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Changes in muscle strength and speed of an unloaded movement after various training programmes

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Summary. The effect of three different training programmes on the maximal speed of an unloaded movement (a karate punch) was studied. Three movement variables were selected: maximal speed of the hand ($v_{h,max}$), maximal speed of the shoulder ($v_{s,max}$) and elbow extension speed ($\dot{\Theta}_E$) simultaneous with $v_{h,max}$. The programmes were: training group 1 (TG 1, $n=8$) – karate students, dynamic heavy progressive resistance exercise (incline situp and incline bench press) + punch bag exercise; training group 2 (TG 2, $n=8$) – karate students, punch bag training; training group 3 (TG 3, $n=5$) – no karate experience, dynamic heavy progressive resistance exercise (as in TG 1). The movement variables were calculated from chrono-cyclo photographic recordings of the punches (100 Hz). The level of significance was set at 5%. Sixteen weeks of training gave the following results: significant increases in dynamic strength in all the training groups (14%–53%). In TG 1 the $v_{h,max}$ increased significantly from 8.49 $m \cdot s^{-1}$, SD 1.19 to 9.35 $m \cdot s^{-1}$, SD 1.29 (10%); $v_{s,max}$ increased significantly in TG 1 by 32% (2.18 $m \cdot s^{-1}$, SD 0.56 to 2.87 $m \cdot s^{-1}$, SD 0.98) and in TG 2 by 14% (2.40 $m \cdot s^{-1}$, SD 0.61 to 2.74 $m \cdot s^{-1}$, SD 0.52), and in TG 3 $\dot{\Theta}_E$ at $v_{h,max}$ increased significantly from 28.6 $rad \cdot s^{-1}$, SD 4.3 to 32.2 $rad \cdot s^{-1}$, SD 4.5 (13%). No significant relationships between the changes in maximal muscle strength and the changes in movement speed were found. The significant changes in v_h and v_s among the karate trained subjects (TG 1 and TG 2) are ascribed to a change in the kinematics of the segmental motions induced by the karate training, to a movement pattern that takes advantage of the potentiating effect of a stretch-shortening cycle on muscle power output in flexor muscles of the shoulder and the extensor muscles of the elbow.

Key words: Heavy progressive resistance exercise – Punch exercises – Maximal muscle strength – Speed of movement – Stretch-shortening cycle

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Introduction

There is still some controversy concerning the interdependency between maximal muscle strength and speed of movement. However, several authors have found that an increase in maximal dynamic muscle strength [one repetition maximum (1 RM)] in a well defined movement is associated with an increase in the velocity of the same movement (Chui 1964; Clarke and Henry 1961; Whitley and Smith 1966; Bürhle and Schmidtbleicher 1977; Schmidtbleicher and Haralambie 1981); however, the correlation between MVC (maximal voluntary isometric strength) and the speed of movement is very low in unloaded movements. The correlation increases with increasing load (Whitley and Smith 1966; Schmidtbleicher 1980) and heavy resistance exercise increases the correlation between MVC and speed of movement (Bürhle and Schmidtbleicher 1977). These findings are supported by additional observations; Absaljamov et al. (1976) have found that contraction times decreases in muscle contractions elicitied by electrical stimuli after a period of heavy resistance strength training. Schmidtbleicher (1980) and Schmidtbleicher and Haralambie (1981) have found that after heavy resistance strength training (isometric, 90%–100% MVC) mainly the fast twitch (FT) fibres of the muscles are activated by electrical stimulation and after training with lower loads mainly the slow twitch (ST) fibres are so activated. Furthermore, they have showed that time to peak tension decreases in motor units with FT fibres after heavy resistance strength training and decreases in the ST-fibres only after resistance strength training with lower loads. It was suggested by Komi (1979) that during fast voluntary movements elicited from the motor cortex the FT fibres are activated and the ST fibres are inhibited.

These findings suggest the possibility of increasing muscular contraction and movement speeds after a period with heavy resistance exercise. In the light of their practical experience many athletes and coaches do not agree with this possibility.

In this study the effect of various training programmes, including maximal progressive resistance exercise on the speed of an unloaded movement, was studied. For the purpose of the study a karate punch [migi jodan gyaku tsuki (Oyama 1972)] very similar to the boxer's straight right was chosen.

Methods

Subjects. Twenty-one male subjects aged 18–23 years participated in the training experiment. Sixteen of these subjects were karate students (full contact, knock-down style) with 1.5–2 years karate experience (yellow and green belts) and 5 had no karate experience but were familiar with training at a non-elite level. None of the subjects was left-handed or had undertaken heavy resistance strength training during the year prior to the expriment commencing.

Design of training

The subjects in the training experiment were divided into three training groups (Fig. 1) and they all trained three times a week.

Training group 1. This group (TG 1) consisted of 8 karate students who had had 16 weeks of heavy resistance strength training (barbells and sandbags) combined with light training with the heavy punch bag, followed by an intensive training period of 4 weeks with punch bag training only.

Training group 2. This group (TG 2) consisted of 8 karate students who had had 20 weeks of intensive punch training with the heavy punch bag, combined with special striking exercises. The training was intensified after 8 and 16 weeks.

Training group 3. This group (TG 3) consisted of 5 subjects with no karate experience who had had 16 weeks of heavy resistence strength training (barbells and sandbags) followed by 7 weeks without strength training.

The subjects in TG 1 and TG 2 were randomly assigned to the two training groups and they continued their ordinary karate-training in the general classes throughout the experimental period.

Training programme

The strength training was performed as a progressive resistance exercise (PRE) with 6 repetition maxima (6 RM) and three sets three times a week (Berger 1962), consisting of:

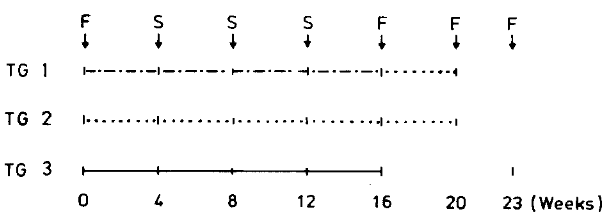

Fig. 1. Time schedule of the training and testing programme for the three training groups TG 1, TG 2 and TG 3.
-•-•-•-, heavy resistance strength training + punch bag training; •••••••, punch bag training only; ——, heavy resistance strength training only; no signature, no training; F, full test programme; S, strength tests only; ↓, time of testing (for further explanation see text)

1. Sit-ups from a 45° head-down position. The load raised was progressively increased during the training period by the subjects themselves by means of sandbags held in straps behind the neck.
2. Incline bench-press with barbells. The inclination of the bench was adjusted to make the arm movements during the bench press exercises similar to the arm movement in the karate punch. The punch bag training was carried out with a 50 kg, heavy punch bag in the karate fighters' class, and with punch exercises with a smaller punch bag (7 kg).

All training sessions were preceded by a 15-min standard warm-up.

Test procedures

The following variables were measured:
1. Body mass.
2. Body height.
3. Volume of the right arm was measured by an immersion technique modified from Miller and Nelson (1976). The arm was submerged in a cylinder filled with water to the border between the biceps brachii muscle and the anterior part of deltoideus muscle and the volume of the displaced water was measured.
4. The incline 1 RM sit-up.
5. The incline 1 RM bench-press.
[Test procedures for measuring 1 RM were as described by Berger (1962)].
6. MVC in the abdominal muscles.
[Test procedures were as described by Asmussen et al. (1959)].
7. MVC in the incline bench press. Measured at three different angles of the elbow joint (45°, 90° and 135°) as described by Voigt (1986).
8. The punch movement was recorded with a chrono-cyclo photographic technique (Hochmuth 1981). A mechanical stroboscope with a time constant (t_k) between 9.35 ms and 9.65 ms corresponding to 107–104 Hz was used. The knuckle of the little finger of the fist and the acromioclavicular joint were marked with tiny light emitting diodes to ensure distinct measuring points. Only punches with the right first were recorded. The distances between the knuckle of the little finger (wrist held straight) and the elbow joint at the lateral epicondyle and the acromioclavicular joint and the elbow joint, corresponding to the distances between the diodes and the elbow joint, were measured at the fist recording session. These measurements were chosen for the calculation of the elbow angle (see below). The subjects were instructed to hit a very light target ball (50 gr) during each recording.

All measurements were carried out on each subject before the start of the training period. After 4, 8 and 12 weeks of training only the strength tests (4–7) were carried out, and after 16 and 20 weeks of training (TG 3, 23 weeks) a full test programme was carried out except for measurement no. 2.

Calculations

The mass of the right arm was calculated from the measured arm volume and a density of the arm estimated to 1.11 $kg \cdot l^{-1}$ according to Miller and Nelson (1976). This calculation ignored changes in the relative tissue composition of the arm due to training.

The linear velocity of the hand (v_h) and shoulder (v_s) during a karate punch was calculated as:

$$v = ds \cdot dt^{-1} \quad (1)$$

where ds = displacement and dt = displacement time.

The angle in the elbow joint (Θ_E) was calculated as

$$\Theta_E = \arccos\,(SE^2 + EH^2 - SH^2) \cdot (2 \cdot SE \cdot EH)^{-1}$$

where SE = the distance from the acromioclavicular joint to the elbow joint at the lateral epicondyle of the humerus; EH = the dis-

Table 1. Anthropometric measurements

Training group	Weeks	Age (years)		Body height (cm)		SE (cm)		EH (cm)		Body mass (kg)		Arm volume (l)	
		mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
TG 1	0	20	1.7	179.4	9.5	33.6	2.4[1]	35.5	1.7	71.6	15.5	2.80	0.71
$n=8$	16	—		—		—		—		73.2	16.1[2]	2.90	0.67[2]
	20	—		—		—		—		74.3	15.9[3]	2.92	0.67
TG 2	0	20	1.7	178.8	8.2	31.8	1.5	35.3	1.7	68.1	7.1	2.77	0.25
$n=8$	16	—		—		—		—		69.8	7.6[2]	2.79	0.24
	20	—		—		—		—		70.9	6.9[3]	2.84	0.27
TG 3	0	22	1.7	176.1	2.8	30.7	0.5	34.8	0.6	77.4	8.6	3.02	0.33
$n=5$	16	—		—		—		—		77.9	7.7	3.02	0.29
	23	—		—		—		—		78.9	8.4	2.92	0.28[4]

TG 1, TG 2 and TG 3 = training groups; SE = the distance between the acromioclavicular joint and the lateral epicondyle of the humerus, right arm; EH = the distance from the lateral epicondyle of the humerus to the metacarpophalangeal joint of the fifth finger (wrist held straight), right arm

[1] TG 1 > TG 2 and TG 3 $P \leq 0.05$; [2] 16 weeks > 0 weeks $P \leq 0.05$; [3] 20 weeks > 16 weeks $P \leq 0.05$; [4] 23 weeks < 16 weeks and 23 weeks < 0 weeks $P \leq 0.05$

tance from the elbow joint at the lateral epicondyle of the humerus to the head of the fifth metacarpal bone of the hand (wrist held straight); *SH* = distance from the acromioclavicular joint to the knuckle of the little finger of the fist.

The angular velocity in the elbow joint ($\dot{\Theta}_E$) was calculated as:

$$\dot{\Theta}_E = d\Theta_E \cdot dt^{-1}$$

where $d\Theta_E$ = change in the angular position of the elbow joint and dt = displacement time.

The average accelerations of the hand and shoulder and the average angular acceleration of the elbow extension during the last 0.05 s before the hand reached maximal velocity were calculated as the average speed during this time interval divided by $5.t_k$.

Statistics

All variables are given as group means and standard deviations (SD). The level of significance was set at 5%.

Non-parametric statistics were used to avoid the assumption of normal distribution of the underlying populations and hence it should be noted that all differences are tested around the group medians and not the group means.

Differences between the three groups at a given time are tested for significance with the Kruskall-Wallis one-way analysis of variance by ranks (*k*-sample case, unrelated samples), and the differences between groups are localized by multiple comparisons. Changes in the measured variables caused by training in each group are tested for significance with the Friedman two-way analysis of variance by ranks (related samples) and changes are localized by multiple comparisons. Correlation between the variables is tested by means of the Spearman rank correlation coefficient (r_s). All the statistics used in the present study are described by Siegel and Castellan (1988).

Results

The training started with a total of 46 subjects, 54% stopped the training for various reasons including lack of interest, examination requirements, illness and one was injured by the training. Thus only 21 subjects completed the training, 8 in TG 1, 8 in TG 2 and 5 in TG 3. On average, 92% of the training bouts were completed by these subjects (TG 1: 98%, TG 2 93% and TG 3: 88%).

The anthropometric measurements of the three training groups are presented in Table 1. The length of the upper arm was significantly longer in TG 1 compared to the two other training groups (about 7%). The body mass increased significantly by 2.2% in TG 1 when compared to the pretraining level (PRTL) and this increase continued with another of 1.6% during the detraining period (16–20 weeks). The same pattern was found in TG 2 where the post-training level after 16 weeks of training (POTL) was 2.5% higher when compared to PRTL followed by a 1.6% increase during the detraining period. In TG 1 the volume of the right arm increased 3.6% compared to PRTL and no significant change occurred during the detraining period. In TG 3 the arm volume decreased significantly by 3.6% during the detraining period compared to PRTL.

The measurements of maximal dynamic muscle strength are presented in Fig. 2. The 1 RM in the incline situp in TG 2 was significantly lower than in the two other groups at PRTL (about 35%). The POTL was also lower (about 34%); however, at the end of the experimental period the difference was no longer significant. The POTL in the 1 RM in the incline bench press in TG 3 was significantly higher (about 27%) than the same level in the two other groups. In all training groups training induced significant increases in maximal dynamic muscle strength when compared to PRTL: 45.8%–53.1% in 1 RM in the incline situp and 13.9%–27.3% in the incline bench press. In TG 1 and TG 2 there were no changes from POTL to the end of the study. In TG 3 there was a significant decrease (−12.3%) during the detraining period (16–23 weeks). This detraining level was still significantly higher than PRTL.

The measurements of maximal isometric strength are presented in Fig. 3. In TG 1 and TG 3 (heavy resistance strength training) there were significant increases

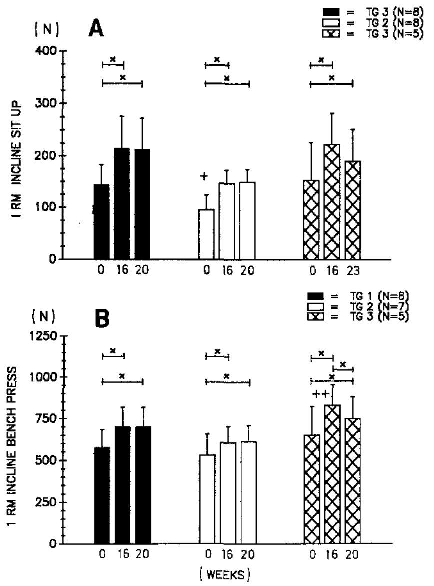

Fig. 2. Dynamic muscle strength. Means and standard deviations. **A** One repetition maximum (1 RM) incline situp. **B** 1 RM incline bench press. TG 1, TG 2 and TG 3, training groups; *, $P \leq 0.05$; +, TG 2 < TG 1 and TG 3 at 0 and at 16 weeks ($P \leq 0.05$); ++, TG 3 > TG1 and TG 2 at 16 weeks ($P \leq 0.05$)

in the isometric abdominal strength (10.3% and 12.9% respectively). No significant changes in isometric strength in the incline bench press at elbow angles 45° and 90° were found in any of the training groups; in TG 1 and TG 2 (karate students) there were significant increases in MVC (17.9% and 19.1% respectively) in the incline bench press at an elbow angle of 135°.

The results from the chrono-cyclo photographic recordings are presented in Fig. 4. In TG 1 a significant 10.1% increase in $v_{h,max}$ was found at POTL. A significant increase in $v_{s,max}$ was found in TG 1 (34.7%) and in TG 2 (34.7%). A significant increase (12.8%) in $\dot{\Theta}_E$ at

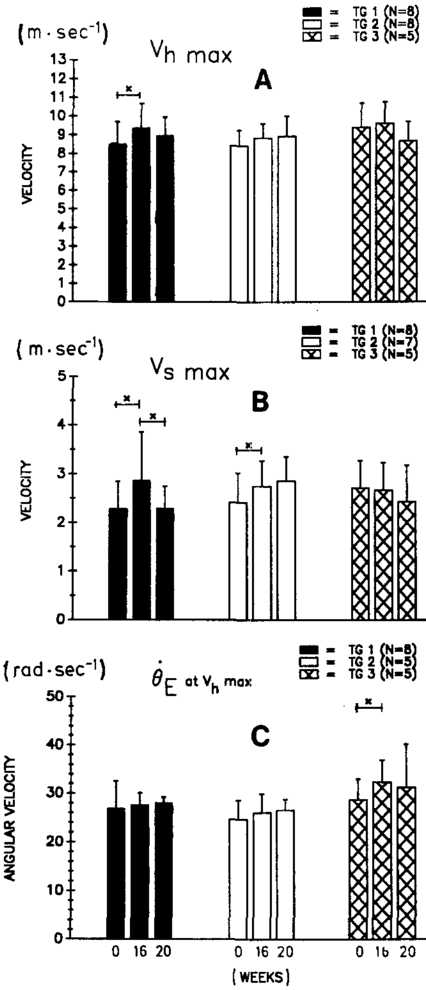

Fig. 4. Speed variables. Means and standard deviations. **A** Maximal speed of the hand ($v_{h,max}$); **B** maximal speed of the shoulder ($v_{s,max}$); **C** speed of elbow extension at the time when the speed of the hand was maximal ($\dot{\Theta}_E$ at $v_{h,max}$); TG 1, TG 2 and TG 3, training groups; $P \leq 0.05$

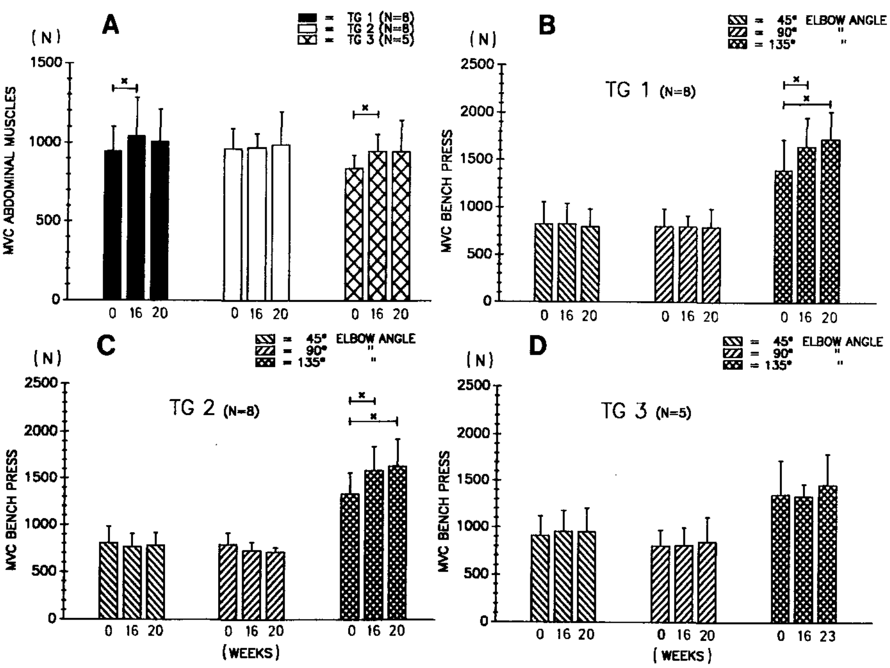

Fig. 3. Isometric muscle strength. Means and standard deviations. **A** MVC (maximal voluntary isometric strength) of abdominal muscles. **B, C, D** MVC of incline bench press at three different elbow angles. TG 1, TG 2 and TG 3, training groups; *, $P \leq 0.05$

Table 2. Training protocols and significant ($P \leq 0.05$) percentage changes (Δ%) in maximal dynamic (1 RM) and maximal isometric strength (MVC) during the experimental period

Training group	Experience	Type of training	Test movement (muscle group)	Days of training	Contractions per day	Relative load % of 1 RM	% 1 RM	% MVC
TG 1 $n=8$	karate students	PRE + punch bag training	including bench press (arm extensors)	48	18	78	22	19†
			including sit up (abdominal muscls)	48	18	78	65	9
TG 2 $n=8$	karate students	punch bag training	including bench press (arm extensors)	48	650–900	—	17	18†
			including sit up (abdominal muscles)	48	650–900	—	67	NS
TG 3 $n=5$	no karate experience	PRE	including bench press (arm extensors)	48	18	78	31	NS†
			including sit up (abdominal muscles)	48	18	78	83	13

The relative load was estimated according to the Eq.: % 1 RM = (−4.18·number of RM) + 103 (valid from 1–12 RM) [McDonagh and Davies (1984)]
† = the angle in the elbow joint = 135°; 1 RM = one repetition maximum; MVC = maximal voluntary isometric strength; PRE = dynamic heavy resistance exercise as progressive resitance exercise; NS = non-significant

$v_{h,max}$ was found in TG 3. No significant changes in the calculated accelerations were found. The averages from all three groups were: acceleration of the hand = 52.5 $m \cdot s^{-2}$, SD 12.9, acceleration of the shoulder = 3.5 $m \cdot s^{-2}$, SD 10.2 and acceleration of the elbow extension = 291.3 $rad \cdot s^{-2}$, SD 71.1.

Discussion

Dynamic strength

The relative training load as a percentage of 1 RM was estimated from the equation: %1 RM = (−4.18 × number of RM) + 103 [valid between 1–12 RM (McDonagh and Davies 1984)]. The relative training load and other training parameters are presented in Table 2 which also includes the percentage increase in 1 RM and in MVC. For comparison similar variables from other training studies are presented in Table 3. As can be seen, the percentage increase of 1 RM in the present experiment (22%–83%) is of the same order of magnitude as found in other investigations, using the same training load and protocol. The percentage increases of 1 RM in the incline situp are overestimated because the loading of the muscles due to the mass of the trunk, neck, head and arms during the exercise is not included in the measurements. From anthropometric data (Winter 1979) it can be estimated that the real average increase in strength of the abdominal muscles is about one sixth of the dynamic values given in Table 2.

The karate students in TG 2, who did not have any heavy resistance training, showed the same pattern in strength gains as the karate students in TG 1 who did. From Table 3 it can be seen that the relative load, the type of dynamic training (PRE or constant load) and the number of contractions are factors determining the gain in strength from training. It can further be seen that at training loads around or below 60% of 1 RM the number of contractions per day may be the determining factor for the gain in strength. The characteristic of the punch bag training and karate training in general is a large number of contractions. During one bout of intermittent sandbag training 650–900 punches were delivered. The intensity of mucle contraction in each punch varies greatly depending on technique, frequency and motivation of the subject. The significant gain in dynamic muscle strength in TG 2 suggests that the contraction levels in the arm extensor muscles and in the abdominal muscles during impact reaches 60% of 1 RM or more.

Isometric strength

From Table 3 it may also be seen that dynamic strength training with a relative load of 66% 1 RM or more produces gains in MVC from 16% to 36%. In this investigation the relative load was 78% 1 RM but only a few significant changes in MVC were found. In TG 1 and TG 2 there was a significant increase in MVC in the incline bench press only at an elbow angle of 135° after 16 and 230 weeks of training. The increase at this specific angle is ascribed to the fact that karate students "catch" their arms in an exaggerated co-contraction between the elbow extensors and the elbow flexors, in a position with the elbow joint at an angle about 135°, hundreds of times during each training session, to protect their elbow joints form overstretch when the basic

Table 3. Dynamic strength training programme and significant ($P \leq 0.05$) percentage changes (Δ%) in dynamic (1 RM) and isometric strength (MVC) from different training studies

Author(s)	Type of training	Test movement (muscle group)	Days of training	Contractions per day	Relative load % of 1 RM	Δ% 1 RM	Δ% MVC
Dons et al. (1979)	PRE	squat (leg extensors)	21	20	50	24 (NS)	NC
Bonde-Petersen et al. (1961)	same load	elbow flexors	30	50	60	27 (NS)	NC
Bonde-Petersen et al. (1961)	same load	elbow flexors	30	100	60	34	NC
Bonde-Petersen et al. (1961)	same load	elbow flexors	30	150	60	29	NC
Berger (1962)	PRE	bench press (arm extensors)	36	30	61[ø]	23	—
McDougall et al. (1980)	PRE + 20 max isokinetic contractions	elbow extensors	60	70	65	98[†]	—
Moritani and de Vries (1979)	PRE	elbow flexors	24	20	66	—	36
Salter (1955)	PRE	supination	16	30	75	—	32
Thorstensson et al. (1976)	PRE + jump (exercises)	squat (leg extensors)	24	18	78[ø]	73	73°:30 90°:16
Berger (1962)	PRE	bench press (arm extensors)	36	18	78[ø]	30	—
Dons et al. (1979)	PRE	squat (leg extensors)	21	12	80	42	NC
Häkkinen et al. (1981)	PRE 75% concentric 23% eccentric	squat (leg extensors)	48	16–22	concentric 80–100 eccentric 100–120	26	21

[ø] = the relative load was estimated according to the equation: % 1 RM = (− 4.18 · number of RM) + 103 (valid from 1–12) [McDonagh and Davies (1984)]
[†] = measured as isokinetic strength at $30° \cdot s^{-1}$; IRM = one repelition maximum; MVC = maximal voluntary isometric strength; PRE = dynamic heavy resistance exercise as progressive resistance exercise; NC = no change; NS = non-significant

punches are performed in open air (imaginary targets). Angle specific isometric strength training effects have been described by Lindh (1979) and Williams et al. (1978), for example.

Changes in speed

The v_h in the punches measured in this investigation had the same order of magnitude as found by Wilk et al. (1983): 5.7–9.8 $m \cdot s^{-1}$ (karate) and Atha et al. (1985): 8.9 $m \cdot s^{-1}$ (boxing).

In the present study no significant correlations between the speed variables of the unloaded punch movement and maximal muscle strength were found. The v_h is the result of a chain of body movements consisting of a shift of mass on the feet, rotation of hips and upper part of the trunk, shoulder flexion and elbow extension. The timing of the movements of the body segments relative to each other during execution of a punch may determine the ability to reach the very high angular velocities in the elbow joint of about (30 $rad \cdot s^{-1}$). Jöris and his coworkers (1985) have studied handball overarm throws and have suggested that by accelerating heavier proximal segments before a relatively light distal segment, an eccentric contraction of the elbow extensors is facilitated and the following concentric contraction potentiated, as described by Cavagna et al. (1968), Bober et al. (1980) and Bober et al. (1987). Before training maximal values of v_h and v_s were reached at the same time during a punch movement by all the subjects. After the training period there was a significant change in the time history of v_h and v_s relative to each other in TG 1 and TG 2 where v_s reached its maximum about 20–30 ms before v_h reached its maximum, and at the same time $v_{s,max}$ had increased significantly in both training groups, while in TG 3 no such change in the v_h–v_s relationship was found. Figure 5 shows the typical time histories of v_s, v_h and $\dot{\Theta}_E$ from a skilled and an unskilled subject. This interaction between the segments is characteristic of a skilled movement which was also shown by Jöris et al. (1985). We suggest that the significant increase in $v_{h,max}$ in TG 1 (and the non-significant increase in TG 2) is partly due to an improved ability to take advantage of the potentiating effect of a stretch-shortening cycle of the shoulder flexor and elbow extensor muscles, and that these kinematic and muscle mechanical factors alone can explain the observed changes in the linear v_h in TG 1 and TG 2. As mentioned above this consecutive sequence of segmental movements was not found in TG 3 (Fig. 5a). If all muscles in this situation contracted simultaneously during the unskilled movement, they would follow the classical force-velocity relationship (Jöris et al. 1985). An increase in movement speed is, therefore, a conse-

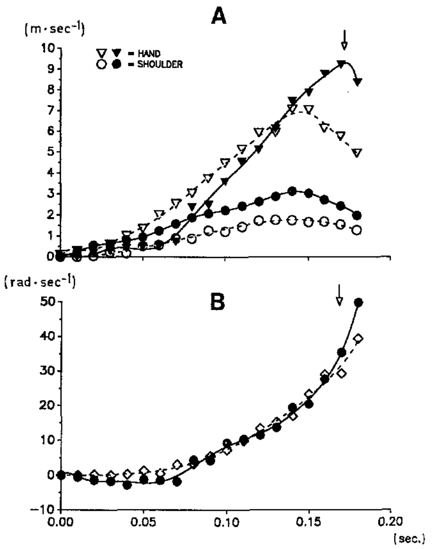

Fig. 5. Typical time histories of the speed of the hand, the shoulder and elbow extension during a straight right punch from a skilled (*filled symbols*) and an unskilled (*open symbols*) subject. **A** Speed of the hand and shoulder; **B** elbow extension speed; ↓, time of contact with the target

quence of an increased muscle contraction speed. This might be the explanation for the 13% increase in $\dot{\Theta}_E$ at $v_{h,max}$ in TG 3.

In TG 1 there was a significant decrease in the $v_{s,max}$ from the 16th to the 20th week without any significant changes in muscle strength. During this period the subjects had stopped the heavy resistance strength training but continued training with punch exercises similar to the training in TG 2. No explanation can be given for this observation.

Conclusion

Heavy progressive resistance exercise alone does not influence the speed of a skilled unloaded movement. Specific punch training develops a skill that increases the speed of an unloaded punch movement by means of a consecutive pattern of segmental motions, which takes advantage of a stretch-shortening cycle in the shoulder flexors and in the arm extensors. Maximal heavy progressive resistance exercise enhances the gain in movement speed, but only when it is combined with specific punch training.

References

Absaljamov TM, Zorin WP, Choose JM (1976) Kontraktionsgeschwindigkeit von Muskeln und ihre Veränderung im sportlichen Training 6:58–61

Asmussen E, Heebøll-Nielsen K, Molbech Sv (1959) Methods for evaluation of muscle strength. Communication Nr. 5, Polio Institute, Hellerup, Copenhagen

Atha J, Yeadon MR, Sandover J, Parsons KC (1985) The damaging punch. Br Med J 291:1756–1757

Berger R (1962) Effect of varied weight training programs on strength. Res Q 33:168–181

Bober T, Jakolski E, Nowacki Z (1980) Study on eccentric-concentric contraction of the upper extremity muscles. J Biomech 13:135–138

Bober T, Putnam CA, Woodworth GG (1987) Factors influencing the angular velocity of a human limb segment. J Biomech 20:511–521

Bonde-Petersen F, Graudal H, Hausen JW, Hvid N (1961) The effect of muscle contractions on dynamic muscle training. Eur J Appl Physiol 18:468–473

Bürhle M, Schmidtbleicher D (1977) Der Einfluss von Maximalkrafttraining auf die Bewegungsschnelligkeit. Leistungssport 7:7–10

Cavagna GA, Dusman B, Margaria R (1968) Positive work done by previous stretched muscle. J Appl Physiol 24:21–32

Chui EF (1964) Effects of isometric and dynamic weight training upon strength and speed of movement. Res Q 35:246–257

Clarke DH, Henry FM (1961) Neuromotor specificity and increased speed from strength development. Res Q 32:315–325

Dons B, Bollerup K, Bonde-Petersen F, Hancke S (1979) The effect of weight-lifting exercise related to muscle fiber composition and muscle cross-sectional area in humans. Eur J Appl Physiol 40:95–106

Häkkinen K, Komi PV, Tesch PA (1981) Effect of combined concentric and eccentric strength training and detraining on force/time, muscle fiber and metabolic characteristics of leg extensor muscles. Scand J Sports Sci (2):50–58

Hochmuth G (1981) Biomechanik der sportlichen Bewegungen. Sport, Berlin

Jöris HJ, van Muyen AJ, van Ingen Schenau GJ, Kemper HC (1985) Force, velocity and energy flow during the overarm throw in female handball players. J Biomech 18:409–414

Komi PV (1979) Neuromuscular performance: factors influencing force and speed production. Scand J Sports Med 1:2–15

Lindh M (1979) Increase of muscle strength from isometric quadriceps exercise at different knee angles. Scand J Rehabil Med 11:33–36

MacDougall JD, Elder GCB, Sale GB, Moroz JR, Sutton JR (1980) Effects of strength training and immobilization on human muscle fibers. Eur J Appl Physiol 43:25–34

McDonagh MJM, Davies CTM (1984) Adaptive response of mamalian skeletal muscle to exercise with high loads. Eur J Appl Physiol 52:139–155

Miller DI, Nelson CR (1976) Biomechanics of sports. Lea and Fibiger, Philadelphia

Moritani T, de Vries H (1979) Neural factors versus hypertrophy in time course of strength gain. Am J Phys Med 58:115–130

Oyama M (1972) This is karate. Japan Publications, Tokyo

Salter N (1955) The effect on muscle strength of maximum isometric and isotonic contractions at different repetition rates. J Physiol 130:109–113

Schmidtbleicher D (1980) Maximalkraft und Bewegungsschnelligkeit. Limpert

Schmidtbleicher D, Haralambie G (1981) Changes in contractile properties of muscle after strength training in man. Eur J Appl Physiol 46:221–228

Siegel S, Castellan NJ jr (1988) Non-parametric statistics. McGraw-Hill Kogakusha, Tokyo

Thorstensson A, Karlsson J, Viitasalo JHT, Luhtanen P, Komi PV (1976) Effect of strength training on EMG of human skeletal muscle. Acta Physiol Scand 98:232–236

Whitley JD, Smith LE (1966) Influence of three different training programs on strength and speed of a limb movement. Res Q 37:132–142

Wilk SR, McNair RE, Feld MS (1983) The Physics of Karate. Am J Phys 51:783–790

Williams KR, Bernauer EM, Ramey MR, Waring WA (1978) A bio-mechanical analysis of individual muscle forces involved in elbow flexion (Abstract) Med Sci Sports (1979) 11:iii

Winter DA (1979) Biomechanics of human movement. Wiley, New York

Voigt M (1986) Changes in speed, acceleration, and impact force after heavy dynamic progressive resistance exercise and/or punch training (in Danish). Thesis, Laboratory for the Theory of Gymnastics, August Krogh Institute, University of Copenhagen, Denmark