PREDICTING PUNCHING ACCELERATION FROM SELECTED STRENGTH AND POWER VARIABLES IN ELITE KARATE ATHLETES: A MULTIPLE REGRESSION ANALYSIS

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1NAR-Nucleus of High Performance in Sport, São Paulo, Brazil; 2Martial Arts and Combat Sports Research Group, School of Physical Education and Sport, University of São Paulo, Brazil; 3Brazilian Karate Confederation, Coaching Staff, São Paulo, Brazil; 4Laboratory of Applied Nutrition and Metabolism, School of Physical Education and Sport, University of São Paulo, Brazil; and 5School of Physical Education and Sport, University of São Paulo, São Paulo, Brazil

ABSTRACT

Loturco, I. Artioli, GG, Kobal, R, Gil, S, and Franchini, E. Predicting punching acceleration from selected strength and power variables in elite karate athletes: A multiple regression analysis. J Strength Cond Res 28(7): 1826–1832, 2014—This study investigated the relationship between punching acceleration and selected strength and power variables in 19 professional karate athletes from the Brazilian National Team (9 men and 10 women; age, 23 ± 3 years; height, 1.71 ± 0.09 m; and body mass [BM], 67.34 ± 13.44 kg). Punching acceleration was assessed under 4 different conditions in a randomized order: (a) fixed distance aiming to attain maximum speed (FS), (b) fixed distance aiming to attain maximum impact (FI), (c) self-selected distance aiming to attain maximum speed, and (d) self-selected distance aiming to attain maximum impact. The selected strength and power variables were as follows: maximal dynamic strength in bench press and squat-machine, squat and countermovement jump height, mean propulsive power in bench throw and jump squat, and mean propulsive velocity in jump squat with 40% of BM. Upper- and lower-body power and maximal dynamic strength variables were positively correlated to punch acceleration in all conditions. Multiple regression analysis also revealed predictive variables: relative mean propulsive power in squat jump (W·kg⁻¹), and maximal dynamic strength 1 repetition maximum in both bench press and squat-machine exercises. An impact-oriented instruction and a self-selected distance to start the movement seem to be crucial to reach the highest acceleration during punching execution. This investigation, while demonstrating strong correlations between punching acceleration and strength-power variables, also provides important information for coaches, especially for designing better training strategies to improve punching speed.

KEY WORDS martial arts, strength training, power training, correlation, combat sports, fighters

INTRODUCTION

Competitive karate performance is a multifactorial phenomenon influenced by technique, tactics, and fitness, among other factors (5). In karate combats, offensive actions are performed at very high speeds; athletes must strike before their opponents are able to defend the attack or counter attack themselves (13). Indeed, studies assessing the speed of high-intensity actions during simulated karate combats reported that they last from 0.3 ± 0.1 seconds to 2.1 ± 1.0 seconds (1,10). In official competitions, it has been reported that punching techniques prevail over kicking techniques, probably because they are faster to execute (4). Thus, punching techniques should be one of the main focuses of high-level karate athletes’ training.

In preparation for competition, karate athletes undertake strength and conditioning programs. This is an important aspect of training, as highlighted by a recent study showing that both upper- and lower-body muscle power are higher in winners as compared with defeated international level karate athletes (20). One can speculate that upper- and lower-body muscle power might influence speed, acceleration, and power of karate techniques, thereby contributing to competitive performance. Therefore, training strategies aiming to maximize muscle power may be of great value for karate athletes. Identifying the physical capacities associated with karate techniques is relevant to improve training methods, especially concerning the exercise type and loads that should be applied to improve karate technique speed, power, and
acceleration. In this regard, it has been suggested that the acceleration of a punch or kick directly affects the impact; Bolander et al. (2) showed that peak force is related to the acceleration of the object at each instant, multiplied by its effective mass. However, the association between muscle power and the ability to perform karate-specific techniques has never been investigated.

In addition to acceleration, the impact caused by a striking technique seems to be influenced by other factors. For example, it was recently demonstrated that the palm strike (a kung-fu technique), when preceded by stepping forward to the target, results in a higher impact as compared with the same technique performed without stepping forward (18). Moreover, athletes may intentionally execute a punch aiming for either maximum speed or maximum impact, depending on whether the competition is “full-contact” or not. During training and competition, athletes may have to punch at different distances from the target, which may also influence the impact generated by the punch. However, the influence of these variables on the acceleration generated by a punch has never been investigated, and the physical capacities that best predict punch acceleration are still unknown. Thus, the objective of this study was (a) to verify whether a goal-oriented instruction (i.e., maximal speed or maximal impact) and the distance from the target affects punching acceleration and (b) to investigate the strength and power abilities that are most associated with punching acceleration.

**METHODS**

**Experimental Approach to the Problem**

After a standardized 15-minute warm-up including general (i.e., running at a moderate pace for 5 minutes followed by 5 minutes of lower and upper limbs active stretching) and specific exercises (i.e., karate-specific punching movements at moderate intensity speed for 5 minutes), athletes were provided with a 5-minute resting interval. Individuals were then required to perform a punch acceleration test under 4 different conditions as follows: (a) fixed distance aiming to attain maximum speed (FS), (b) fixed distance aiming to attain maximum impact (FI), (c) self-selected distance aiming to attain maximum speed (SSV), and (c) self-selected distance aiming to attain maximum impact (SSS). A 3-minute resting interval was allowed between conditions. All tests were performed with athletes using karate gloves, as is standard in competition. An accelerometer (DTS 3D; Noraxon, AZ, USA) with sensors wirelessly connected to a laptop was attached to the athletes’ gloves, and data were recorded in real time (Figure 1). The device sampled at a frequency of 1,500 Hz and worked with a sensitivity equal to 400 mV·G⁻¹. During the tests, athletes were placed in front of a “body opponent bag” (BOB) and instructed to position the guard according to their individual preferences. To establish the BOB height, the athlete performed their preferential guard position and conducted the technique in the sternum region of the BOB, where the punch was executed. After 15-minute recovery, countermovement and squat jump heights were assessed using a contact platform. After a further 10-minute recovery, athletes were required to perform the mean propulsive power assessment. After a final-minimum of 90-minute recovery, participants performed the maximal dynamic strength determination.

**Subjects**

Nineteen professional karate athletes from the Brazilian National Team (9 men and 10 women; age, 23 ± 3 years; height, 1.71 ± 0.09 m; and body mass [BM], 67.34 ± 13.44 kg) volunteered to participate in the study. This group was submitted to the following training schedule in the period of evaluation: karate-specific endurance training: two 45–60 minutes session per week; power/strength training: three 45–60 minutes sessions per week; technical sessions: five 60–90 minutes per week. All procedures were approved by an Institutional Review Board for use of human subjects. After being fully informed of the risks and benefits associated with the study, all participants signed a written informed consent form. All athletes were tested during the competitive phase of training 1 week before the 2013 Pan American Championship, the major competition of the season, suggesting that athletes were close to or at peak performance. In this competition, the Brazilian National Team was the overall champion, winning 6 medals in 12 classes (3 gold, 1 silver, and 2 bronze medals).

**Punch Acceleration Determination**

The athletes were instructed to perform a gatsu-tsuki (i.e., a specific reverse karate’s punch executed by the back arm, using the hips to push it forward) under the 4 different conditions in a randomized order (i.e., FV, FI, SSV, and SSS). In
the fixed distance conditions, athletes were positioned 1 m from the BOB, whereas in the self-selected conditions athletes freely chose their best position for starting the punch. The $G$ acceleration ($G$) was calculated automatically by the device and represented the peak acceleration of the horizontal vector produced throughout the punch execution. Five attempts of each condition were allowed. The data were not filtered. A 15-second resting interval was allowed between attempts. The highest $G$ value of each condition was considered for further analysis (Figure 2). Intraclass coefficient correlations in the 4 conditions were FV = 0.954 (95% confidence interval [CI] = 0.914–0.980); FI = 0.940 (95% CI = 0.888–0.973); SSS = 0.968 (95% CI = 0.940–0.986); SSI = 0.947 (95% CI = 0.900–0.976).

Maximal Dynamic Strength Determination

Maximal dynamic strength was determined for upper body and lower body through 1 repetition maximum (1RM) tests for bench press and squat-machine exercises. All participants performed 2 familiarization sessions before the 1RM session. A 5-minute warm-up was performed on a motorized treadmill at 9 km·h$^{-1}$ followed by 3 minutes of lower limb stretching exercises. Participants then performed 2 warm-up sets: in the first set, they executed 5 repetitions at 50% of 1RM and in the second set, they performed 3 repetitions at 70% of 1RM, with a 3-minute interval between sets. After 3 minutes, participants started the test and were allowed to perform 5 attempts to obtain 1RM load, which was measured to the nearest 1 kg (3).

The squat lift 1RM tests were performed on a squat-machine (Plyo Press, Athletic Republic, Park City, UT, USA), where displacement was controlled, and the participants started the concentric movement from a 90°-knee flexion. Bench press 1RM tests were performed on a “Smith” machine (Technogym Equipment, Cesena, Italy). Correct technique involved lowering the bar in a controlled manner until the bar reaches the chest and then lifting the bar back to the start position until the elbows are fully extended. The head, shoulders, and buttocks remained in contact with the bench throughout the entire execution. Strong verbal encouragement was provided during all attempts.

Squat Jump and Countermovement Jump Heights

In the squat jump, a static position with a 90°-knee flexion angle was maintained for 2 seconds before a jump attempt without any preparatory movement. In the countermovement jump, subjects were instructed to perform a downward movement followed by a complete extension of the lower limb joints and freely determine the amplitude of the countermovement to avoid changes in jumping coordination pattern. Five attempts at each jump were performed interspersed by 15-second intervals. The jumps were performed on a contact platform (Smart Jump; Fusion Sport, Coopers Plains, Australia) with the obtained flight time ($t$) being used to estimate the height of the body’s centre of gravity ($h$) during the vertical jump (i.e., $h = gt^2/8$, where $g = 9.81$ m·s$^{-2}$). A given jump would be considered valid for analysis if the take off and landing positions were visually similar. The best attempt was used for data analysis purposes.

Mean Propulsive Power and Velocity With a Load Corresponding to 40% of Body Mass in Jump Squat and Mean Propulsive Power in Bench Throw

Mean propulsive power was assessed in jump squat and bench throw exercises, both being performed on a Smith machine (Technogym Equipment). Participants were instructed to execute 3 repetitions at maximal velocity for each load, starting at 40% of their BM in jump squat and 30% of their BM in the bench throw. In the jump squat, participants executed a knee flexion until the thigh was parallel to the ground and, after the command to start, jumped as fast as possible without their shoulder losing contact with the bar. During the bench throw, athletes were instructed to lower the bar in a controlled manner until the bar lightly touched the chest and, after the command to start, threw it as high and fast as possible. A load of 10% of BM for jump squat and 5% of BM for bench throw was progressively added in each set until a decrease in mean propulsive power was observed. A 5-minute interval was provided between sets. To determine mean propulsive power, a linear transducer (T-Force, Dynamic Measurement System; Ergotech Consulting S.L., Murcia, Spain) was
**Table 1.** Body mass, power, and strength characteristics of men and women from Brazilian karate team."

<table>
<thead>
<tr>
<th></th>
<th>Men ((n = 9))</th>
<th>Women ((n = 10))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass (kg)</td>
<td>76.7 ± 14.4†</td>
<td>59.1 ± 8.4</td>
</tr>
<tr>
<td>Bench press 1RM (kg)</td>
<td>89 ± 19†</td>
<td>44 ± 5</td>
</tr>
<tr>
<td>Squat-machine 1RM (kg)</td>
<td>201 ± 31†</td>
<td>151 ± 17</td>
</tr>
<tr>
<td>Relative bench press 1RM (kg per bodyweight)</td>
<td>1.16 ± 0.17†</td>
<td>0.78 ± 0.14</td>
</tr>
<tr>
<td>Relative squat-machine 1RM (kg per bodyweight)</td>
<td>2.65 ± 0.32†</td>
<td>2.58 ± 0.38</td>
</tr>
<tr>
<td>Mean propulsive power in jump squat (W)</td>
<td>718 ± 150†</td>
<td>458 ± 66</td>
</tr>
<tr>
<td>Mean propulsive power in bench throw (W)</td>
<td>583 ± 116†</td>
<td>261 ± 51</td>
</tr>
<tr>
<td>Relative mean propulsive power in jump squat ((W \cdot kg^{-1}))</td>
<td>9.49 ± 1.81</td>
<td>7.93 ± 1.75</td>
</tr>
<tr>
<td>Relative mean propulsive power in bench throw ((W \cdot kg^{-1}))</td>
<td>7.68 ± 1.22†</td>
<td>4.48 ± 0.99</td>
</tr>
<tr>
<td>Jump squat velocity with 40% of BM ((m \cdot s^{-1}))</td>
<td>1.23 ± 0.15†</td>
<td>1.10 ± 0.09</td>
</tr>
<tr>
<td>Squat jump (cm)</td>
<td>40.6 ± 5.6†</td>
<td>30.5 ± 3.2</td>
</tr>
<tr>
<td>Countermovement jump (cm)</td>
<td>43.2 ± 5.3†</td>
<td>31.9 ± 4.2</td>
</tr>
</tbody>
</table>

*1RM = 1 repetition maximum; BM = body mass.
†Different from women \((p \leq 0.05)\).

Men displayed higher performance values than women in all variables \((p \leq 0.05); Table 1\), except in the relative squat-machine 1RM and relative mean propulsive power in jump squat.

**Figure 3.** Punch acceleration in different combination of distance and goals for men and women high-level karate athletes (values are mean ± SD). *Different from all other conditions \((p \leq 0.05)\). #All conditions were different between men and women \((p \leq 0.05)\).
and self-selected distance ($p = 0.032$) and impact and self-selected distance ($p = 0.008$) conditions, and lower than women in all other conditions ($p < 0.001$).

Significant correlations ($p \leq 0.05$) were found between punch accelerations in the different conditions and maximal strength and power exercises (Table 2). Both upper- and lower-body power and maximal strength variables were positively correlated to punch acceleration in the different conditions.

<table>
<thead>
<tr>
<th>Condition</th>
<th>FS</th>
<th>FI</th>
<th>SSS</th>
<th>SSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal velocity during jump squat with 40% of BM</td>
<td>0.742 (0.433–0.894)</td>
<td>0.723 (0.400–0.886)</td>
<td>0.722 (0.398–0.886)</td>
<td>0.745 (0.440–0.896)</td>
</tr>
<tr>
<td>Relative mean propulsive power in jump squat</td>
<td>0.765 (0.476–0.905)</td>
<td>0.789 (0.521–0.915)</td>
<td>0.765 (0.477–0.905)</td>
<td>0.804 (0.551–0.922)</td>
</tr>
<tr>
<td>Relative squat-machine 1RM</td>
<td>0.664 (0.300–0.859)</td>
<td>0.672 (0.314–0.863)</td>
<td>0.657 (0.289–0.856)</td>
<td>0.636 (0.255–0.846)</td>
</tr>
<tr>
<td>Relative mean propulsive power in bench throw</td>
<td>0.729 (0.411–0.889)</td>
<td>0.656 (0.288–0.855)</td>
<td>0.652 (0.282–0.854)</td>
<td>0.736 (0.424–0.892)</td>
</tr>
<tr>
<td>Relative bench press 1RM</td>
<td>0.762 (0.470–0.903)</td>
<td>0.707 (0.373–0.879)</td>
<td>0.706 (0.374–0.879)</td>
<td>0.747 (0.443–0.897)</td>
</tr>
<tr>
<td>Squat jump height</td>
<td>0.687 (0.338 to 0.870)</td>
<td>0.669 (0.309–0.862)</td>
<td>0.653 (0.282–0.854)</td>
<td>0.676 (0.320–0.865)</td>
</tr>
<tr>
<td>Countermovement jump height</td>
<td>0.729 (0.411 to 0.889)</td>
<td>0.707 (0.373–0.879)</td>
<td>0.690 (0.344 to 0.871)</td>
<td>0.727 (0.406–0.888)</td>
</tr>
</tbody>
</table>

*FS = fixed distance aiming to attain maximum speed; FI = fixed distance aiming to attain maximum impact; SSS = self-selected distance aiming to attain maximum speed; SSI = self-selected distance aiming to attain maximum impact.

Self-selected distance aiming to attain maximum impact: acceleration ($G = 1.923 + 0.240$ (relative mean propulsive power in jump squat, in W·kg⁻¹) + 0.004 (squat-machine 1RM, in kg) ($R = 0.825, R^2$ adjusted = 0.640)

Self-selected distance aiming to attain maximum impact: acceleration ($G = 2.260 + 0.230$ (relative mean propulsive power in jump squat, in W·kg⁻¹) + 0.006 (bench press 1RM, in kg) ($R = 0.831, R^2$ adjusted = 0.653).

**DISCUSSION**

The main finding of this study is that punching with an impact-oriented goal and from a self-selected distance produces higher accelerations compared with a speed-oriented goal and fixed distance. Moreover, several upper- and lower-body power and strength variables were positively correlated to acceleration in the different punch conditions. According to our results, 56–65% of the variation in punch acceleration in the various conditions could be predicted by a combination of relative mean propulsive power in jump squat, and either squat-machine 1RM or bench press 1RM.

In competitive karate, punches are the most used technique (4). Punching is a highly complex technique that requires the coordinated action of arm, trunk, and leg muscle groups (22). Some authors consider that the lower body is the primary contributor to punch execution, because the ground reaction forces generated by legs would be transferred to the upper body, allowing for a powerful movement (12). Thus, the inclusion of the relative mean propulsive
power in jump squat in all punching acceleration predictive equations is indicative that a higher ground reaction force would result in more acceleration. In fact, Filimonov et al. (7) showed that the better the competitive level, the more the legs contribute to the total impact during straight punching in boxers. According to Turner et al. (22) and Lenetsky et al. (12), leg drive is likely to affect preimpact hand velocity. In World Karate Federation, athletes’ main goal is to score by touching the opponent rather than knocking them out; hence, a higher hand acceleration and speed would be important to land a punch before a response from the opponent (13). Not surprisingly, relative mean propulsive power in jump squat was the only variable that did not differ between men and women, which further strengthens the concept that leg power is crucial for punch acceleration and, therefore, karate performance.

Lower-body maximal strength was also predictive of punching acceleration in all conditions, suggesting that karate athletes aiming at improving punch acceleration should improve both relative lower-body mean propulsive power and lower-body maximal strength. Indeed, Turner et al. (22) have recommended exercises for lower-body maximal strength as an important means to improving punching power, whereas Lenetsky et al. (12) reported that the literature has not extensively explored punching in relation to upper body. Furthermore, our results indicate that maximal bench press strength is related to punch acceleration and, thus, increasing upper-body maximal strength also appears to be important to improve punch performance. However, it is worthy to note that only 56–65% of the variation in punch acceleration was explained by power and strength parameters, suggesting that technical aspects are probably responsible by the remaining variation.

The relationships between strength and power abilities and punching speed for both upper and lower limbs can be explained by the dynamics characteristics of punching. When karate athletes punch at higher velocities, the ability to transfer the linear momentum of force from the lower limbs to the upper limbs is critical to hit the opponent as fast as possible. Indeed, this skill is directly associated with the mechanical impulse generated in a specific movement (i.e., the integral of force over a short time interval). These associations have also been demonstrated in other sports actions performed with the upper limbs; Morris and Bartlett (16) described these mechanisms as critical factors for performance in javelin throwing, whereas Chelly et al. (6) reported a similar relationship in male handball players and predictors of ball throwing velocity. In this study, both maximum strength and relative mean propulsive power were important predictors of punching acceleration. These findings support the mechanical principle that determines the magnitude of a body’s linear momentum, defined as a product of its mass multiplied by its velocity. In this regard, the athletes capable of applying greater amounts of force against the ground and of moving their bodies forward at higher speeds obtain the best outcomes in punching acceleration. These abilities are directly correlated to maximum strength and relative power abilities (8,9,11,14,15,19).

Our results indicated that when athletes where asked to perform a punch with an impact-oriented goal and were free to choose the distance from their target, higher acceleration was achieved. This is likely because of the fact that peak force is related to the acceleration of an object at each instant, multiplied by its effective mass (2). Because peak hand acceleration is correlated to martial arts experience (17) and our athletes were competing at the highest level, it is likely that they were able to adjust the optimal distance to achieve the higher acceleration. This is confirmed by the fact that the speed-oriented and fixed distance condition resulted in the lowest accelerations of all conditions.

**Practical Applications**

The findings presented herein suggest that a training system to improve punching acceleration should include exercises capable of increasing lower-body muscle power and both upper- and lower-body maximal dynamic strength. However, to punch at higher velocities, fighters have to develop the technical ability to transfer the linear momentum of force from the lower limbs to the upper limbs as fast as possible. The inclusion of punching drills, in which athletes attempt to achieve the highest possible impact from a self-selected distance, ought to be considered an essential part of any karate training routine. Longitudinal studies investigating the impact of improving these variables on punch performance should be conducted to further confirm and strengthen the associations found in this study. Future studies should also include trunk-specific exercises as predictive variables for punching acceleration because a stable trunk (especially at the lumbar region) might be important to transmit ground reaction forces throughout the body (12).

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**References**


