Growth and Maturation: The Connection with Physical Activity to Obese Children
運動對肥胖兒童成長的影響

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Abstract

Childhood obesity is expected more serious in the 21st century. The etiology of obesity has been investigated for more than decades and nobody will argue that physical inactivity and high-energy intake are the two core factors. For the sake of prevention and treatment, it is imperative to look into the nature and health-related effects of physical activity towards obesity management. The objective of this chapter is to clarify the effects of physical activity participation on adolescents' body changes and avoid unrealistic expectations from it. The content is mainly focus upon the growth and maturation characteristics of adolescents who are regularly active in physical activity and the cardiovascular changes through physical activity.

摘 要

兒童肥胖問題在廿一世紀將會愈趨嚴重，在過去十多年來研究一直探討其成因，基本上運動與營養控制兩者一致被確認為決定性的因素。因此在預防與治療而言，運動對肥胖處理及治療的效果及性質上，深入的研究探討是必要的，本文旨在釐清兒童在成長過程中參與運動對身體變化的影響，以防止肥胖兒童對身體產生不切實際的期望。

Introduction

The International Consensus Conference on Physical Activity Guidelines for Adolescents 1993 reviewed and summarized the association between physical activity and seven health outcomes. First of all, cardiovascular fitness has been definitely related to adolescents' fitness. But the intensity of physical activity was found higher in order to improve adolescents' fitness than in adults. Risk of osteoporosis in later life could be reduced by enhancing peak bone mass through physical activity in adolescence. Association between physical activity and adiposity for obese people were found most successful when the intervention could be internalized in daily life activities. A modest body fat reduction and fat free mass would be resulted. For obese population, physical activity could also reduce blood pressure. With regard to the HDL-cholesterol, physical activity was found effectively increasing HDL-cholesterol in these high health-risk groups. Finally, psychological health in adolescents like depression, anxiety, stress, self-concept and self-esteem were found a moderate strength relationship with physical activity. To conclude, the health benefits of physical activity were undoubtedly obvious.

In this paper, the author will focus on two main sections. The first section is the growth and maturation characteristics of adolescents who are regularly active in physical activity. The second section is the cardiovascular changes through physical activity. The objective of this chapter is to clarify the effects of physical activity participation on adolescents' body changes and avoid unrealistic expectations from it. Through the correct understanding of physical activity, a more feasible and realistic goal and intervention can be conceived and implemented to the public.

Growth and Maturation

According to Malina (2000), growth refers to an increase in size, either of the body as a whole or of its parts. It involves increases in stature and mass, and related changes in physique, body composition and various systems. Maturation refers to the tempo and timing of progress to the mature state.

Stature and the Growth Spurt

There is ample evidence that regular physical activity participation has no apparent effect on attained stature and rate of growth in stature. Different longitudinal studies have indicated that regular sport and exercise participants have similar stature with inactive counterparts (Malina, 2000). Malina also found that the age at peak height velocity, the time of maximum velocity in stature during the adolescent spurt, is not affected by physical activity. Armstrong and Welsman (1997) stated that the stature of children is mostly inherited from their parents. The overall effect of genotype on stature is about 60% from children to adult. Therefore, children have a tendency to reach similar height with their parents.

Body Mass and Body Composition

Biologically, girls have less relative muscle mass increase than boys during adolescence. On the other hand, girls' body fat increases to about 25% of body mass while boys' decline to about 12-14% from the age 13 to 17. It is clear that sex difference exists and presents a huge gap between them (Armstrong & Welsman, 1997). Thus, separate consideration should be given when looking at boys' and girls' body composition regarding body fat. In contrast to stature, body mass can be changed by regular physical activity, resulting in body composition. Body mass refers to the lumpsum of fat free mass and fat mass. Physical activity is associated with the decrease in fatness and some gain in muscle mass in both sexes. This phenomenon is usually found in regular exercisers and trained athletes. Twisk (2000) has suggested that adolescence is a critical period for developing pattern of body fat and more probably an influential stage regarding adolescents' future cardiovascular disease, morbidity and mortality. According to Twisk, physical activity and exercise have effects on regulating energy intake, suppressing appetite mildly and increasing resting metabolic rate of individuals.

The advantages of regular physical activity participation not only can cause an immediate metabolic rate, but also a persistent increase during the post-activity period. This results in higher and longer energy expenditure for the exercisers (Armstrong & Welsman, 1997, Twisk, 2000). With regard to the degree of changes in body composition, it mostly depends upon the frequency, duration, intensity and type of the physical activity (Corbin, Lindsey & Welk, 2000). But for obese people, the intensity and duration may be more important. Fox (1999a) stated that during very heavy workloads in fitness training, energy is exclusively supplied by glycogen. This energy expenditure of course is not the desirable outcome for fat reduction. Thus, professionals in obesity management recommend that low to medium intensity of workload is desirable to increase the fat utilization. Also, if obese people burden heavier workload in training, it will be unsafe and counter-productive for them, at least at the early stages of exercise program. Fox also pointed out that duration of exercise could facilitate the lipid utilization. The expenditure of fat enhances when period of exercise is extended. In the long term, the energy balance system will increase its fat burning capacity even during light activity and rest.

After all, the maintenance of the exercise lifestyle is indicated as the most important determinant among all influencing factors like the four fitness-training components mentioned above (Armstrong & Welsman, 1997). This is just because we are not going to train an elite athlete but to build up a healthy body. Once you are healthy, physically strong in muscular strength, muscular endurance and power can be developed according to your personal needs. For the guidelines of physical activity, it will be presented in later section.

Skeletal Health

Kemper (2000) has reviewed the development of bone mass development in adolescents and the effects of physical activity as one of the important lifestyle factors in preventing osteoporosis at older age. In this review article, Kemper found that the low-intensity, long lasting exercise could only result in better capillarization and oxygen delivery to the active muscles. For bone mass development, there is no effect at all. The intensity of the forces that act on the bones is the key factor to affect bone health. Weight-bearing exercise such as walking, running, rope skipping, dancing have better and more apparent effect and significant increase in bone mineral density for both girls and boys (Kemper, 2000; Malina, 2000).

Two mechanisms were identified by Kemper (2000) as the main determinants to affect bone mass development. First, it is the centrally regulated hormonal factors like estrogens and testosterone. During exercise, these hormones will be elevated and influence the remodeling activities resulting in bone hypertrophy. Second, local mechanical forces of exercise will cause strain on the bone and calcium accumulation on the concave side of the bending bone. Also, during the overload by mechanical demands, the osteoclasts will be stimulated to remove the damaged structures

and at the same time osteoblasts repair the structure of bone matrix.

Physical activity definitely leads to the increase of serum estrogens and this can diminishes the loss rate of bone mineral density. This dose-response effect was even more obvious and specific to the site at which the mechanical strains occurred (Armstrong & Welsman, 1997; Malina, 2000). Malina claimed that this enhanced bone mineral accretion associated with training of sport and it would offset the reduced estrogen level in later maturation girls. According to Kemper, as long as suitable exercise is adopted, the bone mineral will be maintained and bone thickening will be resulted. For humans, short bursts of weight-bearing exercise are recommended to elevate bone mass such as skipping, stair climbing and jumping. In summary, daily exercise with a pattern of weight-bearing, short duration, low frequency can benefit most to skeletal health and prevention of osteoporosis. With regard to the children skeletal development, these 3 to 5 years of pubertal growth spurt have significant implications for their adult life. This is because the bone mineral content during these years will hugely lay down and prevent or postpone osteoporosis (Kemper, 2000). This notion is consistent with Armstrong and Welsman (1997) that immature bones would result in greater increase in bone mass than the mature bone through weight-bearing activities. For children, the best strategy is to increase their bone mineral density through regular physical activity. Through the intermittent loading, high in magnitude, and high in frequency, few repetitions appeared to be necessary to produce a substantial osteogenic effect. Body mass supporting (running, skipping) rather than body mass-supported activities such as cycling and swimming are recommended. Some resistance training is beneficial and de-training should be avoided whenever is possible (Armstrong & Welsman, 1997). Although children are the main focus of this chapter, it is never too late to be active. For adults, the active lifestyle can minimize the bone loss during aging.

Biological Maturation

Biological maturation is a highly individual characteristic, which is variable in timing and tempo. Skeletal maturation, breast development and menarche in girls, genital development in boys and pubic hair for both sexes are the main secondary sex characteristics. First, the skeletal age appeared more advanced in older adolescent athletes over chronological age in boys. On the contrary, girls were found the opposite. Their skeletal age lagged behind their chronological age in certain sports like gymnastics, ballet and track (Malina, 2000). This phenomenon can be attributed to the selective nature of athletes in certain sports. He concluded the review of different studies that the process of skeletal maturation was not influenced by physical training or sport. Furthermore, longitudinal and cross-sectional studies have indicated that there is no effect of physical activity or training on the timing, and progress of breast, genital and pubic hair development and hormonal profiles in both sexes. Even there is some consensus that girls' menarche occurs later in athletes than non-athletes. It has not been yet shown that exercise delays menarche. Different confounding factors may contribute to this result and remained to be proven.

Blood Pressure, Cholesterol and Cardiovascular Health

According to Riddoch and Boreham (2000). They reviewed that there is minimal effect of exercise on the blood pressure in the normal population of adolescents. However, consistently reduced systolic and diastolic blood pressures were indicated in the hypertensive adolescents after aerobic training. This confirmed the previous findings from Armstrong & Welsman (1997) that the normotensive adolescents showed inconsistent results on blood pressure after exercise training. While aerobic training appeared to be effective in reducing both systolic and diastolic blood pressure of hypertensive children. Resistance training may be effective in maintaining reductions in blood pressure induced by a previous aerobic training program.

With regards to cholesterol, an adverse lipid and lipoprotein profile is considered one of the major four risk factors associated with coronary heart disease (CHD). Where obesity is listed as the first major contributory risk factor in CHD (Armstrong & Welsman, 1997). Clinical findings implied that the origin of atherosclerotic CHD might lie in childhood. As early as 10 to 14 years old children, fatty streak, which is the early stage of atherosclerosis is found. Although there is no conclusive studies to prove physical activity can cause huge reduction in blood cholesterol (Riddoch & Boreham, 2000), physical activity is still found inversely related to the incidence of CHD (Armstrong & Welsman, 1997; Twisk, 2000). Armstrong and Welsman (1997) explained that potential mechanisms by which physical activity may reduce the incidence of CHD are:

1. Improve blood lipid and lipoprotein profile
2. Reduce arterial blood pressure
3. Decrease adiposity
4. Retard atherosclerosis
5. Lower circulating catecholamines
6. Decrease platelet adhesiveness
7. Increase fibrinolysis
8. Increase plasma volume
9. Increase coronary artery diameter
10. Increase coronary collateral vascularization

With regards to the physical activity and blood lipid, the existing literature is mainly available for adults. Studies of the

responses of children and adolescents' blood lipid to physical activity are still sparse. Meta-analyses demonstrated that physical activity results in desirable changes in blood lipids and lipoproteins. The changes are mainly presented in the increase of high-density lipoprotein (HDL) and decrease of low-density lipoprotein (LDL), triglyceride and total cholesterol (Armstrong & Welsman, 1997). Although some studies found no significant relationship between physical activity and blood lipid, it was mostly attributed to the confounding factors like age of subjects, body mass, body fatness, aerobic fitness, cigarette smoking, alcohol consumption, diet, intensity, duration, frequency and type of physical activity. In summary, Armstrong and Welsman (1997) concluded those positive changes in HDL, LDL and triglyceride appeared after the physical activity training programs.

From a more resent review article, Twisk (2000) suggested that human growth hormone might be responsible for the fatty acid mobilization. It was found that growth hormones increased sharply with exercise and this effect would last for several hours during the recovery period. Also, with exercise, adipose tissue would be more sensitive to either the sympathetic nervous system or rises in circulating catecholamines. Either situation would increase fat mobilization. Although these findings were mainly found in adult studies, the association between physical activity and HDL levels was strongly indicated. It is believed that a healthy cardiovascular profile will be developed in children and adolescents through regular physical activity participation.

Guidelines of Physical Activity for Obese Children

Sallis (1995) has developed two physical activity guidelines for adolescents.

Guideline 1: All adolescents should be physically active daily as part of play, games, sports, work, transportation, recreation, physical education or planned exercise in the context of family, school and community activities.

Guideline 2: In addition to the daily activities, three or more sessions per week of activities lasting 20 minutes or more at a time, that require moderate to vigorous levels of exertion are recommended.

The Guideline 1 clearly indicated that any type of daily activities and environments should be well utilized to maximize individuals' energy expenditure. This notion was further supported by Riddoch and Boreham (2000b) that any activities, which can be easily incorporated into the daily routine would be beneficial to children's health, regardless of its intensity, frequency, duration and type of exercise. Epidemiological studies also strongly suggested that improved health status could be resulted from light to medium intensity daily activities instead of highly intensive fitness training. It helps to clarify the common error with the public opinion that individuals have to train intensively to achieve optimum health status. On the contrary, the gap between healthy and unhealthy body is just your choice from sedentary to moderately active. From Fox (1999b), the degree of health benefit is mainly determined through the transition from sedentary to moderately active lifestyle. Once reach the activity threshold, health will be achieved. Highly trained or very active of physical activity, on the other hand, can satisfy high demand on physical strength, power or muscle mass development. Heart rate monitoring is a valid estimate of energy expenditure in higher exercise intensity studies. Riddoch and Boreham (2000b) reviewed that heart rate between 120 to 169 beats/minute are normally considered to be effective in physical activity for children. On the other hand, epidemiological studies strongly suggested that significant health benefits could be demonstrated at an exercise energy expenditure of 500 kcal/week irrespective of its intensity, frequency, duration and type. Based upon the epidemiological findings, the high heart rate physical activity is not a must for achieving health benefits unless the individual wants to improve his/her physical fitness. It is because health benefits can accrue at intensities of activity below those necessary for marked improvements in physical fitness.

Armstrong and Welsman (1997) had outlined the characteristics of an optimal activity program for the management of juvenile obesity. They are:

1. Emphasize use of large muscle groups
2. Moves the whole body over distance
3. Emphasize duration rather than intensity
4. Raises daily energy expenditure by 10 – 15%
5. Includes activities to promote muscle strength
6. Includes daily physical activity
7. Volumes of physical activity is increased progressively
8. Incorporates the child's preferred activities

Basically, daily physical activity is the main theme of tackling the obesity problem in the current literature. Fox (1999b) suggested that any movement expended energy. He recommended that obese individuals should do more weight-bearing movements, longer periods of light to moderate exercise, and reduce time in sedentary pursuits like TV watching. This activity-health relationship is also well supported by Riddoch and Boreham (2000b) that total activity energy expenditure is the key dimension of activity, which will confer health benefits to both children and adults.

Fox (1999b) listed some examples of healthy physical activities to explain how physical activity merges with daily lifestyle in our modern society. They are:

1. Waxing or washing a car for 45-60 minutes
2. Washing windows or floors for 45-60 minutes
3. Gardening for 45-60 minutes
4. Walking 1.75 miles in 35 minutes
5. Cycling 5 miles in 30 minutes
6. Rope skipping for 15 minutes
7. Stair climbing for 15 minutes
8. Walking to schools, shops and work place
9. Greater access to parks or other leisure and sport facilities
10. Find more alternatives to escalators and lifts

Tips for Exercise Prescription and Exercise Safety

The following are exercise tips provided by the guidelines for exercise prescription, American College of Sports Medicine (1999) for overweight and obese individuals.

1. Select convenient hours to exercise in a day
2. Select pleasant surroundings such as parks nearby
3. Select appropriate exercise:

   Emphasize moving the whole body such as walking, distance swimming, walking purposefully in waist-deep water or Cycling and so on. Emphasize all opportunities for walking

4. Emphasize that all daily activities are exercise
5. Provide realistic expectations, no miracle:

   Amount of exercise:

   Frequency——5 to 7 days per week if possible (emphasize daily exercise)

   Intensity——having a feeling of slightly hard and OK!
   Time——30 min. to 90 min. (over 1 hour will be more effective, beginners can start with 30 min.)

   Type ——the best type of exercise is walking, and then swimming, cycling, step aerobics, and whole body movement, activities with low to moderate intensity.

Remark: The above amount of exercise should **maintain for at least 18 weeks** to be effective for fat reduction for the obese.

6. Provide a slow start and increase the amount of exercise gradually such as increase the total walking distance per exercise session.

7. Encourage to exercise with parents, other family members or friends.

8. Make a table to record the amount of exercise done for the comparison of the achievement each time and the improvement as well.

9. The formula for calculating the calories expenditure on walking is as follow:

   Kcal (walk) = 0.7768 X Distance (km) X Weight (kg)

10. Parents should praise and encourage the child whenever the effort is put and the improvements on body weight, fatness, exercise capacity, heart rate, blood pressure, serum lipids, glucose and so on.

With regards to the exercise safety, the following advice are given by the ACSM:

1. Drink water before, during and after exercise (not too much each time, around 200ml) when needed because the obese children can be overheated and dehydrated easily in exercise.

2. Do warm up exercise before starting the program. The warm up should include joint rotation, raising body temperature gradually and activities such as stepping on the spot for a minute, and, stretching exercise.

3. Do cool down activities after the core exercise program by slowing down the exercise gradually such as walking slower and slower, do some deep breathing and then stretch again.

4. For the stretching exercise, static stretching for 10 to 30 seconds is recommended for each major muscle groups. Don't do the bouncy or ballistic movements.

5. If the following condition(s) appear, stop the exercise immediately, take a rest and consult a physician if necessary:
   (a) Pain, discomfort in the chest, neck, jaw or arms
   (b) Shortness of breath
   (c) Dizziness
   (d) Nausea
   (e) Palpitations or irregular heart beats
   (f) Unusual fatigue
   (g) Joint pain such as the knees

6. Proper sports swear during exercise
   (a) Light T-shirt and shorts, which can absorb sweat. Cotton sweater and socks are recommended.
   (b) In cold weather, more thin layers of clothing can be wear to suit the needs of exercise. The layers can be increased or reduced easily.
7. Proper sports shoes which have good shock absorber at the heels and/or at the ball of the feet.

To summarize, maximize any opportunities for body movements is the core concept for obese management. Finally, Riddoch and Boreham (2000b) pointed out the necessity for considering children's specific needs relative to adults when prescribing activity contents for children. This is indicated that children's adherence level is much lower with respect to vigorous and programmed physical activity than it is to the activities with lower intensity and variety. The reason is attributed to the sporadic nature of children. Sustained and rigid adult fitness training criteria did not function in children's developmental nature. Activities with positive, achievable experience, short bouts and more varieties are compatible to what children's needs. As a consequence, an enjoyable experience will be provided to children and lifetime physical activity participation will be feasible.

Conclusion: How Effective Is Physical Activity?

Fox (1999b) stated that exercise has not been given a top priority in obesity management program. It is believed that exercise only contributed limited weight loss and exercise adherence is always a problem. That is why dietary methods are more popular and welcome in the commercial weight loss industry. It is very obvious that exercise cannot compete with dietary methods for rapid weight loss. Based upon the findings of Armstrong and Welsman (1997), a restricted energy intake indeed can promote significant weight loss in the obese. But this strategy alone may induce a marked loss of lean tissue, and a reduction in metabolic rate. As a result, it will increase the likelihood of subsequent reversion to pre-intervention levels. Physical activity and exercise, at this point, can increase the energy expenditure and maintain or enhance the metabolic rate during and after exercise.

Fox also explained that longer period of physical activity could maximize fat oxidation and increase fat free mass. Sufficient evidences show that physical activity is more likely to play a critical role in overweight or mildly obese individuals. With regards to the body fat changes, within the BMI range 20 to 35 is mostly affected by exercise. This evidence reinforces the preventive role of physical activity and exercise in tackling childhood obesity problem. In addition to the dietary modification through education, physical activity will definitely be effective and efficient in producing successful fat reduction in obese population.

In conclusion, this chapter has covered the growth and maturation issues regarding children's development. Nieman (1999) has already summarized the benefits of regular exercise for obese individuals.

1. Improved cardio-respiratory endurance
2. Improved blood lipid profile
3. Improved psychological well-being and decreased anxiety and depression
4. Enhanced social support
5. Decreased health risks related to obesity such as diabetes, coronary heart diseases, cancer, hypertension, etc.

Finally, the author would like to adopt the following statement quoted from the chapter of obesity from Nieman (1999) to finish this chapter. "***Physical activity might have its most significant effect in preventing, rather than in treating overweight and obesity***".

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