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Health benefits of Kung Fu: A systematic review

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Abstract

The Chinese martial arts (Kung Fu) have existed for centuries and are generally accepted as being beneficial for health without much empirical data. The aim of this systematic review was to assess the health effects of "hard" Kung Fu styles by performing electronic and manual searches of the literature. The aspects of health and the Kung Fu style examined varied between most studies; in some cases, the martial art group consisted of practitioners of other martial art styles also. Of 2103 references identified, only nine papers were eligible and reviewed. All were observational studies, observing a range of health aspects possibly related to Kung Fu training or performance. Our findings suggest that there is no evidence that Kung Fu practice is associated with the prevention or treatment of any health condition. However, as a moderate- to high-intensity form of aerobic exercise, it may confer benefits similar to those attributed to other aerobic training modalities. However, this hypothesis remains to be tested in clinical trials. Physiological benefits (e.g., aerobic capacity and bone density) may be associated with long-term Kung Fu practice. Future research in this area should adopt experimental designs, clearly identifying eligibility criteria, testing and training protocols, and include health-related outcomes and documentation of adverse events, to advance knowledge in this field.

Keywords: *Martial arts, Wushu, physiological benefits, exercise*

Introduction

The health benefits of regular physical activity are well established (Fielding, 1995; Karvonen, 1996; Kelley, 1997; Stewart, 2002; WHO/FIMS, 1995), although the effects of many forms of exercise have yet to be scientifically examined. One such exercise modality is Chinese martial arts, otherwise known as Kung Fu or Wu Shu.

Kung Fu was created in the Shaolin Temple in Henan, China in around A.D. 520 by a Buddhist monk, initially as exercises to strengthen the health, fitness, and concentration/focus of the monks. Over the centuries, these movements were refined, modified, and expanded, and they became not only exercises for health and fitness, but also for self-defence and combat (http://www.shaolin.com.au). Throughout its course of development, many different branches or styles/schools of Kung Fu were formed as different practitioners developed their own techniques. During times of political turmoil, many practitioners fled China to neighbouring countries, and continued to pass on their teachings. From this, other martial art schools including Tae Kwon Do, Judo, and Karate were formed (Theeboom & De Knop, 1997).

Given popular belief that Kung Fu is beneficial for health, it is of interest to investigate the currently available literature to identify health and fitness benefits already established for this martial art. Additionally, given that Kung Fu can be practised by young, elderly, and clinically defined cohorts, long-term adherence and safety need to be defined. As with any exercise/activity, the associated injury risk is of importance, for no health/fitness programme should put the participant at undue risk of injury. It would also be of interest to compare martial art training with other exercise modalities in terms of beneficial adaptations, safety, and compliance. Thus, the aim of this investigation was to conduct a systematic review of the effects of Kung Fu training on health status and physiological outcomes in any cohort.

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Methods

Criteria for considering studies for this review

Studies were considered eligible for inclusion if they met the following criteria:

1. "Hard" Kung Fu styles were examined as an intervention or activity of interest. In general terms, Kung Fu styles of a "hard" or "external" nature are those styles that focus on and rely more on a practitioner's physical attributes, whereas "internal" or "soft" Kung Fu styles focus on the cultivation and utilization of internal energy or "Qi".
2. Studies had to report physiological and/or psychological health outcomes associated with the practice of "hard" Chinese martial art (Kung Fu) styles.
3. The study designs could be a randomized controlled trial, controlled trial, uncontrolled trial or cross-sectional/observational study.
4. There were no exclusions or restrictions on the characteristics of the cohorts examined, or the duration, volume or intensity of training.

The following exclusion criteria were applied:

1. Published full-length articles in scientific/medical journals were considered, but magazine articles, monographs, websites, letters, articles on history/description of Kung Fu, case studies/reports, book reviews, conference proceedings or abstracts, articles in any language other than English (there was no funding for translators), and videos were excluded;
2. The specific martial art styles examined were not clearly specified to include Kung Fu or did not present any data for the Kung Fu group individually.
3. Papers on martial art styles other than Kung Fu, due to their different characteristics (such as Karate, Tae Kwon Do, Aikido or Judo), and studies on "soft" Kung Fu styles (including Tai Chi).

Literature search methodology

The following databases were reviewed on 31 May 2007: Allied and Complementary Medicine (AMED); CINAHL (Nursing and Allied Health); EBM Reviews – Cochrane Database of systematic reviews; EBM Reviews, All – Cochrane DSR, ACP Journal Club, DARE, and CCTR; EBM Reviews Full Text – Cochrane DSR, ACP Journal Club, and DARE; Ovid MEDLINE (R) – 1966 to week 4 of July 2006; Ovid MEDLINE Daily update – 7 August 2006; PreMEDLINE (most recently published); Ovid OLDMEDLINE – 1950 to 1965; Sportdiscus – 1830 to May 2006; and University of Sydney's full-text journals at Ovid (including PsycArticles).

Keywords used in the searches included: kung fu; wu shu; wushu; gong fu; gung fu; shaolin; Chinese martial art; martial art; Chinese boxing; choy lee fut; choy li fut. All keywords were searched for individually in all fields, without combining any of them, as they were all different names for the same topic (Chinese Kung Fu), so as to not exclude any eligible studies. Reference lists of collected articles and combat journals were also examined manually for articles of potential interest.

All titles and abstracts were examined by the primary author (T.W.T.), and in cases where the nature of the article (hence eligibility) was unclear, copies were obtained of the full-text either online, from The University of Sydney library, or through inter-library loans from The University of Sydney. If T.W.T. was unsure of the eligibility of an article, the article in question was discussed with one of the co-authors (M.F.S.).

Assessment of methodological quality of included studies

Articles were critiqued using the Delphi quality criteria for assessment of experimental trials (Verhaen *et al.*, 1998) and observational studies (Khan, Ter Riet, Popay, Nixon, & Kleijnen, 2001). If any aspect of the protocol or design was unclear, this was stated. T.W.T. initially examined all articles, and consulted M.F.S. to resolve any questions.

Statistical analysis

Means and standard deviation scores were used in this systematic review. Where raw data on each individual participant and a standard deviation were reported, T.W.T. manually calculated the mean value for the group. For change score data, or results obtained in cross-sectional studies, mean change scores and their standard deviations together with *P*-values were presented. Confidence intervals (95% CI) and Hedge's bias-corrected effect sizes were calculated by the authors using the pre- and post-score data for experimental trials, and in observational studies the mean absolute results when applicable. Hedge's effect size was used as it takes into account the sample sizes of the studies. Clinical meaningfulness was judged using the effect size conventions of Cohen (small ≤ 0.2; moderate $= 0.5$–0.8; large > 0.8) and with reference to known effects of other exercise modalities in the literature. Results were considered statistically significant when the calculated 95% CI did not include 0 or when the *P*-value reported in the studies was less than 0.05.

Results

Results of the search

Figure 1 shows the results of the literature search. The initial search using the keywords and reference lists generated 2103 results. Manual sorting identified 33 papers, of which 24 did not meet full inclusion criteria, leaving nine papers to be included in this review.

Study quality

All nine remaining papers were observational studies: seven cross-sectional, one descriptive, and one retrospective cohort (Table I). No authors reported reliability of their testing methods, or the presence of blinding of assessors (Table I). In general, study quality was poor due to the absence of any experimental study designs or well-controlled, prospective observational studies.

Participant characteristics

A total of 2513 participants (male and female) were evaluated in these studies, of whom 452 were martial art practitioners and 2061 controls. Where reported, the ages of the participants ranged from 18 to 36 years. No study reported any pre-existing health conditions of the cohorts, or targeted participants with a specific health condition. Based on the body mass index (BMI) calculated for each study that reported the height and weight of participants (Gualdi Russo, Gruppioni, Gueresi, Belcastro, & Marchesini, 1992; Jones & Unnithan, 1998; Schneider & Leung, 1991a; Zhao, 2001), participants were within the healthy BMI range in all but one study, where participants were in the overweight range (Jones & Unnithan, 1998), with BMI > 25 kg $\cdot$ m^{-2} (Cole, Bellizzi, Flegal, & Dietz, 2000) (Table II). However, the lack of body composition data precludes identification of this cohort as having excess body fat, as increased muscle mass may also increase BMI above the "normal" range in some sports such as weight-lifting (Prentice & Jebb, 2001).

Outcomes examined

INTENSITY

The intensity of Kung Fu training/performance was examined in three studies (Jones & Unnithan, 1998; Ribeiro, De Castro, Rosa, Baptista, & Oliveira, 2006; Schneider & Leung, 1991a) that directly observed the cardiovascular responses of practitioners while performing specific techniques from different Kung Fu styles (Tables III and IV). Years of training experience ranged from 1.2 to more than 8 years (Jones & Unnithan, 1998a; Ribeiro *et al.*, 2006; Schneider & Leung, 1991a) (Table III).

Results from two of these studies (Jones & Unnithan, 1998; Schneider & Leung, 1991a) were based on oxygen consumption during the repeated performance of a chosen form, while Jones and Unnithan (1998) also observed oxygen consumption during performance of specific punching and kicking techniques (Table IV). Pre- and post-exercise heart rate and blood lactate concentration were observed in the third study (Ribeiro *et al.*, 2006), for which participants performed two different Wu Shu forms (one fist form, the other a sword form) in a competition setting. In Schneider and Leung's (1991a) study, the Wing Chun participants repeated a 1.5-min form over 6 min, while the Tai Chi participants performed approximately 7 min of their 20-min form for data collection. Participants in Jones and Unnithan's (1998) study performed specific techniques at a rate of 80 punches per minute or 40 moves per minute (for the kicking combination) over ten 30-s work periods with equal rest periods in between. For data collection during a form, a 33-s form was performed ten times with an equal work-to-rest ratio. The amount of time taken for the forms performances in the study by Ribeiro *et al.* (2006) was not specified.

The intensity of forms and technique performance between experienced practitioners and novice students with less than 1.5 years' experience (Jones & Unnithan, 1998) are presented in Table IV. Although there were no significant differences in fitness between novice and experienced practitioners in this study (Jones & Unnithan, 1998), novice students worked at a significantly higher intensity than experienced students while performing the same techniques/forms. The associated effect sizes were large (Table IV).

Overall, the participants in these three studies performed their selected techniques and/or forms at intensities ranging between 64.4% (Jones & Unnithan, 1998) and 89.1% (Ribeiro *et al.*, 2006) of maximum heart rate, or 37.5 and 82.1% $\dot{V}O_{2max}$ (Jones & Unnithan, 1998) (Table IV).

PHYSIOLOGICAL OUTCOMES

Acute stress response. Blood pressure responses and hand stability (measured with a Nine holes stability tester) during and after tests designed to elicit physical or mental stress were assessed and compared among Wu Shu practitioners specializing in forms (tolo) or sparring (sanda), and compared with those of tennis players (Cho-yim *et al.*, 1997) (Table V). Changes in systolic blood pressure were significantly smaller during the mental stress test in Wu Shu forms (but not sparring) compared with tennis players, although the effect size was small (Table V). Both Wu Shu groups also had significantly smaller changes in systolic blood pressure

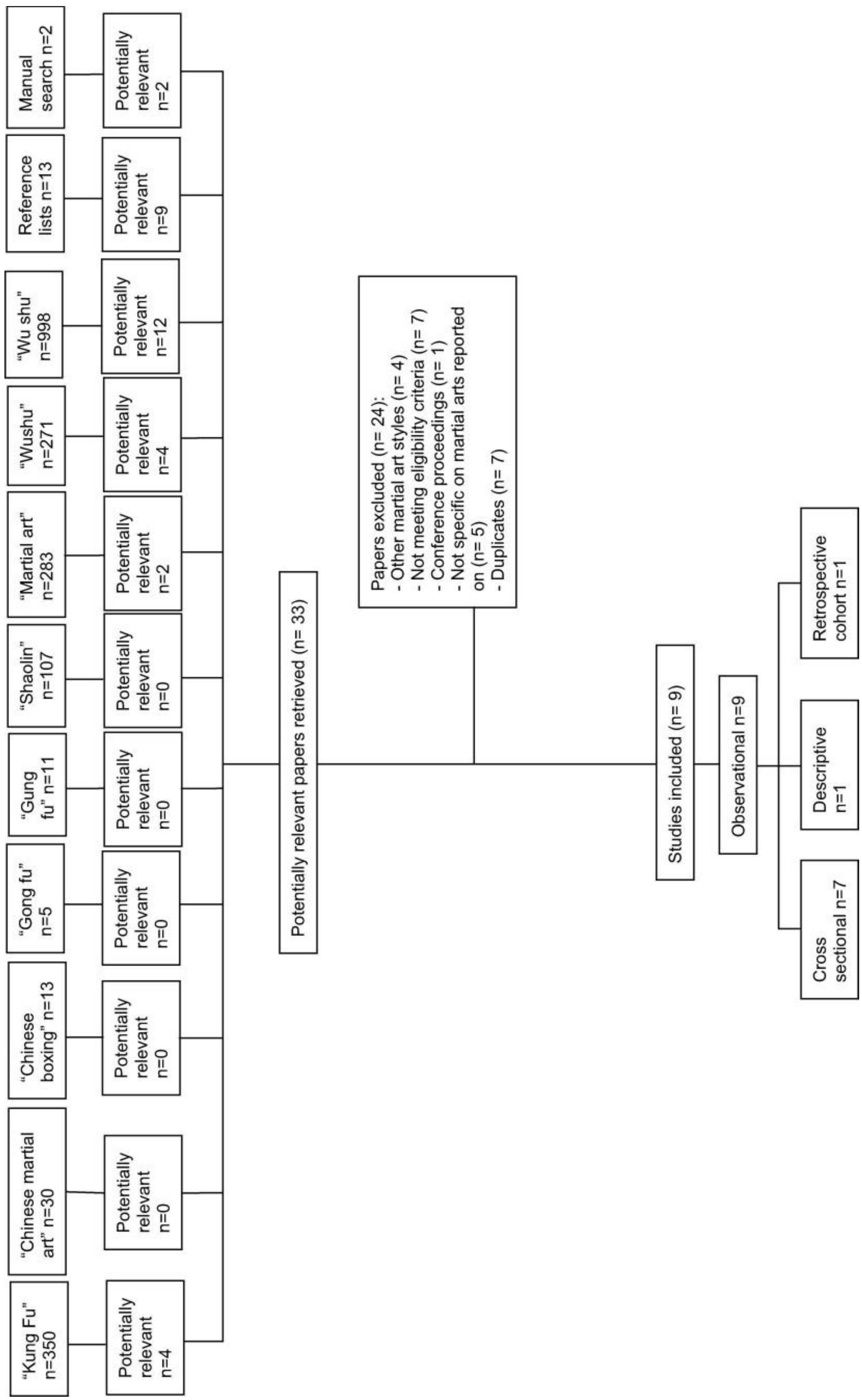

Figure 1. Literature search flow chart.

Table I. Study quality.

Reference	Design	Outcome(s) clearly defined?	Similar controls?	Same assessment techniques for Kung Fu and control groups?	Blinded outcomes assessment?
Gualdi Russo *et al*. (1992)	Cross-sectional	Yes	No (age differences); martial arts participants recruited elsewhere	Yes	Not reported
Cho-yim *et al*. (1997)	Cross-sectional	Yes	No (aptitude level differences)	Yes	Not reported
Zhao (2001)	Cross-sectional	Yes	Yes	Yes	Not reported
Schneider and Leung (1991b)	Cross-sectional	Yes	No (age differences)	No (Wing Chun continuously repeated their form, Tai Chi only completed a fraction of their form)	Not applicable
Jones and Unnithan (1998)	Cross-sectional (pilot)	Yes	No (age differences and intentional experience differences)	Yes	Not reported
Blijd *et al*. (1995)	Descriptive	Yes	Not applicable	Not applicable	No
Zetaruk *et al*. (2005)	Retrospective cohort	Yes	Not reported	Yes	No
Ribeiro *et al*. (2006)	Descriptive (pilot)	Yes	Not appicable	Yes (same protocol for both forms)	Not reported
O'Donovan *et al*. (2006)	Cross-sectional	Yes	Yes	Yes	Not reported

during the physical stress test than tennis players, with a moderate effect size for the sparring group. The authors reported a significant *P*-value, with Wu Shu sparring having greater hand stability after the mental stress test than tennis players, although our calculated 95% CI included zero, and the effect size was small to moderate (0.35). Other outcomes were not statistically significant and/or were not reported.

Reaction time. Reaction and movement time were compared between martial artists and sedentary controls, whereby upon hearing a signal, the participant needed to release a button and depress a stop button 25 cm away (O'Donovan, Cheung, Catley, McGregor, & Strutton, 2006). The time lapse between the aural signal and the participant releasing the start button was the reaction time, whereas the time between release of the start button to depression of the stop button was recorded as the movement time. Participants in the martial arts group consisted predominantly of Tae Kwon Do practitioners ($n = 8$), but it also included five Kung Fu practitioners of two different styles. Martial arts practitioners had significantly faster movement time than controls, but no significant differences were observed in reaction times (Table VI). The effect sizes observed were moderate to large (Table VI).

Body composition. Body composition outcomes were assessed by two studies and included bone mineral density (BMD) using single photon absorptiometry, and body fat estimates via skinfolds and anthropometry (Gualdi Russo *et al*., 1992; Zhao, 2001) (Table VII). One cross-sectional study (Gualdi Russo *et al*., 1992) reported body fat differences between Kung Fu and other athletes, although only anthropometric estimates, as opposed to criterion methods, were used.

When comparing percent body fat and fat-free mass in male martial arts practitioners with participants of other sports, many of the 95% confidence intervals observed excluded zero (Gualdi Russo *et al*., 1992) (Table VII). Male martial arts practitioners of all aptitude levels generally had greater percent body fat than male participants of most other sports. The effect sizes were moderate with skiers and rowers, and large with athletics participants (Table VII).

In this same study, estimated fat-free mass was significantly greater in male martial artists than in athletes and soccer players. In contrast, at high aptitude, male ball game players and gymnasts had significantly greater fat-free mass than male martial artists. All fat-free mass differences were small to moderate in magnitude (up to 3.3 kg; effect size $= -0.48$ to 0.43).

By contrast, female martial artists who were of high aptitude had significantly less body fat than swimmers, ball game players, and gymnasts (Table VII). There were no significant differences between female martial artists and other female sports participants in any other body composition measures in this study, at any aptitude level (Table VII).

Table II. Participant characteristics.

Reference	n	n, sex: Kung Fu/martial arts	n, sex: Comparison	n, sex: P	Health status: Kung Fu/martial arts	Health status: Comparison	Age (years): Kung Fu/martial arts	Age (years): Comparison	Age (years): P (95% CI)	BMI (kg · m^{-2}): Kung Fu/MA	BMI (kg · m^{-2}): Comparison	BMI (kg · m^{-2}): P
Gualdi Russo *et al.* (1992)	1815	171 (138 M, 33 F)	1644 (676 M, 968 F)	NR	NR (sportsmen)	NR (sportsmen)	M: 26.0 ± 6.9 F: 20.9 ± 2.4	M: 20.8[a] F: 19.5[a]	NR (NA)	M: 24.1[a] F: 21.4[a]	M: 22.5[a] F: 21.1[a]	NA
Cho-yim *et al.* (1997)	37	Wu Shu sanda: 10 (M/F NR); Wu Shu tolo: 15 (M/F NR)	12 (M/F NR)	NR	NR (college athletes)	NR (college athletes)	18–25 (total study cohort)	18–25 (total study cohort)	NR (NA)	NR	NR	NA
Zhao (2001)	171	12 M (from PE students group)	159 M (93 PE students; 66 chemical education students – 30 active, 36 sedentary)	NR	NR (university students)	NR (university students)	19.83 ± 0.89	PE students: 20.9[a]Chemical students: Active: 20.44 ± 0.88 Sedentary: 19.75 ± 0.71	NR (NA) NS (−1.4 to 0.01) NS (−0.6 to 0.7)	NR	PE students: 20.01 ± 1.31 Chemical students: Active: 20.65 ± 1.85 Sedentary: 21.56 ± 2.57.	NS
Schneider and Leung (1991b)	20	10 M	10 M	NR	NR (medical clearance obtained)	NR (medical clearance obtained)	30.0 ± 5.0	35.5 ± 3.9	<0.05* (−2.1 to −0.2)*	24.09[a]	24.34[a]	NA
Jones and Unnithan (1998)	18	9 M	9 M	NR	NR (medical clearance obtained)	NR (medical clearance obtained)	32.1 ± 5.5	22.7 ± 3.0	0.001* (0.9 to 3.2)*	26.5[a]	26.9[a]	NA
Blijd *et al.* (1995)	160	160 (114 M, 46 F)	0	NA	NR (national competitors)	NA	NR (19 children, 64 adults, 77 NR)	NA	NA (NA)	NR	NA	NA
Zetaruk *et al.* (2005)	263	39 (M/F NR)	224 (M/F NR)	NR	NR (from MA schools)	NR (from MA schools)	NR	NR	NA (NA)	NR	NR	NA
Ribeiro *et al.* (2006)	4	4 (M)	0	NA	NR (from regional team)	NA	22.5 ± 2.1	NA	NA (NA)	20.7[a]	NA	NA
O'Donovan *et al.* (2006)	25	13 (9 M, 4 F)	12 (8 M, 4 F)	NR	NR (MA practitioners)	NR (sedentary)	23.7 ± 11.2	22.2 ± 2.1	NR (−0.61 to 0.96)	NR	NR	NA

Note: M = male; F = female; M/F = male and female; NA = not applicable; NR = not reported; NS = not significant; PE = physical education; MA = martial arts. [a]Calculated by author for this review, raw data not available to calculate standard deviation.

Table III. Participant activities/training programmes.

Reference	Source of participants		Activity		Supervised training?		Training duration		Training volume	
	Interest	Comparison	Interest/MA style	Comparison	Interest	Comparison	Interest	Comparison	Interest	Comparison
Gualdi Russo *et al.* (1992)	Specialized gymnasiums	Applicants for admission to Exercise and Sport Science degree	MA competitors (Karate, Judo, Wu Shu, Kung Fu)	Participants in other sports: swimming ($n = 152$), skiing ($n = 78$), athletics ($n = 313$), ball games ($n = 593$), gymnastics ($n = 294$), rowing ($n = 19$), soccer ($n = 140$), skating ($n = 30$)	NS	NS	NS	NS	NS	NS
Cho-yim *et al.* (1997)	Collegiate students (world/ national champions)	Collegiate students (university champions)	Wu Shu sanda; Wu Shu tolo	Tennis	NS	NS	NS	NS	NS	NS
Zhao (2001)	Physical Education Department of South China Teachers University	Chemical Education Department of South China Teachers University	Physical education students: Wu Shu ($n = 12$), basketball ($n = 26$), football ($n = 28$), short-distance running ($n = 29$), long-distance running ($n = 10$)	Active and sedentary students	NS	NS	Wu Shu (NS)	NS	NS	NS
Schneider and Leung (1991b)	MA schools or clubs	MA schools or clubs	Wing Chun	Tai Chi	NS	NS	50.2 ± 24.0 months	81.6 ± 40.8 months	NS	NS
Jones and Unnithan (1998)	Kam Lau Fu Kung Fu students – experienced	Kam Lau Fu Kung Fu students – novice	Kam Lau Fu Kung Fu forms and selected techniques	Kam Lau Fu Kung Fu forms and selected techniques	NS	NS	9.5 ± 5.2 years	1.2 ± 0.1 years	NS	NS
Blijd *et al.* (1995)	1993 Dutch National Wu Shu Championships	NA	Forms (50 M, 33 F); semi-contact sparring (52 M, 13 F); sanda (12 M)	NA	NS	NA	NS	NA	NS	NA
Zetaruk *et al.* (2005)	Martial arts schools	Martial arts schools	Kung Fu ($n = 39$)	Other martial arts: Shotokan Karate ($n = 114$); Tae Kwon Do	NS	NS	NS	NS	NS	NS

(*continued*)

Table III. (*Continued*).

Reference	Source of participants		Activity		Supervised training?		Training duration		Training volume	
	Interest	Comparison	Interest/MA style	Comparison	Interest	Comparison	Interest	Comparison	Interest	Comparison
				($n = 49$); Aikido ($n = 47$); Tai Chi ($n = 14$)						
Ribeiro *et al.* (2006)	South Brazil regional Wu Shu team	NA	*Changquan* form	*Daoshu* form	NS	NS	> 8 years	NA	NS	NA
O'Donovan *et al.* (2006)	NS (black/brown belt-level practitioners)	NS	" Hard" MA practitioners: Tae Kwon Do ($n = 8$); Shaolin Nam Pai Chauan Kung Fu ($n = 3$); Wu Shu Kwan Kung Fu ($n = 2$)	Sedentary controls	NS	NS	NS	NS	NS	NS

Note: MA = martial arts; NA = not applicable; NS = not specified; sanda = full-contact sparring; tolo = forms.

Zhao (2001) evaluated bone mineral density in Kung Fu and other young students. This cross-sectional study found significantly greater bone mineral density in Kung Fu students than sedentary chemical education students. Although not reported as significant by the authors, the Kung Fu group also had significantly greater bone mineral density than students of other sports (basketball and long-distance running) as well as active chemical education students (Table VII), based on our calculated 95% confidence intervals that excluded zero and the large effect sizes (0.81–1.82) for the differences observed between Kung Fu students and sedentary or active chemical education students.

Muscle strength. Two studies examined muscle strength in martial artists (O'Donovan *et al.*, 2006; Zhao, 2001), only one of which reported the results specifically for their martial arts group (O'Donovan *et al.*, 2006), although their martial arts group also consisted of Tae Kwon Do practitioners. O'Donovan *et al.* compared relative isometric and isokinetic strength at various speeds of the knee and trunk flexors and extensors (Table VIII). Martial artists had significantly greater isometric knee extension torque (absolute difference = 45%), as well as greater isokinetic torque, at all speeds during knee flexion (martial artists 6–50% greater) and extension (martial artists 6–50% greater) than sedentary controls (Table VIII). These differences were observed despite the martial artists being 1.5 years older than the controls (23.2 ± 11.2 vs. 22.2 ± 2.1 years; 95% CI = -0.61 to 0.96), and a similar gender ratio between the two groups, which makes it unlikely that the gender of the participants influenced the results. As most results were presented by the authors in graphical form, without provision of the raw values, effect sizes and 95% confidence intervals could not be calculated. No other significant differences in leg or trunk strength were observed.

Injuries

Only two of the nine studies reported injury rates (Blijd, Blijd, & Pieter, 1995; Zetaruk, Violan, Zurakowski, & Micheli, 2005), and these are summarized in Table IX. No injuries were reported for Wu Shu athletes when competing in forms events, while females experienced more injuries than males in semi-contact sparring (females 100 and males 48.6 injuries per 1000 athlete-exposures; $P < 0.01$) (Blijd *et al.*, 1995). Still comparing Wu Shu athletes, the injury rate in full-contact sparring males was significantly greater than for semi-contact sparring males (48.61 vs. 150 injuries per 1000 athlete-exposures in semi- and full-contact males respectively; $P < 0.01$) (Blijd *et al.*, 1995) (Table IX).

Table IV. Intensity.

Reference	Kung Fu (mean ± *s*)	Comparison (mean ± *s*)	95% CI (Kung Fu vs. Comparison)	Hedge's ES	*P*
Schneider and Leung (1991b)	$\dot{V}O_2$: 1.65 ± 0.58 litres · min^{-1}	$\dot{V}O_2$: 1.19 ± 0.32 litres · min^{-1}	0.02 to 0.90*	0.94	<0.05*
	$\dot{V}O_2$: 23.3 ± 7.5 ml · kg^{-1} · min^{-1}	$\dot{V}O_2$: 16.0 ± 3.9 ml · kg^{-1} · min^{-1}	1.68 to 12.92*	1.17	<0.05*
	%$\dot{V}O_{2max}$: 52.4 ± 12.5	%$\dot{V}O_{2max}$: 36.4 ± 6.5	6.64 to 25.36*	1.54	<0.05*
	METS: 6.6 ± 2.2	METS: 4.6 ± 1.1	0.67 to 3.63*	1.10	<0.05*
	Heart rate: 137 ± 25 beats · min^{-1}	Heart rate: 116 ± 22 beats · min^{-1}	−1.12 to 43.12	0.85	<0.06
	%HR_{max}: 70.5 ± 13	%HR_{max}: 59.8 ± 9.9	−0.16 to 21.56	0.89	<0.06
	$\dot{V}_E$ (BTPS): 40.2 ± 15.5	$\dot{V}_E$ (BTPS): 25.6 ± 7.5	3.16 to 26.04*	1.15	<0.05*
	$\dot{V}_E/\dot{V}O_2$: 24.2 ± 2.7	$\dot{V}_E/\dot{V}O_2$: 21.7 ± 2.3	0.14 to 4.86*	0.95	<0.05*
	RER: 0.85 ± 0.05	RER: 0.83 ± 0.07	−0.04 to 0.08	0.31	>0.05
Jones and Unnithan (1998)	$\dot{V}O_{2max}$ (cycle ergometer): 53.6 ± 5.7 ml · kg^{-1} · min^{-1}	$\dot{V}O_{2max}$ (cycle ergometer): 56.1 ± 5.2 ml · kg^{-1} · min^{-1}	−7.95 to 2.95	−0.44	>0.05
	$\dot{V}O_{2max}$ (arm ergometer): 44.3 ± 6.7 ml · kg^{-1} · min^{-1}	$\dot{V}O_{2max}$ (arm ergometer): 41.6 ± 4.6 ml · kg^{-1} · min^{-1}	−3.04 to 8.44	0.45	>0.05
	Forms %$\dot{V}O_{2max}$: 71.5 ± 5.3	Forms %$\dot{V}O_{2max}$: 82.1 ± 6.1	−16.31 to −4.89*	−1.77	<0.05*
	Forms %HR_{max}: 76.4 ± 3.6	Forms %HR_{max}: 82.1 ± 4.3	−9.66 to −1.74*	−1.37	<0.05*
	Punching %$\dot{V}O_{2max}$: 37.5 ± 2.1	Punching %$\dot{V}O_{2max}$: 40.6 ± 2.6	−5.46 to −0.74*	−1.25	>0.05
	Punching %HR_{max}: 64.4 ± 3.6	Punching %HR_{max}: 82.3 ± 4.1	−21.76 to −14.04*	−4.42	>0.05
	Punching %U$\dot{V}O_{2max}$: 45.9 ± 5.3	Punching %U$\dot{V}O_{2max}$: 55.2 ± 6.7	−15.34 to −3.26*	−1.47	<0.05*
	Punching %UHR_{max}: 65.9 ± 4.3	Punching %UHR_{max}: 85.3 ± 4.6	−23.85 to −14.95*	−4.15	<0.05*
	Kicking %$\dot{V}O_{2max}$: 63.8 ± 3.0	Kicking %$\dot{V}O_{2max}$: 53.6 ± 3.7	6.83 to 13.57*	2.88	Interaction effect < 0.05
	Kicking %HR_{max}: 74.9 ± 4.0	Kicking %HR_{max}: 81.6 ± 2.5	−10.03 to −3.37*	−1.91	<0.05*
Ribeiro *et al.* (2006)	**Changquan:**	**Daoshu:**			
	Heart rate	*Heart rate*			
	Resting: 76 ± 7 beats · min^{-1}	Resting: 78 ± 9 beats · min^{-1}	−15.95 to 11.95	−0.22	>0.05
	Pre-performance: 82 ± 5 beats · min^{-1}	Pre-performance: 83 ± 7 beats · min^{-1}	−11.52 to 9.52	−0.14	>0.05
	Post-performance: 176 ± 3 beats · min^{-1}	Post-performance: 176 ± 2 beats · min^{-1}	−4.41 to 4.41	0.00	>0.05
	Lactate	*Lactate*			
	Resting: 1.8 ± 0.4 mmol · l^{-1}	Resting: 1.3 ± 0.4 mmol · l^{-1}	−0.19 to 1.19	1.09	>0.05
	Pre-performance: 2.1 ± 0.2 mmol · l^{-1}	Pre-performance: 1.8 ± 0.2 mmol · l^{-1}	−0.05 to 0.65	1.30	>0.05
	Post-performance: 4.4 ± 1.6 mmol · l^{-1}	Post-performance: 5.2 ± 1.1 mmol · l^{-1}	−3.18 to 1.58	−0.51	>0.05

Note: *s* = standard deviation; 95% CI = confidence interval; ES = effect size; HR = heart rate; METS = energy cost; $\dot{V}O_2$ = oxygen consumption; $\dot{V}_E$ = minute ventilation; RER = respiratory exchange ratio; UHR = upper body heart rate; U$\dot{V}O_2$ = upper body oxygen consumption. *Statistically significant ($P < 0.05$ or 95% CI not including zero).

When comparing Kung Fu practitioners with practitioners of other martial arts styles, significant differences were only seen between Kung Fu and Karate practitioners, where Kung Fu practitioners reported fewer injuries, including fewer multiple and major injuries (Zetaruk *et al.*, 2005).

The most prevalent injury type in Wu Shu sparring competitors was contusions. Females were more likely to sustain injury to the lower extremities, while males (semi- and full-contact sparring) sustained most injuries to the head/neck (Blijd *et al.*, 1995) (Table IX). Details of the circumstances and mechanisms of injuries are presented in Table IX. Between practitioners of Kung Fu and other martial arts, significant differences in terms of the body area injured were seen mainly between Kung Fu and Karate. Injuries to the upper and lower extremities, groin, and trunk were more prevalent in Karate than Kung Fu,

Table V. Physiological outcomes: Stress response (Cho-yim *et al.*, 1997).

Kung Fu (mean ± *s*)	Comparison (mean ± *s*)	95% CI (Kung Fu vs. Comparison)	Hedge's ES	*P*
Stroop test SBP change:	*Stroop test SBP change*:			
Wu Shu sanda: 2.8 ± 13.139	13.167 ± 14.415	Wu Shu sanda: −22.74 to 2.01	−0.72	0.096
Wu Shu tolo: 3.33 ± 6.662		Wu Shu tolo: −18.44 to −1.24*	−0.41	0.027*
Stroop test hand stability change:	*Stroop test hand stability change*:			
Wu Shu sanda: 2.46 ± 3.70	1.30 ± 4.183	Wu Shu sanda: −2.39 to 4.71	0.28	0.039*
Wu Shu tolo: 2.88 ± 7.07		Wu Shu tolo: −3.19 to 6.35	0.26	0.501
Stroop test STAI-I: NR	*Stroop test STAI-I*: NR	NA	NA	>0.1
Cycle ergometer SBP change:	*Cycle ergometer SBP change*:			
Wu Shu sanda: 15.3 ± 12.093	30.5 ± 16.048	Wu Shu sanda: −28.06 to −2.34*	−0.64	0.023*
Wu Shu tolo: 18.933 ± 11.405		Wu Shu tolo: −22.45 to −0.68*	−0.24	0.044*
Cycle ergometer hand stability: NR	*Cycle ergometer hand stability*: NR	NA	NA	>0.1
Cycle ergometer STAI-I: NR	*Cycle ergometer STAI-I*: NR	NA	NA	>0.1

Note: *s* = standard deviation; 95% CI = confidence interval; ES = effect size; SBP = systolic blood pressure; STAI-I = State–Trait Anxiety Inventory form X-1; NA = not applicable; NR = not reported. *Statistically significant ($P < 0.05$ or 95% CI not including zero).

Table VI. Physiological outcomes: Reaction time (O'Donovan *et al.*, 2006).

Kung Fu (mean ± *s*)	Comparison (mean ± *s*)	95% CI (Kung Fu vs. Comparison)	Hedge's ES	*p*
Simple reaction time: 210.91 ± 13.5 ms	Simple reaction time: 222.18 ± 22.9 ms	−26.67 to 4.13	−0.59	>0.05
Choice reaction time: 312.33 ± 31.6 ms	Choice reaction time: 343.10 ± 54.4 ms	−67.21 to 5.67	−0.68	>0.05
Simple movement time: 128.07 ± 14.1 ms	Simple movement time: 165.79 ± 15.9 ms	−50.13 to −25.31*	−2.43	<0.05*
Choice movement time: 174.29 ± 30.8 ms	Choice movement time: 197.82 ± 18.1 ms	−44.67 to −2.39*	−0.89	<0.05*

Note: *s* = standard deviation; 95% CI = confidence interval; ES = effect size. *Statistically significant ($P < 0.05$ or 95% CI not including zero).

while head/neck injuries were more prevalent in Karate, Tae Kwon Do, and Aikido than in Kung Fu. Medium to large effect sizes were observed between Karate and Kung Fu in the major and multiple injury rates, and upper and lower extremities, trunk, and head/neck body regions (Table IX).

Zetaruk *et al.* (2005) also reported that risk of injury increased with age (>18 vs. ≤18 years; $P = 0.01$, 95% CI = 1.48 to 9.52), experience (training ≥3 vs. <3 years; $P = 0.003$, 95% CI = 1.51 to 4.02), and duration of training per week (>3 vs. ≤3 h · week^{-1}; $P = 0.045$, 95% CI = 1.52 to 7.32).

Discussion

Study quality

The studies reviewed were limited in number and quality, which demonstrates the paucity of robust research in the area of external Kung Fu styles and health. Due to numerous limitations in study design or reporting of methodology (e.g., lack of randomized design, cohort details, blinding of outcome assessors, use of non-criterion methods, small sample sizes, etc.), few conclusions can be drawn, apart from the intensity of certain techniques from specific Kung Fu styles when performed by adult practitioners, and the mechanisms of and rates of injuries in martial arts competitors. No studies examined the same variables within the same Kung Fu style(s), preventing compilation of data to calculate an overall effect size for any specific variable. Additionally, different Kung Fu styles were studied, with no two studies exclusively examining any one particular style, thus not excluding differences between styles within Kung Fu. It is partly because of the authors' prior knowledge of this potential issue that other "hard" martial art styles were not investigated to prevent further complications.

Aerobic intensity of Kung Fu

Two findings are notable. First, specific techniques from the different styles of Kung Fu were examined in proficient practitioners, and found to be of moderate or high aerobic intensity (depending on the style). Additionally, novice students perform the same techniques with higher oxygen consumption than proficient practitioners, thus demonstrating that they are less efficient. The three studies had small participant numbers, and two (Jones & Unnithan, 1998; Schneider & Leung, 1991a) had significantly different participant characteristics between the Kung Fu and comparison groups, including age and training duration [although admittedly differences in years of experience was intended in one of

Table VII. Physiological outcomes: Body composition.

Reference	Kung Fu (mean ± *s*)	Comparison (mean ± *s*)	95% CI (Kung Fu vs. Comparison)	Hedge's ES	*P*
Gualdi Russo *et al*. (1992)	% Body fat (%BF):	% Body fat (%BF):			
	M: 12.68 ± 4.25	*Swimming*			
	F: 18.96 ± 3.48	M: 11.11 ± 2.62	0.24 to 2.90*	0.39	>0.05
		F: 19.59 ± 3.28	−1.94 to 0.68	−0.19	>0.05
		Skiing			
		M: 10.02 ± 2.1	0.97 to 4.35*	0.66	>0.05
		F: 19.79 ± 3.22	−2.30 to 0.64	−0.25	>0.05
		Athletics			
		M: 9.78 ± 2.27	2.07 to 3.73*	0.83	>0.05
		F: 19.32 ± 3.32	−1.61 to 0.89	−0.11	>0.05
		Ball games			
		M: 11.27 ± 2.86	0.71 to 2.11*	0.41	>0.05
		F: 19.68 ± 3.23	−1.89 to 0.45	−0.22	>0.05
		Gymnastics			
		M: 10.26 ± 2.58	0.85 to 3.99*	0.60	>0.05
		F: 19.34 ± 3.3	−1.59 to 0.83	−0.11	>0.05
		Rowing			
		M: 9.78 ± 2.7	0.92 to 4.88*	0.70	>0.05
		Skating			
		F: 20.15 ± 4.06	−3.09 to 0.71	−0.31	>0.05
		Soccer			
		M: 11.56 ± 3.06	0.25 to 1.99*	0.30	>0.05
	Fat-free mass:	Fat-free mass:			
	M: 63.37 ± 6.83 kg	*Swimming*			
	F: 45.22 ± 4.72 kg	M: 61.92 ± 5.42 kg	−0.76 to 3.66	0.22	>0.05
		F: 46.21 ± 4.63 kg	−2.82 to 0.84	−0.21	>0.05
		Skiing			
		M: 61.78 ± 6.05 kg	−1.25 to 4.43	0.24	>0.05
		F: 45.14 ± 4.61 kg	−1.98 to 2.14	0.02	>0.05
		Athletics			
		M: 61.83 ± 5.57 kg	0.04 to 3.04*	0.24	>0.05
		F: 46.11 ± 4.42 kg	−2.55 to 0.77	−0.20	>0.05
		Ballgames			
		M: 64.72 ± 6.66 kg	−2.73 to 0.03	−0.20	>0.05
		F: 46.34 ± 4.55 kg	−2.76 to 0.52	−0.24	>0.05
		Gymnastics			
		M: 64.38 ± 6.45	−3.66 to 1.64	−0.15	>0.05
		F: 44.07 ± 4.28	−0.42 to 2.72	0.26	>0.05
		Rowing			
		M: 62.49 ± 4.81	−2.32 to 4.08	0.13	>0.05
		Skating			
		F: 45.05 ± 4.3	–2.11 to 2.45	0.04	>0.05
		Soccer			
		M: 61.65 ± 5.77	0.23 to 3.21*	0.27	>0.05
	Middle aptitude %BF:	Middle aptitude %BF:			
	M: 13.19 ± 5.13	*Swimming*			
	F: 14.27 ± 3.21	M: 9.96 ± 2.98	−1.64 to 4.82*	0.66	NR
		F: 14.44 ± 3.03	−1.38 to 1.04	−0.05	NR
		Skiing			
		M: 9.87 ± 3.03	−1.27 to 5.37	0.65	NR
		F: 15.08 ± 3.19	−2.23 to 0.61	−0.25	NR
		Athletics			
		M: 9.44 ± 1.95	2.81 to 4.69*	0.85	NR
		F: 13.69 ± 3.51	−0.71 to 1.87	0.17	NR
		Ball games			
		M: 11.25 ± 3.09	1.14 to 2.74*	0.44	NR
		F: 14.15 ± 3.61	−1.17 to 1.41	0.03	NR
		Gymnastics			
		M: 9.93 ± 2.21	1.40 to 5.12*	0.68	NR
		F: 13.3 ± 3.01	−0.13 to 2.07	0.32	NR

(*continued*)

Table VII. (*Continued*).

Reference	Kung Fu (mean ± *s*)	Comparison (mean ± *s*)	95% CI (Kung Fu vs. Comparison)	Hedge's ES	*P*
		Rowing			
		M: 9.73 ± 2.24	−1.10 to 5.82	0.68	NR
		Skating			
		F: 12.88 ± 3.05	−0.19 to 2.97	0.42	NR
		Soccer			
		M: 12.21 ± 3.14	−0.02 to 1.98	0.21	NR
	Middle aptitude fat-free mass:	Middle aptitude fat-free mass:			
	M: 63.35 ± 7.65 kg	*Swimming*			
	F: 47.4 ± 5.46 kg	M: 61.22 ± 4.32 kg	−0.24 to 4.50	0.29	NR
		F: 48.44 ± 5.49 kg	−3.20 to 1.12	−0.19	NR
		Skiing			
		M: 65.1 ± 9.58 kg	−5.12 to 1.62	−0.22	NR
		F: 47.82 ± 4.41 kg	−2.56 to 1.72	−0.09	NR
		Athletics			
		M: 60.64 ± 3.99 kg	−1.23 to 4.19*	0.40	NR
		F: 48.98 ± 4.48 kg	−3.31 to 0.15	−0.33	NR
		Ball games			
		M: 62.51 ± 6.3 kg	−0.55 to 2.23	0.12	NR
		F: 48.54 ± 5.5 kg	−3.12 to 0.84	−0.21	NR
		Gymnastics			
		M: 61.4 ± 4.04 kg	−0.85 to 4.75	0.27	NR
		F: 46.82 ± 4.05 kg	−0.96 to 2.12	0.14	NR
		Rowing			
		M: 60.05 ± 4.99	−0.27 to 6.87	0.43	NR
		Skating			
		F: 45.8 ± 6.05	−1.30 to 4.50	0.27	NR
		Soccer			
		M: 60.6 ± 6.53	1.07 to 4.43*	0.37	NR
	High aptitude %BF:	High aptitude %BF:			
	M: 12.19 ± 3.56	*Swimming*			
	F: 12.48 ± 2.33	M: 11.58 ± 2.36	−0.51 to 1.73	0.18	NR
		F: 13.8 ± 3.19	−2.51 to −0.13*	−0.43	NR
		Skiing			
		M: 10.15 ± 2	0.62 to 3.46*	0.61	NR
		F: 13.75 ± 3.53	−2.65 to 0.11	−0.40	NR
		Athletics			
		M: 9.87 ± 2.35	1.59 to 3.05*	0.77	NR
		F: 13.51 ± 2.93	−2.09 to 0.03	−0.36	NR
		Ball games			
		M: 11.29 ± 2.83	0.26 to 1.54*	0.29	NR
		F: 13.88 ± 2.97	−2.45 to −0.35*	−0.48	NR
		Gymnastics			
		M: 10.38 ± 2.9	0.46 to 3.16*	0.52	NR
		F: 13.69 ± 2.56	−2.13 to −0.29*	−0.47	NR
		Rowing			
		M: 9.8 ± 2.89	0.70 to 4.08*	0.68	NR
		Skating			
		F: 13.81 ± 3.19	−2.73 to 0.07	−0.45	NR
		Soccer			
		M: 11.28 ± 3.07	−0.13 to 1.69*	0.27	NR
	High aptitude fat-free mass:	High aptitude fat-free mass:			
	M: 63.38 ± 6.52 kg	*Swimming*			
	F: 49.35 ± 5.21 kg	M: 62.21 ± 5.86 kg	−0.99 to 3.33	0.18	NR
		F: 50.47 ± 4.31 kg	−2.91 to 0.67	−0.24	NR
		Skiing			
		M: 61.53 ± 5.37 kg	−0.83 to 4.53	0.29	NR
		F: 48.75 ± 5.14 kg	−1.69 to 2.89	0.11	NR

(*continued*)

Table VII. (*Continued*).

Reference	Kung Fu (mean ± *s*)	Comparison (mean ± *s*)	95% CI (Kung Fu vs. Comparison)	Hedge's ES	*P*
		Athletics			
		M: 62.14 ± 5.9 kg	−0.26 to 2.74	0.20	NR
		F: 49.66 ± 5.12 kg	−2.22 to 1.60	−0.06	NR
		Ball games			
		M: 65.2 ± 6.69 kg	−3.18 to −0.46*	−0.27	NR
		F: 50.08 ± 4.71 kg	−2.44 to 0.98	−0.15	NR
		Gymnastics			
		M: 66.43 ± 7.08 kg	−5.65 to 0.45*	−0.46	NR
		F: 48.28 ± 5.33 kg	−0.86 to 3.00	0.20	NR
		Rowing			
		M: 63.19 ± 4.71 kg	−2.87 to 3.25	0.03	NR
		Skating			
		F: 49.46 ± 4.36 kg	−2.54 to 2.32	−0.02	NR
		Soccer			
		M: 61.89 ± 5.61 kg	0.05 to 2.93*	0.24	NR
Zhao (2001)	Bone mineral density:	Bone mineral density:			
	Wu Shu	Other PE students:			
	0.762 ± 0.038 g · cm^{-2}	*Basketball*			
		0.70 ± 0.04 g · cm^{-2}	0.03 to 0.09*	1.47	NR
		Football			
		0.72 ± 0.06 g · cm^{-2}	0.00 to 0.08	0.81	NR
		Short-distance running			
		0.76 ± 0.05 g · cm^{-2}	−0.03 to 0.03	0.15	NR
		Long-distance running			
		0.70 ± 0.03 g · cm^{-2}	0.03 to 0.09*	1.80	NR
		Active:			
		0.702 ± 0.057 g · cm^{-2}	0.02 to 0.10*	1.12	NR
		Sedentary:			
		0.689 ± 0.04 g · cm^{-2}	0.05 to 0.10*	1.82	<0.01*

Note: *s* = standard deviation; 95% CI = confidence interval; ES = effect size; NR = not reported; F = female; M = male; NR = not reported.
*Statistically significant ($P < 0.05$ or 95% CI not including zero).

these studies (Jones & Unnithan, 1998)]. Both of these studies required their participants to perform specific forms/techniques at a set pace. While Jones and Unnithan (1998) were quite concise in their maintenance of pace using standardized verbal feedback and a metronome, Schneider and Leung (1991a) provided no detail of how their standard pace was maintained. Only Ribeiro *et al*. (2006) assessed their participants in a simulated competition setting, which would have allowed for individual differences in form interpretation or energy expenditure between different practitioners. In Schneider and Leung's (1991a) study, there were also differences in assessment protocols between the Wing Chun (Kung Fu) and Tai Chi (comparison) groups, in that Kung Fu students were asked to perform their form approximately four times, while Tai Chi students only performed half of their form once. This discrepancy may have overestimated the intensity of the Kung Fu group relative to the Tai Chi group. Additionally, Wing Chun practitioners were significantly younger than Tai Chi practitioners in Schneider and Leung's (1991a) study (95% CI = −2.12 to −0.23). As analyses were not adjusted for age, the true differences in energy expenditure between Wing Chun and Tai Chi training may have been underestimated.

Although the three studies reported the intensity of specific techniques in differing Kung Fu styles to be of moderate to high intensity, the reported intensities when performed by novice students were high enough to elicit cardiovascular benefits, but this was not the case for experienced practitioners of the Kam Lau Fu or Wing Chun styles (Franklin, 2000). On the other hand, Ribeiro and colleagues' (2006) pilot study showed that their four participants were performing Wu Shu forms at intensities high enough to elicit cardiovascular benefits. This result may have been partly due to the freedom the participants had to perform the forms at their own pace as they would in a competition, rather than having the flow of their movements restricted via a set pace. Additional studies are required to confirm the aerobic intensity of Kung Fu in various cohorts of practitioners during both training and competition. Presumably, as most time is spent in training rather than in competition,

Table VIII. Physiological outcomes: Muscle strength (O'Donovan *et al.*, 2006).

Kung Fu (mean $\pm$ *s*)	Comparison (mean $\pm$ *s*)	95% CI (Kung Fu vs. Comparison)	Hedge's ES	*P*
Peak isometric knee flexion torque: $\sim$126%	Peak isometric knee flexion torque: $\sim$118%	NA	NA	>0.05
Peak isometric knee extension torque: $\sim$227%	Peak isometric knee extension torque: $\sim$182%	NA	NA	<0.05*
Peak isokinetic knee flexion torque:	Peak isokinetic knee flexion torque:			
$30^\circ \cdot s^{-1}$: $\sim$206%	$30^\circ \cdot s^{-1}$: $\sim$178%	NA	NA	<0.05*
$90^\circ \cdot s^{-1}$: $\sim$ 150%	$90^\circ \cdot s^{-1}$: $\sim$144%	NA	NA	<0.05*
$210^\circ \cdot s^{-1}$: $\sim$189%	$210^\circ \cdot s^{-1}$: $\sim$139%	NA	NA	<0.05*
Peak isokinetic knee extension torque:	Peak isokinetic knee extension torque:			
$30^\circ \cdot s^{-1}$: $\sim$250%	$30^\circ \cdot s^{-1}$: $\sim$200%	NA	NA	<0.05*
$90^\circ \cdot s^{-1}$ $\sim$233%	$90^\circ \cdot s^{-1}$: $\sim$206%	NA	NA	<0.05*
$210^\circ \cdot s^{-1}$: $\sim$150%	$210^\circ \cdot s^{-1}$: $\sim$144%	NA	NA	<0.05*
Hamstring/quadriceps torque ratio: 72.67 $\pm$ 7.9%	Hamstring/quadriceps torque ratio: 73.33 $\pm$ 6.4%	-6.64 to 5.32	-0.09	>0.05
Peak isometric trunk flexion torque: $\sim$193%	Peak isometric trunk flexion torque: $\sim$168%	NA	NA	>0.05
Peak isokinetic trunk flexion torque: $\sim$255%	Peak isokinetic trunk flexion torque: $\sim$215%	NA	NA	>0.05
Peak isokinetic trunk flexion torque:	Peak isokinetic trunk flexion torque:			
$30^\circ \cdot s^{-1}$: $\sim$260%	$30^\circ \cdot s^{-1}$: $\sim$247%	NA	NA	>0.05
$90^\circ \cdot s^{-1}$: $\sim$240%	$90^\circ \cdot s^{-1}$: $\sim$220%	NA	NA	>0.05
Peak isokinetic trunk extension torque:	Peak isokinetic trunk extension torque:			
$30^\circ \cdot s^{-1}$: $\sim$353%	$30^\circ \cdot s^{-1}$: $\sim$247%	NA	NA	>0.05
$90^\circ \cdot s^{-1}$: $\sim$267%	$90^\circ \cdot s^{-1}$: $\sim$220%	NA	NA	>0.05
Trunk flexor/extensor torque ratio: 98.93 $\pm$ 23.8%	Trunk flexor/extensor torque ratio: 95.84 $\pm$ 13.0%	-12.98 to 19.16	0.15	>0.05

Note: *s* = standard deviation; 95% CI = confidence interval; ES = effect size; NA = not applicable. *Statistically significant ($P < 0.05$ or 95% CI not including zero). Strength measures were normalized to body weight.

potential health benefits should be extrapolated from the intensity observed during typical training sessions.

Body composition

Significant differences in participant characteristics were found between Kung Fu and comparison groups in body composition studies, which may have confounded the body composition differences reported, but were not adjusted for in analyses (Gualdi Russo *et al.*, 1992; Zhao, 2001). Specifically, the older age of the male Kung Fu participants (Gualdi Russo *et al.*, 1992) suggests that their higher lean body mass and percent body fat relative to soccer players and all other male participants respectively, may underestimate a potential benefit in terms of lean body mass accretion, while overestimating the contribution of Kung Fu to higher body fat in these participants. On the other hand, high aptitude female martial artists had a lower percent body fat than other sportswomen, which suggests differences between the sexes. The authors suggested that perhaps females with a smaller build may have been more attracted to martial arts training so they could learn how to defend themselves (Gualdi Russo *et al.*, 1992). This was a reasonable explanation, although the significant difference in percent body fat was only observed in females of high aptitude. It is possible that these results reflect a benefit of martial arts training for body composition in females, which is only achieved after long-term training.

There are a number of methodological concerns in the body composition study (Gualdi Russo *et al.*, 1992). Most importantly, skinfolds were used to estimate fat and lean mass, rather than a criterion method (Durnin & Womersley, 1974). Second, inter-rater reliability, known to be of critical importance (Kispert & Merrifield, 1987) in anthropometric assessment, was not reported. Finally, the martial arts group also consisted of competitors of a range of different martial art styles, including Karate, Judo, Wu Shu, and Kung Fu, although because the participant numbers within each martial arts style was not outlined, we reported the data collated for all martial arts – not just Kung Fu/Wu Shu. Thus, the effect of Kung Fu on fat and lean tissue remains to be determined in more robust studies using criterion methods.

Bone mineral density was appropriately measured using dual-energy absorptiometry, although details of analysis precision were not presented. Adult Wu Shu students had significantly greater bone mineral

Table IX. Injuries.

Reference	Kung Fu (mean ± *s*)	Comparison (mean ± *s*)	95% CI (Kung Fu vs Comparison)	Hedge's ES	*P*
Blijd *et al.* (1995)	Forms: No injuries	NA	NA (no standard deviations reported)	NA	
	Injury rates per 1000 athlete-exposures: F: 100 M: 48.61 M Sanda: 150				F vs. M: <0.01* M vs. M Sanda: <0.01*
	Injury rates per 100 competitors: F: 30.77 M: 13.46 M Sanda: 25.99				NR
	Injury locations: F: lower extremities (75%); trunk (25%) M: head/neck (14.3%); trunk (57.1%); lower extremities (28.6%) M Sanda: head/neck (66.7%); lower extremities (33.3%)				NR
	Injury types (% of all reported injuries): F: contusion (100%) M: contusions (71.4%); epistaxis (14.3%); other (14.3%) M Sanda: contusion (33.3%); laceration (33.3%); concussion (33.3%)				NR
	Circumstances of injury: F: attacking with a kick M: unblocked blow (71.4%); attacking with a punch (28.6%) M Sanda: attacking with a punch (66.7%); attacking with a kick (33.3%)				NR
	Injury mechanism: F: simultaneous kicks (75%); delivering a kick (25%) M: receiving a kick (57.1%); receiving a punch (28.6%); receiving a leg sweep (14.3%) M Sanda: simultaneous blows (66.7%); receiving a punch (33.3%)				NR
Zetaruk *et al.* (2005)	Injuries (%): 15 ± 38.5	Injuries (%):			
		Karate: 34 ± 29.8	−30.81 to −7.19*	−0.59	NR
		Tae Kwon Do: 29 ± 59.2	−35.80 to 7.80	−0.27	NR
		Aikido: 24 ± 51.1	−28.74 to 10.74	−0.19	NR
		Tai Chi: 2 ± 14.3	−8.27 to 34.27	0.38	NR
	Major injuries (%): 7 ± 17.9	Major injuries (%):			
		Karate: 19 ± 16.7	−18.23 to −5.77*	−0.70	NR
		Tae Kwon Do: 13 ± 26.5	−15.85 to 3.85	−0.26	NR
		Aikido: 13 ± 27.7	−16.24 to 4.24	−0.25	NR
		Tai Chi: 1 ± 7.1	−3.92 to 15.92	0.37	NR
	Multiple injuries (%): 9 ± 23.1	Multiple injuries (%):			
		Karate: 21 ± 18.4	−19.22 to −4.78*	−0.61	NR
		Tae Kwon Do: 22 ± 44.9	−28.74 to 2.74	−0.35	NR

(*continued*)

Table IX. (*Continued*).

Reference	Kung Fu (mean ± *s*)	Comparison (mean ± *s*)	95% CI (Kung Fu vs Comparison)	Hedge's ES	*P*
		Aikido: 15 ± 31.9	−18.17 to 6.17	−0.21	NR
		Tai Chi: 0 ± 0	−3.47 to 21.47	0.44	NR
	Upper extremity (%):	Upper extremity (%):			
	8 ± 20.5	*Karate*: 19 ± 16.7	−17.50 to −4.50*	−0.62	NR
		Tae Kwon Do: 20 ± 40.8	−26.24 to 2.24	−0.36	NR
		Aikido: 20 ± 42.6	−26.82 to 2.82	−0.35	NR
		Tai Chi: 1 ± 7.1	−4.29 to 18.29	0.38	NR
	Lower extremity (%):	Lower extremity (%):			
	14 ± 35.9	*Karate*: 26 ± 22.8	−21.79 to −2.21*	−0.45	NR
		Tae Kwon Do: 28 ± 57.1	−34.85 to 6.85	−0.28	NR
		Aikido: 16 ± 34	−17.02 to 13.02	−0.06	NR
		Tai Chi: 1 ± 7.1	−6.51 to 32.51	0.41	NR
	Groin (%):	Groin (%):			
	2 ± 5.1	*Karate*: 1 ± 0.9	0.02 to 1.98*	0.37	NR
		Tae Kwon Do: 9 ± 18.4	−13.04 to −0.96*	−0.49	NR
		Aikido: 3 ± 6.4	−3.52 to 1.52	−0.17	NR
		Tai Chi: 0 ± 0	−0.75 to 4.75	0.45	NR
	Trunk (%):	Trunk (%):			
	5 ± 12.8	*Karate*: 17 ± 14.9	−17.28 to −6.72*	−0.83	NR
		Tae Kwon Do: 12 ± 24.5	−15.61 to 1.61	−0.34	NR
		Aikido: 12 ± 25.5	−15.93 to 1.93	−0.33	NR
		Tai Chi: 1 ± 7.1	−3.27 to 11.27	0.34	NR
	Head/neck (%):	Head/neck (%):			
	4 ± 10.3	*Karate*: 11 ± 9.6	−10.58 to −3.42*	−0.71	NR
		Tae Kwon Do: 15 ± 30.6	−21.18 to −0.82*	−0.46	NR
		Aikido: 15 ± 31.9	−21.60 to −0.40*	−0.44	NR
		Tai Chi: 1 ± 7.1	−3.00 to 9.00	0.31	NR

Note: *s* = standard deviation; 95% CI = confidence interval; ES = effect size; NR = not reported; NA = not applicable; F=female; M=male.
*Statistically significant ($P < 0.05$ or 95% CI not including zero).

density than their fellow students who either competed/participated in other sports or were sedentary (Zhao, 2001). However, genetic differences, age differences, dietary intake patterns, and duration/intensity of training or habitual activity levels may have also contributed to differences in bone mineral density, and future studies will need to include such covariates before definitive conclusions can be drawn about the osteogenic potential of Kung Fu training.

Exercise capacity

As mentioned previously, muscle strength was assessed in two studies (O'Donovan *et al*., 2006; Zhao, 2001), although the results were only reported by one study for martial artists alone (O'Donovan *et al*., 2006). The strength testing methodology was clearly presented in this study, and similar protocols have been widely used in the past (Beunen, Huygens, Peeters, Thomis, & Vlietinck, 2004; Brown, Ellenbecker, McCormick, & Roetert, 1996; Chan, Chan, Li, Maffulli, & Wu, 1996; Grewar, Hill, & McGregor, 2004). However, the actions examined for these tests were not specific to martial arts movements (whether it be Tae Kwon Do or Kung Fu as in this study), where power is generated at much faster speeds, using the whole body, rather than one isolated muscle. Despite the utilization of this non-specific test, martial artists still showed greater isokinetic strength at all speeds tested, compared with sedentary controls, which indicates a more general effect on isotonic muscle strength from martial arts training. On the other hand, no significant differences were seen in isometric strength between groups during knee flexion and extension, perhaps because of the lack of relevance/specificity of the position of the contraction in martial arts. Studies on other aspects of exercise capacity, such as muscle power, muscle endurance, aerobic capacity, balance, and flexibility, are currently not available.

Other adaptations

Martial artists were found to have superior movement speed compared with controls (O'Donovan *et al.*, 2006), perhaps due to similar actions required in sparring. This is a relevant area of function, given its decline with ageing and relevance to falls prevention in the elderly (Lord & Fitzpatrick, 2001), which should be explored in future studies.

The acute stressor response was studied in collegiate athletes of Wu Shu (sanda or forms) and tennis. The use of four variables to estimate stress including two physiological measures (systolic blood pressure and heart rate), one functional measure (hand stability), and a subjective measure (via a questionnaire) seems adequate. Wu Shu athletes had a lower stressor response to mental stress, reflected by lower systolic blood pressure and better hand stability. Similarly, Wu Shu athletes also had a lower response to a physical stressor than tennis players. Resting blood pressure values were not presented, so it is unknown whether both groups had normal resting blood pressure, and the authors alluded to possible differences in fitness between the Wu Shu and tennis groups, as the Wu Shu group consisted of national/international champions, whereas the tennis players were champions at the university level only. It is well known that exercise training attenuates acute physical and mental stressor responses (Blumenthal *et al.*, 1990). Thus, controlling for baseline fitness level prior to analysing acute stress responses in Kung Fu practitioners and comparison groups would have provided a more robust analysis of possible group differences. Therefore, these results, although provocative, cannot be considered definitive. Overall, these results suggest that Kung Fu training may attenuate the acute stressor response relative to another form of aerobic training, but the differences are small and of unknown clinical significance.

Risk of injury

Practitioners competing in a national Wu Shu forms competition in the Netherlands sustained no injuries, with the only injuries recorded being sustained in competitors in the semi- and full-contact Wu Shu sparring events (Blijd *et al.*, 1995). Additionally, the majority of injuries reported were not serious (being contusions) (Blijd *et al.*, 1995). When looking at the isolated cases presented in these studies, the injury rates seem moderate to high (Blijd *et al.*, 1995; Zetaruk *et al.*, 2005), although when comparing injuries sustained during combative sports participation resulting in hospital admission, common sports including basketball, football, and cycling had higher injury rates (National Center for Health Statistics, 2007). The main limitations in these prevalence studies were related to the scope of investigation (for instance, only observing injuries within one competition) (Blijd *et al.*, 1995), volunteer bias (Zetaruk *et al.*, 2005), and small participant numbers, mainly in terms of Kung Fu practitioners (Blijd *et al.*, 1995; Zetaruk *et al.*, 2005). The exact styles of Kung Fu practised by these participants was not specified either.

As injuries sustained during martial arts practice often occur during contact/sparring activities, and in those with greater age and experience (Blijd *et al.*, 1995; Zetaruk *et al.*, 2005), oriental martial arts training may be considered relatively safe for beginners/intermediate students. As in many Kung Fu training programmes, beginners/intermediate students are usually restricted to learning forms and basic techniques and fundamentals, and are not permitted to spar at this stage. If any sparring is permitted for intermediate students, it is usually light contact. However, it should be mentioned that the Kung Fu injury rate data are still limited, with no data on cohorts other than healthy young adults, and no direct comparisons with other sports.

Conclusions

There is no robust information regarding the health benefits or effects of Kung Fu, as no well controlled cross-sectional studies, case-control studies or randomized controlled trials have been published in the English language. A possible major limitation in this review was the inability to review non-English studies. From the currently available English literature, specific Kung Fu techniques are of moderate to high aerobic intensity (depending on the Kung Fu style and student experience), and Kung Fu training may be associated with higher strength and bone mineral density, lower body fat in females, and blunting of the acute stress response to physical and mental stimuli. These potential aspects of Kung Fu are of interest, given the health benefits associated with aerobic and muscular fitness (Brill *et al.*, 1999; Dionne, Ades, & Poehlman, 2003) and higher bone mineral density (Buchner, Beresford, Larson, Lacroix, & Wagner, 1992; Kell, Bell, & Quinney, 2001), and are worthy of further study. Future investigations into this form of martial arts should utilize randomized controlled-trial or case-control designs, with clear descriptions of the cohort, training dose, assessment and training methodology, and Kung Fu style examined, adequate tracking of adverse events, and criterion methods for outcome assessment. Much more data are needed on a range of outcomes including safety, feasibility, long-term adherence, and clinical outcomes associated with this form of training before any recommendations can be made to advocate its use for health promotion and disease prevention in any cohort.

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