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# The Influence of a Padded Hand Wrap on Punching Force in Elite and Untrained Punchers

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**Abstract**
Punching is integral to success in combat sports, making it a frequent activity during practice/training. Improving safety of this activity benefits both the athlete and training partners. This study was designed to 1) test the precision and reliability of a commercially available striking device and 2) assess the influence of a novel padded hand wrap on punching force in elite and untrained punchers. Fourteen male professional boxers and mixed martial artists (PRO; age=29.2±5.6y; height=180.3±9.0cm; mass=87.1±17.9kg, winning %=73.8±13.8%, number of victories via knockout/technical knockout=35.6± 21.9%) and 24 untrained male punchers (UNT; 27.6±6.9y, 177.6±18.3cm, 84.3±16.9kg) wore a standardized boxing glove and performed 20 maximal punches (4 sets of 5) into a device designed to measure punching force. All participants performed, in a counterbalanced order, 2 sets of 5 with a standardized hand wrap and 2 sets of 5 with the same wrap plus an additional 1.2cm thick cylinder 4g foam-like pad (WRAP) placed over the knuckles. PRO produced significantly more punching force than UNT, regardless of condition. Punching force was lower by 12.6% ($p<0.05$) for PRO and 8.9% ($p<0.05$) for UNT with WRAP (compared to no WRAP). These findings suggest WRAP significantly reduces punching force, which may be important for long-term safety of the puncher's hand and/or the person receiving the strike.
**Keywords:** safety, punching, striking, hitting, combat, pad

## 1. Introduction

Combat sports such as mixed martial arts (MMA), karate, and boxing are internationally popular. A number of factors determine success in these sports. One in particular, is how effectively an athlete can use his/her own hand(s) to inflict physical damage on his/her opponent. Relative to the popularity of these sports, researchers know little about punching impacts (Nakano, Iino, Imura, & Kojima, 2014). What is known, however, is these impacts are significant enough to result in traumatic injuries to the person being hit (Bledsoe, Hsu, Grabowski, Brill, & Li, 2006; Fife, O'Sullivan, & Pieter, 2013; Heath & Callahan, 2013; Hutchison, Lawrence, Cusimano, & Schweizer, 2014; McClain et al., 2014; McCrory, Zazryn, & Cameron, 2007; Scoggin et al., 2010; Stojsih, Boitano, Wilhelm, & Bir, 2010; Walrod, 2011; Warner, 2014; T. Zazryn, Cameron, & McCrory, 2006; T. R. Zazryn, McCrory, & Cameron, 2009a, 2009b) and to cause fractures/dislocations (or other related injuries) to the puncher's hand (Bartsch, Benzel, Miele, Morr, & Prakash, 2012; Hutchison, et al., 2014; Lystad, 2014; McClain, et al., 2014; Scoggin, et al., 2010; Seidenberg, 2011; Shirani, Kalantar Motamedi, Ashuri, & Eshkevari, 2010; Walrod, 2011; T. R. Zazryn, et al., 2009b).

The resulting injury rate during striking sport competitions is between ~10-30% (Bledsoe, et al., 2006; McClain, et al., 2014; McCrory, et al., 2007; Ngai, Levy, & Hsu, 2008; T. Zazryn, et al., 2006; T. R. Zazryn, et al., 2009a, 2009b). Recent reports in boxing and MMA indicate professionals fighters are 2-3 times more likely to suffer fractures and other injuries during competition than amateurs (McClain, et al., 2014; Rainey, 2009; T. Zazryn, et al., 2006; T. R. Zazryn, et al., 2009a). Although the reason for this difference is multifaceted (e.g. longer competitions, more professional and financial desire to continue fighting, etc.), one likely explanation is simply that professionals are capable of generating greater impact when punching. Furthermore, injury frequency is more than double when MMA contests end via knock-out versus submission or time limit. These data collectively suggest the striking portion of combat sports represents the greatest area of risk.

Numerous changes in sport rules and regulations over recent years have greatly improved fighter safety (McClain, et al., 2014). For example, wrapping the hands in gauze or other athletic tape is now mandated in all sanctioned striking competitions (Comissions), even though the direct force of hand padding on punching force has not been studied. Nonetheless, these standardization steps appear to be reducing striking related injuries during competition (McClain, et al., 2014). While this is beneficial, recent data suggest long-term injuries are the result of an accumulation of damage accrued during both competition and practice (McCrory, et al., 2007; McKee et al., 2009; McKee et al., 2010; McKee et al., 2013). The lack of regulation over damage absorbed in practice is especially problematic considering the major consequences of continual traumatic brain injuries. For example, recent boxing data reveal that punching impacts delivered by males and females during normal practice is enough to cause severe head injury (Stojsih, et al., 2010). Thus, practice injury may actually play a larger role in long-term health outcomes than in-competition regulations, yet mandating athlete's use protective equipment during preparation for the competition is unfeasible.

The implementation of a hand-wrapping strategy that reduces punching force and is applicable to practice situations, could therefore decrease injury risk and potentially improve the long-term health prognosis of both the competitors and their practice partners. Thus, the purpose of this study was to 1) assess the precision and reliability of a commercially available device designed to measure martial arts striking impact and 2) assess the influence of a padded hand wrap on punching force in both elite and untrained punchers.

## 2. Methods

### *2.1 Experimental Approach*

This investigation consisted of two, interrelated, cross-sectional studies. The first tested the precision and reliability of a commercially available device (STRIKE) designed to measure martial arts striking (i.e. punching, kicking, etc.) impact ("StrikeMate"™, Strike Research Limited, Norwich, United Kingdom). Reliability was assessed by dropping a standard weight from a known height onto the center of STRIKE (Figure 1). This was performed both with and without a commercially available hand-padding insert (Radius Wrap™, Dana Point, CA). The insert (WRAP) was a 1.2 cm thick cylinder foam-like (proprietary) pad (mass = 4 g) that slides into hand wraps and fits over the knuckles (Figure 2).

The second study used STRIKE to compare forces of both elite and untrained punchers when they punched maximally with (PAD) and without the hand-padding insert (CON). Each participant was blinded to the full purpose of the study (they were told the purpose was to test the reliability of STRIKE and to establish normative values) and were instructed to use the same technique to maximally punch STRIKE 20 times (10 PAD, 10 CON: in a counterbalanced order). The study design and informed consent document were approved by the local Institutional Review Board and were in accordance to the standards set by the Helsinki declaration for subjects participating in human experiments. All participants gave written informed consent prior to performing any activity.

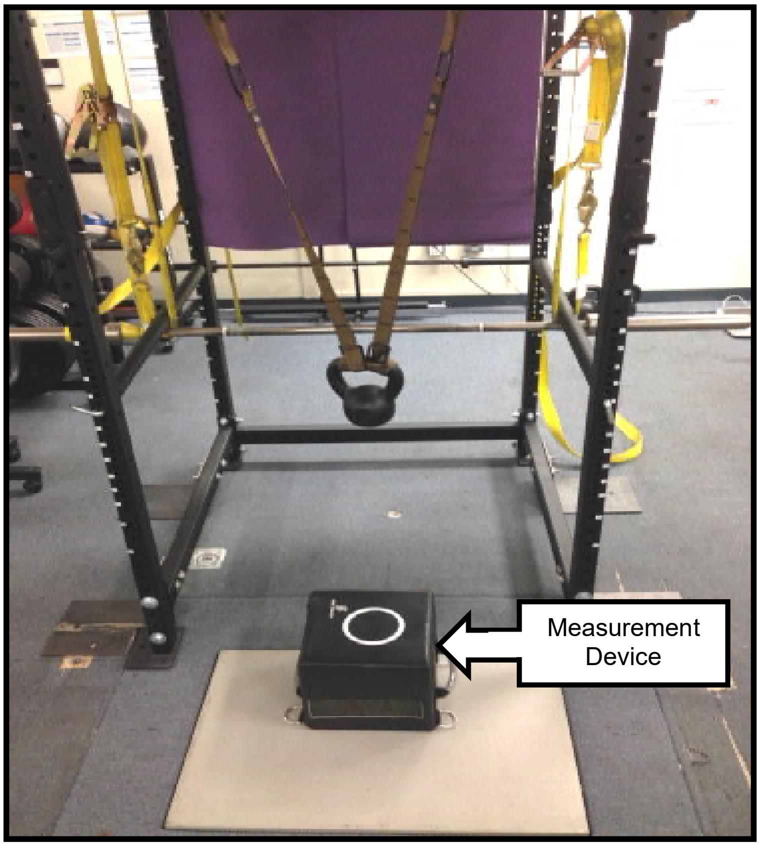


Figure 1. Image of the set-up for reliability trails (repeated with 8.0, 17.9, and 24.0 kg weights) for Study one. Picture depicts the 8.0 kg trail. All measurements (reliability and human) were performed on the "StrikeMate" (Strike Research Limited, Norwich, United Kingdom) device (black box).

Figure 2. Image of "Radius Wrap" (Radius Wrap, Dana Point, CA), the device used for all WRAP trials. The same WRAP was used for all trials.

*2.2 Study One: StrikeMate $^{TM}$ Precision and Reliability Testing*

Part A: STRIKE contains two accelerometers (one in the front, one in the back: further details are proprietary) and built-in software that allows instantaneous recording and storage of impact measurements on a USB-connected laptop. Reliability and precision of STRIKE were measured by using a pulley system to drop three different known masses (8.0, 17.9, and 24.0 kg) from a fixed height (100 cm), ten times each onto a force plate (Advanced Mechanical Technology, Inc, Watertown, MA, USA) (Figure 1, Table 1). The kettlebells were dropped in three additional trials, but from three different heights. Altogether, these trials allowed for development of a regression equation between the impact value given on STRIKE and actual force production measured on the force plate. The equation was used to convert STRIKE values obtained during human trials into newtons of force. The masses and heights for all drops were chosen so the forces measured covered the entire anticipated range of punching forces in the human trials.

Table 1. Reliability and precision of punch measurement device

| | |
|---|---|
| **Part A Trials** | |
| ICC | 0.99 |
| CV (8.0 kg) | 6.01% |
| CV (17.9 kg) | 4.52% |
| CV (24.0 kg) | 5.68% |
| **Athlete Trials** | |
| ICC | 0.82 |
| CV (CON) | 8.54% |
| CV (PAD) | 10.54% |

Part B: The same set-up was used to examine if WRAP altered impact. The 17.9 kg mass was covered with a normal boxing hand wrap (Figure 2), set at the 100 cm height, and dropped 20 times (30s between each drop to mimic the time period used in the experimental trials, as well as to reduce any chances of error due to compression of the measurement device). The same process was repeated (20 drops from standard height) with WRAP inserted in the boxing hand wrap on the flat bottom portion of the mass such that WRAP was directly between the mass and STRIKE. The 17.9 kg mass was chosen as pilot data indicated it represented an impact value that most closely resembled the punching impacts obtained during human trails.

*2.3 Study Two*

2.3.1 Participants

A convenience sample of thirteen elite, male, professional boxing and MMA athletes (PRO) (29.2 ± 5.6y; 180.3 ± 9.0cm; 87.1 ± 17.9kg, winning % = 73.8 ± 13.8%, number of victories via knockout/technical knockout = 35.6 ± 21.9%) and 24 untrained punchers (UNT) (27.6 ± 6.9y, 177.6 ± 18.3cm, 84.3 ± 16.9kg) volunteered for the study. All participants were free of any musculoskeletal injury or acute illness that influenced their ability to punch maximally. Participants were considered PRO if they 1) had ≥ 1 y of competitive striking training (e.g. Muay Thai, Boxing, MMA, etc.), 2) had competed professionally in a striking sport ≥ 3 times (with ≥ 1 of those competitions coming in the last 18 months), and 3) had been training in striking ≥ 2 times per week for the last month. Participants were considered UNT if they had < 6 months of competitive striking training and had never competed (at any level) in a related sport (e.g. Karate, Tae Kwon Do, etc.).

2.3.2 Experiment

All data were collected during a single visit for each participant. Following a 15 min self-selected warm-up (e.g. jogging, arm circles, shadow boxing, etc.), participants performed a standardized warm-up which included punching the center of STRIKE with a standardized 14 oz. boxing glove (397 g) 3 times at 50% of their perceived maximal punching effort (30s rest between punches). This was followed by an additional 3 punches at 70%, 2 at 85%, 1 at 95%, and 1 at 100% of their perceived maximal effort (30s rest between punches). A maximum of 10 additional single punches were allowed at participant discretion to ensure maximal comfort with STRIKE and complete physical preparation. Participants then rested for 5 min before performing 4 sets of 5 maximal punches. Two of the sets were under PAD, and two sets were under CON condition. The condition (PAD or CON) did not change during each set of 5 punches; but set order was randomized between participants and counterbalanced within participants (Figure 3).

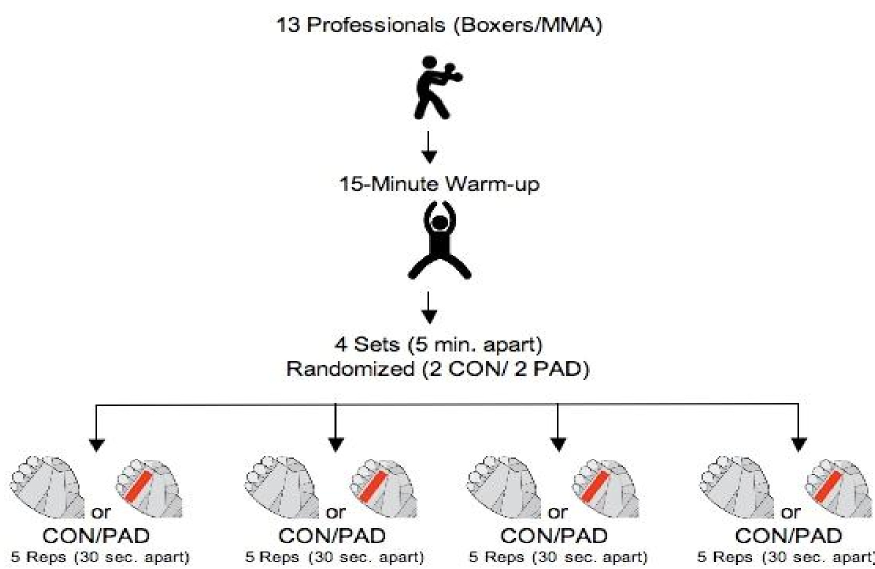


Figure 3. Schematic of research design used in Study 2 for professional athletes. The same approach was used for untrained punchers as well

Each set of 5 was separated by a 3-min rest, and each repetition was separated by 30s of rest. All strikes were performed in a standing position, with the device latched firmly against a wall at a height determined by the participant (Figure 4). Participants were reminded to 1) punch as hard as possible, 2) use the exact same striking technique, and 3) aim for the exact same spot on STRIKE before every repetition. However, no feedback regarding performance or other motivation was given during data collection. If unaware of their strongest punch, they were instructed to use a rear-punch (Nakano, et al., 2014). The same member of the research team did all hand-wrapping. Moreover, the condition (PAD or CON) was blinded such that the researcher wrapping the hand was separate from the researcher collecting the punching data, and vice versa. A third member of the team decoded and matched the condition and punching impact data at a separate location.

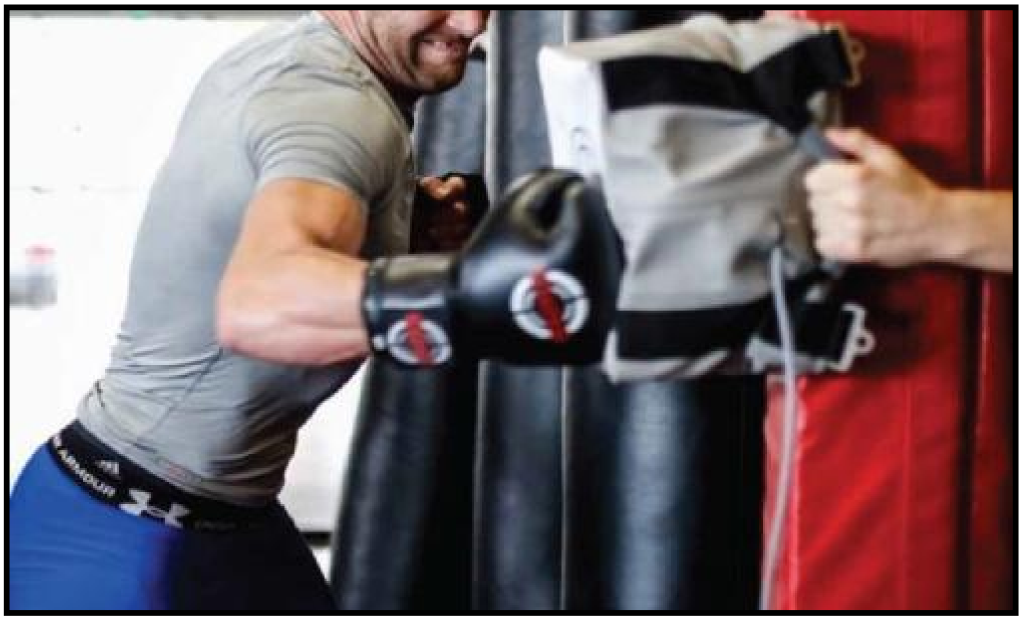

Figure 4. Representative image of an athlete during testing.

*2.4 Statistical Analyses*

All analyses were performed with IBM SPSS Statistics version 21.0 (SPSS, Inc, Chicago, IL, USA). Alpha was set at a-priori at $p < 0.05$ and values are reported as mean (± SD). Intraclass correlation (ICC) and coefficient of variance (CV) were used to establish reliability of and precision of STRIKE in both the mechanical (Study one; Part A) and human (study two) conditions. A linear regression analysis was used to convert STRIKE impact values collected during all human trials to force. A dependent t-test was used to analyze differences in force with WRAP (Study one; Part B). For study two, a 2 x 2 (group x condition) repeated-measures ANOVA was used to analyze punching force. Where appropriate, Tukey's post hoc was used for pairwise comparisons. Results are presented as mean ± standard deviation, unless otherwise stated.

**3. Results**

Reliability and precision results are presented in Table 1. The regression equation ($Y = 4.163x + 1306.7$) was significant ($p < 0.05$) and had an R value of 0.84. Force was reduced ($p < 0.05$) with WRAP compared to no WRAP (Figure 5) when a standard weight was dropped from a standard height (Study one; Part B). In Study two, a significant interaction ($p < 0.05$) was detected such that force was significantly ($p < 0.05$) greater for PRO compared to UNT, and CON compared to PAD (Figure 6).

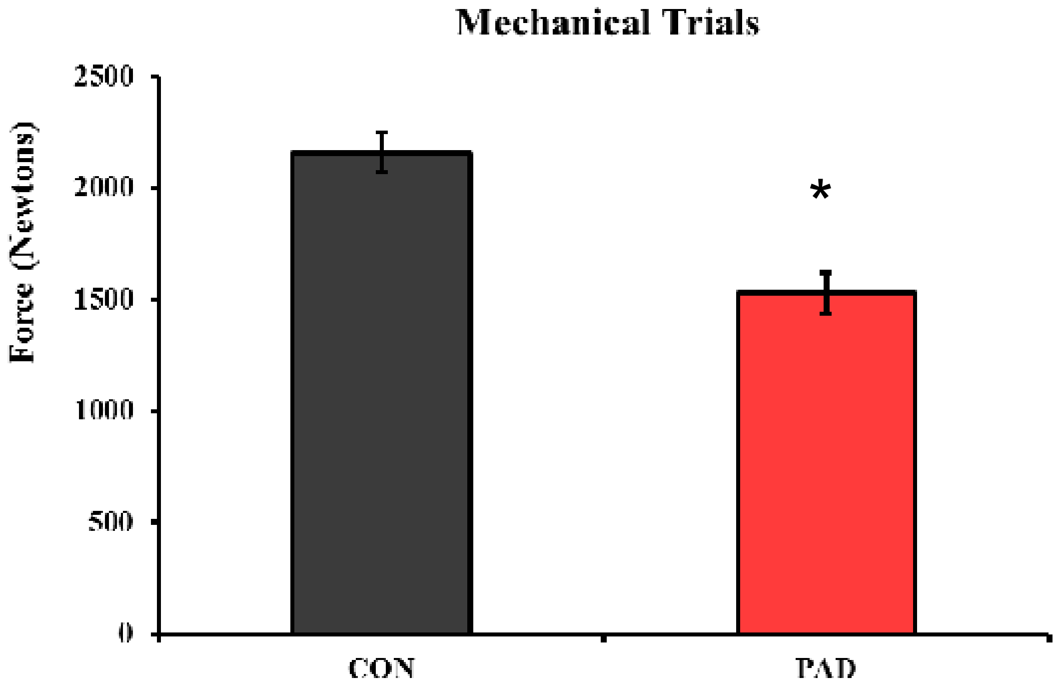


Figure 5. Difference in impact under the same condition (Study one; Part B) using WRAP. * indicates significant difference ($p < 0.05$).

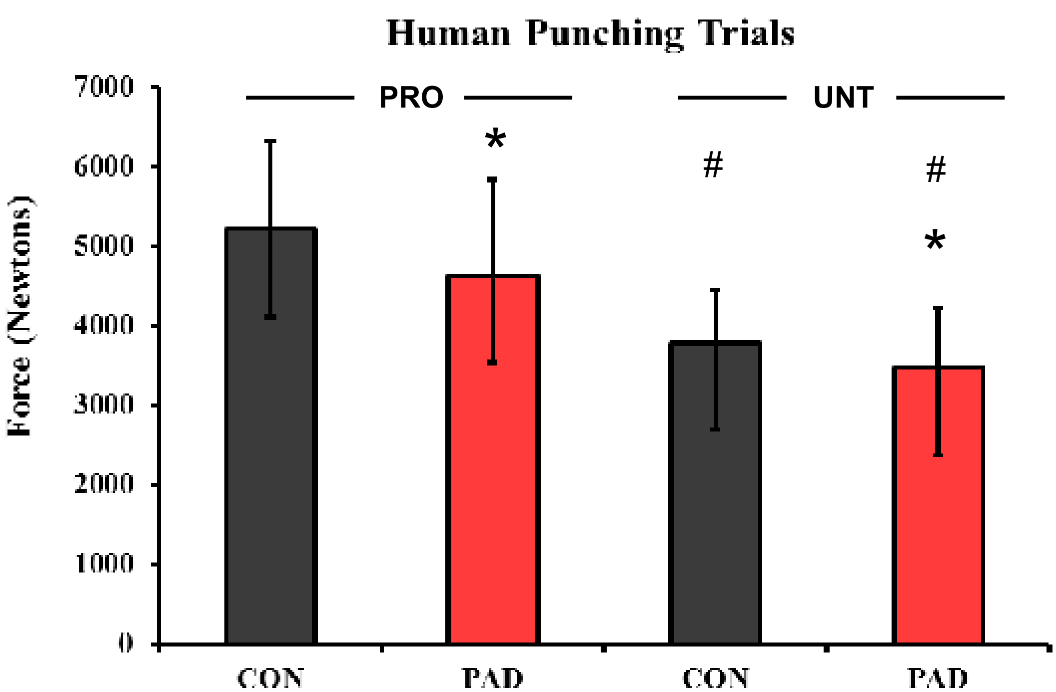


Figure **6.** Difference in punching impact during CON and PAD for PRO and UNT. * indicates significantly ($p < 0.05$) different from CON, within groups (PRO or UNT). # indicates significantly different from both PRO conditions (CON and PAD).

## 4. Discussion

The purpose of this study was to 1) assess the precision and reliability of STRIKE and to 2) assess the influence of a padded hand wrap on punching force in both elite and untrained punchers. The device used for force analysis was specifically designed for punching, and showed high reliability and precision in both mechanical and human conditions

(Table 1). Similar to previous research, PRO hit significantly harder than UNT (~80%)(Neto, Magini, & Saba, 2007; Neto, Magini, Saba, & Pacheco, 2008; Smith, Dyson, Hale, & Janaway, 2000). More importantly, punching force was significantly reduced with WRAP during the mechanical (29.3%) and human (PRO = 12.6%, UNT = 8.9%) settings. These initial findings suggest padded hand wraps such as the one used in this study significantly reduce punching force, which may be important for long-term safety considerations in combat sports.

Although certainly related, the magnitude of linear force on a stationary object (i.e. straight punch into our fixed device) is not directly indicative of the amount of physical damage or severity of injury in human combat situations. Velocity, force, acceleration/deceleration, momentum, impulse, power, and effective mass all likely play significant roles in impact related injuries during real-life human activities (Nakano, et al., 2014; Stojsih, et al., 2010). However, no single variable stands-out as more important than another because additional factors like impact location, the area over which the force is acting, and resulting rotation (Broglio et al., 2010; Ommaya, Goldsmith, & Thibault, 2002) complicate the issue. This partially explains why a universal method of assessing striking impact does not exist (Atha, Yeadon, Sandover, & Parsons, 1985; Gulledge & Dapena, 2008; Neto, Magini, & Pacheco, 2007; Neto, et al., 2008; Smith, et al., 2000; Walilko, Viano, & Bir, 2005).

Recent studies have used telemetry methodologies during boxing sparring sessions to analyze real-time head impacts (Stojsih, et al., 2010). Others have used a Crash Dummy to assess the resulting acceleration of a fake head during Taekwondo and boxing strikes (Fife, et al., 2013). While this work has produced important information, these systems are designed to predict head injury, not measurement of maximal punching force. Moreover, they only measure the resulting movement of the head and do not account for the safety of the punchers hand. Our specific research question focused on whether or not WRAP altered punching force. Thus, we chose to use STRIKE as our primary concern was obtaining a reliable and precise method of measuring maximal punching force in a fixed system. Our findings suggest implementation of a small padding on directly over the knuckles reduces punching force, even when worn in combination with a standard boxing glove. This supports the need for future investigations which use measurement devices (e.g. head impact telemetry, Hybrid II, etc.) to directly analyze the ability of WRAP to reduce punching impact in a live sport practice.

Clearly defined limits of impact in human tissue do not exist, making it difficult to draw direct comparisons between impact reduction and injury prevention. However, a linear relationship exists between impact and tissue deformation, and both factors contribute to injury outcome (Ghasemlou, Kerr, & David, 2005). Examination of sport movements (e.g. running, gymnastics, etc.) also suggests greater impacts are usually associated with more frequent injuries (Hreljac, 2004; Mills, Yeadon, & Pain, 2010). For example, Mills et al. (2010) found only a mild reduction (0.5%) in floor stiffness reduced peak vertical and horizontal ground reaction forces by 12% and bone bending moments by 6% (Mills, et al., 2010). Research on force tolerance of facial bones also shows a slight difference between the amount of impact which causes fracture, and those that do not (Cormier et al., 2011). Simulated traumatic brain injury studies indicate the greater the kinetic energy transfer to the brain, the greater impact intracranial pressure and resulting cytotoxic brain edema (von Holst & Li, 2013). Moreover, skeletal muscle damage persisted for 120 hours and was highly dependent on the number of heavy collisions absorbed during an Elite Rugby League match (McLellan, Lovell, & Gass, 2011). With this collective knowledge of impact and injury, it is highly likely the ~9-29% reduction noted with WRAP is significant enough to reduce injury rates in actual sport situations in the person being punched, the hand of the puncher, and/or both.

The cause of this reduction is unknown, but likely a result of WRAP absorbing a portion of the force. We can therefore conclude that force in the entire system was reduced, but cannot identify the exact location. In other words, conclusions of safety implications for the puncher's hand and the force area cannot be differentiated. Future research should attempt to develop methodologies that simultaneously measuring impact in the punching pad and the hand. Other factors such as punching style (Nakano, et al., 2014) and distance of the strike (Falco, Molina-Garcia, Alvarez, & Estevan, 2013) influence impact as well. These do not explain our findings as all participants were required to use the same punching style throughout the entire study and foot movements (other than rotation) were not allowed. Finally, it is unlikely the small mass (4 g) associated with WRAP was significant enough to hinder impact.

## 5. Conclusion

Practitioners should consider utilizing hand-padding strategies such as this during practice/sparring as the reduction in punching force will likely have important long-term health implications for both the puncher and the person absorbing the punch. An important follow-up study would be to compare WRAP to traditional wrapping techniques during actual sparring sessions using a system like head impact telemetry to assess whether or not WRAP actually reduces head impact during sport.

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