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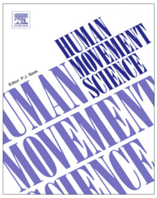

Is effective mass in combat sports punching above its weight?

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ABSTRACT

The segmental and muscular complexity of the human body can result in challenges when examining the kinetics of impacts. To better understand this complexity, combat sports literature has selected effective mass as a measure of an athlete's inertial contribution to the momentum transfer during the impact of strikes. This measure helps to clarify the analysis of striking kinetics in combat sports. This paper will review: (1) effective mass as a concept and its usage as a measure of impact intensity in combat sports, (2) the neuromuscular pattern known as "double peak muscle activation" which has been theorized to help enhance initial hand velocity upon impact and joint stiffening during impact, (3) the methods and equations used to calculate effective mass, and (4) practitioner recommendations based on the literature. We will argue in this manuscript that the act of punching presents unique challenges to the current understanding of effective mass due to additional force application during impact. This review will improve the understanding of effective mass and its roles in effective striking serving to underpin future research into performance enhancement in striking based combat sports.

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1. Introduction

In the seminal work *Tao of Jeet Kune Do* (Lee, 1975) author and martial artist Bruce Lee brings the reader's attention to the importance of relaxing their body as they strike, tensing at the last possible moment before impact. It is suggested by Lee that this will produce a strike of great force. Similarly, the world champion boxer Jack Dempsey (Dempsey, 1950) writes in his 1950 guide to boxing *Championship Boxing* that punches should be thrown as relaxed as possible only to become "frozen, steel hard" at impact. These great athletes are referring to methods that they have anecdotally experienced as being effective in transferring momentum in their strikes. Intuitively the advice makes sense, but lacks what is commonly seen in combat sports, a scientific rational (Lenetsky & Harris, 2012). In the context of our current scientific understanding this would be interpreted as maximizing the effective mass of the strike (Derrick, Dereu, & Mclean, 2002). If an athlete is able to increase the effective mass of their strike (i.e. inertial contribution), they will transfer more momentum at impact. If an athlete is able to relax their arm throughout a strike, and then stiffen their arm at the last possible moment, theoretically that strike would impact with greater force than one thrown with constant activation. The stiffening of the arm gives a better connection of the hand to the rest of the body, utilizing some of the momentum of the body. This paper will explore the theory of effective mass and its relation to momentum transfer in a strike. The current literature will also be examined regarding both the monitoring of effective mass and muscular activation in combat sports and the methods by which combat sport athletes modify their potential to enhance effective mass. Finally, a series of evidence based recommendations for the modern combat sport athlete to utilize in the practical environment are proposed.

2. Effective mass

2.1. Effective mass as a concept

As shown in the previous paragraphs, this term "effective mass" has become a common parameter in the sports science community. To understand effective mass we first must look at its use in ballistic spring mass modeling. The spring mass model is used in sports science to simplify the complexity of the human body (Blickham, 1989). Traditionally, effective mass used in the spring mass model has been applied to ballistic impacts, such as, kicking a ball, lands on trampolines, and contact during running (Derrick et al., 2002; Khorashad, 2013; Southard, 2014). The spring mass model breaks the body into a simple construct of a massless springs connected to blocks of mass (Blickham, 1989; Derrick, Caldwell, & Hamill, 2000). This simplified model allows for a conceptual understanding of impacts relating to the human body.

If an athlete was a solid uniformly shaped block of mass, determining the impact force and effective mass upon impact would be a simple calculation of the mass of the whole system and the acceleration it was experiencing (Derrick, 2004). In this example the effective mass would simply equal the mass of the system. Instead, athletes are made of multiple moving segments, containing both rigid structures (bone) and soft structures (muscle, tendon and ligaments), which upon impact can deform, reducing impact forces (Gruber, Ruder, Denoth, & Schneider, 1998). The deformation prone mass in humans has been referred to as "wobbling mass" and is unable to transmit impact forces as effectively as rigid mass (Gruber et al., 1998). During a collision the greater the rigidity of the impacting mass, the less elastic the collision. The less elastic a collision, the greater the momentum imparted into the target or opponent (Pain & Challis, 2002).

To properly quantify impacts of the human "wobbling mass", effective mass is used. Effective mass reflects the spring stiffness in the spring mass model and the role that the various blocks of mass play in that impact by equating the human shaped "wobbling mass" as a single uniformly shaped mass that has a similar elasticity to every involved segment. For example, Derrick et al. (2002) examined the impacts of participants during an exhaustive run. Rather than only exploring the impacts as a result of the mass of the body as a whole, Derrick et al.'s (2002) use of effective mass accounts for the mass of the foot and some of the mass of the leg, torso, and even upper extremities. Additionally, the use of