Design and assessment of a school-based circuit training programme for the promotion of physical activity, fitness and movement competency

A report for Sport and Recreation New Zealand

by

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EXECUTIVE SUMMARY

Physical inactivity in NZ children is a major growing public health concern. Recent information from the Ministry of Health (2003) has shown almost a third (31%) of 5-14 year olds were overweight or obese, with particularly high prevalence in Pacific Island (61%) and Maori populations (41%). Consequently, they have also highlighted that finding ways of increasing physical activity is an urgent public heath requirement. Circuit training (CT) is a type of exercise which involves various types of exercises, with and without equipment, designed to improve both cardiovascular fitness and muscular strength endurance, as well as improving balance, coordination and movement competency. Circuit training may be a fun, cost and time effective method of exercising and can be administered to large groups of children at the same time. As well as physical benefits, CT may also enhance motor control and fundamental movement abilities if designed appropriately. Thus, the aim of the present study was to determine the effect of a school-based, CT programme on the health, fitness, physical activity levels, and movement competency in young children.

A randomised control trial involving a total of 35 children (17 boys and 18 girls) with a mean age of 9.9 ± 0.7 years was completed. The intervention group was comprised of 10 girls, and 7 boys; while the control group included 9 girls and 8 boys. A range of anthropometric, fitness, and metabolic assessments were determined at baseline prior to commencing the training intervention. The children attended 3 x 30-40 min supervised CT sessions per week, for seven weeks, during school time. The CT programme was specifically designed to provide variation and stimulation in order to maximally engage children and to ensure adherence and enjoyment, whilst aiming to promote positive changes in health, fitness and movement competency.

The groups were matched in terms of physical and movement abilities pre-intervention. For anthropometric measures, the CT programme resulted in no pre-post changes in any group. Significant improvements in strength, power and aerobic fitness existed in the intervention group, but differences were not greater than the control group. Significant improvements were observed for movement competency after CT, and these improvements were significantly greater than those of the control group.

In conclusion, a school-based CT programme had beneficial effects on a range of fitness measures. However, in the short term, it offered limited additional physical benefit over those activities typically gained from standard school physical activity for normal-weight children. The long term benefits of CT as a health promoting tool for prevention of undesirable weight-gain are unknown. The substantial improvement of movement abilities of children after CT was a positive finding. These movement skills will likely be transferred to other aspects of their lives, ensuring good general posture, and effective movement in a variety of physical activities, sports and game play. For these reasons, and given its low cost and suitability for large groups, CT may be a useful exercise method to adopt in schools.

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Introduction

There is a worldwide problem of obesity, with 250 million people (7% of the population) classed as obese and the prevalence of obesity is continually increasing. The World Health Organization estimates 1.9 million deaths a year worldwide are due to chronic diseases caused by physical inactivity and a sedentary lifestyle (Dobbins, De Corby, Robeson, Husson, & Tirilis, 2009).

Physical inactivity in NZ children is a major growing public health concern. Recent information from the Ministry of Health (2003) has shown that almost a third (31%) of 5-14 year olds were overweight or obese, with particularly high prevalence in Pacific Island (61%) and Maori populations (41%). Similarly, over the last 15 years the prevalence of childhood obesity has increased by 50% in the USA (Westcott, Tolken, & Wessner, 1995). Obesity is mostly caused by a decrease in energy expenditure, rather than an increase in caloric intake (Seidell, 1999). For example, in a study of schools in the US, Powell et al. (2009) reported that over half of adolescents didn’t meet aerobic fitness standards, which led to further health-related physical fitness problems.

An obvious way to prevent obesity is by increasing physical activity levels of children and adolescents. Flores, (1995) emphasised the importance of a physical activity programme for children and adolescents, due to the onset of cardiovascular disease starting at a young age. Physical inactivity can lead to many negative diseases (cardiovascular disease, obesity, diabetes) which a physical activity programme could prevent. In addition, physical activity has been linked to improving psychological conditions, for example limiting emotional distress and enhancing self-esteem in adolescents (Bonhauser et al., 2005). Therefore, effective management of inactive, unfit and overweight children with physical interventions is clearly worthwhile.

Various physical training interventions have been used to enhance the health of children. Many of the interventions have been aimed at obesity and inactive children with a focus on improving overall lifestyle, nutrition as well as addressing physical inactivity. A study by Sung et *al.,* (2002) showed that a 6-week strength training and dietary intervention for obese children led to a 2.3% increase in fat free mass and a decrease in HDL:LDL cholesterol ratio. Chiodera, et *al.,* (2007) showed specifically designed and structured physical education (three lessons a week for an 8 month period), helped improve coordinative abilities but not conditional abilities. Resistance training can be effective at lowering BMI, body fat and weight (Sothern et al., 2000).

Jamner, Spruijt-Metz, Bassin and Cooper (2004) reported that a school-based intervention in which students participating in a special physical activity class increased cardiovascular fitness. They also found an increase in the level of physical activity for sedentary adolescent girls. Carrel et *al*. (2005) found significant loss of body fat, increase in cardiovascular fitness and improvement in fasting insulin levels through a life-style focused, fitness orientated gym class intervention in school, compared with students who participated in the school curriculum gym classes. There is some evidence to suggest that physical programmes to prevent obesity are effective when delivered through the school setting. Comparing a number of school-based physical activity interventions, Dobbins et *al*., (2009), have shown that the majority have a positive effect on VO_{2max}, blood cholesterol, duration of physical activity and television viewing duration but also that school-based intervention had no harmful effects so they were highly recommended. The school setting could be more beneficial than the home environment as parental obesity increases the risk of children being obese in adulthood, independent of current body size, (Whitaker, Wright, Pepe, Seidel, & Dietz, 1997). Lifestyle patterns and habits are established early on in life usually during childhood (Westcott et al., 1995).

Circuit training (CT) is a type of exercise which involves exercises designed to improve both cardiovascular fitness and muscular strength endurance. Circuit training may be a fun, cost, and time effective way, and able to be administered to large groups of children at the same time, whilst still being effective. There is some evidence to suggest that school-based CT leads to positive changes in body composition (Westcott et al., 1995). As well as physical benefits, CT may also enhance motor control and fundamental movement abilities if designed appropriately. Development of such abilities at a young age may be beneficial in the long term. However, no study has assessed the effects of CT on both physical fitness and movement abilities in a school-based programme.

Aim of Study

The aim of the present study was to determine the effect of a school-based, circuit training programme on the health, fitness and movement competency of young New Zealand children.

Methodology

Experimental Design

The study was a randomised controlled trial designed to assess the effect of a 7-week circuit training programme in young children. All year 5 and 6 students at a local school (n=120) were invited to participate and 35 volunteered. A range of anthropometric, fitness and metabolic variables were determined at baseline prior to commencing the training intervention. At the conclusion of the intervention the same measures were assessed.

Subjects

A total of 35 children (17 boys and 18 girls) with a mean age of 9.9 ± 0.7 years volunteered for the study. The intervention group was comprised of 10 girls, and 7 boys; while the control group included 9 girls and 8 boys. Participant characteristics are presented in Table 1. Prior to participating in any assessment or training, the subjects and their parents were given detailed information about the study and subsequently provided informed consent regarding their child's participation. Each child also provided assent to participate. The study was approved by Auckland University of Technology Ethics Committee.

Procedures

Anthropometry

Body mass was measured using an electric scale (Seca 770 scales) to the nearest 0.1kg, and height by a stadiometer to the nearest 0.5cm, with the children dressed in light clothes but no shoes. Waist and hip circumferences were measured with a tape measure to the nearest 0.5cm. Body composition was measured using a single frequency (50Hz) hand to foot bioelectrical impendence device (ImpDF50 (Impedimed, Brisbane, Australia) according to the method of Rush et al. (2003). The bioimpedance measurement required careful placement of four electrodes on the hand and foot. The bioimpedance meter was attached to the limbs via leads to the electrodes and a small 500-800 micro-amp; 50 kilohertz signal measured the body's ability to conduct the current. The more lean tissue present in the body the greater the conductive potential, measured in ohms. Body fat percentage was estimated using the formula of Rush et al. (2003).

Resting Metabolic Rate

After an overnight fast, resting metabolic rate (RMR) was determined. Participants were positioned comfortably in the supine position in a quiet area for 20 minutes during which a gas analysis (Metamax 3b, Cortex, Leipzig, Germany) was used to measure oxygen uptake and carbon dioxide production on a breath-by-breath basis. The mean in the final 5 minutes was used for analysis.

Strength and Power

Muscle strength was assessed using standard upper and lower limb 1RM tests (seated chest press, and horizontal leg press) following standard protocols (Earle & Baechle, 2004). A five repetition warm-up was conducted using a light weight and then the weight was increased until they were no longer able to lift the load safely. The subject's score was recorded as the most amount of weight they were able to lift for a single repetition with correct form. Leg power was measured through assessment of maximal jump height using a Yardstick (Swift Performance, Australia) jump meter. In this jump-and-reach test, the jump height was determined by subtracting standing reach height from jumping reach height. The test was performed from countermovement with the arm swing as suggested by the original protocol (Markovic, Dizdar, Jukic, & Cardinale, 2004). The greatest height of two attempts was recorded as the score.

Aerobic Fitness

Aerobic fitness was assessed using the incremental whole-body shuttle test (Ramsbottom, Brewer, & Williams, 1988). The test required the participants to run for as long as possible between two lines set 20 m apart. The pace required was set to gradually increase and conveyed by audible beeps at appropriate intervals. Velocity was set at 8 km/hr for the first minute, and increased by 0.5km/hr every minute thereafter. The children were instructed to complete as many stages as possible. They ran in groups of two or three and were always supervised and actively encouraged by an instructor regardless of which group they belonged. The test was stopped when a subject was unable to follow the pace. The maximal running velocity attained during the test was adjusted in terms of the length of time the final stage was maintained using the equation of Leger et al (1982): VO_{2max} = 31.025 + (3.238 x V) - (3.248 x A) + (0.1536 x A x V) where VO_{2max} is expressed in ml; V is the maximal velocity in km attained in the last stage; and A is the age expressed in years.

Movement Competency

To assess 'movement competency' participants were filmed (Sony Handycam DCR-HC96E) whilst they performed four specific movements: bodyweight squats, forward lunge with a twist, push-ups and single-leg squats. Standing posture was initially assessed by asking the children to stand still facing the camera for a few seconds. The required movement was then demonstrated once with very little instruction, so as to not influence natural technique. Three repetitions of each movement were completed at each of two camera angles; facing forward and side-on. During analysis each movement was scored out of a total score of 10, based on pre-determined postural and movement criteria. The total score recorded was the sum of the scores for standing posture and the four movements.

Daily Physical Activity (diaries and pedometers)

The mean daily physical activity levels of participants before and after the intervention were determined using pedometers (Yamax, Japan) in accordance with recommended procedures (Rowe, Mahar, Raedeke, & Lore, 2004). Briefly, each child wore the pedometer for at least three weekdays, and two weekend days. Participants were requested to wear the pedometer at all times throughout the day except when involved in contact sports (e.g. rugby, karate) or when swimming or bathing. Physical activity diaries were also maintained to determine each participant's physical activity to and from school, during school and after school. The diaries were developed specifically for children, containing examples of types of physical activity in the three sections, and written in easily understood language.

Dietary Intake

Nutritional (food and fluid) intake was evaluated using dietary logs, which were developed specifically for use with children. A typical day was included in the diary as an example, and each child, and their parent, was given verbal and written instructions on how to record what they had eaten with reference to types and quantities of food.

Intervention

The children attended three 30-40 min supervised CT sessions during school time. The weekly CT programme was specifically designed to provide variation and stimulation in order to maximally engage children and to ensure adherence and enjoyment, whilst achieving positive changes in health and fitness outcome measures. Each CT session was preceded by a dynamic warm-up; and concluded with a cool-down and stretch period. Specifically, CT sessions consisted of total body workouts using a combination of different exercises, supervised by a qualified fitness instructor. The two instructors who conducted the session, ensured posture and technique were correct and motivated the children with enthusiasm and excitement. Body weight exercises and power exercises were incorporated into the programme. Variation of exercises also included jumping, agility and core work. The aim was to use exercises that required minimal equipment, were fun and enjoyable but effective. Equipment used included strength and power bags (as opposed to barbells), medicine balls, jump spots, skipping ropes, and ladders; as well as popular music recorded to signify time spent at each station. Pictures of the respective exercise were placed at each station to show the required movement. These were appropriate as they depicted children correctly performing the exercise. The programme consisted of varying training loads within each week of training (i.e. undulating variation) as well as increasing intensity with concomitant decreasing volume over the duration of the study. This type of programme has been previously shown to be effective for improving body composition in normal weight boys (Volek et al., 2003) and overweight boys and girls (McGuigan, Tatasciore, Newton, & Pettigrew, 2009). For an outline of the programme design, see Table 1. The circuit was designed as a series of five rows, each consisting of four stations. Each row included different types of exercises, specifically, strength, core and agility exercises, with an additional station for a rest and stretch period. Strength exercises were chosen to provide a total body workout at completion of the circuit, and therefore integrated shoulders, chest, back and legs (hamstrings and quadriceps) muscle groups. The children were instructed to start with one child at each station, and move through their row a total of three times, before moving to the next row (to their right). They were instructed to perform the exercise pictured at each station for the duration of the music (30 seconds) before moving sequentially to the next station. A five second break in the music allowed enough time for movement between stations. For the complete programme refer to Appendix 1. The control group continued to participate in their typical school activity.

Table 1: Circuit training programme outline

STRENGTH ENDURANCE TRAINED					STRENGTH TRAINED			
TIMED WORK PERIODS					TIMED WORK PERIODS / REP RANGES			
			ADV. EX	INC. TIME	ADV. EX		ADV. EX	
	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8
DAY 1	1 SET TECHNIQUE	3 SETS 30sec/ex	3 SETS 30sec/ex	3 SETS	30sec/ex	3 SETS 30sec/15RM	3 SETS 30sec/15RM	3 SETS 12RM
DAY 2	2 SETS TECHNIQUE	3 SETS 30sec/ex	3 SETS 30sec/ex	3 SETS	30sec/ex	3 SETS	30sec/15RM	3 SETS
DAY 3	3 SETS TECHNIQUE	3 SETS 30sec/ex	3 SETS 30sec/ex	3 SETS	30sec/ex	3 SETS	30sec/15RM	12RM

	10minx3	10minx3	10minx3	10minx3	10minx3	10minx3	10minx3
	30min	30min	30min	30min	30min	30min	30min

Statistical Analysis

Data are presented as mean ± standard deviation. A commercially available statistical software package (SPSS V16.9, Chicago, US) was used to analyse data. Pre- and post-intervention data within groups was compared using paired t-tests. The mean of the differences in each group were compared using unpaired (unequal variances assumed) t-tests. Statistical significance was set at P≤0.05.

RESULTS

All 35 subjects who commenced the study completed the study. There was a 97% adherence rate to the CT programme. No significant between-group differences were observed for any of the dependent variables at baseline.

Anthropometric

At the completion of the circuit training programme, no significant differences in anthropometric measures were evident. Tables 2 and 3 present the anthropometric data for both groups; including body mass, waist to hip ratio, body mass index and body fat percentage.

Table 2: Age, body mass, waist:hip ratio of participants

		Training Group	Control Group	Training Group Males	Training Group Females	Control Group Males	Control Group Females
Age (years)		9.94 ± 0.75	10.13 ± 0.5	9.71 ± 0.76	10.10 ± 0.74	10.13 ± 0.35	10.13 ± 0.64
Body Mass (kg)	Pre-Test	37.53 ± 11.41	38.43 ± 9.55	33.1 ± 3.02	40.49 ± 14.05	35.81 ± 8.11	41.05 ± 10.68
	Post-Test	37.87 ±	39.28 ±	33.55 ±	40.76 ±	36.60 ±	41.95 ±

		11.03	9.86	2.91	13.58	8.27	11.13
Waist: Hip	Pre-Test	0.79 ± 0.04	0.81 ± 0.05	0.78 ± 0.03	0.79 ± 0.47	0.83 ± 0.04	0.78 ± 0.05
	Post-Test	0.80 ± 0.05	0.80 ± 0.03	0.80 ± 0.02	0.80 ± 0.06	0.81 ± 0.02	0.79 ± 0.03

Table 3: Body composition measures: BMI and percentage of body fat of participants

		Training Group	Control Group	Training Group Males	Training Group Females	Control Group Males	Control Group Females
BMI	Pre-Test	18.83 ± 3.67	18.38 ± 3.11	18.38 ± 3.03	19.12 ± 4.14	18.10 ± 3.05	18.61 ± 3.36
	Post-Test	18.95 ± 3.61	18.63 ± 3.11	18.56 ± 3.18	19.18 ± 4.00	18.41 ± 2.97	18.83 ± 3.42
Body Fat (%)	Pre-Test	23.22 ± 6.86	20.65 ± 7.72	20.54 ± 6.51	24.89 ± 6.93	18.61 ± 9.51	22.18 ± 6.32
	Post-Test	23.22 ± 6.44	20.75 ± 7.48	21.62 ± 7.24	24.22 ± 6.18	18.36 ± 8.90	22.55 ± 6.21

Strength and Power

The results for strength and power measures are presented in Table 4. In the training group improvements were observed in both lower and upper body power measures, although upper body power did not improve significantly. Jump height increased by 15.4% (P=0.011), and throw distance improved by 2.9% (P=0.342). The control group jump height also improved, but only by 8.0% (P=0.023). Throw distance for the control group decreased at post-testing (P=0.314). Improvements were observed for lower and upper body strength in the training group (16.7% and 10.3% respectively, P= 0.034 and 0.042 respectively). The control group also showed increases in lower and upper body strength (6.9% and 2.1% respectively) though differences compared to the training group were not significant (P=0.082 and 0.438 respectively).

Table 4: Strength and power (jump height, throw distance, leg press, chest press) abilities of participants

		Training Group	Control Group	Training Group Males	Training Group Females	Control Group Males	Control Group Females
Jump Height (cm)	Pre-Test	26.44 ± 3.85	26.92 ± 5.18	27.17 ± 4.17	26.00 ± 3.80	27.17 ± 3.60	26.67 ± 6.77
	Post-Test	30.5 ±	*29.08 ±	30.50 ±	30.50 ±	28.33 ±	29.83 ±

		3.74*	6.16	4.14	3.72	4.46	7.88
Throw Distance (cm)	Pre-Test	401.00 ± 82.99	435.91 ± 91.07	387.50 ± 52.23	411.13 ± 102.81	429.33 ± 89.45	443.80 ± 102.92
	Post-Test	413.43 ± 75.42	417.10 ± 61.12	383.33 ± 65.63	436.00 ± 78.29	401.33 ± 55.12	436.00 ± 68.72
Leg Press 1RM (kg)	Pre-Test	32.15 ± 8.70	36.00 ± 8.53	36.00 ± 8.16	30.44 ± 8.82	40.00 ± 8.94	33.14 ± 7.56
	Post-Test	37.54 ± 9.87*	38.50 ± 10.55	41.00 ± 10.00	36.00 ± 10.00	44.00 ± 13.04	34.57 ± 6.90
Chest Press 1RM (kg)	Pre-Test	25.50 ± 7.10	25.64 ± 8.52	26.57 ± 3.21	24.67 ± 9.22	27.60 ± 12.44	24.00 ± 3.79
	Post-Test	28.13 ± 6.09*	26.18 ± 6.16	28.29 ± 4.54	28.00 ± 7.35	28.80 ± 7.82	24.00 ± 3.79

Where: *, significantly higher than pre-test (P≤0.05)

RMR, Fitness and Physical Activity

There were no significant differences observed between groups for aerobic fitness, or resting metabolic rate measures. The Beep Test Score of the training group increased 9.9% (P=0.006). The VO_{2max} increased 4.0% (P=0.006) in the training group. Average step count decreased in both groups at post-testing. Table 5 presents the results for aerobic fitness, resting metabolic rate and pedometer measures.

Table 5: Aerobic fitness (beep test score, VO_{2max}), metabolic (RMR) and physical activity measures (total step count, average step count)

		Training Group	Control Group	Training Group Males	Training Group Females	Control Group Males	Control Group Females
Beep Score	Pre-Test	5.63 ± 2.13	6.20 ± 2.23	5.99 ± 2.15	4.88 ± 2.10	7.70 ± 1.48	4.95 ± 2.02
	Post-Test	6.19 ± 2.02*	6.22 ± 1.78	7.01 ± 2.36	5.56 ± 1.55	7.50 ± 0.82	5.15 ± 1.67
VO_{2max} (ml.kg.min)	Pre-Test	49.63 ± 5.36	50.36 ± 5.28	51.54 ± 4.52	48.14 ± 5.74	53.91 ± 3.58	48.00 ± 5.06
	Post-Test	51.60 ± 5.04*	50.82 ± 4.16	53.97 ± 4.92	49.77 ± 4.56	54.17 ± 1.89	48.59 ± 3.74
RMR (ml.kg.min)	Pre-Test	6.48 ± 2.05	6.61 ± 1.73	6.51 ± 1.59	6.47 ± 2.39	7.30 ± 2.18	6.03 ± 1.07
	Post-Test	6.62 ± 2.32	6.67 ± 1.83	6.28 ± 0.84	6.79 ± 2.86	7.53 ± 1.43	5.93 ± 1.91
Step Total	Pre-Test	47001.7 ± 21224.2	51831.7 ± 17546.3	58973.5 ± 20108.18	41015.8 ± 20291.4	50955.0 ± 28123.3	52270.0 ± 13248.9
	Post-Test	37207.75 ± 20032.4	72693.8 ± 91827.9	40162.5 ± 21435.7	35730.38 ± 20644.712	139991.67 ± 150745.1	39044.83 ± 18056.4
Step	Pre-Test	10974 ±	11477 ±	13284 ±	9819 ±	13524 ±	10454 ±

Average		3436	2719	3700	2847	1612	2650
	Post-Test	10519 ± 2720	10619 ± 3459	12101 ± 2327	9728 ± 2676	12668 ± 2637	9595 ± 3547

Where: *, significantly higher than pre-test (P≤0.05)

Movement Skills

The training group showed marked improvement in movement competency after the circuit training intervention. Although an improvement was evident in both training and control groups the difference was greater in the training group. The overall score for the training group increased 42.2% (P=0.001), whereas the control group score increased 14.0% (P=0.220). The greatest improvement was the squat which increased 94.7% (P=0.00) in the training group. Movement competency scores for both groups are presented in Table 6.

Table 6: Movement competency tests (squat, lunge, push up, single leg squat and total score)

		Training Group	Control Group	Training Group Males	Training Group Females	Control Group Males	Control Group Females
Squat	Pre-Test	3.79 ± 2.37	4.07 ± 4.05	5.14 ± 2.58	2.85 ± 1.76	4.79 ± 4.21	3.44 ± 4.08
	Post-Test	7.38 ± 1.75*	5.03 ±3.57	7.29 ± 1.44	7.45 ± 2.02	6.50 ± 2.75	3.75 ± 3.86
Lunge & Twist	Pre-Test	4.18 ± 2.16	3.97 ± 1.62	3.86 ± 2.39	4.40 ± 2.09	3.93 ± 1.34	4.00 ± 1.93
	Post-Test	6.50 ± 1.90*	4.93 ± 1.92	6.79 ± 1.41	6.30 ± 2.24	5.14 ± 1.65	4.75 ± 2.22
Push-up	Pre-Test	3.93 ± 3.13	3.36 ± 2.53	3.08 ± 2.40	4.50 ± 3.55	4.00 ± 2.90	2.88 ± 2.30
	Post-Test	6.03 ± 2.42*	4.43 ± 2.87	5.50 ± 2.24	6.39 ± 2.61	4.42 ± 3.97	4.44 ± 2.03
Single-leg Squat	Pre-Test	5.91 ± 1.64	4.47 ± 3.09	5.57 ± 1.69	6.15 ± 1.65	4.64 ± 3.59	4.31 ± 2.83
	Post-Test	6.79 ± 1.62	5.17 ± 2.74	6.07 ± 1.57	7.30 ± 1.53	5.29 ± 2.67	5.06 ± 2.97
Overall	Pre-Test	18.03 ± 6.10	15.89 ± 7.67	17.25 ± 7.09	18.56 ± 5.74	17.58 ± 8.49	14.63 ± 7.32
	Post-Test	25.63 ± 4.74*‡	18.11 ± 8.55	23.25 ± 5.37	27.22 ± 3.77	19.33 ± 10.66	17.19 ± 7.23

Where: *, significantly higher than pre-test (P≤0.05); ‡, significantly greater than control group (P≤.05)

Discussion

Anthropometric

At the commencement of the intervention, the mean body composition of children was classified as normal in both groups. Both BMI and BF% compared well to national and international healthy children of similar age (Rush et al., 2003). Given such normality, we would anticipate minimal change to occur to such measures. Indeed, we observed no significant change in any anthropometric measure. Only with extremely heavy resistance training might we see increases in fat-free mass in such a young cohort, and such training is generally not advised (Committee on Sports Medicine and Fitness, 2001). In support of our findings, previous research has not shown any favourable changes in BMI after resistance training relative to healthy controls (Benson, Torode, & Fiatarone Singh, 2007). Likewise, a recent wider review of school-based childhood obesity prevention programs also showed no change in weight after acute intervention (Zenzen & Kridli, 2009). However, whilst our results, and others (Zenzen & Kridli, 2009), may initially be viewed as ineffective from an acute (short term) perspective, it should be acknowledged that the benefit of participating in such school-based physical activity programmes long term (chronically) likely serves as a preventative tool.

Strength and Power

Both strength and power of the training group were improved after the circuit training programme. The programme included resistance exercises such as presses, and squats. The strength bags used ranged from 1kg to 5kg, and 10kg. The children were not used to these types of movements, but were taught proper technique and instructed to complete as many repetitions as possible in the given time. Large gains in strength were not expected, due to the time allocated for resistance exercise being less than in other studies (Benson et al., 2007). For example, Shaibi reported a 26% change in bench press 1RM, and a 28% change in leg press 1RM (Shaibi et al., 2006). This is much higher than the respective 10.3% and 16.7% observed in our study. This is probably because the proportion of resistance exercise was only a small portion of the overall training time (i.e. ~25% of the 20 minutes) which is dissimilar to other studies, where the resistance component alone totalled 20 – 30 minutes. Exercises that relate more to power improvements in the present study were skipping, ladder hops and lateral jumps. The increase in lower body power is evident in the 15.3% increase in jump height at post-test. Upper body power did not improve as much, which can be attributed to the nature of the power movements being lower body dominant in the present study. In future it may be that some upper body power movements are included in this type of programme.

RMR, Fitness, and Physical Activity

The mean pedometer step count at the start of the study was less than previously published data for NZ children (Duncan, Schofield, & Duncan, 2006), but was comparable to data from US children of similar age (Flohr, Todd, & Tudor-Locke, 2006). Post-intervention, we unexpectedly found that the pedometer data showed a decrease in average step count over three weekdays and two weekend days, in both groups. This is difficult to explain, but may be due to the fact that: 1) the children were more eager to wear the pedometer at pre-testing, whereas at post-testing they were not as diligent; and/or, 2) children were motivated to be more active at the pre-intervention stage as a result of being excited by the study and a novel research tool (pedometer).

The metabolic effect of the intervention appeared negligible. Previous studies have found little metabolic change after resistance training in children (Benson, Torode, & Singh, 2008). Our results support these findings. Given we used a light resistance (20% of 1RM) we would anticipate that the effect of the intervention on RMR would be small. The lack of change in fat-free mass would also likely result in minimal change in RMR. Similarly, the aerobic fitness of participants was unchanged and did not differ between groups (Table 5). Although previous studies have reported improvement in aerobic fitness after resistance training in normal weight (Faigenbaum et al., 2007) and overweight (Wong et al., 2008) children, these have used a much more intense exercise intervention than ours. We attempted to get a balance between exercise intensity and quality of movement - a consequence of this is less change in metabolic measures at least in normal weight children. Conversely, in overweight children, the intervention may have been sufficient to result in a change in metabolic and aerobic measures that may serve to increase total daily energy expenditure.

Movement Competency

The literature shows improvements in movement competency in children as a result of physical activity interventions (Marshall & Bouffard, 1997), especially in children who are less movement competent to begin with. In agreement, we observed substantial improvements in the squat, lunge and twist and push-up movements, and identified statistical differences between intervention and control groups. The improvement in movement competency of the training group is likely due to the emphasis on proper technique as instructed throughout the study. In addition, proper posture and technique was demonstrated by the instructors to the participants with visual aids (teaching cards) at every exercise station. Initially these exercises were performed with bodyweight as the only resistance, and once the individuals demonstrated good technique, resistance in the form of weighted strength bags were added. The correct form for the squat technique was constantly re-iterated, which is evident by the great improvement in the squat score. The movement screening method used was different to those used in other studies which primarily assess locomotion and object control skills, such as running, jumping, catching, throwing and kicking (Coots, De Martelaer, Samaey, & Andries, 2008). The reason for the chosen movement screen was its relation to the prescribed intervention, which aimed to educate children about fundamental movement patterns. The squat for example is a movement used often in activities of daily living as well as in various sports (Kritz, Cronin, & Hume, 2009). Also, the gross motor skills assessment tools used in research with children are more appropriate for preschool age children, in terms of their stage of development.

Limitations

The subjects' heart rate was not monitored during the circuit training sessions, so there is no certainty of the intensity each child was working at. Also, the lack of between group changes could be attributed to the frequent physical education sessions provided by the school which we were unable to monitor. The control group was therefore not sedentary during the programme, but this allows us to compare against current practice. Some of the control group children were also involved in after school sport which may have influenced some measures. Whilst we requested children maintain their normal routine throughout the duration of the study, we were unable to control the intensity of such sports participation.

The instructors of the programme aimed to motivate the children to work hard during the circuit training sessions, but found that during some resistance exercises the children were not as enthusiastic. This may because of a lack of understanding on the part of the children as to the reason for completing numerous repetitions of the same movement. Exercises that were perceived to be "more fun" were skipping, ladder hops, and trampoline jumping. An improved strength outcome relies upon a certain number of reps and sets of the resistance exercise being completed with effort, and this may have been an area where the children did not push themselves hard enough. This, however, is probably to be expected at this stage of development. Engaging children continuously throughout such exercise routines is clearly a challenge for physical education instructors.

Conclusion/Summary

In conclusion, while the effect of an acute school-based circuit training programme had beneficial changes to strength and aerobic fitness, it offered limited additional physical benefits over those activities typically gained from standard school physical activity. However, the movement abilities of children after the circuit training intervention were significantly better than the control group. These skills will likely be transferred to other aspects of their lives, ensuring good general posture, and effective movement in a variety of physical activities, sports and game play. For these reasons, and given its low cost and suitability for large groups, CT may be a useful exercise method to adopt in schools. The long term (chronic) use of such physical activity interventions for normal and overweight children is an area for future research.

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Appendix 1:

Table A1: The CT programme

	ROW 1	ROW 2	ROW 3	ROW 4	ROW 5
Outline	**SHOULDER**	**CHEST**	**BACK**	**LEGS 1**	**LEGS 2**
	weight	weight	weight	weight	weight
	core	core	core	core	core
	aerobic/footwork	aerobic/footwork	aerobic/footwork	aerobic/footwork	aerobic/footwork
	rest / flexibility	rest / flexibility	rest / flexibility	rest / flexibility	rest / flexibility

WEEK 1	**SHOULDER**	**CHEST**	**BACK**	**LEGS 1**	**LEGS 2**
30sec ea	front raise-ball	cht press-bag	rows-bag	sing leg lunge bag	bilat squat-bag
exercise	plank hold	stalkstand-cls eye	reverse crunch	arm supermans	half up hold
(LEARN)	lat jump over bag	skipping	lat shuffle	ladder (fwd/side)	marker spots
tot:3sets	rest / stretch	rest / stretch	rest / stretch	rest / stretch	rest / stretch

WEEK 2	**SHOULDER**	**CHEST**	**BACK**	**LEGS 1**	**LEGS 2**
30sec ea	front raise-bag	cht press-bag	rows-bag	sing leg lunge bag	bilat squat-bag
exercise	plank hold	stalkstand-cls eye	reverse crunch	arm supermans	half up hold
	lat jump over bag	skipping	lat shuffle	ladder (fwd/side)	marker spots
tot:3sets	rest / stretch	rest / stretch	rest / stretch	rest / stretch	rest / stretch

WEEK 3	**SHOULDER**	**CHEST**	**BACK**	**LEGS 1**	**LEGS 2**
30sec ea	medial raise - bag	wall pushup	supine row	walk lunge bag	sumo squat-bag
exercise	plank-feet on bag	balance board	rev crunch-bag	superman	half up twists ball
ADV. EX	lat jump 2 bags	alt 1leg skip	for/back shuffle	ladder(hops)	marker spots
tot:3sets	rest / stretch	rest / stretch	rest / stretch	rest / stretch	rest / stretch

WEEK 4	**SHOULDER**	**CHEST**	**BACK**	**LEGS 1**	**LEGS 2**
30sec ea	medial raise - bag	wall pushup	supine row	walk lunge bag	sumo squat-bag
exercise	plank-feet on bag	balance board	rev crunch-bag	superman	half up twists ball
	lat jump 2 bags	alt 1leg skip	for/back shuffle	ladder(hops)	marker spots
tot:3sets	rest / stretch	rest / stretch	rest / stretch	rest / stretch	rest / stretch

WEEK 5	**SHOULDER**	**CHEST**	**BACK**	**LEGS 1**	**LEGS 2**
30sec ea	upright row bag	pushup off bags	row-2bags	alt lunge - bag	sg leg squat-bag
exercise	sgl arm plank-bag	bal board 1leg	hip raise	sman-hd on ball	sit up ball throw
ADV. EX	hop(bag)knee up	high knee skip	t-drill	ladder(sing hop)	marker spots
	rest / stretch	rest / stretch	rest / stretch	rest / stretch	rest / stretch

WEEK 6	**SHOULDER**	**CHEST**	**BACK**	**LEGS 1**	**LEGS 2**
30sec ea	upright row bag	pushup off bags	rows-2bags	alt lunge - bag	sg leg squat-bag
exercise	sgl arm plank-bag	bal board 1leg	hip raise	sman-hd on ball	sit up ball throw
	hop(bag)knee up	high knee skip	t-drill	ladder(sing hop)	marker spots
	rest / stretch	rest / stretch	rest / stretch	rest / stretch	rest / stretch

WEEK 7	**SHOULDER**	**CHEST**	**BACK**	**LEGS 1**	**LEGS 2**
30sec ea	bilat lat row bag	pushup feet up	pull-up / hang	split jump-bag	squat jump-bag
exercise	sg arm/sg leg plk	bal board-cls eye	hip raise -bag	sman-hd on ball	ball pike
ADV. EX	hop(bag)knee up	skip knee to chst	t-drill	ladder	marker spots
	rest / stretch	rest / stretch	rest / stretch	rest / stretch	rest / stretch