

# Mechanical Examination of Swords in the Eastern Mediterranean from the Late Bronze Age to the Early Iron Age

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## Introduction<sup>1</sup>

This paper offers a new approach for studying the functionality of swords, by conducting mechanical tests on 3D models of swords created in Solidworks, a computer-aided design (CAD) and computer-aided engineering (CAE) program. The main aim of this study is to investigate the functional role and thus the capacity of a variety of swords of Late Bronze Age (LBA) and Early Iron Age (EIA) from the Aegean to the Near East. During the latter part of the LBA and EIA, swords gradually played an ever-increasingly important role in the Eastern Mediterranean and the Near East (Drews 1993: 33-163; Molloy 2010: 421; Schulz 2014: 259; Mehofer and Jung 2017: 397). In recent years, numerous studies have been dedicated to them, examining their typology, their symbolic role and their use as weapons. The restricted accessibility and the limited publications for use wear analysis or experimentation on Near Eastern swords (in contrast with the Aegean material), along with the high-cost of experimental studies, turned our attention towards 3D modelling. Solidworks offers the possibility to design a variety of swords and create a controlled virtual environment in order to evaluate their resistance to force and therefore examine their capability as weapons. This method allows us to determine whether the swords had the necessary structural integrity which would allow them to withstand a significant amount of force applied to them and creates opportunities for future fruitful collaboration with metal wear analysis and experimental archaeology, in order to understand better the manner of use of these weapons. Our method offers an answer to the following question: was it possible to use the LBA-EIA swords in actual fighting and how much force could they handle?

The number of studies devoted to the examination of the sword are indeed numerous from Europe to the Near East. These studies are divided into two main categories, those which treat the sword as a symbol of elevated social status and power, as well as part of the warrior's identity (Malafouris 2008: 7; Harell 2009: 86, 105; for the Near East: Massafra 2012), and those which highlight the functional side of the artefact, by exploring its performance as a weapon and its manufacture (Molloy 2010, 2011; Herman *et al.* 2020).

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The earlier studies concentrated on the typologies of swords, which are fundamentally important for the observation of the morphological evolution of the artefact. As far as the LBA is concerned, the Aegean swords were classified by many authors, who organized the main types of swords with a brief contextual analysis (Sandars 1963; Kilian Dirlmeier 1993). The few bronze Cypriot swords were first published in some articles (Catling 1956, 1964) and then in a monograph (Matthäus 1985), while the Anatolian swords are presented in various publications (Müller-Karpe 1994; Yalçikli 2006; Roháček 2018). The Near Eastern swords have been studied in detail in recent years, taking into consideration their typology, metallurgy and their meaning (Maxwell-Hyslop 1946; Shalev 2004; Gernez 2007; Massafra 2012; Vogel 2013; Schulz 2014), albeit neglecting their functional aspect. The typological studies of swords from the EIA are limited (Snodgrass 1964; Matthäus 1985; Muscarella 1988; Kilian Dirlmeier 1993), and for this reason, the majority of iron swords are presented in individual publications (Maryon *et al.* 1961; Karageorghis 1983; Muscarella 1988: 187, 112-20; Karg 2001; Malekzadeh *et al.* 2017).

Recent experimental studies of swords have enlightened the question of their efficacy as weapons, the manner of their use, and the process of their manufacture (Molloy 2008, 2010, 2011, 2019; Anderson 2011; Mödlinger 2011; Mödlinger *et al.* 2011; O'Flaherty *et al.* 2011; Crellin *et al.* 2018; Dolfini *et al.* 2018; Gentile and van Gijn 2019; Knight 2019; Hermann *et al.* 2020), revealing details such as the post-cast treatment of the blade, the hardening of the edges and the mechanical properties of the weapons (For spears: Anderson 2011; for halberds: Mödlinger 2011; O'Flaherty *et al.* 2011). The majority of these studies examine the traces of use on the surface of ancient swords (metal wear analysis), which are compared with the traces of use on replicas, after being tested in experiments conducted in the field and in the laboratory (Bridgford 2000; Soriano and Gutiérrez 2009; Molloy 2011, 2019; Gutiérrez-Sáez and Lerma 2015; Dolfini and Crellin 2016; Crellin *et al.* 2018; Gentile and van Gijn 2019; Hermann *et al.* 2020). Thus, they establish a protocol of marks, which reveal the possible manner of use of a sword. Lately, 3D models are being used for archaeological artefacts (Dolfini and Collins 2018; Molloy and Milić 2018), sometimes in connection with metal wear analysis (Molloy *et al.* 2016) and other times in connection with their mechanical behavior (Miller 2017). There is also a satisfactory number of archaeometallurgical studies (Kayafa 1999; Kouï *et al.* 2006; Tselios 2013; Molloy and Doonan 2015; Mehofer and Jung 2017). In the case of Cypriot and Near Eastern swords, though, there is only a limited number of archaeometallurgical and use wear analyses,<sup>2</sup> as well as experimental attempts (for bronze sickle type swords: Sapiro and Webler 2016) and studies of alloys (Shalev 2004: App.1-2; Gernez 2007: 527-38).

<sup>2</sup> For bronze swords: Khalil 1980; Yener 2000; Shalev 2004; Charalampous and Kassianidou 2012; Mehofer and Jung 2017; Van Brempt and Kassianidou 2017; For MBA weapons: El Morr and Pernot 2011; For iron swords: Maxwell-Hyslop and Hodges 1966; Rehder 1991; Yalçin 2005, 499, figs. 7-8.