

## Clinical Study

# Kung Fu Training Improves Physical Fitness Measures in Overweight/Obese Adolescents: The “Martial Fitness” Study

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Received 21 November 2009; Revised 8 March 2010; Accepted 8 April 2010

Academic Editor: Jonatan R. Ruiz

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**Aim.** To examine the efficacy of a six-month Kung Fu (KF) program on physical fitness in overweight/obese adolescents. **Methods.** Subjects were randomly assigned to the KF or sham exercise (Tai Chi, TC) control group. Physical measurements in cardiovascular fitness and muscle fitness occurred at baseline and after 6 months of training thrice weekly. **Results.** Twenty subjects were recruited. One subject was lost to follow-up, although overall compliance to the training sessions was  $46.7 \pm 27.8\%$ . At follow-up, the cohort improved in absolute upper ( $P = .002$ ) and lower ( $P = .04$ ) body strength, and upper body muscle endurance ( $P = .02$ ), without group differences. KF training resulted in significantly greater improvements in submaximal cardiovascular fitness ( $P = .03$ ), lower body muscle endurance ( $P = .28$ ; significant 95% CI: 0.37–2.49), and upper body muscle velocity ( $P = .03$ ) relative to TC training. **Conclusions.** This short-term KF program improved submaximal cardiovascular fitness, lower body muscle endurance, and muscle velocity, in overweight/obese adolescents with very low baseline fitness.

## 1. Introduction

Apart from being associated with increased risk of cardiovascular disease and type 2 diabetes, people who are obese are also more susceptible to impairments in muscle strength, cardiovascular fitness, and physical performance [1–6]. Impaired physical function and low cardiorespiratory fitness are associated with poorer general health [1], and increased metabolic risk [7, 8], and may lead to pain and discomfort, as well as reduced mobility [9]. In more recent years, the physical function of obese adults has worsened compared to a decade ago [10], which has grave implications for today's youth, in which obesity prevalence is steadily increasing [11]. Even by high school age (mean age: 16 years), relationships between overweight/obese status and increased functional limitation [1] and poorer cardiorespiratory fitness [12] have been established in adolescents. Additionally, there is now evidence to show that poorer muscle strength is linked to higher levels of insulin resistance and metabolic syndrome,

not only in adults [13], but also in adolescents [14], further justifying the need to investigate physical fitness outcomes in the overweight/obese adolescent population.

Aerobic exercise and/or resistance training programs have been shown to improve cardiorespiratory fitness [15–18] and muscle strength [19–22] in overweight/obese adolescents in many controlled trials. It is thus clear that high intensity aerobic or resistance programs are beneficial to physical fitness in overweight and obese youth. However, many of the interventions used in these previous studies may not be easily accessible to adolescents in the general community, as they were either specifically tailored aerobic programs [15–18, 20] and/or required access to exercise equipment (e.g., treadmills, cycle ergometers, and resistance training machines) which often further required familiarisation and instruction with the equipment [18, 20–23]. For an adolescent in search of a form of fitness and strength-enhancing exercise to participate in, they may experience difficulties in finding a gymnasium or class which offers

the same aerobic programs previously proven effective; or if they choose to join a health club for the aerobic exercise machines and/or resistance training machines and equipment, some may not know how to correctly and safely use the equipment, nor how to exercise to improve fitness and strength. Therefore, it is of interest to examine the effects of readily available programs or forms of exercise to see if they benefit cardiorespiratory and muscle fitness, and to then compare the magnitude of the improvements gained to previously successful programs. One exercise form potentially of interest in this regard is martial arts, as there are already numerous martial art schools worldwide.

Martial arts are the third most prevalent nonteam sports in Australian youth (4.9% participation rate), after swimming (16.6%) and tennis (8.6%) [24]. Due to differences in “energy” and technical focus between different martial art styles, Kung Fu (KF), a Chinese form of martial arts, was selected as the focus for this trial.

Observational studies have found that various KF styles have been of moderate-to-high intensities adequate for cardiovascular benefits, ranging from 52.4 to 82.1% of maximal oxygen consumption ( $VO_{2\max}$ ), or 70.5 to 89% of maximum heart rate for whole body techniques [25–27]. More recently, observational studies have compared the muscle strength of KF practitioners to either active (non-martial arts or novice KF students) or sedentary controls, and have reported greater relative isometric and isokinetic leg muscle strength [28], muscle power [29], and velocity [30] in the experienced KF practitioners. Despite this promising information about KF training, no randomised controlled parallel trials have yet been published to our knowledge in any cohort.

Hence, the purpose of this trial was to examine the effects of a six-month KF program on cardiorespiratory and muscle fitness in overweight and obese adolescents, compared to a sham exercise (Tai Chi, TC) control program. We hypothesised that peak and submaximal aerobic capacity, as well as peak muscle strength, velocity, power, and endurance would improve more in the KF group than in the TC group over time.

## 2. Methods

**2.1. Study Design.** The study was a randomised sham-controlled trial. All outcomes were double-blind at baseline and single-blind (participant) at follow-up. Ethics approval was obtained from The Children’s Hospital at Westmead and The University of Sydney, Australia (ACTRN: 012605000716662).

**2.2. Eligibility and Exclusion Criteria.** Included were participants who were in school years 6–12, overweight/obese [31], and sedentary (not partaking in  $>2\text{ h}\cdot\text{wk}^{-1}$  of regular, organised physical activity/sports or exercise excluding compulsory physical education classes) within the last 4 months. Participants had no previous experience with any martial arts within the past year, nor any other commitments that interfered with their participation in all scheduled exercise and testing sessions.

Exclusion criteria included: any cognitive, visual, mobility, or congenital/genetic/growth impairment or disorder; any condition that might be worsened by the exercise or testing procedures; type 1 diabetes; amputation proximal to the fingers and/or toes; or if they had fractured a limb within the past six months. Participants who were participating in other research studies which might affect or be affected by their participation in the current study, as well as those who were pregnant, were also excluded.

**2.3. Recruitment and Screening.** Participants were recruited from The Children’s Hospital at Westmead as well as from the general community via advertisements, referrals, and word-of-mouth. A “Telephone Screening Form” was used by the assessor to initially screen those who were interested, which was developed for the trial based on the inclusion and exclusion criteria. Participants who were deemed potentially eligible after this interview were invited to attend the study clinic for baseline measurements and a physical examination (including maturation assessment using the Tanner method [32, 33]) by the study physician. Informed consent was obtained from participants and their parent/guardian at the first assessment session.

**2.4. Outcome Measures.** Physical fitness measures were assessed on two occasions: at baseline (0 months) and follow-up (6 months). All physical fitness tests were performed within the same day, over a period of approximately 4–6 hours, with rest periods between each physical test. Questionnaires were also completed between physical tests [34]. The order of the physical fitness tests were as follows.

**2.4.1. Cardiovascular Fitness.** Participants underwent a volitional peak stress test, using a modification of the Bar-Or walking protocol [35], in which initial treadmill slope was 6% with increments of 2% each minute until a slope of 22% was attained, after which speed increased  $1\text{ km}\cdot\text{h}^{-1}$  each minute until the participant requested to stop. Initial walking speed was determined by the assessor’s observations of the participant’s gait during a brief (1–2 minutes) familiarisation period on the treadmill, as a speed at which the participant appeared to be walking briskly but comfortably. Expired gases were monitored throughout the test using the Ultima PFX (Medgraphics, St Paul, Minnesota, USA), which was calibrated to known gases immediately prior to the test, and 15sec averaged data analysed using BreezeSuite 6.2A software (Medical Graphics Corporation, St Paul, Minnesota, USA). Heart rate (HR) was monitored at rest/recovery and throughout the test using 12-lead ECG (Quinton 4500, Bothell, WA, USA). The test was terminated according to the recommendations of the American College of Sports Medicine [36], and efforts were considered peak if both a respiratory exchange ratio (RER)  $>1.0$ , and a HR of  $\geq 90.0\%$  of age-predicted maximum HR ( $HR_{\text{peak}}$ ) were reached [15, 37]. The same protocol (including the same starting speed) was used at baseline and follow-up. Variables recorded included: test duration; peak oxygen consumption ( $VO_{2\text{peak}}$ ) relative to body mass and leg lean body mass (LBM); anaerobic threshold (AT) using the V-slope method

[38] (in  $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ); and oxygen uptake efficiency slope (OUES, a unitless measure) [39] relative to body mass.

**2.4.2. Muscle Fitness.** Upper and lower body maximal muscle strength, power, and endurance were assessed on Keiser pneumatic-resistance training equipment (K400 series, Keiser Sports Health, Inc., Fresno, CA, USA), using the bilateral leg and chest press machines. All tests were demonstrated by the assessor beforehand.

**Maximal Muscle Strength.** The 1-repetition maximum (1RM) test was used to determine maximal muscle strength [40] in absolute terms (N), and relative to leg or arm LBM (assessed using dual-energy X-ray absorptiometry (see Tsang et al. for details [41, 42]) for the leg press and chest press respectively. Attempts were made to complete the tests within 10 repetitions to minimise effects of fatigue on test outcomes, and a rest period of at least 1 minute was provided between repetitions. One unloaded practice lift repetition was given, after which the load was progressively increased (based on the assessor's discretion and the participant's rating on the Borg 6–20 rating scale [43]) until the participant could not lift a given load with proper technique and to their unloaded range of motion, after two attempts.

**Peak Muscle Power.** Participants were asked to lift the loads as quickly as they could, “*Like a bullet out of a gun*”. This was repeated at loads of 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% of their most recent 1RM. Each load was lifted once. Peak power (W) and peak velocity ( $\text{cm} \cdot \text{s}^{-1}$ ) was recorded. At follow-up, the relative load at which peak power occurred was performed first, after an unloaded familiarisation repetition, to minimise the effects of fatigue. At least 1min rest was given between each repetition.

**Muscle Endurance.** Muscle endurance was assessed at 80% baseline 1RM (even at follow-up). An initial unloaded assessment of range of motion was performed, before the test load was set and the participant asked to, “*Slowly lift the weight and lower it: 3 seconds up, 3 seconds down. Keep doing this over and over again without stopping, until I ask you to stop*”. The number of repetitions successfully completed was recorded, and the test terminated if the participant paused for  $\geq 1$  seconds, or could no longer perform the repetitions with good posture/technique. In addition to the number of successful repetitions performed, the fatigue ratios for the upper and lower body were recorded as the work performed in the last repetition divided by the work performed in the first repetition (Joules).

## 2.5. Covariates

**2.5.1. Habitual Physical Activity.** The sixty-minute screening measure for moderate to vigorous physical activity: PACE+ (Patient-centered assessment and counseling for exercise) [44], was used to estimate habitual physical activity at baseline and at follow-up in all participants. This questionnaire enquired about the frequency and duration of any moderate

to vigorous physical activity habits (MVPA) over the previous seven days, and has been validated against accelerometer data [44].

**2.5.2. Adverse Events.** Throughout the six-month training period, participants were asked to complete a weekly questionnaire about any illnesses, injuries, or new symptoms they may have experienced during the previous week, any changes in their medications, visits to health care professionals, and reasons for any missed exercise sessions. These questionnaires were completed during the exercise session or via interview over the phone if a participant did not attend the sessions during a given week. These questionnaires were also used to capture adverse events and changes in health status, related or unrelated to study participation. Possible adverse events defined *a priori* included new physical or mental symptoms of any kind, and any injuries sustained during or outside of the training sessions.

**2.6. Randomisation.** Randomisation to either the KF or TC (sham exercise control) group was performed after completing all baseline assessments. Randomisation was performed by a researcher who had no contact with any of the participants, using a computer randomisation program, available at: <http://www.randomization.com/> [45]. Participants were stratified by gender and body mass index (BMI) category (overweight versus obese).

**2.7. Training Interventions.** Both groups were offered three one-hour sessions each week of either TC (Yang style 24-forms) or KF (Choy Lee Fut Hung Sing Gwoon basic techniques and forms) training, over a period of six months. There was one instructor per class, and TC and KF classes were held at the same time, in different rooms within the hospital to avoid contamination. All TC and KF sessions began with warm-up exercises specific to the martial art, and a short (1-2 minutes) drink break was provided in the middle of each session. All instructors were told to refrain from providing any lifestyle, behavioural, or dietary advice, and to also avoid encouraging (or even mentioning) home practice. Attendance was recorded by the instructors at each session.

After warm-up exercises, the KF sessions generally included stance and footwork exercises, punching and kicking techniques and combinations with and without contact (on focus pads or kicking shields), and forms practice. The TC sessions involved gentle practice of the Yang style 24-forms, with quiet and relaxing Chinese-style music playing in the background. As detailed elsewhere [46], TC was utilized as a sham exercise because previous studies have shown that TC has no effect on the primary outcomes of this trial. The use of a sham exercise control group was also preferable to a nonexercising control group in order to control for the amount of contact both groups received as well as any effects of learning a new physical skill. Blinding of participants could also be achieved with the use of a sham exercise group. Both KF and TC programs were progressive in nature, where further techniques were taught as the participants demonstrated proficiency with their training.

Previous studies have reported that the intensity of TC was low, while KF ranged from moderate to high intensity [47], which further supported our choice of TC as a sham exercise.

**2.8. Statistical Analysis.** Statistical analyses were performed using Statview, version 5.0 (SAS Institute, Cary, NC). All data were visually and statistically inspected for normality of distribution (skewness  $> -1$  or  $< 1$ ). Non-normally-distributed data were log-transformed, or if necessary, transformed using  $1/x$ . All values were reported as mean  $\pm$  SD; non-normally-distributed data reported as median (range). Baseline comparisons (mean differences, confidence intervals (95% CI),  $t$  tests, and chi square tests) and changes over time between groups were compared using repeated measures analysis of variance (ANOVA) for continuous variables. All analysis of covariance (ANCOVA) models for change scores by group assignment included the baseline scores for that variable and attendance. Change scores and SD at six months were used to calculate weighted mean differences, 95% CIs, and Hedge's bias corrected and relative effect sizes (ES) [48] for each group. A  $P$  value of  $< .05$  and 95% CI excluding 0 were accepted as statistically significant. Robustness of effects was assessed by calculating ES [49] and clinical meaningfulness (by comparing changes to the literature) of any changes observed. Relationships between changes in variables were determined using simple linear regression models. An all available data design was selected rather than an intention-to-treat design, due to the novelty of this efficacy trial. Thus, the results reflect the effects of the treatments on participants regardless of compliance with the exercises sessions, in those in whom follow-up data was obtained. Missing follow-up data were not imputed.

### 3. Results

**3.1. Participant Characteristics.** Recruitment occurred between March 2006 to May 2007, and 150 adolescents screened. Among the 20 participants recruited, 12 were randomised to the KF group, and eight to the sham exercise group. Participants were aged  $13.1 \pm 2.1$  years on average, and 12/20 (60%) were female. Eighty percent of the participants were classified obese for their gender and age [31], with an average BMI of  $32.9 \pm 6.7 \text{ kg}\cdot\text{m}^{-2}$ , and one-half of participants were at Tanner stage 5 for maturation.

At baseline, TC participants had a higher number of physically active friends than KF participants (KF:  $2.8 \pm 1.4$ ; TC:  $4.1 \pm 1.0$ ;  $P = .02$ ). There were no other baseline differences between the groups.

**3.2. Attendance and Compliance.** Nineteen of the twenty (95%) participants returned for follow-up assessments. One KF participant could not participate in follow-up testing as she had medical complications with her Crohn's disease and was due to have surgery at that time.

Out of 72 offered classes, participants attended  $36.1 \pm 14.8$  ( $50.1 \pm 20.6\%$ ) and  $29.9 \pm 26.7$  ( $41.5 \pm 37.1\%$ ) sessions in the KF and TC groups respectively ( $P = .51$ ). Further

details on attendance and compliance have been reported elsewhere [41].

**3.3. Adverse Events.** Most adverse events reported by participants were not related to study participation (99%). There were no significant differences between groups in adverse events, whether they were related to study participation (KF: 0 (0–2) versus TC: 0 (0–0);  $P = .30$ ), or not (KF:  $13.9 \pm 9.6$  versus TC:  $7.1 \pm 4.2$ ;  $P = .08$ ).

The study-related adverse events occurred to two KF participants only, where both participants fell (on separate occasions) during the jogging/star-jump-type exercise warm-up. One of these two same participants also reported knee pain during kicking practice. No other participants experienced any adverse event related to their study participation.

### 3.4. Outcomes

**3.4.1. Cardiovascular Fitness.** At both baseline (KF: 3; TC: 4) and follow-up (KF: 2; TC: 5), seven participants did not reach peak efforts during the treadmill test with  $\text{HR}_{\text{peak}} < 90\%$  of age-predicted maximum and/or with  $\text{RER} < 1.0$  [15, 37]. At baseline, all tests were terminated with an  $\text{RER} > 1.0$ ; while at follow-up, the peak  $\text{RER}$  of two TC participants was  $< 1.0$  ( $\text{RER}_{\text{peak}}$ : 0.95 and 0.98). The average percent  $\text{HR}_{\text{peak}}$  reached at baseline and follow-up was similar (baseline:  $92.5 \pm 6.7\%$ ; follow-up:  $92.4 \pm 5.6\%$ ). The range of  $\text{HR}_{\text{peak}}$  reached in those who did not reach 90.0%  $\text{HR}_{\text{peak}}$  was 80.5–88.8% at baseline, and 84.5–89.7% at follow-up.

**Peak Cardiovascular Fitness ( $\text{VO}_{2\text{peak}}$ ).** After six months, there were no significant changes over time or group effects on  $\text{VO}_{2\text{peak}}$  (Table 1).

Regression models showed that improvements in peak fitness were strongly related to improved OUES ( $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ;  $r = 0.81$ ,  $P < .0001$ ;  $\text{mL}\cdot\text{legLBM}^{-1}\cdot\text{min}^{-1}$ ;  $r = 0.78$ ,  $P < .0001$ ), and AT, both representative of better submaximal exercise performance/capacity ( $\text{mL}\cdot\text{legLBM}^{-1}\cdot\text{min}^{-1}$ ;  $r = 0.51$ ,  $P = .03$ ). Changes in peak fitness were not related to attendance ( $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ;  $r = -0.08$ ,  $P = .74$ ;  $\text{mL}\cdot\text{legLBM}^{-1}\cdot\text{min}^{-1}$ ;  $r = 0.04$ ,  $P = .99$ ) or changes in habitual physical activity level ( $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ;  $r = 0.08$ ,  $P = .74$ ;  $\text{mL}\cdot\text{legLBM}^{-1}\cdot\text{min}^{-1}$ ;  $r = -0.02$ ,  $P = .93$ ).

**Submaximal Cardiovascular Fitness (AT and OUES).** Estimation of AT via the V-slope method was possible in all but one (KF) participant at baseline. There were no significant group or time effects on AT in unadjusted models (Table 1), but after ANCOVA adjustment for baseline value and attendance, the improvement in AT from KF training was significantly greater than from TC (KF:  $+0.71 \pm 2.32$  versus TC:  $-0.91 \pm 2.29 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ,  $P = .03$ ; Figure 1). However, OUES, the other submaximal cardiovascular fitness measure, did not change over time or differentially between groups after six months (Table 1).



TABLE 1: Outcomes, physical function/capacity.

Characteristic	KF Group		Sham exercise control group		Mean difference (95% CI)	ES P	Time effect P	Group × time interaction
	Baseline n = 12	Follow-up n = 11	Baseline n = 8	Follow-up n = 8				
<i>Cardiovascular fitness:</i>								
Exercise test duration (min)	7.5 ± 2.5	8.5 ± 1.6	6.8 ± 1.8	7.4 ± 2.7	0.52 (-1.67–2.71)	0.22	.13	.73
VO <sub>2peak</sub> (mL·kg <sup>-1</sup> ·min <sup>-1</sup> )	23.9 ± 5.2	23.8 ± 3.0	19.2 ± 7.3	20.0 ± 6.9	-0.92 (-6.88–5.04)	-0.14	.93	.43
VO <sub>2peak</sub> (mL·legLBM <sup>-1</sup> ·min <sup>-1</sup> )	126.2 ± 25.3	127.6 ± 14.1	120.1 ± 23.9	126.5 ± 22.6	-4.89 (-1.10–0.72)	-0.19	.59	.60
AT (mL·kg <sup>-1</sup> ·min <sup>-1</sup> )	12.21 ± 2.23	12.93 ± 1.47	11.19 ± 3.79	10.28 ± 3.23	1.63 (-1.25–4.51)	0.55	.86	.12
OUES	24.63 ± 5.49	24.26 ± 4.89	23.79 ± 5.76	23.95 ± 5.80	-0.30 (-5.79–5.19)	-0.05	.80	.72
<i>Muscle fitness:</i>								
Absolute lower 1RM (N)	567.0 (356.0–976.0)	576.0 (340.0–1059.0)	464.5 (359.0–606.0)	534.0 (373.0–804.0)	-71.89 (-226.47–82.69)	-0.44	.04*	.18
Lower 1RM (N·LegLBM <sup>-1</sup> )	0.04 ± 0.01	0.04 ± 0.01	0.03 ± 0.01	0.04 ± 0.01	-0.01 (-0.01–0.00)	-0.64	.28	.18
Absolute upper 1RM (N)	164.5 ± 26.4	178.4 ± 32.1	141.8 ± 25.2	156.5 ± 28.5	-0.89 (-26.32–24.55)	-0.03	.002*	.93
Upper 1RM (N·ArmLBM <sup>-1</sup> )	0.034 ± 0.005	0.034 ± 0.006	0.029 ± 0.006	0.030 ± 0.005	0.0 (-0.01–0.00)	-0.18	.59	.31
Lower peak power (W)	337.8 (201.0–393.5)	288.0 (192.5–517.0)	282.0 (182.0–603.5)	316.0 (195.0–450.0)	6.77 (-87.34–100.88)	-0.06	.78	.95
Upper peak power (W)	101.5 ± 27.4	112.4 ± 29.6	92.9 ± 24.1	92.9 ± 31.8	10.76 (-14.88–36.40)	0.39	.31	.32
Lower peak velocity (cm·s <sup>-1</sup> )	91.6 ± 16.9	97.3 ± 16.3	103.8 ± 21.6	91.6 ± 20.2	17.82 (-0.67–36.30)	0.90	.49	.06
Upper peak velocity (cm·s <sup>-1</sup> )	129.0 ± 26.2	139.8 ± 20.3	130.9 ± 20.8	121.8 ± 26.9	19.94 (-3.82–43.71)	0.79	.83	.03*
Lower endurance (reps)	10.2 ± 4.8	14.5 ± 12.6	16.0 ± 8.9	20.3 ± 6.6	0.04 (-6.50–6.58)	0.01	.07	1.0
Upper endurance (reps)	5.0 ± 2.5	7.4 ± 3.0	5.9 ± 1.9	7.5 ± 2.3	0.74 (-1.51–2.99)	0.31	.02*	.68
Lower fatigue ratio	1.5 ± 1.3	3.0 ± 6.2	0.9 ± 0.2	0.9 ± 0.04	1.43 (0.37–2.49)*	1.29	.48	.28
Upper fatigue ratio	1.1 ± 0.4	0.9 ± 0.2	1.0 ± 0.2	1.0 ± 0.09	-0.30 (-0.64–0.04)	-0.84	.44	.49

Values are mean ± SD, or median (range) for non-normally distributed data. P values were generated between treatment groups from independent *t*-tests for continuous data, and chi square tests for categorical data. Mean difference was calculated by subtracting the change in TC from the change in KF.

KF: Kung Fu; ES: effect size; 95% CI: 95% confidence interval; VO<sub>2peak</sub>: peak oxygen consumption; AT: anaerobic threshold; OUES: oxygen uptake efficiency slope, expressed relative to body mass; lower: lower body; upper: upper body; 1RM: 1 repetition maximum; \*P value < .05 or 95% CI excluding zero denotes statistical significance.

Increased (improved) AT was associated with fewer new symptoms ( $r = -0.49$ ;  $P = .04$ ).

### 3.4.2. Muscle Fitness

**Muscle Strength.** Absolute upper (+14.3 ± 16.6 N;  $P = .002$ ) and lower body strength (+51(-242–324) N;  $P = .04$ ) improved after six months, with no differences between groups (Table 1). There were no significant changes over time or group effects for relative upper or lower body strength (Table 1).

A significant relationship was observed between increased upper body strength (N) and increased arm

lean mass (the significant increase in arm lean mass observed in this trial has been reported elsewhere [41];  $r = 0.46$ ;  $P < .05$ ). However, increased lower body strength was not related to increased leg lean mass ( $r = 0.19$ ;  $P = .44$ ).

**Peak Muscle Power.** Upper and lower body muscle power did not change over time or between groups after six months (Table 1).

**Peak Muscle Velocity.** Upper body peak muscle velocity improved in the KF group, but declined in the TC group after six months (KF: +10.9 ± 20.1 cm·s<sup>-1</sup>; TC: -9.1 ±

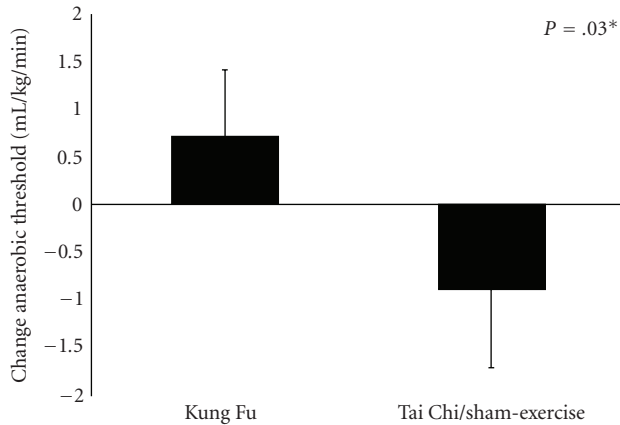


FIGURE 1: Graph of change in anaerobic threshold ( $\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ) after 6 months of Kung Fu or Tai Chi/sham exercise control training (ANCOVA model of change score adjusted for baseline value of anaerobic threshold and attendance rate), with standard error bars.

$13.1\text{ cm}\cdot\text{s}^{-1}$ ;  $P = .03$ ; Table 1). This group effect increased slightly in significance after adjusting for attendance in ANCOVA models, further supporting its relationship to the actual intervention ( $P = .04$ ).

Similarly, the improvement in lower body peak velocity (group effect) seen in the KF group was borderline significant when compared to the decline in the TC group (KF:  $+5.9 \pm 13.5\text{ cm}\cdot\text{s}^{-1}$ ; TC:  $-12.1 \pm 24.7\text{ cm}\cdot\text{s}^{-1}$ ;  $P = .056$ ). However, this group effect was attenuated slightly after ANCOVA adjustment for attendance ( $P = .13$ ).

**Muscle Endurance.** Upper body muscle endurance improved significantly over time ( $+2.0 \pm 3.2$  reps;  $P = .02$ ) after six months, although no group differences were observed (Table 1), even after ANCOVA adjustment for attendance ( $P = .94$ ). Similarly, the improvement over time seen in lower body muscle endurance tended towards significance ( $+4.3 \pm 9.2$  reps;  $P = .07$ ), again without significant group differences either before ( $P = 1.00$ ) or after adjustment for attendance ( $P = .60$ ). Fatigue ratios did not change over time (Table 1). Although there was no significant group effect, the 95% CI of the mean difference between groups for lower body fatigue ratio excluded zero (Table 1), and the ES large (1.29), indicating a greater increase from KF training, despite a nonsignificant  $p$  value for the group  $\times$  time interaction in this small study ( $P = .28$ ). The  $P$  value for the lower body fatigue ratio group effect remained nonsignificant after ANCOVA adjustment for attendance (KF:  $+1.66 \pm 6.38$  versus TC:  $-0.01 \pm 0.23$ ;  $P = .42$ ).

**3.4.3. Habitual Physical Activity.** Self-reported moderate-to-vigorous physical activity participation did not change over time ( $P = .40$ ) or between groups ( $P = .63$ ; ES:  $-0.20$ ), according to MVPA scores.

## 4. Discussion

This is the first randomised, sham-controlled trial of KF to our knowledge in any cohort published in the English language. Kung Fu training significantly improved muscle velocity and submaximal cardiovascular fitness (anaerobic threshold), more than sham exercise; while muscle strength and endurance improved significantly over time in both groups, a likely consequence of increases in LBM over six months and/or repeat testing in these overweight/obese sedentary adolescents. By contrast, peak cardiovascular fitness and muscle power did not change significantly over time in either group. These physical benefits gained from participation in our six-month KF program show that this is a form of exercise worthwhile investigating further for the sedentary, overweight/obese adolescent population.

The significant improvement to submaximal cardiovascular fitness from KF training (5.8%) was within the range of submaximal cardiovascular fitness improvements seen from other short-term, although specifically-aerobic interventions (3.2% to 8.8%) [15–17]. This is notable, as the KF lessons were not continuous (interrupted by corrections of technique), and did not focus on specifically maximising energy expenditure, or improving fitness or body composition. Rather, the KF sessions were more focused on teaching and training martial art techniques. The repeated and continuous performance of various KF techniques of other, similar KF styles has been demonstrated as being of moderate-to-high intensity [25, 47], although as eluded to above, we did not attempt to maintain a particular intensity or HR during the sessions as done in previous aerobic exercise trials [15, 16, 50]. Hence, the improvement to submaximal cardiovascular fitness achieved from such a program, which is comparable to that achieved from much more aerobically-focused and intensive interventions, is worth investigating further.

Difficulties in obtaining true peak efforts in overweight cohorts have been documented [51], so our submaximal (AT) data are likely to be more indicative of our group's cardiorespiratory fitness than the  $\text{VO}_{2\text{peak}}$  data. As noted above, 7/20 participants did not meet criteria for peak cardiorespiratory fitness testing at both time points. Another advantage of utilising a submaximal parameter is that it is more reflective of activities done in daily living, as opposed to maximal, exhaustive values [52, 53]. In this case, by improving submaximal fitness, our KF participants should theoretically be able to undertake their usual activities of daily living with more ease, which will permit these participants to increase their physical activity habits without becoming exhausted or discouraged as readily as before. This hypothesis should also be tested in future trials.

Participation in this martial arts trial improved muscle strength and endurance, regardless of TC or KF allocation (although KF also appeared to improve lower body fatigue ratio). The 9.5% average increase in muscle strength from TC and KF participation in our trial was greater than strength gains after an aerobic intervention (6.7% [19]), but lower than the 15.1% to 96.1% gains from resistance training programs and circuit programs incorporating resistance training [20–23]. The gain we observed was greater than that

expected due to growth at this age (2.8% [54]), although a nonexercise control group would have more definitively shown that the gains in muscle function were not simply related to accretion of lean tissue in adolescence.

The gain in upper body strength appeared to be a result of the increased arm lean mass (which may be related to adolescent growth in this cohort), while learning due to repeat testing may have been the mechanism underlying the lower body strength gains, since increased leg lean mass was not related to the strength gains of the lower body. It is likely that other factors were more important in the improved muscle strength and endurance, such as familiarisation or neural adaptation and motor learning adaptations with the leg press procedure [55, 56], since we did not have familiarisation sessions for our assessments.

It is not clear whether exercise training or other factors were responsible for the change in upper body strength. It cannot be objectively explained why the nonimpact TC sessions improved upper body strength to a similar extent as the purportedly higher intensity, light-to-medium contact (on focus mitts) KF sessions, particularly since performing strikes with impact have been shown to elicit greater activity from the triceps brachii, and brachioradialis than without impact [57]. It is possible however, that KF participants only struck the focus mitts lightly in fear of injury to their hands, and hence the difference in muscle activity between striking with and without impact was not large. Another explanation is that the isometric contractions of the arm and trunk muscles required by the TC sessions could have contributed to better performance on the chest press machine used for upper body testing, which involves pectoral, shoulder, and upper arm musculature. Isometric contractions have been shown to result in significant gains in dynamic muscle strength in other studies [58], although dynamic exercises are generally preferred as a training technique for this outcome. Finally, a less likely explanation is that the TC participants adopted more physical activity involving the upper body outside of their TC sessions during the six-month trial, despite no changes in MVPA. However, reliability of self-reported habitual physical activity is problematic [59], and therefore this etiology cannot be confidently assessed.

Our KF program improved muscle velocity and had a large effect size on lower body endurance (fatigue ratio), relative to sham/TC exercise, while both the TC and KF programs improved upper body muscle endurance (repetitions completed) in our cohort. In contrast to muscle strength, muscle velocity, power, and endurance have been rarely if ever assessed as outcomes in weight-reduction trials, despite their links to physical function [60, 61], which is impaired in obese individuals [62]. Age-related declines in muscle power have been increasingly noted in older adults, with declines beginning in midlife, and power changes are generally larger, and even more functionally relevant, than strength changes [63, 64]. Slower contraction velocity has previously been linked to poorer balance and gait impairment in older adults [60], and lower muscle endurance to poorer mobility [65]. It is not known if these functions were improved in our cohort who were too young and healthy to have obvious deficits in these domains. Further investigations into the benefits of this form

of training to other physical functions (e.g., gait and balance [9]) would be of great interest in this cohort as they mature, as impaired physical function may emerge over time [9, 62].

The main limitations of our trial were the small sample size, poor attendance rates [41], lack of exercise intensity measures, and the absence of a nonexercising control group. The utilization of a sham exercise control group aimed to control for any effects of learning a new physical skill in a group situation, and regular contact with the instructors/researchers and other study participants, as well as to successfully blind the participants—features which would have been difficult to achieve with a nonexercising control group. However, it is possible that the TC program used did in fact elicit some of the improvements observed in this study, despite our observations in previous investigations of TC [66, 67]; hence an additional nonexercising control group would have helped to clarify the actual effects of the exercises. A more minor limitation is that the martial art sessions were conducted in a hospital setting, rather than in a more realistic martial art school setting, which may have affected attendance rates and also our results, if the proper setting were to have a greater effect on motivation for the participants to push themselves during sessions for example. Regardless, our KF intervention resulted in improvements to unique and clinically relevant components of muscle fitness (velocity and endurance) as well as submaximal cardiorespiratory fitness. Notably, previous trials of a single exercise modality which also measured both cardiorespiratory fitness and muscle fitness have generally found only improvements to one outcome but not both [19, 21]. Thus, if our results are confirmed in larger, long-term trials, this single exercise modality may have cross-training effects in musculoskeletal and cardiovascular domains. Given the increasing evidence that both musculoskeletal [14, 68, 69] and cardiovascular [14, 70–72] fitness are related to metabolic and cardiovascular health and mortality, time-efficient, feasible single interventions that dually target these domains early in life are critical for health promotion and disease prevention.

As this study was performed in a hospital setting examining overweight and obese adolescents from the general community, future studies on this topic should consider conducting the sessions within established martial art classes/schools, and assessing physical function measures such as gait and mobility, and difficulty in participation in social, recreational, and work-related activities related to fitness levels in this overweight/obese cohort. In conclusion, this novel randomised, sham exercise controlled clinical trial of martial arts found that KF training improved muscle velocity, lower body muscle endurance, and submaximal cardiorespiratory fitness in overweight/obese adolescents with poor initial fitness, compared to our sham exercise control (TC).

## Acknowledgments

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