A COMPARISON OF THE REVERSE AND POWER PUNCHES IN ORIENTAL MARTIAL ARTS

by

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A COMPARISON OF THE REVERSE AND POWER PUNCHES IN ORIENTAL MARTIAL ARTS

(Thesis Abstract)

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This study compared mechanical factors in the reverse and three-inch power punches. Twelve expert male martial artists stood on a force plate, and executed reverse and power punches against a padded target affixed to a wall-mounted force plate. The force plates measured horizontal forces, and subsequently impulses and body center of mass (c.m.) velocity changes. The motions of four markers attached to the arm were also collected, and were used to compute the horizontal velocities of the knuckle and of the arm c.m. The power punch produced smaller velocities immediately before impact than the reverse punch for the whole body c.m. (0.14 vs. 0.31 m·s⁻¹), for the arm c.m. (2.86 vs. 4.68 m·s⁻¹), and for the knuckle (4.09 vs. 6.43 m·s⁻¹). The peak force exerted by the fist was much smaller in the power punch than in the reverse punch (790 vs. 1446 N).

However, the linear impulse exerted by the fist during the first 0.20 s of contact was slightly larger in the power punch than in the reverse punch (43.2 vs. 37.7 N·s). The results indicated that the power punch is less potent than the reverse punch, but slightly more effective for throwing the opponent off balance.
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INTRODUCTION

Traditional punches in martial arts rely on the acceleration of the combined mass of the arm and part of the torso through a rather long distance to generate momentum for transfer to the target. A typical example is the reverse punch. This is a full-range punch characterized by the projection of the hand ipsilateral to the foot positioned furthest from the target at the initiation of the punch, and it is very similar to a boxer’s cross or rear hand punch. (See Figure 1.)

Figure 1. Example of a reverse punch.

There also exists a collection of very short-ranged martial arts maneuvers called “focus striking techniques”. Perhaps the simplest example is the power punch. (For a detailed description, see DeMile, 1992.) This punch exists in several forms; one version is called the three-inch punch. In this technique, the martial artist begins with the knuckles of the punching hand about three inches (5-10 cm) away from the target, and then drives directly into the target from that position without first drawing away from it. (See Figure 2.)
Some martial artists believe that the power punch is an extremely effective and/or potent technique. This is surprising, because the limited range of motion should not be expected to allow the fist to reach a large velocity before impact. Nevertheless, many practitioners maintain that the power punch is at least as potent as the reverse punch. This issue has long been debated among martial artists, and is reflected in discussions on Internet bulletin boards.

![Figure 2. Example of the three-inch power punch.](image)

During the impact of the power punch, the body transitions suddenly from a largely relaxed state to a fully "tightened" state, and then it returns to a relaxed state upon withdrawal of the fist. Advocates of the power punch contend that the sudden rigidity of the linkage between the fist and the rest of the body during impact promotes an improved transmission of force through the kinetic chain to the target, and thus results in a potent impact despite the presumed lower velocity of the fist in the power punch in comparison to the reverse punch (Fightingarts.com, 2001-2005; 2005). Bul (2004) used the term "fa jing" or "explosive power" to describe this phenomenon. In contrast, other martial arts
practitioners deny the efficacy of the power punch. They believe that the power punch is a hoax, or that it is a push rather than a punch. Some of these practitioners think that if equal time were spent training the power punch and a traditional punch such as the reverse punch, the traditional punch would easily be more effective and/or potent than the power punch (Fightingers.com, 2001-2005, 2005; Sisco, 2005).

The speed of the fist in reverse punches has been reported by numerous researchers (Feld, McNair, & Wilk, 1979; Jordan, 1973; Kato, 1958; Nakayama, 1966; Powell, 1989; Shibayama & Fukashiro, 1997; Smith & Hamill, 1986; Stul, 1986; Walker, 1975; Yoshihuku, Ikekami, & Sakurai, 1987), but no speed data are available for the power punch. Also, several studies have measured or estimated the force exerted through the fist in the reverse punch by martial artists (Feld, McNair, & Wilk, 1979; Girodet, Vassilin, Dabonville, & Lacouture, 2005; Jordan, 1973; Powell, 1989) and by boxers (Smith, Dyson, Hale, & Janaway, 2000), as well as the acceleration imparted to a target (Chiu and Shing, 1999; Schwartz, Hudson, Fernie, Hayashi, & Coleclough, 1986) and the linear momentum transmitted by a fist impact to a hanging punching bag (Smith & Hamill, 1986) by martial artists using the reverse punch, but again no kinetic information is available for the impact of the fist using the power punch.

The purpose of this investigation was to find out if the power punch is as potent as the reverse punch.
METHODS

Set-up and general procedures

Twelve expert male martial artists (black belt or equivalent) with previous training in both the reverse and power punch techniques served as test subjects (height = 1.73 ± 0.08 m; mass = 91.9 ± 23.9 kg). All subjects punched right-handed. (One subject reported that he was actually left-handed for everyday activities but ambidextrous for punching.) Each subject was allowed to warm up and practice both punches on the testing equipment prior to data collection. The subject stood on a portable force plate placed horizontally on the ground (Kistler 9286A), and threw punches at a padded target affixed to a second force plate (AMTI OR6-7) mounted vertically on a wall. The target was a Kingside Contender "Focus mitt" of the type used in sparring practice, with the grips removed (thickness: 6 cm). The position of the ground force plate and the height of the target affixed to the vertical force plate were adjusted to the preference of the subject for each type of punch. The forces exerted by the feet on the ground plate and by the fist on the vertical plate through the padded target were measured with the force plates. Three-dimensional (3D) coordinates of selected body landmarks were obtained for each punch with a Northern Digital Optotrak 3020 optical motion analysis system. For qualitative analysis, two-dimensional images of the punching action were also recorded with a high-speed video camera (Basler A600f) at 100 Hz from a side view perpendicular to the direction of the punch.

After the subject finished warming up, the position of the ground force plate was adjusted to the preference of the subject for the punch type that was assigned to the first
trial, and this position was measured. A baseline for the knuckle position at contact was established by recording the marker positions with the Optotrak system while the subject touched lightly the surface of the padded target. The subject was then asked to stay still in his preferred stance for the first punch type to be tested. After that, the subject threw a maximum effort punch into the target while data were recorded with both force plates and the Optotrak system. This procedure was repeated until at least three satisfactory trials were recorded. Then the subject switched to the other type of punch. If necessary, the position of the ground force plate was adjusted, and its location re-measured. The entire procedure was repeated for the second type of punch. The two types of punch were executed by all the subjects in counter-balanced order.

Reference frames

All kinematic and kinetic data were expressed in a right-handed orthogonal inertial reference frame. The origin of the reference frame was located directly below the center of the contact surface of the wall-mounted force plate, and at the level of the top surface of the horizontal force plate. The Y axis was horizontal, perpendicular to the surface of the wall-mounted force plate, and pointed into the plate; the Z axis was vertical, and pointed upward; the X axis pointed in the direction of the cross product of Y and Z. All analysis was restricted to the Y direction of motion.

Data obtained from the Optotrak system

Four markers were attached to the right (punching) arm of each subject. The markers were infrared light-emitting diodes connected to the Optotrak system. Three
markers were taped to the skin at the approximate positions of the shoulder, elbow and wrist joint centers, respectively; the fourth marker was taped to the skin near the center of the third metacarpal bone. The distance from the fourth marker to the forward surface of the third knuckle was measured directly on each subject with a metric tape. The Optotak cameras obtained the 3D locations of the four markers at a frequency of 500 Hz, and a file containing the location-time data was created for each trial. The measured distance between the metacarpal marker and the forward surface of the third knuckle was used, together with the 3D positions of the wrist and metacarpal markers, to estimate by extrapolation the 3D location of the forward surface of the third knuckle throughout each trial. Quintic spline functions (Woltring, 1986) were fitted with no smoothing to the location-time coordinates of the shoulder, elbow, wrist and knuckle. The instantaneous velocities of these anatomical landmarks throughout the punch were obtained from the first derivatives of the functions. The linear velocity of the center of mass (c.m.) of the whole arm in the horizontal Y direction was then calculated throughout the entire punch from the velocities of the anatomical landmarks and Zatsiorsky's body segmental parameters, as adjusted by de Leva (1996).

Data obtained from the force plates

Each force plate yielded the values of three orthogonal force components. Data from the two force plates were collected at 960 Hz, and recorded with an Oxford Metrics Vicon system. The forces were then transformed from the local force plate reference frames into the global reference frame used for the project.
The first instant in which the force exerted on the wall-mounted force plate rose above the background noise in the raw force plate data was clearly visible in all trials. The time of impact was estimated as half-way between this instant and the previous instant in the force plate record.

Quintic spline functions (Woltring, 1986) were fitted to the force values, and smoothed with a smoothing factor equivalent to a 200 Hz low-pass filter. Horizontal impulses were calculated from the force-time data using trapezoidal integration. The impulses exerted on the wall-mounted force plate were calculated for three periods: between the instant of impact and instants 0.05 s, 0.10 s and 0.20 s after impact, respectively. The impulses exerted on the ground plate were calculated for these same periods, and also for the period between the start of force collection (when the subject was still motionless) and impact. In all trials, the punching force had dwindled to a very small value 0.20 s after impact, and therefore no data were analyzed beyond that time. The cumulative horizontal reaction impulses received by the subject through the feet and through the punching hand yielded the cumulative changes in the horizontal linear momentum of the subject. The horizontal linear momentum values were divided by the subject's mass to calculate the horizontal linear velocities of the subject's c.m. at impact and at instants 0.05 s, 0.10 s and 0.20 s after impact.

Statistical treatment

Statistically significant differences between the two punches were checked through paired t-tests.
RESULTS

The maximum velocity of the knuckle in the horizontal $Y$ direction was larger in the reverse punch than in the power punch ($6.68 \pm 0.95 \text{ m/s}^2$ vs. $4.17 \pm 0.52 \text{ m/s}^2$; $p<0.001$), and relative to the instant of impact this maximum velocity occurred slightly earlier in the reverse punch than in the power punch ($0.006 \pm 0.005 \text{ s}$ before impact vs. $0.001 \pm 0.001 \text{ s}$ after impact; $p<0.01$). The velocities of the knuckle and of the centers of mass of the arm and of the whole body in the $Y$ horizontal direction at the initial instant of impact were all significantly larger for the reverse punch. (See Table I.) In the reverse punch, the fastest subject reached a maximum knuckle velocity of $7.67 \text{ m/s}$, and $7.44 \text{ m/s}$ at impact. The corresponding values for the fastest subject in the power punch were $4.99 \text{ m/s}$ and $4.83 \text{ m/s}$, respectively.

During the first $0.20 \text{ s}$ after impact, the ground exerted a positive horizontal impulse on the subject through the foot. By itself, this impulse tended to increase the velocity of the c.m. by $0.05 \pm 0.09 \text{ m/s}^2$ in the reverse punch, and by $0.15 \pm 0.10 \text{ m/s}^2$ in the power punch ($p<0.01$). However, during this same period all subjects also received through the punching hand a larger negative impulse, which by itself tended to reduce the velocity of the c.m. by $0.42 \pm 0.17 \text{ m/s}^2$ in the reverse punch, and by $0.48 \pm 0.17 \text{ m/s}^2$ in the power punch ($p<0.02$). Therefore, all subjects experienced a net overall loss of horizontal velocity during this period in both punches ($\Delta v = -0.37 \pm 0.16 \text{ m/s}$ in the reverse punch, and $-0.33 \pm 0.16 \text{ m/s}$ in the power punch; no significant difference between punches). At the end of the $0.20$-second period, most of the subjects had a negative horizontal velocity in both types of punches, and this velocity had a larger negative value in the power punch than in the reverse punch ($p<0.01$). (See Table I.)
Table I. Velocities in the horizontal Y direction (mean ± s). Statistical significance values below 0.05 are shown in the last column.

<table>
<thead>
<tr>
<th></th>
<th>Reverse punch</th>
<th>Power punch</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>at impact:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knuckle (m·s⁻¹)</td>
<td>6.43 ± 0.82</td>
<td>4.09 ± 0.52</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Arm c.m. (m·s⁻¹)</td>
<td>4.68 ± 0.53</td>
<td>2.86 ± 0.22</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Body c.m. (m·s⁻³)</td>
<td>0.31 ± 0.13</td>
<td>0.14 ± 0.10</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>0.20 s after impact:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body c.m. (m·s⁻³)</td>
<td>-0.07 ± 0.10</td>
<td>-0.19 ± 0.10</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Table II. Forces and impulses exerted by the fist on the wall-mounted force plate in the horizontal Y direction (mean ± s). Statistical significance values below 0.05 are shown in the last column.

<table>
<thead>
<tr>
<th></th>
<th>Reverse punch</th>
<th>Power punch</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Force (N)</td>
<td>1446 ± 292</td>
<td>790 ± 134</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Time of peak force (s)</td>
<td>0.011 ± 0.002</td>
<td>0.016 ± 0.004</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Linear impulse t=0.00-0.05 s (N·s)</td>
<td>25.8 ± 6.7</td>
<td>24.1 ± 5.0</td>
<td></td>
</tr>
<tr>
<td>Linear impulse t=0.00-0.10 s (N·s)</td>
<td>32.3 ± 10.1</td>
<td>35.1 ± 9.2</td>
<td></td>
</tr>
<tr>
<td>Linear impulse t=0.00-0.20 s (N·s)</td>
<td>37.7 ± 14.6</td>
<td>43.2 ± 15.3</td>
<td>&lt;0.02</td>
</tr>
</tbody>
</table>
Figure 3 shows the horizontal Y force exerted by a typical subject on the wall-mounted force plate in the two types of punches. Table II shows that the peak force was much larger in the reverse punch than in the power punch, and that it occurred sooner after the start of contact in the reverse punch. The largest force exerted on the wall-mounted force plate by any subject was 1831 N in the reverse punch, and 2016 N in the power punch.

Table II also shows that the average impulse exerted on the wall-mounted force plate was similar in both types of punch during the first 0.05 s and 0.10 s after impact, and about 15% larger for the power punch during the first 0.20 s after impact (p<0.02).

**DISCUSSION**

During martial arts training, it is common to throw punches without a physical target ("air punches"), and the patterns of motion used for air punching are different from those used for impact punches which hit a target (Nisticò, 1982). It is often unclear if the subjects in a particular study from the literature throw air punches or impact punches. The studies by Jordan (1973), Powell (1989), Shibayama & Fukushiro (1997), Smith & Hamill (1986) and Stull (1986) were the only ones in which it was clear that the subjects hit physical targets. These studies dealt exclusively with the reverse punch, and they
reported maximum hand velocities between 7.2 m·s\(^{-1}\) and 12.3 m·s\(^{-1}\). In the reverse punch, the average subject in our study reached a maximum knuckle velocity of 6.68 m·s\(^{-1}\), and 6.43 m·s\(^{-1}\) at impact; the corresponding largest values for individual subjects were 7.67 m·s\(^{-1}\) and 7.44 m·s\(^{-1}\), respectively. Thus, the knuckle velocity values of our subjects were near the low end of the range reported by previous authors.

The amount of trauma inflicted on human tissue is dependent on a complex interaction of kinetic and kinematic factors (Arabi et al., 2003; Hodgson, 1970; Ommaya, 1970). It is not clear which is the most useful way to measure the potency of a punch, but the amount of force exerted is obviously important, probably in combination with a distance component (work performed or energy transmitted) or a time component (linear impulse).

As the fist strikes the opponent’s body, it exerts a force on the skin. This force might be measured with a thin pressure-sensitive sheet similar to the ones that are inserted inside shoes for the measurement of forces exerted by the foot on the shoe during gait. However, this would be problematic due to the marked amount of deformation to which the pressure-sensitive sheet would be subjected in a martial arts punch and to other technical limitations of the currently available pressure-sensitive sheets. In addition, the force exerted by the fist on the skin may not be the force of greatest interest to us, as will be discussed next.

As the fist exerts force on the opponent’s skin, the skin and the tissues behind it accelerate backward, producing progressive compression of the deeper tissues. One might say that the force exerted on the skin is transmitted to the inside of the body. In this process, the targeted individual experiences different amounts of compressive force
at various internal points, depending on the force exerted by the fist on the skin surface and on the viscoelastic properties of the tissues that intervene between the point of impact of the fist and the internal point. These internal compressive forces are likely to be more important than the force exerted by the fist on the skin.

Punching a padded force plate should give a reasonable approximation of the compressive forces exerted on the deeper tissues of the body. The surface of the force plate represents an internal body plane for which we want to know the amount of compressive force; the padding is a surrogate for the tissues that intervene between the surface on which the fist makes impact and the internal body plane. The closer the padding imitates the viscoelastic properties of the intervening tissues, the more representative the force plate readings will be.

If the goal is to compare the relative effects of two different impact conditions, such as those produced in the power punch and in the reverse punch, accurate matching of the viscoelastic properties of the padding to those of the human body becomes less important. If the viscoelastic properties are not perfectly matched, the absolute values of the measured forces will not be equal to the actual internal forces that would be produced in the human body, but the condition that produces a larger force on the force plate should be expected to produce also a larger internal force in the human body.

The maximum force values previously measured for the reverse punch ranged between 1550 N and 5800 N (Girodet, Vasilin, Dabonneville, & Lacoume, 2005; Jordan, 1973; Powell, 1989; Smith, Dyson, Hale, & Janaway, 2000). The maximum force values obtained for the reverse punch in the present study (average of all subjects = 1466 N; overall maximum of 1831 N in one of the subjects) fell near the low end of the range.
reported in the literature. The force values reported in all these studies were probably valid for comparisons between conditions within each study, but due to variation in the type and thickness of padding at the fist/force plate interface, force values should not be compared across studies.

The linear impulse exerted with the reverse punch on the vertical force plate during the first 0.20 s in the present study was $37.7 \pm 14.6$ N·s. This was somewhat smaller than the value of $42.0 \pm 18.7$ N·s reported by Smith & Hamill (1986) for hits on a hanging punching bag using a bare-handed reverse punch.

As previously explained, it is not appropriate to compare the fist forces from different studies. However, the hand velocities and fist impulses can be compared, and the values of these parameters indicated that the impacts made on the target by our subjects' reverse punches were rather modest in relation to those of previous studies. The reasons for this are not clear, but in any case it should not pose a serious problem for our purposes, since in our study both types of punch were executed by the same subjects and in the same testing conditions.

The results of the present project show that the reverse punch produced a larger amount of forward momentum of the body before impact than the power punch, and also larger linear velocities of the whole arm and of the knuckle. These were advantages that favored the exertion of a larger force on the target with the reverse punch. During the period of contact of the fist with the target, the body lost forward velocity in both types of punch, and in most trials it was moving backward after 0.20 s of contact. In the reverse punch, the body c.m. had more forward velocity than in the power punch at the beginning of the period of contact, and less backward velocity after 0.20 s of contact. These
conditions of the body during contact also favored the exertion of a larger force on the target with the reverse punch.

The maximum amount of force exerted on the target with the reverse punch was almost twice as large as the amount exerted with the power punch, and therefore the reverse punch was by far the more potent of the two. This was the key advantage of the reverse punch over the power punch, the end result of the larger forward velocities discussed above.

However, disabling the opponent through a potent impact may not be the only goal of a martial arts punch; another possible goal is to throw the opponent off balance. The effectiveness of a punch toward the achievement of this second goal may be measured best through the total impulse exerted on the opponent, and in this regard the power punch performed well. Although the reverse punch exerted a larger maximum force than the power punch, the force decreased more slowly in the power punch (see Figure 3), and therefore the impulses exerted on the target were not very different in the two types of punch. In fact, the cumulative impulse exerted on the target during the first 0.20 s of contact was somewhat larger in the power punch than in the reverse punch. This supports the concept of the power punch as a push rather than a punch, but keeping in mind that the force exerted on the target during its execution is by no means trivial.

Given these characteristics, several conclusions can be drawn in regard to the use of the two punches in combat or sport. The power punch will be slightly more effective than the reverse punch when the goal is to throw the opponent off balance. In addition, it may provide the advantage of surprise, since less time is required for its execution. It is also possible that the power punch might be the most effective for the delivery of a
disabling blow in certain combat situations in which only limited amounts of space and
time are available for the delivery of a punch. However, when sufficient space and time
are available, it is clear that the reverse punch will be the most potent.
REFERENCES


DeMille, J. (1992). *Bruce Lee’s 1 and 3 inch power punch (1. ed.)*. Kirkland, WA: Tao of Wing Chun Do.


dimensional kinematic and dynamic analysis of a karate straight punch. *Computer Methods in Biomechanics and Biomedical Engineering*, 8, **Supplement 1**, 117-118.


APPENDIX

EXTENDED REVIEW OF LITERATURE
Examining the kinematics

Kato (1958) used high-speed cinematography to measure the speed of the striking fist in reverse punches by novice, good, and excellent karate practitioners. He obtained maximum velocities between 5.3 and 8.1 m s⁻¹, and final velocities between 3.2 and 5.7 m s⁻¹. It is unclear whether his subjects struck a target. Nakayama (1966) claimed, without citing a source, that karate punches can travel at 13.1 m s⁻¹. He further cited unspecified work by Kato showing maximum velocities ranging from 4.68 to 7.10 m s⁻¹ in the straight punch (a technique similar to the reverse punch, but with the feet equidistant from the target plane, which allows for less hip rotation). Jordan (1973) measured hand velocities and impact forces using a force plate and cinematography at 200 frames/s. Taping and bag gloves (the gloves used for hitting punching bags) protected the hands of the subjects as they struck an unpadded force plate. He found that a higher velocity of the fist did not necessarily produce a larger peak force. The fastest reverse punch thrown by Jordan’s subjects was reported at 10.67 m s⁻¹ while the largest force was produced by a punch with a velocity of 8.52 m s⁻¹. Walker (1975) used high-speed cinematography to measure a peak speed of about 5.6 m s⁻¹ in a reverse punch. It was not clear if his subject struck a solid target or if the punch was thrown in the air.

Feld, McNair, & Wilk (1979) used stroboscopic photography at 120 frames/s to analyze the motion of the striking fist in reverse punches, and obtained peak speeds between 5.7 and 9.8 m s⁻¹. In this study, it was also not clear if the subjects struck a solid target or if the punches were thrown in the air. Stull (1986) used cinematography at 100 frames/s to
analyze reverse punches thrown at a padded hand target ("focus mitt") held by an assistant, and he found maximum wrist velocities ranging from 7.19 to 10.11 m·s⁻¹.

Smith & Hamill (1986) used cinematography at 100 frames/s to study the effects of skill level and glove type on momentum transfer. Subjects of differing skill levels and using different glove types struck a hanging punching bag (mass of 33.45 kg) with a reverse punch. Pre-impact fist velocities ranged from 10.48 to 12.34 m·s⁻¹ across conditions.

Yoshikazu, Ikegami, & Sakurai (1987) used cinematography at 250 frames/s to examine energy flow through the body to the striking limb of a reverse punch. The fist reached maximum velocities of 8.07 m·s⁻¹ and 8.69 m·s⁻¹ just before impact in their two subjects.

Powell (1989) used cinematography at 64 frames/s to study reverse punches of subjects striking an unpadded force plate attached to a hanging punching bag (mass of 31.5 kg). The subjects wore hand tape and bag gloves with approximately 6 mm of padding. Powell found pre-impact velocities between 8.10 and 8.65 m·s⁻¹. Shibayama & Fukashiro (1997) used video at 200 frames/s to measure the peak velocity of reverse punches against a padded solid target. They reported a peak velocity of about 8.4 m·s⁻¹ for one of their subjects.

During martial arts training, it is common to throw punches without a physical target ("air punches"), and the patterns of motion used for air punching are different from those used for impact punches which hit a target (Nistico, 1982). About half of the studies mentioned above, the authors did not state whether the subjects threw impact punches or air punches. It is clear that the punches in Jordan (1973), Powell (1989), Shibayama & Fukashiro (1997), Smith & Hamill (1986) and Stull (1986) hit physical targets. It also seems likely that the punches in Feld, McNair, & Wilk (1979), Walker
(1975), and Yoshihaku, Ikegami, & Sakurai (1987) were air punches. We were unable to
judge whether the punches reported in Kato (1958) and Nakayama (1966) were impact
punches or air punches. Most of the studies of unequivocal impact punches reported
maximum velocities between 8 m s⁻¹ and 11 m s⁻¹. The only exception was the 12.34
m s⁻¹ value reported by Smith & Hamill (1980).

Examining the kinetics

Jordan (1973) analyzed the karate reverse punch. The subjects wore hand tape
and bag gloves to strike a vertically mounted, unpadded force plate. The maximum
recorded force was between 1500 and 2200 N. Smith et al. (2000) analyzed boxers
performing a rear hand full range punch, very similar to the Oriental martial arts reverse
punch. The subjects wore hand wraps and 10 oz boxing gloves, and struck a cushion
attached to a wall-mounted force plate. The maximum force was between 1900 and 5800
N. Powell (1989) examined the forces exerted by participants with taped and gloved
hands punching an unpadded force plate attached to a 31.5 kg hanging punching bag.
The average value of the maximum force recorded for the reverse punch across
conditions and subjects was 3500 N, and the single best trial yielded a peak force of 3900
N. Girodet et al. (2005) examined a single expert subject executing a straight punch
(reverse punch) against a padded, instrumented target block attached to the top of a
vertically mounted flexible lath. The measured peak force was found to be 1745 N.
Feld, McNair, & Vilk (1979) considered the energy needed for the destruction of a
concrete brick to infer that a maximum punching force of at least 3100 N can be achieved
in a karate punch.
Schwartz et al. (1986) examined the effects of punching on the head of a target mannequin (50th percentile Hybrid II, head mass = 5.08 kg) that had an accelerometer attached. They reported head acceleration values between 40 and 120 g's, depending upon the particulars of the technique and safety equipment employed. Their values were probably valid for comparison of the various conditions, but the head mass and acceleration could not be used to infer forces, because the motion of the head was partly restricted by springs that connected it to the rest of the mannequin body. Chiu & Shiang (1999) also used an accelerometer to determine the acceleration of a simulated head. In this case, the "head" (a metal cylinder wrapped in padding) was suspended from the ceiling. The male subjects in their study produced head accelerations between 43 and 54 g's, and the females between 24 and 39 g's. They did not report the mass of their "head".

Smith & Hanill (1986) used cinematography at 100 frames/s to measure the linear momentum transferred to a hanging punching bag (mass of 33.45 kg) by a reverse punch under conditions of varying skill and glove type. They reported linear momentum values between 42 and 61 kg·m·s⁻¹ across conditions, with the largest impulse given by highly skilled practitioners wearing 19 oz boxing gloves. Girodet et al. (2005), in addition to their measurement of the peak force exerted on the target, used high-speed cinematography at 125 Hz to calculate the linear momentum of a 12-segment body system, and an instrumented target to measure the impulse exerted by the fist on the target. The linear momentum of the subject immediately before impact was 26.11 kg·m·s⁻¹; the velocity of the 68-kg subject's c.m. was 0.38 m·s⁻¹. The impact with the target lasted 0.015 s, and produced a linear impulse of 17.37 N·s. According to the cinematographic data, the subject's linear momentum during the period of impact
decreased by 2.38 kg·m·s⁻¹. This represented a reduction of 0.04 m·s⁻¹ in the velocity of
the subject.

Additional Reference

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