A Comparison of Ballistic-Movement and Ballistic-Intent Training on Muscle Strength and Activation

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Purpose: Studies have both supported and refuted the concept that it is the intent to perform ballistic contractions that determines velocity-specific gains in resistance training. The purpose of this investigation was to determine whether ballistic intent is as effective as ballistic movement in improving muscle activation, force, movement time, and reaction time. Methods: Subjects completed 8 wk of punch training. A dynamic (DYN) group trained with elastic resistance bands, and the isometric (ISO) group trained with an unyielding strap. A control (CTRL) group was also tested. Pretesting and posttesting measures included isometric force; electromyography (EMG) of triceps, biceps, pectoralis major, and latissimus dorsi; movement and reaction time of both arms; and a quick-hands test of coordination. Results: Triceps iEMG increased by 63% in the ISO group (P = .03). Pectoralis major iEMG increased by 65% in the DYN group (P = .007). Movement time decreased 17.6% in the DYN training group (P = .001). Isometric force did not improve in either training group or in the CTRL group. Conclusions: Because of its specificity of movement, dynamic training might be a more appropriate method to improve punching speed for martial artists and boxers. The intent to contract explosively over a short duration does not appear to be beneficial in increasing force production or speed of movement in punching.

Key Words: punching, martial arts, force, cocontractions, electromyography

Training that is specific to an athlete’s sport is a vital component of any strength and conditioning program and is advocated for many sports. In considering sport-specific training, the velocity and movement should match the sport setting as closely as possible to achieve optimal transfer to performance. Many sports typically involve high-velocity, explosive movements and ballistic contractions. Research on ballistic movements has both supported and refuted claims regarding the efficacy of their inclusion in sport-training programs, in that both slow- and fast-velocity training have been implicated in sport-specific improvement. Behm and Sale investigated the effect of the intention to contract explosively and reported that it was the intent to contract explosively, not the actual movement itself, that is a key factor in improving peak torque and rate of torque development in the dorsiflexors.

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In a more recent study, Olsen and Hopkins,\(^8\) using a ballistic intent to contract, found that subjects who trained using conventional and isometric ballistic kick training increased their speed but decreased the amount of force produced. Based on the contradictory literature in this area further research is necessary to determine the neuromuscular training factors associated with velocity-specific adaptations to force, rate of force development, and muscle activation.

In an attempt to add clarity to the inconsistent findings of the previous research, the purpose of the current study was to determine whether it is the intent to contract at a high velocity (using isometric training) or the actual movement speed (using dynamic training) that determines the greatest gains in strength, reaction and movement time, and other velocity-related performance measures. Changes in electromyographic (EMG) activity were also examined in an attempt to understand possible mechanisms.

**Methodology**

**Subjects**

Twenty subjects participated in this study. They were free of injury, recreationally active, and participating in either resistance training or martial arts 3 to 6 d/wk but not competitive in their chosen activity (Table 1). Subjects were recruited from the Memorial University of Newfoundland population and greater St John’s area. All subjects read and completed an informed-consent form and were given the opportunity to ask questions of the researcher regarding the study. Approval for this study was granted through the university’s Human Investigation Committee.

**Testing Design**

Subjects underwent testing of both the dominant and nondominant arms before and after an 8-week training program. To remove possible confounding effects of cross-education, subjects trained with a single arm. Testing consisted of measuring EMG, force, and movement and reaction time and the quick-hands test. To establish intraclass reliability coefficients, the tests were performed twice before training, with a 1-week interval between testing sessions. Each subject completed the tests 3 to 5 times, and the average of the best 3 trials was taken.

The subjects then began their training program immediately after the second testing session. Two to three days after completing the training program, subjects began the posttraining testing. The tests completed in the initial testing session were repeated.

**Table 1  Subject Characteristics**

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (y)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Recreationally active</th>
<th>Martial artists</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (n = 6)</td>
<td>21.3 ± 1.6</td>
<td>177.5 ± 10.7</td>
<td>82.7 ± 29.9</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Dynamic (n = 7)</td>
<td>28.1 ± 9.7</td>
<td>168.9 ± 5.2</td>
<td>67.5 ± 11.6</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Isometric (n = 7)</td>
<td>22.1 ± 2</td>
<td>170.3 ± 6.3</td>
<td>80.5 ± 20.1</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>
Maximal Voluntary Contraction. Each subject lay supine on a table, with straps placed slightly below the knee and above the hip to restrict movement. The subject held a handle that was fixed to a strain gauge (Wheatstone bridge configuration, Omega Engineering Inc, LCCA 250, Don Mills, ON, Canada) with the arm held at 45° abduction from the body and the elbow bent at a 90° angle. The length of the handle restricted the subject to a 90° angle at the elbow. The subject was instructed to hold one side of the table with the hand that was not being tested and to maintain this position throughout testing (Figure 1). On instruction from the researcher, the subject attempted to perform a maximal voluntary contraction in the form of a punch by executing an elbow-extension movement. The contraction was held for 1.5 to 2 seconds.

Figure 1 — Position of subject in preparation for force/EMG data collection.
**EMG.** Electrodes (MediTrace, Kendall, 1-cm silver/silver chloride recording area, 3-cm interelectrode distance) were placed on the muscle belly of the following muscle groups: midway between the acromion and olecranon processes on both the biceps brachii and triceps brachii, midway between the axilla and thelium on the pectoralis major, approximately 1 to 2 cm below the inferior angle of the scapula, and midway from the inferior angle of the scapula to the axilla, on the latissimus dorsi. All electrodes were placed in line with the direction of fibers of the corresponding muscle. EMG activity was sampled at 2000 Hz, filtered with a Blackman 61-dB band-pass filter (10–500 Hz), amplified (bipolar differential amplifier, input impedance = 2 MΩ, common-mode rejection ratio > 110 dB min [50/60 Hz], gain ×1000, noise > 5 µV), and analog-to-digitally converted (12 bit; Biopac Systems, Santa Barbara, CA).

**Quick-Hands Test.** Each subject faced a contact mat, which was fixed to a wall at approximately shoulder height. The subject stood with arms fully extended, palms against the mat. He or she was then instructed to step forward and keep the hands on the mat so that the elbows were bent to approximately 70°. The subject reacted after a verbal command (“go”) from the researcher. The subject was instructed to hit the mat with the palms of the hands as many times as possible for 10 seconds. No encouragement was given from the researcher. The subject stopped when she or he heard the “stop” command from the researcher. The total number of contacts over 10 seconds and the average number of contacts made in 1 second were calculated. Data were collected using the Innervations kinematic measurement system, version 2004.2.0. Data were collected on a computer (Sona Computers, St John’s NL, Canada; Pentium 4, 2.8-GHz processor, 512 MB RAM).

**Movement and Reaction Time.** The movement–reaction-time apparatus was developed by Memorial University Technical Services (Newfoundland, Canada) and consisted of a stop clock (58007, Lafayette Instrument Co, Lafayette, IN) and analog timer (L15-365/099, Triton Electronics, Great Britain), an incandescent light, a trigger plate, and a subject-activated movement–reaction-time initiator. This final component consisted of a custom-designed box (62 × 15.5 × 9 cm) with a start button and stop button positioned 50 cm apart. The subject was seated such that the initiator apparatus was placed laterally to his or her body. The height of the chair was adjusted so that when the subject sat and placed his or her hand on the button, elbow flexion was approximately 90°. The subject held down a blue button so that the distal end of the metacarpals touched. When the researcher activated the switch for the light, the subject was instructed to hit the red button as fast as possible. Turning on the light started both the movement and reaction-time clocks. Reaction time was taken as the time between the flash of the light and the release of the blue button. Movement time was taken as the time between the release of the blue button to when the red button was compressed. Subjects completed this test 4 times with both the trained and the untrained limb, and the mean of the 4 trials for each limb was used for analysis.

**Training Program**

Each subject participated in an 8-week training program, with a training frequency of 3 d/wk. Subjects were randomly assigned into an isometric-training (ISO),
dynamic-training (DYN), or control group. The goal of the program was to progressively increase the amount of resistance used (for the DYN group) or the effort exerted (for the ISO group) during punching. In weeks 1 and 2, subjects performed 3 and 4 sets, respectively, of 10 repetitions. In weeks 3 through 8, they performed 5 sets of 10 repetitions. Subjects rested between 45 and 60 seconds between sets. Each session was approximately 10 minutes long. Subjects were instructed to train a single arm (dominant or nondominant), which was randomly chosen by the researcher. All subjects were asked to perform the movement as fast as possible. Training was monitored on a regular basis by the primary investigator.

In the DYN group, sessions consisted of using an elastic band to train the arm for hand punching (Figure 2[a]). The initial amount of elastic resistance used was determined by a trial-and-error method. The subject was given a series of elastic bands that progressively increased in resistance with which to practice the punch movement. The elastic bands varied in tension, from 3.2 kg (7 lb) to 11.5 kg (25.3 lb) at 250% elongation (Theraband Systems Inc). Subjects used either a single band or a combination of resistance bands for their training program. When a subject could barely extend his or her arm fully, this was determined to be the starting resistance used. The subject was then instructed to continue adding elastic bands as necessary to ensure that sufficient overload was maintained throughout the training program. The range of motion was such that each subject began the movement with the elbow abducted approximately 45° from the body and flexed at approximately 90°. The subject then extended his or her arm fully. During the eccentric portion of the movement, the subject returned the hand back to the start position.

Subjects in the ISO group performed punching movements against an immovable object using heavy cording fixed to a handle (Figure 2[b]). The duration for each repetition was less than 1 second. The training occurred with the elbow abducted approximately 45° from the body and flexed at approximately 90°. Although ISO subjects attempted to perform maximal contractions at every testing and training session, they were continually instructed to increase the effort and force used when punching throughout the training program. Previous research has demonstrated increases in maximal isometric strength when subjects trained with maximal isometric contractions.\textsuperscript{10}

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**Figure 2** — Apparatus for (a) dynamic and (b) isometric training.
Because the act of hand punching works primarily the triceps brachii, pectoralis major, and deltoid muscles, there is a potential to create imbalances between anterior and posterior muscles. To correct this, subjects performed pulling movements. This ensured that muscles that assist in flexion/pulling (latissimus dorsi, trapezius, and biceps brachii) were trained. The training variables (sets, repetitions, resistance, and speed) were the same as for the hand-punching movement.

Data Analysis

EMG activity was full-wave rectified and filtered (10–500 Hz) over a 200-millisecond period at and before the peak of the force. The integral of the EMG (iEMG) activity was calculated from these samples (AcqKnowledge software, Biopac Systems, Santa Barbara, CA). All data for EMG were collected on a computer (Sona Computers, St John’s, NL, Canada; Pentium 4 2.8-GHz processor, 512 MB RAM).

Statistical Analysis

The study was a between-groups, repeated-measures design. Subject data were examined pretraining and posttraining and compared against a control group. Statistical analysis was performed using SPSS (v 12.0). Separate 3-way ANOVAs were implemented for the EMG activity of each muscle tested, force, reaction time, and movement time (type of training [isometric, dynamic, and control] × trained state [trained and untrained arm] × time [pretest and posttest]). A 1-way ANOVA was conducted on the quick-hands test (pretest to posttest). Significance was present if $P < .05$. A Bonferroni post hoc test was conducted if significant results were present after the ANOVA (trials). Intraclass correlation coefficients were calculated on the quick-hands test (.90), force (.95), and all integrated electromyography (iEMG) recordings (.65–.75).

Results

Measures of Reliability

Intraclass Correlations. Reliability has been previously established in this laboratory for movement and reaction time with correlation coefficients of .93 and .8, respectively. Intraclass correlations were moderate to strong for the quick-hands test (.90), force (.95), and all integrated electromyography (iEMG) recordings (.65–.75).

Test of Homogeneity. A Levene test of homogeneity was performed on force and EMG measures. Significant findings were found in the control (CTRL) group.
for the biceps brachii ($P = .007$) and in the isometric (ISO, $P = .05$) and dynamic (DYN, $P < .001$) training groups for the latissimus dorsi. These variances can be accounted for by the small sample size of each group in the study and corresponding variability in the data.

**Force Production**

No significant differences in force production were seen between groups across trials (within the pretesting and posttesting sessions) or between pretraining and posttraining measures.

**Electromyography**

There were no significant iEMG activity changes with the untrained arm. There was a significant ($P < .05$) main effect for time, with a 20.3% increase in EMG activity.

**Triceps Brachii.** A significant ($P = .03$) increase of 63% was observed for triceps brachii iEMG with the ISO training group between pretraining and posttraining measures (training type $\times$ time interaction; Figure 3). No significant differences were seen in either the CTRL ($P = .45$) or DYN ($P = .60$) group.

**Biceps Brachii.** A tendency for an increase of 26% of the biceps brachii iEMG was found in the DYN group between pretraining and posttraining measures, but this was not significant ($P = .08$; Figure 4). No significant differences were seen in either the ISO ($P = .76$) or CTRL ($P = .19$) group. There was no significant difference between training groups.

**Pectoralis Major.** A significant ($P = .007$) increase of 65% with pectoralis major iEMG was seen in the DYN group posttraining (training type $\times$ time interaction; Figure 5). No significant time differences were seen in either the ISO ($P = .58$) or CTRL ($P = .56$) group.

![Figure 3 — iEMG of the triceps brachii muscle group. *$P = .03$. Columns and bars represent means and SDs, respectively.](image)
Latissimus Dorsi. No significant differences were found in the latissimus iEMG between training groups or pretraining and posttraining.

Movement and Reaction Time

There were no significant changes in movement and reaction time for the untrained arm; therefore, the following data reflect a main effect for time. A significant 17.6% decrease ($P = .001$) in movement time was seen in the DYN training group between pretraining and posttraining measures (Figure 6). No significant differences in
either the CTRL or ISO group were seen. There were no significant differences in reaction time for any variable or group.

**Quick-Hands Test**

No significant differences were seen in the number of contacts made per second between groups or pretraining and posttraining measures. A tendency was seen for a decrease by 16.8% in the total number of contacts per trial in the ISO group posttraining. Although this finding was not significant ($P = .07$), an effect size^{14,15} of 1.32 indicates that the finding could be considered a moderate^{15} to large^{14} effect (Figure 7).

![Figure 6](image1)

**Figure 6** — Movement time pretraining and posttraining. *$P = .001$. Columns and bars represent means and SDs, respectively.

![Figure 7](image2)

**Figure 7** — Quick-hands test: number of contacts per 10-second trial. Columns and bars represent means and SDs, respectively.
Discussion

The most important findings of the study were the changes in movement speed with training. Dynamic training improved basic movement speed, whereas there was a tendency for a decrease in the rate of coordinated movement after isometric training. There were also training-specific changes in iEMG activity.

Force Production

No changes in force production were seen in any groups tested. Previous studies have demonstrated significant increases in strength, hypertrophy, and iEMG with high-velocity or explosive-contraction training. Olsen and Hopkins, however, found a decrease in force in subjects who trained with ballistic intent and conventional weight training to improve punching and kicking. Conversely, Behm and Sale also used ballistic-intent training and found an increase in peak torque of dorsiflexors posttraining. The differences in results might be explained by the fact that both kicking and punching are complex, multijoint movements that require coordination and balance. Dorsiflexion, however, is a single-joint movement. Olsen and Hopkins argued that force might have been decreased because subjects concentrated on maintaining balance, control, and correct technique while attempting to kick. Furthermore, they noted that less-skilled subjects (in martial arts) demonstrated decreases in force that were greater than for subjects who were more skilled. A similar argument could be made for the ISO and DYN groups in the current study; 10 subjects who participated in the training were untrained in boxing or martial arts and might have been concentrating on performing the movement correctly instead of moving quickly and forcefully. It is also possible that the more experienced martial-arts subjects would have less scope for improvement in the quick-hands test, which would affect the results. Although the researcher ensured a standard punching method across all subjects, and this technique was maintained throughout training, the goal of the study was not to teach subjects to develop specific punch technique; it was instead to execute the movement quickly and explosively.

Time under tension might be a factor involved in strength gains or fiber hypertrophy with resistance training. Gillies et al demonstrated greater increases in types I and IIA muscle fibers with training using concentric contractions lasting 6 seconds than with concentric contractions lasting 2 seconds. In addition, leg-press strength was greater when training involved 6-second eccentric muscle actions (contractions) than when 2-second eccentric muscle actions (contractions) were employed. Liow and Hopkins demonstrated that slower resistance training as opposed to ballistic movements was more effective, as seen in improvements during the acceleration phase of a sprint in kayaking. In the current study, contractions during training and testing were brief (less than 1 second), so sufficient time under tension might not have been provided to elicit significant strength gains.

Kanehisa and Miyashita examined the effects of isokinetic and isometric training on static strength and dynamic power. Similar to the DYN group in the current study, no changes in isometric strength were seen after the dynamic training. McBride et al examined the effects of heavy- and light-load jump squats on various speed, strength, and power tests. Improvements in velocity-related
components were seen in the light-load group, whereas the high-load group showed improvements in strength- and power-related components. In the same context, the high contraction speeds in the current study did not provide isometric strength gains but did ameliorate movement speed.

**Electromyography**

Triceps brachii iEMG increased significantly by 63% posttraining in the ISO group but not in the DYN group. The increase in the ISO group might be a result of the position of the pectoralis major during the action. The force–length relationship of the pectoralis major in this position would result in poor force-production capabilities. Because muscle tension is one of the major factors contributing to the training-induced stress necessary for strength and activation adaptations, the reduced force output of the pectoralis major during ISO training would have minimized iEMG changes. The possibility of less pectoralis major force contribution would result in a greater contribution from and increased tensile stress on the triceps brachii muscle.

An increase in triceps brachii EMG activity without an increase in force output might seem perplexing. Increases in EMG activity, however, are not solely attributable to increased recruitment of motor units. Increased synchronization of motor-unit firing has been demonstrated to occur with training, which can increase the area of the iEMG signal. Increased synchronization, however, does not increase peak force or rate of force development. Furthermore, increases in rate coding can also occur with training but will contribute more to an augmentation of rate of force output rather than peak force output. The emphasis in the current study on explosive-intent contractions should have emphasized the firing frequency of motor-unit impulses, which are directly related to the rate of tension development.

Conversely, pectoralis major iEMG increased significantly posttraining by 65% in the DYN group but not the ISO group. The pectoralis major experienced a wide range of motion during DYN training, and when considering both the length–tension and force–velocity relationships, this would lead to greater force-production capabilities at the more optimal joint angles. With the pectoralis major providing a greater contribution, and perhaps a higher degree of momentum, during training, the triceps brachii activation would have contributed less to movement in the DYN group than in the ISO group.

The biceps brachii iEMG demonstrated a tendency to increase in the DYN group posttraining, although not significantly. Its role in shoulder stability and punching actions, however, should not be ignored. Increases in biceps brachii EMG can be seen when the shoulder is in an unstable environment. Here, the biceps brachii participates in a compensatory role in attempting to correct instability, which is not seen in a stable shoulder joint. The punch action executed by the DYN group can be considered unstable because of the multiple planes of movement allowed with the elastic tubing. Thus, increased instability in the shoulder joint, combined with increased agonist (pectoralis major) forces on the joint, might explain the trend for increased iEMG of the biceps brachii with the DYN group and not the ISO group.
Movement Time

A significant decrease in movement time was seen in the DYN group posttraining but not the ISO group. This might be a result of training specificity, because the apparatus used to measure movement time more closely reflected the action used by the DYN group than the ISO group. Duchateau and Hainaut found dynamic training to cause an increase in maximal shortening velocity of the adductor pollicis when subjects trained with fast contractions (<0.5 seconds). The intent to contract explosively does not appear to be a factor leading to improvements in movement speed, because no differences were seen in the ISO group. Although previous studies have demonstrated increased rate of torque development and increased movement speed with intended ballistic training, the current study does not support those results. The training program conducted by Behm and Sale was 16 weeks in length, and Olsen and Hopkins had subjects train for 10 weeks. Conversely, the length of the current study’s program was only 8 weeks, and a longer training program might produce more stable results in the ISO group. Furthermore, both Behm and Sale and Olsen and Hopkins trained lower limbs, whereas the current study emphasized upper limb training. In addition, Olsen and Hopkins’ subjects were all martial artists who maintained their martial-arts training throughout the experimental protocol.

A second mechanism providing insight on increases in movement speed in the DYN group could be the role of the biceps brachii as an antagonist muscle. Jaric et al argued that although a strong agonist is responsible for acceleration of limb movement, the antagonist muscle is responsible for halting that movement, which would allow the acceleration phase to be longer. In punching movements, a properly timed activation of the biceps brachii (acting as an antagonist) would allow the triceps brachii to contract for a longer duration because of the longer acceleration phase, thus making the punch move more effective in terms of movement speed (by decreasing movement time). Furthermore, performing a dynamic punch movement, as opposed to an intended punch movement, might cause an increase in biceps brachii activation (as seen in the data cited previously, albeit nonsignificant). This might also be a contributing factor to the decreases in movement time (and thus increases in movement speed) seen in the DYN group but not the ISO group.

Quick-Hands Test

The ISO group had a tendency to decrease the number of total contacts per trial in the quick-hands test posttraining. This test requires cyclical flexion and extension of the elbow. The lack of statistical significance \( P = .07 \) might be attributed to the unilateral training, which did not correspond directly (lack of training specificity) with the bilateral testing mode.

Practical Applications

The findings of the current study suggest that dynamic rather than static (isometric) high-speed training is a requisite for improving movement speed. Static or isometric training might actually hinder high-speed, coordinated, bilateral movement (ie,
quick-hands test). The lack of improvements in strength with this study implies that a sufficient time under tension is necessary to elicit strength gains, because neither the DYN nor the ISO group improved in force-production capabilities. Thus, short-duration, ballistic-intent isometric contractions might not be adequate to provide a range of changes in unilateral and bilateral movement speed and strength. Dynamic punch training improved movement speed and pectoralis major iEMG. Isometric punch training improved triceps brachii iEMG but did not improve movement speed and might impair bilateral arm-movement coordination. Because of its specificity of movement and because of the results cited herein, dynamic training might be a more appropriate method to improve punch ability for martial artists and boxers. Intended explosive contractions do not appear to be as effective as dynamic explosive training in improving movement.

Acknowledgments

The Natural Sciences and Engineering Research Council (NSERC) of Canada supported this research. Theraband Inc supplied the training tubing.

References