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Review article

Effects of exercise training on blood lipids and lipoproteins in children and adolescents

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Abstract
The following review aims to describe what is known about the effects of exercise training in children and adolescents on the following blood lipids and lipoproteins: total cholesterol (TC), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), and triglycerides (TG). Only studies that described mode, frequency, duration and intensity of the exercise were included in the review. The results of the studies reviewed were equivocal. Clearly the effects of exercise training on the blood lipid and lipoprotein levels of normolipidemic children and adolescents are equivocal. Of the 14 studies reviewed, six observed a positive alteration in the blood lipid and lipoprotein profile, four of the studies observed no alteration in the blood lipid and lipoprotein profile and one study observed a negative effect on HDL-C but an overall improvement in the lipid and lipoprotein profile due to the decrease in the TC/HDL ratio. It appears that methodological problems present in the majority of the exercise training studies limits the ability to make a conclusive, evidence based statement regarding the effect exercise training has on blood lipid levels in normolipidemic children. Most of the research design flaws can be linked to one or more of the following: small numbers of subjects in each study, low or no representation of girls, inclusion of both boys and girls in the subject pool, inclusion of boys and girls at different maturational stages in the subject pool, exercise training regimes that do not adequately control for exercise intensity, exercise training regimes that do not last longer than 8 weeks and exercise training studies that do not have an adequate exercise volume to elicit a change. Ideally, future research should focus on longitudinal studies which examine the effects of exercise training from the primary school years through adulthood.

Key words: Cardiovascular risk factors, children, adolescents, aerobic exercise training.

Introduction

Cardiovascular heart disease (CHD) remains one of the greatest contributors to morbidity and mortality in industrialized nations and as a result is responsible for a substantial amount of money spent by health care systems to both treat CHD and its symptoms. It is now well accepted that CHD has its genesis in childhood despite the fact that clinical symptoms of the disease do not become apparent until later in life (Berenson et al., 1988; Kannel and Dawber, 1972; Lauer et al., 1975). Since 1998, The American Academy of Pediatrics (1998) as stated that elevated cholesterol levels in children and adolescence increases the risk for CHD later in life although the exact risk remains unknown. In response to the rising incidence of CHD in adults, the American Heart Association and other governing bodies have continued to emphasize the importance of exercise in childhood as a means of preventing CHD later in life (Kavey et al., 2003).

Several landmark studies have repeatedly identified a sedentary lifestyle as a major risk factor for the development of CHD in adults (Blair et al., 1995; Morris et al. 1980; Paffenbarger and Hyde, 1980). Unfortunately, unlike studies involving adults, the role regular exercise has on CHD risk factors in children and adolescents remains unclear. The review aims to describe what is known about the effects of exercise training in children and adolescents on the following blood lipids and lipoproteins: total cholesterol (TC), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), and triglycerides (TG). The following paragraphs describe in detail studies that described mode, frequency, duration and intensity of the exercise. Although Gilliam et al. (1978) did not meet these criteria, they are included because they represent one of the first training studies to have both exclusively included girls in the subject pool and examined exercise training effects on blood lipids and lipoproteins.

In addition, the review is limited to those studies that only examined exercise-training effects in apparently healthy children and adolescents.

Table 1 clearly demonstrates that the effect of exercise training on blood lipids and lipoproteins is equivocal. Gilliam and Burke (1978) reported a six-week study involving 14 females ages 8-10 years. The subjects participated in various aerobic activities for 35 minutes per session. The results showed a significant ($p<0.05$) increase in HDL-C levels with no change in TC levels. No other variables were reported. The main flaw in this study was a lack of a control group. Additionally, intensity was described as “strenuous” but was not quantified, the length of the study was short (six weeks) and the frequencies of the exercise sessions were not reported.

In 1981, Gilliam and Freedson (1980) conducted a second training study on 11 girls ages 7-9 years. This time they included a control group and the length of the study was extended to 12 weeks. After a four-day per week training program at a “moderately high” intensity, no alterations in TC or TG were observed. No other variables were reported. Lack of an appropriate tight control on training intensity clouds the interpretation of this study.

Linder et al. (1983) examined the effect of an eight-week walk/jog program at a heart rate (HR) intensity of 80 % of peak HR on 29 boys, ages 11-17 years. No effect was observed for TC, TG, HDL-C, or LDL-C. The inherent problem in this study was the inclusion of boys who are at differing maturational stages.

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Savage et al.'s (1986) walk/jog/run program with 8-9 year old boys resulted in no alterations in TC or LDL-C or HDL-C levels after the 11-week study. However, they did note an overall improvement in the TC/HDL ratio.

Ignigo and Mahon (1995) examined the effects a 10-week exercise-training program had on TC, TG, HDL-C and LDL-C in boys and girls ages 9-10 years. Eighteen children participated in an exercise training program and 10 children served as controls. The exercise program included 60 minutes of aerobic activity, three times per week at an exercise intensity that elicited heart rates of 160-180 $b \cdot min^{-1}$ (80-90 % of peak HR). TG was the only variable that was favorably altered after the 10-week exercise intervention. Again, the control for exercise intensity is not clear. Although the authors mentioned the use of heart rate monitors, they also mentioned that heart rates were monitored by pulse counting and thus it is not clear how many subjects were using heart rate monitors at any one time. Additionally, the inclusion of both boys and girls in a relatively small sample size may result in an affect that is independent of the exercise intervention.

Blessing et al's. (1995) 16 week training study is one of the longest to date, however intensity was not clearly described nor accurately controlled for. Their subjects were 25 males and females who ranged in age from 13-18 years. The 16-week training program involved 40 minutes of various aerobic activities at an intensity that was to approach 90% of previously determined peak work capacity. Intensity was measured by the subjects obtaining a radial pulse. The results showed a positive alteration in TC, HDL-C, LDL-C, TC/HDL-C levels after the 16 weeks of exercise training. The inherent problem with this study is the inclusion of both males and females in the same study. Additionally, the age range of 13-18 years, is too broad due to the differing maturational stages of this group.

Rowland et al. (1996) conducted a 13-week study that included 34 boys and girls ages 10-13 years. First, there was not a control group. Instead, the subjects acted as their own controls to try and minimize the genetic effects of trainability between subjects. However, this study design does not control for the effects growth and maturation may have on the measured variables. Second, although heart rate monitors were used to measure exercise intensity, only seven subjects used the monitors during each exercise session and as a result, exercise intensity was only collected on each subject for one out of the three exercise sessions each week. A final source of error is again subject heterogeneity. As previously mentioned, the inclusion of adolescent boys and girls in the subject pool makes interpretation of blood lipid and lipoprotein changes difficult.

Stergioulas et al. (1998) examined the effect exercise training had on HDL-C levels in 18 boys' ages 10-14 years. The subjects were chosen from a group of 1000 Greek subjects who participated in a survey that was conducted in 1993. HDL-C levels increased significantly ($p < 0.05$) after the eight-week training program. There were several inherent problems with this study. First, it is difficult to ascertain how exercise intensity was measured. They indicated that exercise was set at 75 % of physical working capacity that was an exercise heart rate of 170 $b \cdot min^{-1}$. However, it is not clear whether a peak exercise test was completed prior to the exercise intervention or whether peak heart rate information was gathered from the Greek survey results of 1993. If exercise heart rate was estimated, than it is questionable that a heart rate of 170 $b \cdot min^{-1}$ would be accurate for boys with an age range of 10-14 years. Second, the authors do not describe whether or not heart rate was monitored during the exercise sessions. A final source of error is subject heterogeneity. Although only boys participated in the study, their maturity level was not assessed. Assessment of maturity level is pertinent because there were most likely significant differences in the boys who ages ranged from 10-14 years and, as mentioned above, testosterone has been shown to adversely affect the blood lipid and lipoprotein profile of males.

Stergioulas et al. (2006) conducted a second study with 10-14 year old boys. In this study all subjects completed peak exercise tests for the determination peak HR. The subjects completed 4 training sessions per week at 80 % of their peak HR for 8 weeks. Significant, positive alterations were observed for all variables at the end of the 8 weeks. However, it again needs to be pointed out that the probable maturity differences among the subjects makes the data difficult to accurately interpret.

Stoedefalke et al. (2000) has the longest well controlled exercise training study to examine the effects of exercise training on post menarchial 13-14 year old girls. The 20-week study included 20 experimental subjects and 18 control subjects. All subjects underwent peak exercise tests to determine maximal HR values. Subjects exercised three times per week for 20 minutes on either a treadmill or cycle ergometer. Exercise intensity was kept at 75-80% of maximal HR as verified by HR monitors. No significant change in TC, HDL-D, LDL-C or TG was observed in either group.

Welsman et al. (1997) examined the effect two separate modes of aerobic training had on TC levels in 35 girls' ages 9-10 years. The exercise intervention lasted eight weeks and exercise intensity was set at approximately 80 % of peak HR. All subjects underwent peak exercise tests to determine peak HR values. No change in TC or HDL-C was observed in either group. Subjects exercising on the cycle ergometers wore heart rate monitors so that exercise intensity could be accurately measured. Subjects who participated in the aerobic dance program underwent a pilot study to determine which routines would consistently elicit heart rates above 150 $b \cdot min^{-1}$. The principal weakness of this study was that the study only lasted eight weeks. Additionally, if the subjects in the aerobic dance group experienced a decline in submaximal HR than the dance routines may not have been rigorous enough to elicit HR levels of 150 $b \cdot min^{-1}$ in the latter weeks of the study.

Tolfrey et al. (1998) conducted a very well controlled study with 48 prepubertal boys and girls of which 28 of the subjects completed an exercise training intervention. They controlled for exercise intensity by using HR monitors and through constant encouragement, they were able to have all subjects maintain an exercise intensity of 79% of peak HR. The subjects pedaled on cycle ergometers three times per week for 12 weeks. The results showed that there was no difference over time for TG and TC between the two groups. However, the exercise group experienced an increase in

HDL-C and a decrease in LDL-C levels. Changes in the blood lipid profile were independent of alterations in peak $\dot{V}O_2$. In fact, the control group started out with a higher peak $\dot{V}O_2$ and maintained the greater peak $\dot{V}O_2$ until the end of the study suggesting that it is the exercise training which directly effects blood lipid profiles and not peak $\dot{V}O_2$. This was the first study that had adequately controlled for exercise intensity and, although it is probably unrealistic to expect children to continue to exercise at a constant intensity, doing the same mode of exercise outside of an experimental setting, the study does advance our knowledge of the effects a highly structured exercise training program has on blood lipids and lipoproteins in prepubertal children. The major design flaw is the inclusion of both boys and girls in the study. Additionally, as mentioned above, few studies have lasted longer than 12 weeks and it would have been beneficial to observe whether a longer training period resulted in more dramatic differences.

Tolfrey et al. (2004) conducted a second training study with 34, 10-11 year old boys and girls. All subjects exercised three times per week at 80 % of peak HR. Again all subjects wore HR monitors for the 12-week exercise-training program. Unlike other studies, the study was unique in that exercise duration was individualized to match energy expenditure targets. Two groups were established. A LOW group that expended 100 $kcal·kg^{-1}$ and the MOD group that expended 140 $kcal·kg^{-1}$. The exercise-training program elicited no change in TC, HDL-C or LDL-C irrespective of exercise duration and energy expenditure. The authors suggest that the exercise volume may have been insufficient to elicit a change.

Williford et al. (1996) is the only study to examine exercise-training effects in black, male adolescents. Twelve boys completed a 15 week, 5 day per week exercise training program. The exercise sessions took place for 30 minutes during a regularly scheduled physical education class. The subjects jogged at 70-90 % of their pre-determined peak heart rates. It is not clear how HR was monitored. Unique to this study was the inclusion of a weight-training program that took place two times per week. The 15-week exercise-training program resulted in significant increases in HDL-C and significant decreases in LDL-C. No change in TC occurred. The authors point out that further research is needed regarding the effects of ethnicity and the effects of exercise training on blood lipids and lipoproteins.

Conclusions and recommendations for future research

Part of the difficulty in determining whether exercise training has a positive effect on the blood lipid profile of children is that well controlled studies remain scarce. Additionally, methodological problems present in the majority of the exercise training studies limits the ability to make a conclusive, evidence based statement regarding the effect exercise training has on blood lipid levels in normolipidemic children.

- small numbers of subjects in each study;
- low or no representation of girls;
- inclusion of both boys and girls in the subject pool;
- inclusion of boys and girls at different maturational stages in the subject pool;
- exercise training regimes that do not adequately control for exercise intensity;
- exercise training regimes that do not last longer than 8 weeks;
- exercise training studies that do not have an adequate volume to elicit a change.

In addition it should be noted that studies conducted prior to 1990 need to be viewed with caution due to the lack of interlaboratory lipid and lipoproteins measurement standardization

The main flaw in all of the above studies is that the exercise intervention length is probably not long enough. Superko (1991), in his review of the adult literature, concluded that exercise training programs lasting longer than four months, are needed to see a positive alteration in blood lipids and lipoprotein levels in most adults.

Therefore, although the research appears to be equivocal with regard to the effects of an exercise-training program on blood lipids and lipoprotein levels in children and adolescents, it may be that the exercise interventions were not long enough. Additionally there is a clear lack of representation of adolescent females. Therefore it is not possible to make an evidence based conclusion of the exercise training effects on blood lipids and lipoproteins in this population.

From a broader perspective, it is important to determine whether regular exercise training in children and adolescents results in regular exercise participation through the lifespan. Ideally, a longitudinal study which examines the effects of exercise training from the primary school years through adulthood would be best. Major goals of such a study would include the following:

- an examination of the fitness variable changes measured periodically from puberty, through adolescence into adulthood.
- observation of selected behavior changes as they relate to exercise.
- the effect family exercise patterns have on exercise patterns in children.
- the effect the PE curriculum has on promoting exercise through the lifespan.

The second area of research should focus on the effects exercise has on children who already exhibit a risk for CHD. Children to be included would be those with a strong family history of CHD, who are hyperlipidemic, hypertensive or obese. Currently there are data which support the notion that regular exercise reduces the severity of both hyperlipidemia and hypertension in children. Well controlled exercise training studies in children who had adverse blood lipid and lipoprotein profiles showed positive alterations in their profiles (Rimmer et al., 1997;

Stergioulas et al., 1998; Tolfrey et al., 1998). Similarly, Alpert and Wilmore's (1994) review of the literature found a decline in blood pressure in hypertensive children after exercise although few of the subjects reached normal levels.

Clearly the effects of exercise training on the blood lipid and lipoprotein levels of normolipidemic children and adolescents are equivocal. Of the 14 studies reviewed, six observed a positive alteration in the blood lipid and lipoprotein profile (Blessing et al., 1995; Savage et al., 1986; Stergioulas et al., 1998; Sterigioulas et al., 2006; Tolfrey et al., 1998; Williford et al., 1996), five of the studies observed no alteration in the blood lipid and lipoprotein profile (Gilliam and Burke, 1978; Gilliam and Freedson., 1980; Linder et al., 1983; Rowland et al., 1996; Welsman et al., 1997; Stoedefalke et al., 2000) and one study observed a negative effect on HDL-C but an overall improvement in the lipid and lipoprotein profile due to the decrease in the TC/HDL ratio (Savage et al., 1986).

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Key points

- Exercise training has limited to no effect on blood lipid levels in children and adolescents.
- Few well controlled studies have been done to examine the effect exercise training has on selected cardiovascular risk factors and those studies that have been completed contain methodological flaws which makes interpretation of the results difficult.
- More studies, particularly those of a longitudinal design, are required before a conclusion can be drawn regarding the effects exercise training has on selected cardiovascular risk factors in children and adolescents.

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Table 1. Effects of exercise training on blood lipids and lipoproteins in Children and Adolescents.

Authors	Subjects Age (yr)	Control group	Mode	Frequency (days/week)	Intensity	Duration (minutes)	Length (weeks)	Dependent variables	Results
Blessing et al. (1995)	N=15 males 10 females Age=13-18	N=14 males 10 females	Various aerobic activities	3	Variable Up to 90%	40	16	TC, LDL-C HDL-C TG TC/HDL-C	decreased increased no effect decreased
Gilliam and Burke (1978)	N=14 females Age=8-10	None	Various aerobic activities	unknown	"strenuous"	35	6	TC HDL-C	no effect increased
Gilliam and Freedson (1980)	N=11 females Age=7-9	N=12	Various Aerobic activities	4	"moderately high intensity"	25	12	TC TG	no effect no effect
Ignico et al. (1995)	N=10 males, 8 females, Age=8-11	N=7	Aerobic games	3	160-180 $b{\cdot}min^{-1}$	few to 60	10	TG TC, HDL-C LDL-C	decreased no effect no effect
Linder et al. (1983)	N=29 males Age=11-17	N=21	3 days walk/jog	4	80% of max HR	25-30	8	TC, HDL-C TG, LDL-C	no effect no effect
Rowland et al. (1996)	N=11 males, Ages=10-12 N=20 females Ages=10-12	Subjects served as their own control	Various Aerobic Activities	3	170-180 $b{\cdot}min^{-1}$	25	13	TC TG HDL-C LDL-C	no effect no effect no effect no effect
Savage et al. (1986)	N=12 males Ages=8-9	N=10	Walk/jog/run	3	75% of peak HR	2.4 km per session progressing to 4.8 km per session	11	TC HDL-C LDL-C	no effect decreased no effect
Stergioulas et al.(1998)	N=18 males Ages=10-14	N=20	aerobic activities	4	75% of peak $\dot{V}O_2$	Unclear (60which included warm-up and cool-down)	8	HDL-C	increased
Stergioulas et al. (2006)	N=12 males	17		4		60	8	TC HDL-C TG	no effect increased decreased
Stoedefalke et al. (2000)	N=20 girls Ages=13-14	N=18	Aerobic activities	3	75%-85%	Polar computer interfaceHR monitors	20	TC, LDL-C, TG, HDL-C	no effect
Tolfrey et al. (1998)	N=12 boys 14 girls	N=10 boys 10 girls	cycle ergometer	3	79.3%	Telemetry HR Monitors	12	TC, TG LDL-C HDL-C	no effect decreased increased
Tolfrey et al. (2004)	N= 19 boys 15 girls Ages=10-11	Acted as own controls	Cycle ergometer	3	80 %	Polar computer interfaceHR monitors	12	TC, TG LDL-C HDL-C	no effect
Welsman et al. (1997)	N=35 females Ages=10	N=16	17 did aerobic dance 18 did cycle ergometry	3	160-170 $b{\cdot}min^{-1}$	20-25 for aerobic dance 2 for cycle ergometry	8	TC HDL-C	no effect no effect
Williford et al. (1996)	N=12 males Ages=13	N=5	Walking or jogging	5	70-90% of peak HR	30	15	TC LDL-C HDL-C	no effect decrease increase