# Benefits of physical activity on nutrition and health status: studies in China

Chen Ji-Di, MD

*Research Division of Sports Nutrition and Biochemistry, Institute of Sports Medicine, Beijing Medical University, Beijing, China.*

The significance of physical activity for fitness is that it may change risk factors for chronic disease and improve functional and psychological status. Rational nutrition and scientific training are prerequisites for safe and useful exercise. Even mild iron deficiency anemia can affect physical capacity. Intensive exercise has been found to increase serum and erythrocyte lipid peroxide levels. Moderate exercise decreases the blood lipid peroxides and increases free radical elimination enzyme (SOD, GSH-Px, CAT) activities. Elite athletes have significantly lower Malonic dialdehyde (MDA) levels and higher SOD and GSH-Px activities. Zinc deficiency not only leads to an increase in free radical generation and lipid peroxidation and a depression of SOD activity, but also is harmful to immune function. Exercise can exacerbate the damage induced by iron deficiency or zinc deficiency. Long term diet restriction by gymnasts to control weight showed detrimental effects including growth retardation, menstrual disturbances, malnutrition, mental stress and muscle weakness. Comprehensive nutrition promotes growth rate and corrects malnutrition without a body fat increase in athletes. Exercise benefits the growth and development of bone and muscle and enhances muscle strength. The prevention of obesity is particularly important during periods of rapid growth. The establishment of an exercise life style during childhood will favor the best health.

## Introduction

The importance of exercise for fitness is becoming clearer every day and it is a popular topic of conversation. People generally have a surface knowledge of the following:

1. Exercise may lower some risk factors for chronic diseases. Physical demands at work, at home and in transit have been dramatically reduced by modernization. People are leading a more and more sedentary lifestyle that leads to a progressive increase of such chronic diseases as obesity, coronary heart disease, diabetes, osteoporosis, and back pain. Exercise combined with a proper diet lowers certain risk factors for chronic disease. Thus it has important implications for health and is worth recommendation[1-4].

2. Exercise improves human functional status and metabolism. The oxygen uptake ($VO_2$), maximal oxygen uptake ($VO_2$ max), cardiac output (CO), and stroke volume increased significantly after running training[5]. Heart rate recovered faster after a 30 meter run at full speed in exercise trained children than non-trained controls[6]. Microcirculation, heart function, and lipid profiles improved in aged people that jog or practice Qi-gong or Tai-chi as compared to control subjects[4,7-10].

3. Exercise improves psychological state and capacity to cope with stress. Regular exercise yields physical fitness, good mood, and well being across all ages and both sexes. The findings are supported by psychological, physiological, including neuromuscular, evidence[11]. Quality of life scores improved significantly with condition training. With prolonged exercise training, runners seem to become more self-sufficient and more relaxed than before running. Jasnoske and Holmes have observed significant correlation between aerobic capacity and greater self-assurance and reduced tension[11]. However, overexercising and repetitive competition can have harmful physical (staleness), psychological (tension, anxiety, and depression), and social (isolation) consequences[12]. The interaction of many factors--expectation, distraction, self-motivation, social interaction and therapeutic attention--has been suggested to be the cause of the beneficial effects of exercise on psychological status. Physiological effects include improved cardiovascular fitness, increased cortical cerebral blood flow and hemispheric synchronization, and reduced resting muscle action potential. Biochemical changes include increased peripheral and central catecholamine levels and activation of the opioid-hypothalmic-pituitary-adrenal axis with co-release of beta-endorphins[13,14].

## Rational nutrition is a prerequisite for exercise.

The famous saying, Life is an exercise" illustrates the importance of exercise. However, the best effects of exercise on health are achieved with scientific guidance for training with rational nutrition. For example, iron

Correspondence address: Professor Chen Ji-Di, The Third School of Clinical Medicine of Beijing Medical University, 49 North Garden Road, Haidian District, 100083, Beijing, China
Tel: +86-01-201-7691 Fax: +86-01-201-7700

deficiency is the main cause of anemia in Chinese children and adolescent athletes[15]. Iron deficiency anemia (IDA), even in a mild form affects physical work capacity and work efficiency[16,17]. In turn, exercise affects iron absorption[18] (Table 1).

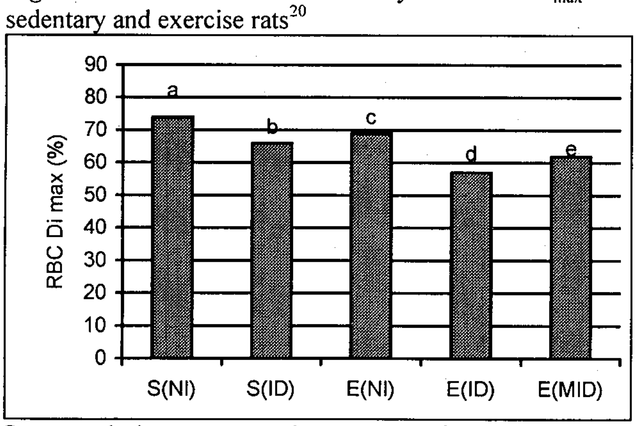
**Table 1**. Effects of exercise training on iron absorption rate of child soccer players

| Indices | Training period | Non-training period |
|---|---|---|
| Dietary $^{58}Fe$ intake during expt'l period (μg) | 221 ± 40 | 226 ± 42 |
| Oral intake of $^{58}Fe$ (μg) | 923 ± 0 | 923 ± 0 |
| Total amount of $^{58}Fe$ intake (μg) | 1144 ± 40 | 1148 ± 42 |
| Output of fecal $^{58}Fe$ (μg) | 1056 ± 56 | 1012 ± 68 |
| Iron absorption rate (%) | 9.1 ± 2.9* | 11.9 ± 4.7 |

(Adapted from Huo Zhou Ping and Chen Ji Di et al[18])
*Data compared to non-training period showed significance, P< 0.05

The proportion of dietary heme iron of Chinese athletes is low. The loss of iron through sweat in athletes cannot be neglected[19]. A study of the affects of IDA on erythrocytes showed that the damage was more serious in exercised rats with IDA. Loss of the band 3 protein of erythrocyte (RBC) membrane and the significant decrease of RBC deformability index percentages in the exercised rats with IDA implicated RBC membrane skeleton damage and a shortening of RBC life span[20] (Fig 1).

**Figure 1**. Effects of iron deficiency on RBC $Di_{max}$% of sedentary and exercise rats[20]




Data not sharing a common letter on top of the columns differ significantly. S-sedentary; E- exercise; NI- normal iron feed (iron content: 44ppm); ID- iron deficiency feed (iron content: 4ppm); MID- mild iron deficiency feed (iron content: 14ppm)

**Table 2.** Changes of RBC MDA levels, RBC SOD and GSH-Px activity of athletes after a bout of aerobic exercise

| | RBC MDA (nMol/gHb) | RBC SOD (μg/gHb) | RBC GSH-Px (μ/gHb) |
|---|---|---|---|
| Pre-exercise | 21.5±0.9 | 399.3±12.0 | 687.5±20.3 |
| Post-exercise | 31.4±1.3* | 397.2±13.6 | 859.5±26.9** |

(Adapted from Cao Guo Hua and Chen Ji Di[21])
*Data compared with pre-exercise, P< 0.05
**Data compared with pre-exercise, P< 0.01

These results have provided evidence for the importance of iron nutrition for athletes. Intense exercise, with or without stress, was found to increase serum lipid peroxide levels. Lipid peroxides accumulated in the body are a direct cause of many diseases including age-related disease and even aging itself. RBC malonic dealdehyde (MDA) increased significantly after a bout of acute aerobic exercise (cycling at heart rate 170/min on a Monark Ergometer for 60 min)[21] (Table 2).

If the activities of free radical elimination enzymes such as superoxide dismutase (SOD) and glutathione peroxidase (GSH-PX) increase concurrently, the appropriate defensive system is working during exercise. Moderate exercise, especially after physical load has been adapted, has been found to decrease blood MDA levels and increase the free radical elimination enzyme activities[21-22]. RBC MDA levels were significantly lower and SOD and GSH-PX activities were significantly higher in elite athletes from the national training team than in those from university because nutritional and training status were both much better in elite athletes (Table 3).

**Table 3**. Comparison of MDA levels and SOD and GSH-Px activity between elite athletes and student athletes

| | Elite athletes (n=30) | Student athletes (n=12) |
|---|---|---|
| Plasma MDA (nMol/ml) | 1.58 ± 0.04 | 1.87 ± 0.25 |
| RBC MDA (nMol/gHb) | 16.26 ± 1.12 | 21.21± 0.87** |
| RBC SOD (μg/gHb) | 500 ± 20 | 408 ± 11* |
| RBC GSH-Px (μg/gHb) | 873 ± 10.6 | 657 ±18.8** |

**Data compared with elite athletes, P< 0.001 * P< 0.05
(Adapted from Cao Guo Hua and Chen Ji Di[23])

It was also found that RBC SOD activity was significantly correlated with RBC zinc levels (r = 0.495, P < 0.05)[23]. Zinc deficiency leads to an increase of free radical generation, lipid peroxidation, and a depressed hepatic CuZn-SOD activity in both sedentary and exercised mice. Exercise strengthened the free radical elimination but zinc deficiency abolished the exercise induced adaptation[24] (Table 4,5).

**Table 4.** Effects of zinc deficiency on MDA levels of liver tissue of mice (n= 8)

| | | cytoplasm (nMol/mg prot) | mitochondria (nMol/mg prot) |
|---|---|---|---|
| Zinc deficiency | Non-exerc | 0.184±0.017[a] | 0.174± 0.007[a] |
| | Exerc | 0.171± 0.014[a] | 0.205± 0.013[b] |
| Pair fed | Non-exerc | 0.093± 0.005[b] | 0.111+ 0.006[c] |
| | Exerc | 0.123± 0.007[c] | 0.171± 0.010[ad] |
| Normal control | Non-exerc | 0.120± 0.008[c] | 0.145± 0.011[d] |
| | Exerc | 0.121± 0.007[c] | 0.148± 0.006[d] |

Data sharing a common letter at the upper right does not differ significantly, P> 0.05 (Data adapted from Cao Guo Hua and Chen Ji Di[31])

**Table 5.** Effects of zinc deficiency on SOD activity of mice

| | | Blood (μ/ml ) | Liver cytoplasm (μ/mg prot ) | Liver mitochondria (μ/mg prot ) |
|---|---|---|---|---|
| Zinc deficient | non-exerc | 480±15.1[a] | 84.9±2.3[a] | 21.9±1.6[a] |
| | exerc | 513±19.8[ab] | 86.6±3.1[ab] | 24.9±1.2[ab] |
| Pair fed | non-exerc | 508±21.7[ab] | 91.3±2.4[bc] | 23.7±0.9[a] |
| | exerc | 551±11.6[bc] | 98.5±5.1[c] | 28.7±1.8[b] |
| normal control | non-exerc | 527±14.3[b] | 95.9±2.4[c] | 22.1±0.9[a] |
| | exerc | 593±20.0[c] | 119.2±3.9[c] | 27.6±1.5[b] |

(Adapted from Cao Guo Hua and Chen Ji Di[24]) No significant differences were seen if the data share a common letter at the upper right, P>0.05 n=8

Study of the effect of exercise and zinc deficiency on murine immune function showed that zinc deficiency and food restriction are both harmful to T-cell function. There is a decrease in splenic mononuclear cell (MNC) number, and a reduction in proliferation response of splenic cell to Con A and of IL-2 secretion[25] (Table 6). Exercise exacerbated the damage caused by zinc deficiency and food restriction. Zinc repletion only partially repaired the damage of immune function induced by zinc deficiency.

**Table 6.** Effects of zinc deficiency and exercise on murine splenic lymphocytes (X±SD)

| | | MNCx10[6] spleen | Con A (cpm) | IL-2 (cu/ml) |
|---|---|---|---|---|
| n | | 9 | 8 | 6 |
| ZD | T | 6.08±1.85[a] | 3867 ±231[a] | 3.27 ± 0.65[a] |
| | S | 8.66±2.75[a] | 5353± 1967[a] | 4.08± 1.86[ab] |
| PF | T | 16.02±7.67[ab] | 6294± 1836[b] | 5.32± 3.48[b] |
| | S | 22.06±12.79[b] | 15469±5228[c] | 15.15±5.81[c] |
| AL | T | 35.9±18.84[c] | 18275±5195[c] | 32.93±11.18[d] |
| | S | 43.77 ±14.17[c] | 19472± 1967[c] | 23.97[e]±10.82 |

ZD: zinc deficiency; PF: pair fed; AL: ad libitum T: exercise group; S: sedentary group. Data without a same letter differ significantly, P< 0.05 (Adapted from Feng Jian Ying and Chen Ji Di[25])

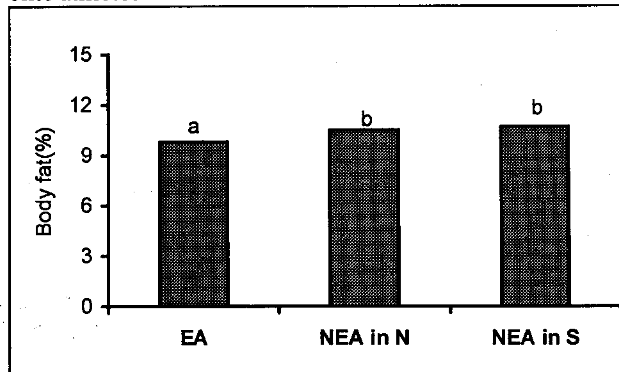
A three year follow-up study of a group of female gymnasts on long term weight control diets showed detrimental effects including growth retardation, menstrual disturbances, malnutrition, mental stress, and muscular weakness. The weight and height of the gymnasts were much smaller and shorter respectively than similarly aged urban girls. This effect may reflect both diet and selection of gymnasts. The menarche was delayed by one to two years, the average age for the observed gymnasts to have their first menstruation was 15.6 ± 1.58 years. It was 17.8 ± 0.57 years for those who had developed secondary amenorrhea and took medicines for the retarded menstruation. Energy, protein and minerals were in negative balance.

Diet improvements for female gymnasts included an increase of calories to > 90% of the recommendation and protein intake to 1.9g/ kg of weight. Increased vegetable, fruit, and milk product intakes to ensure adequate of mineral and vitamin status were encouraged. There were improvements in growth and development, nutrient balance, and mental stress, with no increase of body fat. Weight reduction should be discouraged if athletes train normally and their body fat does not increase or is under 10% of their total weight[26,27].

**Exercise should begin in childhood.**

Adequate exercise training with proper nutrition, started during childhood, will produce the best health benefits. Differences in diet, exercise, and health may affect the growth and development stages to a certain extent. Exercise is important for skeletal development[28]. Physical exercise probably induces bone mass increment by stimulating osteogenic cells by a piezoelectric mechanism. A sedentary lifestyle will induce bone mineral absorption due to poor mechanical stresses acting on the bone with an increase in urinary calcium excretion. In general, exercise during growth, creates a skeleton composed of denser, stronger bone that is better able to withstand stress[28,29].

**Figure 2.** Comparison of body fat between elite and non-elite athletes[26]




Data not sharing a common letter on the top of the columns differ significantly EA: elite athletes from national team; NEA in N: non-elite athletes in Northern parts; NEA in S: non-elite athletes in Southern parts

Exercise started in childhood is also very important in the prevention of obesity. Obesity is known to be related to an increased risk of more than 20 diseases such as hypertension, coronary heart disease, diabetes, hyperlipidemia, cholelithiasis, cancer, and osteoarthritis. When several risk factors are combined, the overall risk is many times greater. Obesity induces serious psychological effects as well. Obese people can have less muscle mass than people of normal weight if not active. In addition, the cardiovascular demands of activities are greater in the obese[28]. Limitation of physical activity may contribute to begin a vicious cycle. The prevention of obesity is particularly important during periods of rapid growth, as fat cells multiply during these times. Body fat tissues can be enlarged by increasing either the amount of fat stored in each cell or by increasing the number of cells in adipose tissue. The number of fat cells seems to increase up to about 16 years of age, after which increased fat ordinarily accumulates by increasing the size of cells already present. Fat cell number does not decrease with weight loss, but the size of the cells can be dramatically reduced by diet and exercise. Obesity of childhood onset is the most severe and is characterized by adipose tissue which contains 4-5 times the number of fat cells as people of normal weight.

Approximately 80% of obese children remain obese as adults and thus the outcome of obesity treatment is much more likely to be difficult and negative[30]. Body fat of students who exercise regularly compared to less physically active students is often lower and lean body mass tends to be higher[31]. Percentages of body fat of elite national gymnasts were significantly less than those of provincial athletes[26] (Fig. 2).

The evidence shows that regular exercise and appropriate diet may prevent the development of fat cells and thus be a factor in lifelong weight control[28,30]. Exercise not only promotes growth and development of bone and muscle, it also enhances the growth of muscle strength and improves muscle coordination capacity through the central nervous system. Thus, children and adolescent athletes are much stronger in coping with physical load and stress than less active children, and the onset of fatigue comes late in athletes with physical load[28,30]. Therefore, the fostering of regular exercise habits early in childhood can play an important role in the life-long maintenance of health. Medical professionals, parents, and educators should ensure that children grow into accomplished and secure adults by encouraging physical activity.

**Conclusions**

1. The benefits of exercise are:
(1) Exercise may reduce the risk factors for chronic diseases such as obesity, coronary heart disease, diabetes, and osteoporosis.
(2) Exercise may improve human functional status and metabolism.
(3) Exercise improves psychological status and capacity to cope with stress.

2. Adequate physical load defined scientifically and rational nutrition are the prerequisites for exercise. Malnutrition such as iron or zinc deficiency, not only affects work capacity, but also induces an increase in lipid peroxide levels and impairs immune function. Long term food restriction is harmful for adolescent athletes and should be discouraged.

3. The fostering of regular physical activity habits early in childhood can play an important role in the maintenance of health and quality of life. Physical exercise stimulates bone and muscle development. Exercise during growth creates a skeleton composed of denser, stronger bone and muscle mass that is better able to withstand stress because muscle strength is improved. Exercise started in childhood helps prevent obesity and is crucial for good mood and psychological state.

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Benefits of physical activity on nutrition and health status: Studies in China

# 运动的益处

陈吉棣

北京医科大学运动医学所营养生化研究室

**摘要：**

运动对健康的重要意义在于运动可改变慢性病的危险因素、改善人体机能和心理状态。合理营养和科学指导训练是运运的前提。研究表明即使是轻度的缺铁性贫血、也会影响体力工作能力。剧烈运动会增加血清和红细胞脂质过氧化物水平，但中小强度运动会减少脂质过氧化物水平并增加自由基清除酶(SOD，GSH－px 和 cat)活力。优秀运动员体内 MDA 水平低、GSH－$p_x$ 酶活力高。锌缺乏不仅会引起自由基生成和脂质过氧化物增加和 SOD 酶活力下降、还有害于免疫功能。缺铁或缺锌引起的损伤可因运动加重。体操运动员长期控制饮食的有害影响包括生长后延、月经紊乱、营养不良、精神紧张和肌肉无力等。全面营养改善促进生长、校正营养不良状况但不引起体脂增加，运动有利于骨骼与肌肉的生长发育，加强肌肉力量。快速生长期予防肥胖特别重要。儿童期建立运动的生活方式将取得最佳的健康效益。

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