clear by the end product whether or not an experimenter has the skills to accurately replicate a stone tool, even if not in the same time frame, or with the same process. For judging weapon performance - a category that includes measures such as accuracy, velocity, force, flight behaviour or maximum distance - comparison is more difficult because we cannot easily ‘see’ these in the archaeological record. While experimental studies of spears or bone damage thought to result from spear use sometimes hope to identify delivery method (Hutchings, 2011; Iovita, et al., 2014; Gaudzinski-Windheuser, et al., 2018), such studies rely either on use of humans or on problematic data from human performance studies.

We cannot realistically compare performance of weapons without a foundational understanding based upon human use. In addition to experimental use, we can approximate performance by studying the ethnohistoric and ethnographic records (See Figure 3). These data provide invaluable insights into how weapon use relates to environment, landscape, prey, hunting strategies and gestures (Roth, 1890; Churchill, 1993; Kortlandt, 2002). In analysing this valuable record, as well as existing experimental estimates and designing further human performance studies, we also need to take into account what we know so far about how and when humans learn skills, and how physiology may contribute to performance of tools such as hunting weapons.

Skills for Spear Use

We understand little about the skills of prehistoric hunters, particularly of different species of *Homo*, who had different physiologies, and likely had different social structures, capacity for language, and cognitive abilities than humans today. Contemporary studies of how play and deliberate practice influence skill acquisition can help us think about how and when learning may have taken place in the past. Voelcker-Rehage (2008, p.7) defines "gross motor skills" as those that involve the entire body and/or multiple limbs and further classifies them as "complex" if they cannot be mastered in a single session, a classification that can certainly be applied to use of hand-delivered spears. Ford, et al. found that both play and deliberate practice of a specific physical activity during childhood and adolescence positively influences skill level later in life (2009). In addition to practice and play, the learning of gross motor skills looks to be influenced by certain preconditions, including a person's strength and endurance (Voelcker-Rehage, 2008). Although physical skill acquisition looks likely to be optimal between the ages of 15-29, in one study all age groups ranging from 6-89 years demonstrated the ability to learn new complex gross motor skills (Voelcker-Rehage and Willimczik, 2006). However, age-related differences in performance are more obvious with increasing task complexity, as well as in tasks that require physical fitness (Voelcker-Rehage, 2008). Together these studies suggest that while we can learn skills such as spear use in older adulthood, useful for those aiming to replicate weapon use in archaeological research, we need to discuss and account for age and fitness level as well as the number of years and intensity of training.

Among the Hadza, who use bow and arrows for hunting, boys begin using bows as young as two years old (Blurton Jones and Marlowe, 2002). Interestingly, time taken out of living in the bush in order to attend school did not appear to negatively impact their ability to hit a target. Although the authors argue that practice is almost certainly significant for technical skills in archery, strength and body mass may outweigh the contribution of practice time, at least during adolescence. In fact the best archers in the study group were older, with accuracy peaking around 40 and typically remaining stable throughout middle and older age. Other studies confirm that strength correlates with hunting success in bow and arrow use (Apicella, 2014). This suggests that, at least in the case of archery, age and the experience that brings, physical fitness, and body size, are all likely significant factors. On the other hand we still cannot discount cognitive development in relation to early childhood play, practice and observation. Furthermore, it is poorly understood how this might apply to spear use, which has not been studied in the same way. Perhaps more importantly, learning is socially embedded (Coles, 1979) and the learning of subsistence skills does not just involve motor skills gained from play and deliberate practice, but also inputs from observation, imitation and teaching (Dira and Hewlett, 2016; Lew-Levy, et al., 2017).

Ethnographic literature shows that in spear-using societies, spear training begins early in childhood, forming a significant part of the 'education' of male children (Bourke, 1890; Davies, 1846; Hart and Pilling, 1960). Amongst the Chabu in Ethiopia, children use spears from about 6 years old, learn to hunt small animals from age 7, and participate in spear hunts between the ages of 9-12. Similar to the studies of groups using bow and arrows, they learn skills - including spear handling skills - through "listening, observation, demonstration, advice from others, and participation" (Dira and Hewlett, 2016, p.78).

Human Physiology and Spear Use

The significance of physiology including body mass, height, strength, and overall physical fitness in relation to hand-delivered spear use is also a relatively underexplored question. As discussed above it looks likely to influence accuracy in bow and arrow use. Some suggest that spear use may require not only greater skills but also potentially greater body mass and strength than what is needed for effective use of complex projectiles (Cundy, 1989; Whittaker, Pettigrew and Grohsmeyer, 2017; Milks, Parker and Pope, 2019). This theory requires further data from systematic studies and for the time being should be taken into account.

A study has shown that pre-Holocene *Homo*, including *H. sapiens*, had high levels of bone density compared with post-Holocene humans, including in both their upper and lower limbs (Chirchir, et al., 2015). The authors mention that this was likely due in part to increasing sedentary lifestyles in comparison with hunter-gatherers. Physical activity contributes to muscle mass, which in turn affects bone density (Proctor, et al., 2000). Therefore we can correlate Chirchir, et al.'s (2015) findings with overall greater strength and fitness of prehistoric hunters than the average person today. Looking deeper in time, the Middle Pleistocene humans who made and used the earliest known spears were tall and robust in comparison with our own species (Ruff, et al., 2018).

In addition to preconditions of physiology, we should consider how adrenaline would affect outcomes. The adrenaline response is triggered by challenging situations and can improve athletic performance (Blascovich, et al., 2004; Jones, et al., 2009). The adrenaline response is difficult to trigger in a systematic experimental setting, but is likely to have played a role in how spears perform in dynamic hunting of larger prey and violent human-human encounters. It is hypothesised that threat states may limit physiological performance, with the body 'closing in', while challenge states may result in energy bursts that improve physical performance (Jones, et al., 2009).

Setting Standards

As most anthropologists and archaeologists do not lead lives with equivalent levels of physical activity to hunter-gatherers, we must reconsider the accuracy of using researchers to launch weapons in experimental studies. By ignoring the problem of our present day skills shortage we end up with what we might call 'the replicator's conceit'. The effects of skill and physiology in archaeological experimentation in general is not a new subject (for example Coles, 1979; Kelterborn, 1990; Tichy, 2005), but there are still many published experiments either using unskilled participants and making conclusions on that basis, or using participants with a degree of skill but failing to report on key aspects and discuss limitations of these participants. Fortunately, many archaeologists replicating early spears have begun to recognise these methodological problems and are working to address them, both by re-exploring the foundations of estimates or by using skilled participants.

There are several reasons researchers would choose to use human participants for replicating spear thrusting and throwing. First, spear thrusting is most accurately replicated by humans (Hutchings, 2011; Milks, et al., 2016). Replicating spear throwing using mechanical methods can require specialist equipment that can be costly and difficult to acquire. Assuming appropriate recording steps are taken, use of human participants further contributes to data on ballistics and biomechanics of hand-delivered spears and makes for a better understanding of spear throwing in naturalistic settings. No single study will be large or varied enough to provide us with a full picture, but by creating a body of work researchers begin to provide means and range data on key parameters. These data are essential for accurate comparisons of hand-delivered spears with complex projectiles as well as for setting up controlled experiments.

However, even data from studies using trained participants must be used with caution; as argued above, the humans typically used in research now are by no means perfect proxies for those in the past. Two of my own human performance studies cited in this paper serve to illustrate my point: neither military personnel nor javelin athletes have the same skills or experience as prehistoric hunters. Although their physical stature was selected for accordingly and both groups were selected for their training in activities relatable to spear throwing and thrusting, the purpose and extent of this training are not perfect representations of a lifetime of technical skill, experience of hunting with spears, need to acquire food, and concomitant physical fitness.

Three categories of standards are proposed here for experimental protocols that will help the discipline evaluate existing and future studies. We should view these as an enhancement of our ability to interpret the archaeological record, rather than solely as limitations of experiments.

1) Proficiency	Skills of human participants need to be considered in experimental design. Unskilled participants should only be used when it is the aim of the study to understand the significance of unskilled use. 'Skill' should be explored and discussed in terms of both qualitative and quantitative parameters, such as years and type of training and/or experience, and if possible quantified with measures such as personal bests or recognised competence levels. Whether skilled or unskilled, the limitations of

	participants should be acknowledged and discussed. Controlled experiments should explore and justify the foundations of the parameters set (for example velocity), and the skill level they are based upon.
2) Physiology	When experimenting using human participants as spear users, we should consider their heights, body masses and physical fitness levels and compare how these compare to data on humans from the period studied. Physical attributes of participants should be recorded including body mass, height, age, and ideally grip strength as a measure of overall strength (Trosclair, et al., 2011). These attributes should be explored in analyses. We should acknowledge and discuss potential physical limitations of our participants and account for this in results. Controlled experiments should explore and justify the foundations of the parameters set and consider the impact of this on results.
3) Data recording	We should aim to record as many data as possible from spear experiments using human participants, cost and time permitting. This is useful even if the experimenters choose unskilled participants, because these data facilitate building a big picture of relationships between proficiency, physiology and outcomes.

Naturalistic experiments will not provide a definitive answer to any question, because there are multiple technological and behavioural approaches to any given scenario. Therefore while appreciating the value of human experience, we must be careful not to translate this into dogma. It is necessary to continue to recognise human behavioral and physiological variability and accept the coincident challenges and limitations of archaeological experiments. If we can view human-weapon performance studies as collaborative research, building a picture of weapons that expands our understanding of the possible range, then we have the best chance of understanding spear performance. It is then the job of controlled experimenters to decide upon suitable means or ranges of a given variable on the basis of the scaffolding that skilled performance studies provide.

In this paper I have highlighted some problems and questions regarding early spear research that I believe have seriously hampered our ability to interpret the archaeological record because estimates and conclusions have been drawn on the basis of use of these weapons by those whose skills lie elsewhere, or whose skills are uncritically presented as representative of those in the past. At the same time I have provided good practice examples that are providing useful alternative estimates on early spears. I hope the evidence outlined will encourage debate on the significance of technical skills and physical fitness on the outcomes of archaeological experiments that involve human participants, something that may extend beyond the use of hand-delivered spears. The proposals can be built upon and refined which in turn should form the basis of improved protocols, enhancing the reliability of results and expand our understanding of the complex interactions between humans and their tools.

Acknowledgments

This paper is the result of conversations I have had with colleagues from multiple disciplines over the years as an experimental archaeologist, in particular with my PhD supervisor Matt Pope, ballistics engineer Debra Carr, social anthropologist Sheina Lew-Levy, and prehistoric weapon researcher John Whittaker. I thank Kenneth Mackriell for comments on an earlier draft of this paper.

Keywords spear
weapon
skill

Country United Kingdom

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Gallery Image

FIG 1. FILIPINO MARTIAL ARTS EXPERT KRISHNA GODHANIA DEMONSTRATING ONE OF MANY POSSIBLE SPEAR THRUSTING TECHNIQUES.

FIG 2. JAVELIN COACH AND THROWER DAVID PARKER PREPARING TO THROW A PLEISTOCENE SPEAR REPLICA.

FIG 3. TIWI MEN PARTICIPATING IN A SPEAR THROWING COMPETITION. FROM SPENCER, W. B. NATIVE TRIBES OF THE NORTHERN TERRITORY OF AUSTRALIA. (MACMILLAN AND CO., 1914), PUBLIC DOMAIN.