RELATIONSHIPS BETWEEN PUNCHING IMPACT FORCE AND SELECT ANTHROPOMETRIC MEASUREMENTS

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INTRODUCTION: A punch can be defined as the ability to throw the arm through space in an attempt to make physical contact with a target. Boxing and mixed martial arts (i.e., MMA) requires the production of high levels of velocity, force, and torque to produce powerful striking movements (Trial and Wu, 2014). Body composition has been shown to have positive and negative effects upon human movement and posture in sports, ergonomics, rehabilitation and orthopedics (Handsfield, Knaus, Fiorentino, Meyer, Hart, and Blemker., 2017; Nakano, Lino, Imura A, Kojima., 2014). Thus, anthropometrics and body mass proportion characteristics would appear to be important factors effecting striking impact forces, as force is equal to Mass x Acceleration. The concept of effective mass has been outlined previously by Lenetsky (Lenetsky, Harris,and Brughelli., 2013) where by the fist and forearm may be "braced" prior to impact thus amplifying momentum (Mass x Velocity; M x V) transfer and resultant impact force. Being able to quantify the contributions of body mass and individual body segments to impact force along with effective mass could further the understanding of punching impacts (Nakano et al., 2014; Guidetti,, Musluini, and Baldari., 2002; Piorkowski, Lees, and Barton., 2011; Lenetsky, Harris,and Brughelli., 2013; Turner, Baker, and Stuart., 2011). Therefore, the purpose of this study was to determine the relationship between select anthropometrics, girth measurements, segmental masses, and right rear punching maximal impact force.

METHODS: Thirty subjects (21 males: 21.68±4.46 y, 180.63±9.41cm, 97.16±20.77 kg; 9 females: 21.56±2.55 y, 162.85±5.12 cm, 65.37±8.13 kg) volunteered to participate in the study. Subjects provided written informed consent approved by the Institutional Review Board at Coastal Carolina University. Subjects striking proficiency ranged from novice to amateur boxer status. Select circumference girths were measured from the waist (87.23±10.58 cm), chest (103.15±10.80 cm), wrist (17.17±1.92 cm), and fist (21.61±2.45 cm) by a single investigator on the right side of the body. Estimated segmental mass was calculated for the foot (mean: 0.89±0.23 kg, 1%), lower leg (4.23±1.15 kg, 4.8%), thigh (11.45±2.37 kg, 12.3 %), torso (29.20±8.17 kg, 33%), upper arm (2.11±0.59 kg, 2.4%), and lower arm (1.44±0.48 kg, 1.7%) from subjects total body mass using the Dumas modification of Dempsters data (Dumas, Cheze, Verriest., 2007).

Before the start of the right rear hand punch (RRHPmax) testing, subjects performed a standardized warm up consisting of six repetitions using 4.55kg kettlebells of shoulder shrugs, upright rows, shoulder press with neutral wrist, unweighted internal/external rotations, torso twists with arms crossed over the chest, six seconds of wrist rolls with hands interlocked, neck flexions and neck extensions. These were followed 60 seconds later by four maximal countermovement jumps (CMJ) with arm swing. A 60 second rest period was taken before beginning the punch protocol with all punches conducted using the right arm.

A combination of physical and verbal instructional demonstration was provided to the subjects to standardize the punching technique and consistency of the impact surface. Subjects were instructed to perform punches using 50% and 75% perceived maximal effort before attempting four maximal punches with the average of the best two used in data analysis. A

Myotest Pro Accelerometer (Myotest SA, Sion, Switzerland) was used sampling at 500Hz in trainer mode to record maximal impact force (Fmax, N). Previous work by Bompouras, Relph, Orme, and Esformes., (2013) found that the Myotest Pro was a valid and reliable tool for assessing Fmax in the field. The device was secured using athletic tape and aligned in parallel with the site of impact on a 113.64 kg Rival Banana Punching Bag. Participants wore Fighting Sport S2 Pro gel under gloves (2.5 oz.) and Rival boxing gloves (10 oz.). A correlation matrix was produced in SPSS (version 24) for multiple Bivariate Pearson Correlation Coefficients and RRHPmax. Significance was set a priori at a *p* value of ≤ 0.05. The practical magnitude of the correlations were based off Hopkins criteria for trivial (<1.0), small (0.1 – 0.3), moderate (0.3 – 0.5), large (0.5 – 0.7), very large (0.7 – 0.9), or nearly perfect (>0.9) correlations (Hopkins, Marshall, Batterham, & Hanin, 2009).

TABLE 1. Relationships between punching impact force and select upper body circumferences

		Waist	**Chest**	**Wrist**	**Fist**
Fmax	Pearson's r	0.557**	0.638***	0.530**	0.657***
	Magnitude	Moderate	Large	Moderate	Large

*Fmax = Right rear hand punch maximum impact force (N). *Denotes significant at p < 0.05. **Denotes significant at p < 0.01 *** Denotes significant at p < 0.001.*

RESULTS: For anthropometric data, a large correlation was found between maximal force and body mass (r = .677) whereas only a moderate correlation was determined between maximal force and height (r = .578). Refer to Table 1 and Table 2 for relationships between maximal force and anthropometric circumferences as well as maximal force and segmental body mass measurements. All correlations found to be significant at $p \leq 0.05$.

TABLE 2. Relationships between punching impact force and segmental body mass measurements

		Foot	**LLeg**	**ULeg**	**Trunk**	**LArm**	**UArm**
Fmax	Pearson's r	0.677**	0.691**	0.460*	0.696**	0.714**	0.916***
	Magnitude	Large	Large	Moderate	Large	Large	Near Perfect

*Notes: All segmental masses were measured in kg. Foot = foot mass; LLeg= lower leg mass; ULeg = upper leg mass; Trunk = trunk mass; UArm = upper arm mass; Larm = lower arm mass; Fmax = Right rear hand punch maximum impact force (N). *Denotes significant at p < 0.05. **Denotes significant at p < 0.01, ***Denotes significant at p < 0.001*

DISCUSSION: In a previous investigation, anthropometric testing reported a strong correlation (r=0.780, p<0.05) between wrist circumference and boxing performance (Guidetti et al., 2002). This was in partial agreement with the current study but more similar to the correlation found for fist circumference (r=0.657). Typically, larger individuals have greater wrist and fist circumferences as well as higher body mass (Dumas et al., 2007). As the wrist and the closed fist represent the terminal distal segment making contact with a striking surface, respective circumference and size may help with the transfer of momentum (M x V). However, higher lean body mass as a result of appropriately structured resistance training should have a greater effect than increasing body mass alone. Strong to very strong correlations were also shown between RRHPmax and upper arm mass (p=0.916) and lower arm mass (p=0.714) suggesting the mass of the right upper extremities had a direct effect upon the resultant RRHPmax. As a punch is thrown and not pushed it would seem logical that the combined mass of the arm, wrist and fist would have a significant effect upon impact force (Turner at al., 2011; Nakano et al., 2014; Lenetsky et al., 2013). If subjects are also stronger and more skillful, and able to appropriately brace just prior to impact, effective mass may be amplified. Effective mass, as highlighted by the equation, $m_eV_p = (m_h + m)V_h$ (Lenetsky et al., 2013) proposes the transfer of momentum and resultant impact force is directly related to the effective mass of the lower arm and fist (Lenetsky et al., 2014). Bracing milliseconds prior to impact amplifies segmental mass at a small cost to segmental velocity, thus increasing momentum transfer at impact.

The strongest correlations found were between upper arm mass, lower arm mass, lower leg mass, and trunk mass. The majority of the subjects where males who on average have a greater upper body mass, as well as proportional mass within the upper extremities (Dumas et al., 2007). Piorkowski et al., (2011) suggested that maximal punches rely upon a significant contribution from lower extremities. Bouhel et al., (2007) showed power produced by the legs of javelin throwers was positively correlated to maximal power and distance thrown. During the current study, stronger correlations between upper arm mass, lower arm mass, trunk mass, and chest circumference, compared to upper and lower leg mass and foot mass where found. The majority of subject's had "novice" technique; therefore, a greater reliance upon upper extremity force production may have been utilized.

The results of this study demonstrate a significant relationship between body mass, height, limb, and torso circumference, and segmental mass. Practically, using appropriately periodized and planned resistance training and dietary interventions for boxers could help increase lean muscle mass, strength and power which could translate to increased punching power and impact force when accompanied by technique-based training. Such training should focus upon using a combination of bilateral and unilateral resistance exercises to target proximal muscles in the lower extremities and trunk, (to increase force, rate of force development and power expression) (Handsfield at al., 2017) and upper and lower arms (to increase mass of distal segments being "thrown"). Punching skill practice may further increase impact force by increasing effective mass and momentum transfer at impact (Lenetsky et al 2013).

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