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Research article

AN INVESTIGATION OF LEG AND TRUNK STRENGTH AND REACTION TIMES OF HARD-STYLE MARTIAL ARTS PRACTITIONERS

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ABSTRACT
The purpose of this study was to investigate trunk and knee strength in practitioners of hard-style martial arts. An additional objective was to examine reaction times in these participants by measuring simple reaction times (SRT), choice reaction times (CRT) and movement times (MT). Thirteen high-level martial artists and twelve sedentary participants were tested under isokinetic and isometric conditions on an isokinetic dynamometer. Response and movement times were also measured in response to simple and choice auditory cues. Results indicated that the martial arts group generated a greater body-weight adjusted peak torque with both legs at all speeds during isokinetic extension and flexion, and in isometric extension but not flexion. In isokinetic and isometric trunk flexion and extension, martial artists tended to have higher peak torques than controls, but they were not significantly different ($p > 0.05$). During the SRT and CRT tasks the martial artists were no quicker in lifting their hand off a button in response to the stimulus [reaction time (RT)] but were significantly faster in moving to press another button [movement time (MT)]. In conclusion, the results reveal that training in a martial art increases the strength of both the flexors and extensors of the leg. Furthermore, they have faster movement times to auditory stimuli. These results are consistent with the physical aspects of the martial arts.

KEY WORDS: Isometric, isokinetic, dynamometry, martial art, reaction.

INTRODUCTION

The martial arts are ancient forms of self-defence. Predominantly conceived in East Asia there are many styles practiced all over the world not only for self-protection but also as a competitive sport and a form of exercise. Traditional styles of martial arts can be categorised as either "soft" or "hard". Although each individual martial art has some elements of both groups, the central principle of each martial art defines whether it is labelled hard or soft. Rigid stances, powerful strikes and its technique of meeting hostility with speed, power and a proactive approach constitute a hard-style approach. Conversely Tai Chi Chuan is a Chinese system of slow meditative physical exercise designed for relaxation, balance and health, best known for its soft, evasive techniques that meet aggression with subtle redirection rather than force. Its pupils do not train specifically for strength or speed, nor do they spar.

Training for martial arts can bring about many physiological benefits including improved aerobic performance (Douris et al., 2004; Heller et al., 1998; Lan et al., 1996; 1998; Zehr and Sale, 1993), anaerobic performance (Heller et al., 1998; Melhim, 2001; Zehr and Sale, 1993), blood pressure (Young et al., 1999), body fat and blood adiposity (Douris et al., 2004; Heller et al., 1998; Lan et al., 1996), balance (Douris et al., 2004; Jacobson et al., 1997; Tse and Bailey, 1992), kinaesthetic sense (Jacobson et al., 1997), flexibility (Douris et al., 2004; Heller et al., 1998; Lan et al., 1996) and muscle endurance (Douris et al., 2004). Furthermore, several studies have reported alterations in muscle strength (Christou et al., 2003; Douris et al., 2004; Heller et al., 1998; Jacobson et al., 1997; Lan et al., 1998; Voigt and Klausen, 1990).

The complex nature of the hard-style martial arts requires co-ordination and strength. There are many muscles involved in the delivery of a kick, including the muscles of the trunk and abdomen that rotate the body, and the extensor and flexor muscles of the knee. However, to date, there have been no investigations of trunk strength in hard-style martial artists.

In addition to the muscular requirement for effective martial arts practice, reaction time and speed are also important. There are two types of perceptual ability related to performance in sport. The first is based on primitive, basic sensory functions which are not related to the athlete's area of expertise and include such factors as visual acuity and visual field (Mori et al., 2002). It is thought that training specific to these skills does not improve sporting ability (Abernethy and Neal, 1999; Mori et al., 2002; Wood and Abernethy, 1997). The second type is the sport-specific sensory skills developed through the practice of that sport (Mori et al., 2002). The simple reaction time is the shortest interval of time required to respond to a single stimulus. Some reports have found no difference in simple reaction time between athletes and non-athletes (Mori et al., 2002) suggesting that it cannot be trained. Choice reaction time is the shortest interval needed to respond to a stimulus that is presented as an alternative to a number of other stimuli (Scmidt, 1990). There is some evidence that choice reaction times can be trained (Johnson et al., 1991), linking it to the second group of perceptual abilities.

Participants who partake in general physical activity have significantly shorter reaction times than those who do not (Arito and Oguri, 1990; Brisswalter et al., 1997). Studies have also shown this to be true for specific activities (Hascelik et al., 1989; Madanmohan et al., 1992; Malathi and Parulkar, 1989) including martial arts (Lee et al., 1999; Mori et al., 2002).

The aims of this study are to measure strength characteristics of leg and trunk muscles and to measure simple and choice reaction and movement times in those trained in a hard-style martial art and compare these to those who lead a more sedentary lifestyle.

METHODS

Participants

With local ethical approval and informed consent 13 practitioners of hard-style martial arts (9 male: 4 female, mean (±SEM) age 23.7 (±3.1) years and 12 control participants (8 male: 4 female, mean age 22.2 (±0.6) years were recruited for this study. The martial arts group was composed of 8 who practiced Tae Kwon Do, 3 Shaolin Nam Pai Chauan Kung-Fu and 2 Wu Shu Kwan Kung-Fu. Eleven of the martial artists had black belts and 2 were senior brown belts in training for their black belt. All were in regular training. Participants' height and weight were measured; the dynamometer normalised the torque measurements to the participants' body weight.

Study protocol

Strength testing

Parameters of trunk and lower limb flexion and extension strength were recorded under isometric and isokinetic conditions on a Cybex Norm Isokinetic Testing System (Henley Healthcare, USA).

Leg strength

Each participant was seated comfortably and the knee isolated as much as possible using a strap across the thigh of the leg being tested and a four-strap seat belt to prevent use of thorax and abdominal muscles. The equipment was arranged so that the dynamometer was aligned with centre of rotation of the knee joint being tested. The shin pad was strapped as distally on to the tibia making sure dorsiflexion of the ankle was not restricted. The protocol was repeated for the opposite leg and the order in which the legs were tested was randomised. Participants performed isokinetic concentric knee flexion and extension at speeds of 30, 90 and 210$^{\circ}\cdot s^{-1}$ with a trial and five repetitions at each speed with the maximal value being used in the subsequent analysis. This was followed by a maximal isometric contraction in flexion followed by extension at 45° of flexion. Participants were encouraged to be

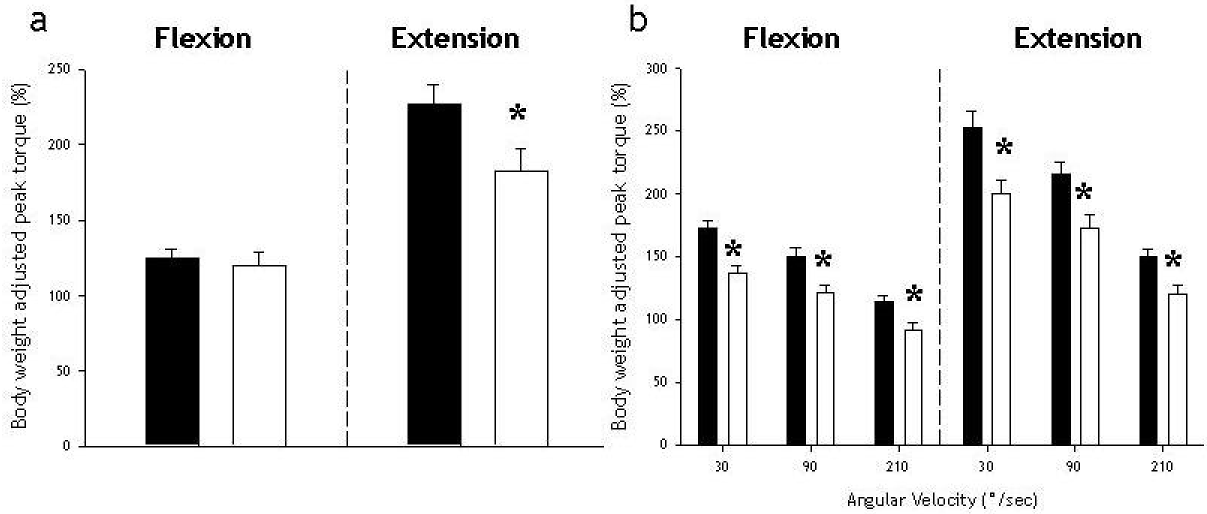

Figure 1 Peak isometric (**a**) and isokinetic (**b**) weight adjusted torque in the knee flexors and extensors in martial artists (black bars) and controls (white bars). * $p < 0.05$ with respect to the martial artists.

relaxed and a level of verbal encouragement constant for all participants was given throughout testing to prevent "psyching-up", known to affect muscle power (Tod et al., 2003).

Trunk strength

The lower limbs were stabilised by tibial and thigh pads. A belt secured the pelvis to limit the involvement of the hip flexor muscles during testing. Range of motion was recorded from –10° of hyperextension to 80° flexion as recorded through the Cybex system, which represented the limits of range of the system rather than the ranges of the individuals.

Participants performed isokinetic concentric trunk flexion and extension at speeds of 30 and $90°\cdot s^{-1}$ with five repetitions at each speed. This was followed by a maximal isometric contraction at +10° flexion, and then at -10° extension.

Measurement of reaction times

All participants performed trials to assess simple reaction time (SRT), choice reaction time (CRT) and their speed of movement once they had reacted in both the SRT (simple movement time; SMT) and CRT (choice movement time; CMT) tasks. Movement times were measured between release of an initiation button and depression of a stop button 25 cm away. Both hands were used in random order to perform the reaction time test by releasing a button in response to a tone. An in-house computer program running on an IBM compatible PC was used to measure reaction and movement times (for full protocol see Davey et al., 2001).

Statistical analyses

Body weight adjusted peak torques under the various conditions were investigated for differences between the left and right legs and also between the martial artists and the controls using the Student's *t*-test. Reaction and movement times were compared between the dominant hand and the non-dominant hand within the groups and also between the groups using the Student's *t*-test. Results were considered statistically significant when $p < 0.05$.

RESULTS

Strength

Leg strength

There were no differences (for either flexion or extension) between the dominant and non-dominant legs for either group under isometric testing or at any of the speeds under isokinetic testing. The data were therefore pooled for both legs. The martial artists had a higher mean body weight adjusted peak isometric torque than the controls only in extension (Figure 1a). Under isokinetic testing the martial artists had a higher torque than the controls in flexion and extension at all speeds (Figure 1b).

The hamstrings/quadriceps torque ratios were not significantly different between the martial artists the controls at any of the isokinetic speeds (mean [±SEM] ratio over all speeds; martial artists 72.67±2.19%, controls 73.33±1.86%).

Trunk strength

There were no significant differences between the martial artists and the controls under isometric testing or at any of the speeds under isokinetic testing for either flexion or extension. However, martial artists did consistently have slightly higher

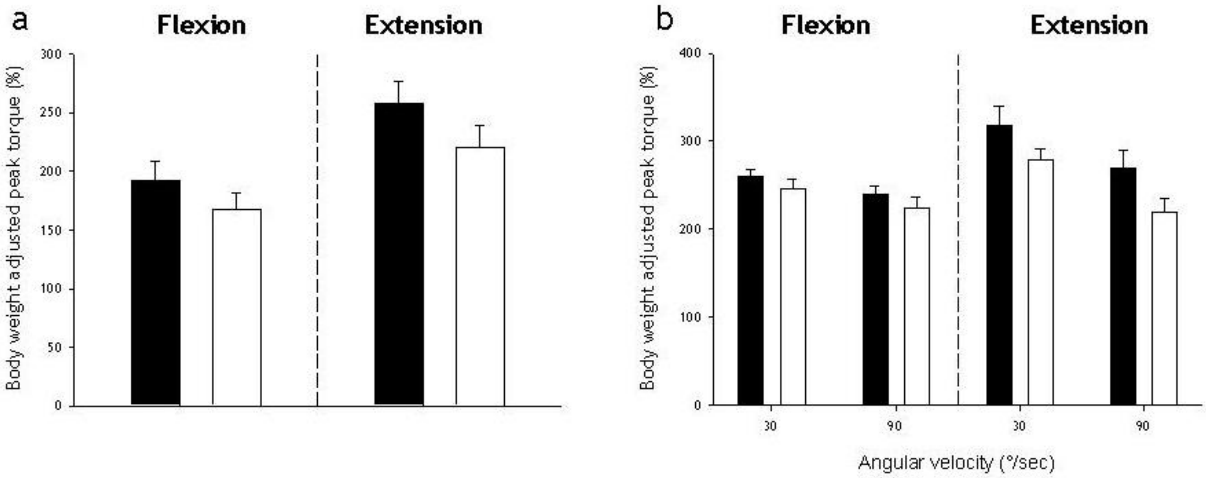

Figure 2 Peak isometric (**a**) and isokinetic (**b**) weight adjusted torque in the trunk flexors and extensors in martial artists (black bars) and controls (white bars).

(not significantly) torque for all testing conditions (Figure 2a and 2b).

The flexor/extensor torque ratios were not significantly different between the martial artists the controls at either of the isokinetic speeds (mean [±SEM] ratio over all speeds; martial artists 89.93±6.61%, controls 95.84±3.76%). Concurrent with previous results on isokinetic testing (Chan and Maffulli, 1996; Lord et al., 1992) it can be observed that as the speed of movement increases the peak torque decreases (Figures 1b and 2b).

Reaction times

There were no differences in RT or MT in the simple or choice tests between the dominant and non-dominant hands for either group. The data were therefore pooled for both hands. The RTs for the simple and choice tests were not different between the martial artists and the controls (simple RT for controls = 222.18 ± 6.61ms, martial artists = 210.91 ± 3.75 ms; choice RT for controls = 343.10 ± 15.69ms, martial artists = 312.33 ± 8.77ms). However, the MT was significantly faster in the martial artists for both tests and resulted in a faster total RT for the martial artists (simple MT for controls = 165.79 ± 4.58ms, martial artists = 128.07 ± 3.90ms; choice MT for controls = 197.82± 5.23ms, martial artists = 174.29 ± 8.54ms; see Figure 3).

DISCUSSION

The martial artists in this study showed greater torque in isokinetic and isometric testing of the legs and a slightly (but not significantly) higher trunk torque. Our results support and extend previous studies on quadriceps strength in practitioners of various forms of martial arts (Heller et al., 1998; Jacobson et al., 1997; Lan et al., 1998; 2000). No previous study, however has investigated the effects of training in the hard style martial arts on knee flexor strength. The significantly higher strength of

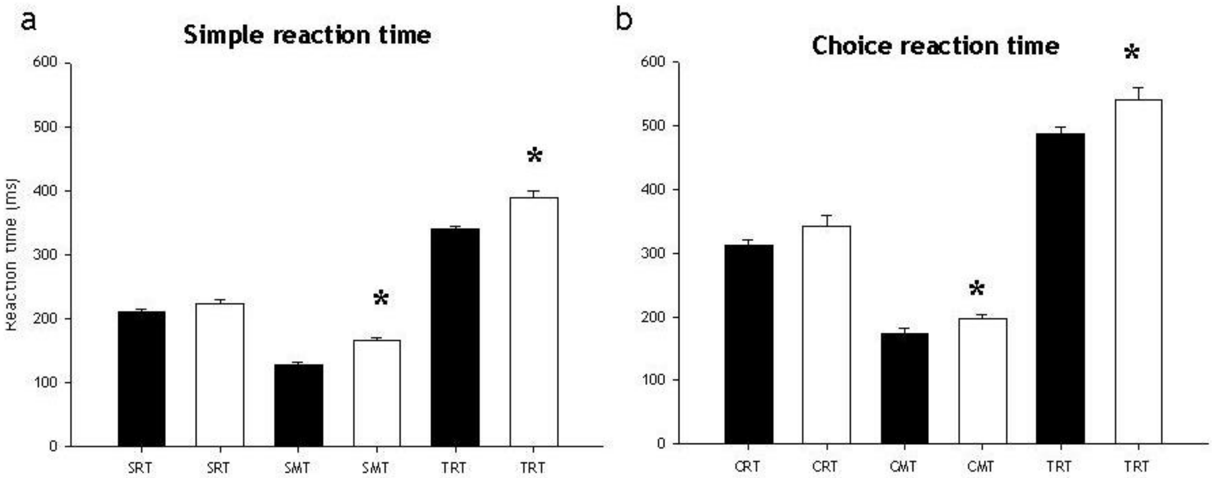

Figure 3 Simple (**a**) and choice (**b**) reaction times in martial artists (black bars) and controls (white bars). RT-reaction time; MT-movement time; TRT-total reaction time * $p < 0.05$ with respect to the martial artists.

training in the hard style martial arts on knee flexor strength. The significantly higher strength of the knee flexors reported here suggests that these are also developed in martial arts training. Training in the softer style Tai Chi martial art has been shown to increase the strength of the knee extensors and flexors (Lan et al., 1998; 2000), but Tai Chi places emphasis on different qualities in its practitioners to those in the harder styles studied here. Indeed, the increases in strength found by Lan et al. (1998) after training were less than the differences found between the martial artists and the controls in this study. This could be due to the age differences between the participants in their study and ours or could indicate that training for the harder style martial arts has a more substantial effect on the strength of the knee flexors and extensors.

The results of isometric testing of the legs support a previous study (Douris et al., 2004) showing that martial artists practising a mixed soft and hard style were stronger in extension. Since the form of martial arts practised by the participants in the present study require the participants to adopt low stances with their legs flexed for long periods of time (using predominantly quadriceps muscles), this may account for the increased strength.

The hamstring/quadriceps ratios is a commonly used indicator of the balance of agonist and antagonist muscles (Aagaard et al., 1995; Seto et al., 1988; St Clair et al., 2000) and may be a predictor of injury. Although the martial artists here had higher torques this ratio was no different from the control group. Therefore, although participation in the martial arts is associated with higher risk of injury (Zetaruk et al., 2005) muscle imbalance may not be a key factor.

The strength of the trunk muscles is enhanced by physical training (Andersson et al., 1988; Chan et al., 1996; Peltonen et al., 1998; Williams and Singh, 1997) and in martial arts these muscles are required to stabilise the body during kicking and punching, and maximise the effectiveness of force transfer onto the target. However, although the trunk flexors and extensors did tend to have larger torque values under both isokinetic and isometric testing, these differences did not reach significance. On further analysis of the isokinetic peak torque, there was a greater difference between the two groups in trunk extension than in flexion. Trunk extension movements are necessary to avoid kicks or punches to the face level, and certain kicking techniques require extension of the trunk.

There was no significant difference in the trunk flexion to extension ratio. However, the martial artists did tend to have lower ratios at both speeds, most likely due to stronger trunk extensors. While the relevance of trunk muscle strength with respect to low back pain has been widely studied, results are equivocal. Back extensor strength has been reported to be low in low back pain sufferers (Iwai et al., 2004; Kankaanpaa et al., 1998) and exercises that strengthen the extensors have been shown to be beneficial for low back pain (Carpenter and Nelson, 1999). However, previous research has not found significant correlations between trunk strength and back pain (Balague et al., 1993; Shirado and Kaneda, 1992). None of the martial artists in the present study reported any back pain.

It has been reported that physically fit participants show faster simple reaction times than their less fit counter parts (Arito and Oguri, 1990; Brisswalter et al., 1997; Hascelik et al., 1989; Malathi and Parulkar, 1989) and sportspeople have superior sports–specific perceptual skills compared to novices (Kioumourtzoglou et al., 1998; Mori et al., 2002). In the present study, we were able to divide the more commonly measured total reaction time into the reaction time (RT) and the movement time (MT) components. Results indicated that movement time scores largely explained faster reaction times for martial artists. Therefore, we conclude that difference in the total reaction time is solely due to the martial artists being able to move their limb faster than the controls and not due to any superiority in simple or choice reaction or pre-motor time itself. This is in-keeping with previous studies showing highly skilled professional cricketers have been shown to take as long as novice players to pick up the ball flight information from a film of bowlers (McLeod, 1987) and martial arts training improves the speed of movements (Lee et al., 1999).

APPLIED IMPLICATIONS OF THE STUDY

This study has revealed (rather surprisingly) that the trunk strength is not significantly increased in practitioners of hard-style marital arts. Given that this physically demanding sport is associated large and random movements of the trunk, it would be wise for training regimes to increase focus on trunk stability exercises to increase strength of the abdominal and back muscles. This may lead to an increase in performance and possibly lessen the likelihood of injury or incidence of low back pain; this however, would require further research.

CONCLUSIONS

This study reveals that practitioners of hard-style martial arts produce higher torques in their knee flexors and extensors under isokinetic testing and only in their extensors under isometric testing. Furthermore, martial artists can produce slightly (but not significantly) higher torques in the trunk muscles. In addition, they have faster reaction times; however, this effect is largely explained by a faster movement time.

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KEY POINTS

- Martial artists undertaking hard-style martial arts have greater strength in their knee flexor and extensor muscles as tested under isokinetic testing. Under isometric testing conditions they have stronger knee extensors only.
- The trunk musculature is generally higher under both conditions of testing in the martial artists, although not significantly.
- The total reaction times of the martial artists to an auditory stimulus were significantly faster than the control participants. When analysed further it was revealed that the decrease in reaction time was due to the movement time component of the total reaction time.
- The training involved for the practice of the hard-style martial arts increases the strength of muscles involved in kicking. This increased strength is not seen in the trunk muscles. Furthermore, martial artists have a faster response time; the cause of which appears to be only the faster movement time.

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