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

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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.

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.

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Bibliography

Apicella, C.L., 2014. Upper-body strength predicts hunting reputation and reproductive success in Hadza hunter-gatherers. *Evolution and Human Behavior*, 35(6), pp.508–518.

Blascovich, J., Seery, M.D., Mugridge, C.A., Norris, R.K and Weisbuch, M., 2004. Predicting athletic performance from cardiovascular indexes of challenge and threat. *Journal of Experimental Social Psychology*, 40(5), pp.683–688.

Blurton Jones, N. and Marlowe, F.W., 2002. Selection for delayed maturity: Does it take 20 years to learn to hunt and gather? *Human Nature*, 13(2), pp.199–238.

Bourke, J.G., 1890. Vesper Hours of the Stone Age. *American Anthropologist*, 3(1), pp.55–64.

Bradfield, J. and Lombard, M., 2011. A macrofracture study of bone points used in experimental hunting with reference to the South African middle stone age. *South African Archaeological Bulletin,* 66(193), pp.67–76.

Chirchir, H., Kivell, T.L., Ruff, C.B., Hublin, J.J., Carlson, K.J., Zipfel, B. and Richmond, B.G., 2015. Recent origin of low trabecular bone density in modern humans. *Proceedings of the National Academy of Sciences*, 112(2), pp.366–371.

Churchill, S.E., 1993. Weapon Technology, Prey Size Selection, and Hunting Methods in Modern Hunter-Gatherers: Implications for Hunting in the Palaeolithic and Mesolithic. *Archeological Papers of the American Anthropological Associatio*n, 4(1), pp.11–24.

Coles, J., 1979. *Experimental Archaeology*. London: Academic Press.

Cundy, B.J., 1989. *Formal Variation in Australian Spear and Spearthrower Technology*. BAR International Series 546. Oxford: British Archaeological Reports.

Davies, R.H., 1846. On the aborigines of Van Diemen's Land. *Tasmanian Journal of Natural Science*, 2(January), pp.409–412.

Dira, S.J. and Hewlett, B.S., 2016. Learning to Spear Hunt Among Ethiopian Chabu Adolescent Hunter-Gatherers. In: B.S. Hewlett and H. Terajima, eds. *Social Learning and Innovation in Contemporary Hunter-Gatherers*. Tokyo: Springer Japan. pp.71–81.

Dobrovolskaya, M., Richards, M.P. and Trinkaus, E., 2011. Datations directes par radiocarbone des sépultures du Gravettien d'Europe de l'Est à Sunghir, Russie. *Bulletins et mémoires de la Société d'anthropologie de Paris,* 24(1-2), pp.96–102.

Eerkens, J.W., 2000. Practice Makes Within 5% of Perfect: Visual Perception, Motor Skills, and Memory in Artifact Variation. *Current Anthropology*, 41(4), pp.663–668.

Eren, M.I., Lycett, S.J., Patten, R.J., Buchanan, B., Pargeter, J. and O'Brien, M.J., 2016. Test, Model, and Method Validation: The Role of Experimental Stone Artifact Replication in Hypothesis-driven Archaeology. *Ethnoarchaeology*, 8(2), pp.103–136.

Ford, P.R., Ward, P., Hodges, N.J. and Williams, A.M., 2009. The role of deliberate practice and play in career progression in sport: the early engagement hypothesis. *High Ability Studies*, 20(1), pp.65–75.

Gaudzinski-Windheuser, S., Noack, E.S., Pop, E., Herbst, C., Pfleging, J., Buchli, J., Jacob, A., Enzmann, F., Kindler, L., Iovita, R., Street, M. and Roebroeks, W., 2018. Evidence for close-range hunting by last interglacial Neanderthals. *Nature Ecology & Evolution*, 2, pp.1087–1092.

Guthrie, R.D., 1984. Osseous Projectile Points: Biological Considerations Affecting Raw Material Selection and Design Among Paleolithic and PaleoIndian peoples. In: J. Clutton-Brock and C. Grigson, eds. *Animals and Archaeology Vol. 1*, Hunters and their Prey. BAR International Series 163. Oxford: British Archaeological Reports. pp. 273–294.

Hart, C.W.M. and Pilling, A.R., 1960. *The Tiwi of North Australia*. New York: Holt, Reinhart & Winston.

Howard, C.D., 1974. The atlatl: function and performance. *American Antiquity*, 39(1), pp.102–104.

Huckell, B.B., 1982. The Denver elephant project: A report on experimentation with thrusting spears. *The Plains Anthropologist*, 27(97), pp.217–224.

Hughes, S.S., 1998. Getting to the point: evolutionary change in prehistoric weaponry. *Journal of Archaeological Method and Theory,* 5(4), pp.345–408.

Hutchings, W.K., 2011. Measuring use-related fracture velocity in lithic armatures to identify spears, javelins, darts, and arrows. *Journal of Archaeological Science*, 38(7), pp.1737–1746.

Iovita, R., Schönekess, H., Gaudzinski-Windheuser, S. and Jäger, F., 2014. Projectile impact fractures and launching mechanisms: results of a controlled ballistic experiment using replica Levallois points. *Journal of Archaeological Science*, 48, pp.73–83.

Jones, M., Meijen, C., McCarthy, P.J. and Sheffield, D., 2009. A Theory of Challenge and Threat States in Athletes. *International Review of Sport and Exercise Psychology,* 2(2), pp.161–180.

Kelterborn, P., 1990. Preconditions and Strategies for Experimental Archaeology. In: *Le Silex de sa Genése á L'Outil: Vth International Flint Symposium. Bordeaux, France, 17 September–2 October 1987*. Paris: Centre National de la Recherche Scientifique. pp. 599–602.

Knecht, H., 1997. The History and Development of Projectile Technology Research. In: H. Knecht, ed. *Projectile Technology.* New York: Plenum Press. pp. 3–35.

Kortlandt, A., 2002. Neanderthal anatomy and the use of spears. *Evolutionary Anthropology: Issues, News, and Reviews*, 11(5), pp.183–184.

La Porta, A., Hosfield, R. and Hurcombe, L., 2018. The contribution of experimental archaeology to understanding hunting activities: testing the effectiveness of Middle Palaeolithic stone-tipped spears. In: *International Union of the Prehistoric and Protohistoric Sciences, 18th UISPP World Congress*. Paris, France, 4–9 June 2018.

Lew-Levy, S., Reckin, R., Lavi, N., Cristóbal-Azkarate, J. and Ellis-Davies, K., 2017. How Do Hunter-Gatherer Children Learn Subsistence Skills? *Human Nature*, 28(4), pp.367–394.

Lombard, M., Parsons, I. and van der Ryst, M.M., 2004. Middle Stone Age lithic point experimentation for macro-fracture and residue analyses: the process and preliminary results with reference to Sibudu Cave points. *South African Journal of Science*, 100(3/4), pp.159–166.

Milks, A., Champion, S., Cowper, E., Pope, M. and Carr, D., 2016. Early spears as thrusting weapons: Isolating force and impact velocities in human performance trials. *Journal of Archaeological Science: Reports*, 10, pp.191–203.

Milks, A., Parker, D. and Pope, M., 2019. External ballistics of Pleistocene hand-thrown spears: experimental performance data and implications for human evolution. *Scientific Reports*, 9(1), pp. 1–11.

Nami, H., 2010. Theoretical Reflections on Experimental Archaeology and Lithic Technology: Issues on Actualistic Stone Tools Analysis and Interpretation. In: H. Nami, ed. *Experiments and Interpretation of Traditional Technologies: Essays in Honor of Errett*

Callahan. Buenos Aires: Ediciones de Arqueología Contemporánea. pp. 91–168.

Nikolskiy, P. and Pitulko, V., 2013. Evidence from the Yana Palaeolithic site, Arctic Siberia, yields clues to the riddle of mammoth hunting. *Journal of Archaeological Science*, 40(12), pp.4189–4197.

Parsons, I. and Badenhorst, S., 2004. Analysis of lesions generated by replicated Middle Stone Age lithic points on selected skeletal elements: research letter. *South African Journal of Science*, 100(7), pp.384–387.

Proctor, D.N., Melton, L.J., III, Khosla, S., Crowson, C.S., O'Connor, M.K. and Riggs, B.L., 2000. Relative Influence of Physical Activity, Muscle Mass and Strength on Bone Density. *Osteoporosis International*, 11(11), pp.944–952.

Rieder, H., 2001. Erprobung der Holzspeere von Schoeningen (400000 Jahre) und Folgerungen daraus. In: G.A. Wagner and D. Mania, eds. *Frühe Menschen in Mitteleuropa: Chronologie, Kultur, Umwelt*. Aachen: Shaker. pp. 91–98.

Rios-Garaizar, J., 2016. Experimental and Archeological Observations of Northern Iberian. Peninsula Middle Paleolithic Mousterian Point Assemblages. Testing the Potential Use of Throwing Spears Among Neanderthals. In: R. Iovita and K. Sano, eds. *Multidisciplinary Approaches to the Study of Stone Age Weaponry*. Cham, Switzerland: Springer. pp. 213–225.

Roth, H.L., 1890. *The Aborigines of Tasmania*. London: Kegan Paul, Trench, Trübner & Co.

Rots, V. and Plisson, H., 2014. Projectiles and the abuse of the use-wear method in a search for impact. *Journal of Archaeological Science*, 48, pp.154–165.

Ruff, C.B., Burgess, M.L., Squyers, N., Junno, J.A. and Trinkaus, E., 2018. Lower limb articular scaling and body mass estimation in Pliocene and Pleistocene hominins. *Journal of Human Evolution*, 115, pp.85–111.

Sano, K. and Oba, M., 2015. Backed point experiments for identifying mechanically-delivered armatures. *Journal of Archaeological Science*, 63, pp.13–23.

Schmitt, D., Churchill, S.E. and Hylander, W.L., 2003. Experimental Evidence Concerning Spear Use in Neandertals and Early Modern Humans. *Journal of Archaeological Science*, 30(1), pp.103–114.

Schoch, W.H., Bigga, G., Böhner, U., Richter, P. and Terberger, T., 2015. New insights on the wooden weapons from the Paleolithic site of Schöningen. *Journal of Human Evolution*, 89, pp.214–225.

Schoville, B.J., Wilkins, J., Ritzman, T., Oestmo, S. and Brown, K.S., 2017. The performance of heat-treated silcrete backed pieces in actualistic and controlled complex projectile experiments. *Journal of Archaeological Science: Reports*, 14, pp.302–317.

Smith, G., 2003. Damage inflicted on Animal Bone by Wooden Projectiles: Experimental Results and Archaeological Implications. *Journal of Taphonomy*, 1(2), pp.105–114.

Stout, D., Toth, N., Schick, K. and Chaminade, T., 2008. Neural correlates of Early Stone Age toolmaking: technology, language and cognition in human evolution. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363(1499), pp.1939–1949.

Thieme, H., 1997. Lower Palaeolithic hunting spears from Germany. *Nature*, 385, pp.807–810.

Tichy, R., 2005. Presentation of Archaeology and Archaeological Experiment. *euroREA*, 2, pp.113–119.

Trosclair, D., Bellar, D., Judge, L., Smith, J., Mazerat, N. and Brignac, A., 2011. Hand-Grip Strength as a Predictor of Muscular Strength and Endurance. *Journal of Strength and Conditioning Research*, 25(March)(Suppl.), p.S99.

Voelcker-Rehage, C., 2008. Motor-skill learning in older adults—a review of studies on age-related differences. *European Review of Aging and Physical Activity*, 5(1), pp.5–16.

Voelcker-Rehage, C. and Willimczik, K., 2006. Motor plasticity in a juggling task in older adults—a developmental study. *Age and Ageing*, 35(4), pp.422–427.

Whittaker, J.C. and Kamp, K.A., 2006. Primitive Weapons and Modern Sport: Atlatl Capabilities, Learning, Gender, and Age. *Plains Anthropologist*, 51(198), pp.213–221.

Whittaker, J.C., Pettigrew, D.B. and Grohsmeyer, R.J., 2017. Atlatl Dart Velocity: Accurate Measurements and Implications for PaleoIndian and Archaic Archaeology. *PaleoAmerica*, 3(2), pp.161–181.