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Effect of Mountaineering Training on Selected Body Measurements and Physical Fitness in Children

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ABSTRACT Among the sojourners, there is a general decline in work efficiency at high altitude. Muscular activity is limited by the rate at which the muscles are supplied with oxygenated blood in the rarefied atmosphere. During exercise, oxygen consumption is greater both at sea level and at high altitude. Low oxygen pressure coupled with physical exercise has a tremendous pressure on human beings. Mountaineering training imparts not only the skills for scaling the vast heights, but also improves performance of individuals at high altitude. The present study was conducted to study the effect of mountaineering training on selected body measurements and physical fitness tests on a group of Adventure course students (Boys = 40, Girls = 38) of Nehru Institute of Mountaineering, Uttarkashi, India. There is an improvement in most of the measurements and physical fitness tests after training. For example, grip strength of the hands, muscular endurance, cardio-respiratory endurance, agility and balance improved significantly after training for mountaineering both in the boys and the girls. From the study, it may thus be concluded that mountaineering training promotes healthy living and is also useful for acclimatization to high altitude.

INTRODUCTION

The highest pinnacle on earth, the Himalayas, has beckoned the mountaineers and novices since ages. The spirit and lure of the Himalayas is being spread rapidly over the globe, specially among the adventurous lot. Also, recent advances in transport technology and an increased interest in adventure sports have expanded the geographical areas to human activity. However, scaling these vast heights is no child's play. It has increased the risk of high altitude disorders among the untrained people. Recognising the fact that adventure sans training may prove detrimental, many institutes and voluntary organisations have started imparting proper mountaineering training along with necessary aids and equipment viz., crampons, ice-axes, ropes and guides, etc. Every year numerous individuals interested in expeditions enrol themselves in one of such institutes in order to gain hands-on experience before venturing out there on their own. Many a times this training also becomes mandatory because of the need of getting acclimatised to high altitude conditions, especially for the lowlanders.

High altitude is a multiple environmental stressor which consists, besides hypobaric hypoxia, of cold, dry air, difficult terrain and increased cosmic radiation. The most important stress at high altitude is low atmospheric/ oxygen pressure. Shortly after arrival at high altitude, even light exercise induces an acute reduction in the degree of arterial haemoglobin saturation. To encounter this, physiological functions, particularly cardio-respiratory functions, are improved to release the required energy by supplying adequate amount of oxygen to the tissues (Baker,1969; Frisancho,1969; Malik and Singh, 1979; Meer et al., 1995; Beall et al., 1998).

At high altitudes, where the ambient oxygen partial pressure is low, the arterial haemoglobin oxygen saturation is also low even in a well-acclimatised and healthy person. High altitude natives are considerably better adapted to the environmental conditions there as compared to the visitors of the area (Balke, 1972; Ward, 1975; Meer et al., 1995). It is well documented that shortly after arrival at high altitudes, even healthy subjects suffer severe fatigue or dyspnea following light work or exercise (Pugh et al., 1964; Shigeru et al., 1995). The working capacity of the high altitude visitors is, therefore limited by dyspnea, whereas, the high altitude natives can work without experiencing any such symptoms due to suitable acclimatisation in them (Lahiri, 1972). Apart from physiological responses, an interacting complex of socio-cultural, demographic and biological factors play a significant role to cope up with this situation. Among the sojourners, acclimatisation to high altitude takes place gradually over a period of time. An immediate response to high altitude exposure is hyperventilation, which is one of the most effective mechanisms of altitude acclimatisation during the initial phase. However, the initial increase in the cardiovascular parameters of the visitors on exposure to high altitude gradually reverses with the process of acclimatisation (Pace et al., 1964; Cunningham et al., 1965; Hoon et al., 1976; Selvamurthy et al., 1981; Purkayastha et al., 1989). Acclimatisation to high altitude depends on the point in time the exposure starts and on the severity of the exposure and occurs during the lifetime of an individual.

Acclimatisation to high altitude conditions is a form of acquired adaptation. Previous investigators have reported the instances of acclimatisation and related changes in the mountaineers (Green et al., 1989a, 1989b; Rose et al, 1988). An important aspect of acclimatisation to high altitude is to get used to the progressive lack of oxygen in the atmosphere. A few preliminary practice sessions of short trekking in the hilly areas, coupled with moderate exercises to increase oxygen intake capacity, appear to be suitable means of enhancing the level of acclimatisation among the visitors as well as the natives. The intermittent working habits of the natives provide them an edge over the continuous working schedules (involving exercise) of the high altitude visitors. As a consequence, the visitors get exhausted faster than the high altitude natives. Besides, some other limiting factors of exercise at high altitude are diffusing capacity of the lungs and cardiac output.

Initially on exposure to high altitude, while the diffusing capacity of the lungs decreases slightly among the high altitude visitors after exercise, cardiac output on the other hand, increases. Also, physical performance at high altitude improves after periods of long stay at high altitude (Ward et al., 1989; Serebrovskaya and Ivashkevich, 1992). Even during short stay, physical working capacity of the visitors can be enhanced to some extent by providing them proper training (Pugh et al., 1964; Shigeru et al., 1995).

Mountaineering training is known to improve the aerobic capacity of both trained athletes and novices (Ward, 1975; Ward et al., 1989; Meer et al., 1995). During this training, the body undergoes several changes, particularly in physiology, that are beneficial for the overall well-being of the individual. The present study attempts to explore the changes in selected body measurements and improvement in the performance of certain physical fitness tests after undergoing a training in mountaineering in a group of Adventure course (Beginners' Level) individuals.

AIMS OF THE STUDY

The present study examines the role of mountaineering training in enhancing the general level of physical fitness in children. The study aims at reporting and comparing the pre-training and post-training observations in selected body measurements and physical fitness tests in a group of boys and girls undertaking a beginners' level training course in mountaineering at one of the prestigious Mountaineering Institutes in India.

MATERIALS AND METHODS

Forty boys and thirty-eight girls of Adventure Course (110 and 111 Batch respectively), of Nehru Institute of Mountaineering (NIM), Uttarkashi (Uttar Pradesh, India) in the age range of 13-17 years were selected for the present study. All the subjects were apparently healthy, physically fit and keenly interested in the outdoor activities. Most of them belonged to schools in Dehradun, Tehri and other nearby areas. The duration of the Adventure Course was 20 days. Out of these, initial three days were spent at the base camp (Institute) where lectures on mountaineering were provided along with physical training to handle the mountaineering kit. The students were taken every morning for a long walk/ trekking in the hilly terrain to build up stamina. A doctor, who trained them to use oxygen mask in case of an emergency, accompanied the group during the entire training session.

The pre-training measurements were taken immediately on the arrival of the respective batches of boys and girls at the Institute, before the actual training started. After the initial training at the base camp (Institute), the students were taken to different camps at varying altitudes where they were trained to indulge actively in various events, such as rowing, canoeing, digging, camping (using make-shift tents), etc. After completion of the outdoor training, the students returned to the base camp at the Institute. The post-training measurements were taken at this stage respectively for boys and girls in the order of their arrival at the base camp. Due to strictness in adherence of the rules of the Institute, only a limited time was provided by the training instructors to enable us record these measurements.

The body measurements selected for the study included body weight, upper arm circumference, calf circumference, skinfold at triceps, skinfold at subscapula, skinfold at suprailic and skinfold at calf. These measurements were taken using standard techniques (Tanner et al., 1969). The physical fitness test items selected for the study comprised of right and left hand grip dynamometer, sit-ups, shuttle run, balance flamingo, limb movement, rapid fitness index, systolic blood pressure, diastolic blood pressure and pulse count. The fitness test battery items were selected and administered following the guidelines provided in earlier studies (Council of Europe -Eurofit Manual, 1988; Claessens et al., 1990). The fitness test battery comprised few items of health related component of physical fitness, whereas other items belonged to motor fitness component of physical fitness. For example, right and left hand grip dynamometer, rapid fitness index, sit-ups belong to health related aspect of physical fitness and shuttle run, limb movement, balance flamingo belong to motor fitness aspect of physical fitness (Gakhar and Malik, 1999).

All the measurements were taken twice, i.e., before and after training. Using paired analysis of variance (paired ANOVA), differences were observed before and after training in each body measurement and physical fitness test to understand the effect of mountaineering training. Significance of F values between pre- and post-training observations was checked at 5% probability level.

RESULTS AND DISCUSSION

The mean values and their standard deviations of the pre-training and post-training body measurements and physical fitness test results in boys and girls are presented in table 1 and table 2 respectively. Results of paired analysis of variance (ANOVA) are also provided in these tables. Body weight decreases significantly in boys as a result of mountaineering training, whereas it increases significantly in girls (Table 1; Fig. 1). Besides the differences in body

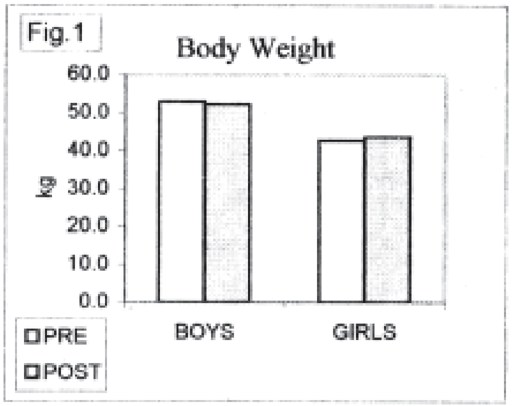
Table 1: Distribution of body measurements, by sex, by training

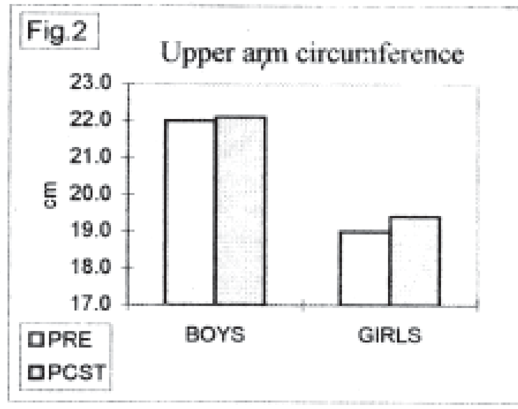
Variables	*Pre-training*		*Post-training*		*Paired ANOVA*			
	Mean	*S.D.*	*Mean*	*S.D.*	*Mean difference*	*S.D.*	*Value of F*	*Probability*
Males								
Body weight (kg)	52.9	6.99	52.2	7.04	0.7	1.56	7.73	.05>P>.02
Upper arm circumference (cm)	22.0	3.22	22.1	3.15	0.0	0.75	0.07	.8>P>.7
Calf circumference (cm)	31.5	2.75	32.1	2.78	0.5	0.80	17.90	P<.001
Skinfold at triceps (mm)	28.4	3.08	28.5	3.38	0.1	0.98	0.48	.5>P>.4
Skinfold at subscapula (mm)	28.6	6.84	30.3	5.24	1.7	5.58	3.51	.1>P>.05
Skinfold at suprailiac (mm)	28.6	4.20	28.9	6.21	0.3	5.81	0.12	.8>P>.7
Skinfold at calf (mm)	27.6	6.98	23.9	8.19	3.7	4.24	31.09	P<.001
Females								
Body weight (kg)	42.6	6.20	43.6	6.03	1.0	1.23	25.11	P<.001
Upper arm circumference (cm)	19.0	1.53	19.4	1.54	0.4	1.11	5.78	.05>P>.02
Calf circumference (cm)	28.8	1.92	29.1	1.99	0.3	0.58	11.19	P<.001
Skinfold at triceps (mm)	29.1	5.27	29.2	5.26	0.1	2.72	0.03	.9>P>.8
Skinfold at subscapula (mm)	30.1	3.44	30.8	3.68	0.7	3.16	1.85	.2>P>.1
Skinfold at suprailiac (mm)	30.3	3.54	30.4	3.99	0.2	3.09	0.09	.8>P>.7
Skinfold at calf (mm)	31.9	6.48	30.4	7.09	1.5	3.16	8.64	P<.001

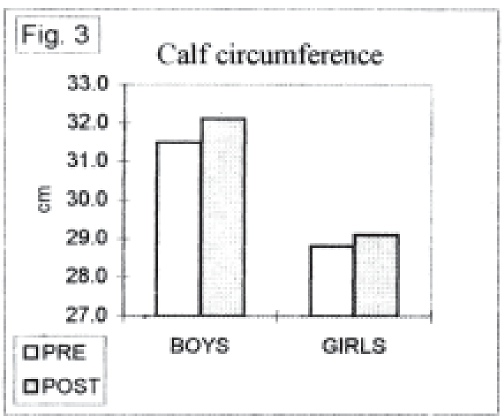
Table 2: Distribution of physical fitness tests by sex, by training

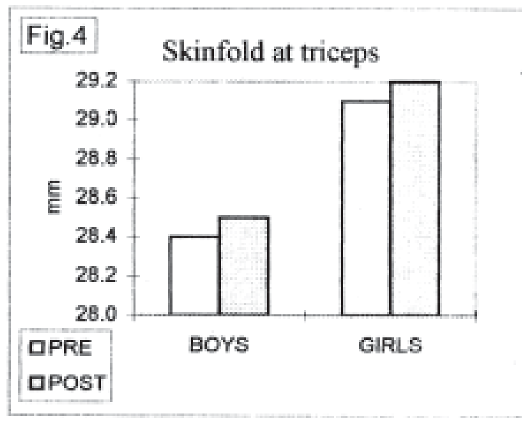
Variables	*Pre-training*		*Post-training*		*Paired ANOVA*			
	Mean	*S.D.*	*Mean*	*S.D.*	*Mean difference*	*S.D.*	*Value of F*	*Probability*
Males								
Right hand grip strength (kg)	34.6	6.99	36.4	6.51	1.8	1.29	72.94	P<.001
Left hand grip strength (kg)	34.1	6.36	35.2	6.01	1.1	1.50	19.57	P<.001
Sit-ups (number of sit-ups/min.)	29.8	3.35	38.6	2.80	8.8	3.96	195.96	P<.001
Shuttle run (time taken in sec.)	14.3	0.67	13.7	0.57	0.6	0.78	23.30	P<.001
Balance Flamingo (no. of falls/min.)	2.0	1.28	1.2	0.80	0.9	1.09	23.93	P<.001
Limb Movement (no. of taps/20 sec.)	88.6	4.55	91.0	4.66	2.4	3.76	16.57	P<.001
Rapid Fitness Index	72.1	4.16	90.8	6.85	18.6	6.68	311.97	P<.001
Systolic Blood Pressure (mm Hg)	119.4	5.44	118.8	2.82	0.6	5.18	0.45	.5>P>.4
Diastolic Blood Pressure (mm Hg)	76.8	4.09	78.4	2.27	1.6	4.22	5.72	.05>P>.02
Pulse count (beats/min.)	81.6	8.85	75.5	3.32	6.1	6.58	33.75	P<.001
Females								
Right hand grip strength (kg)	23.3	4.00	24.9	3.74	1.6	1.48	42.87	P<.001
Left hand grip strength (kg)	21.2	4.36	22.2	4.32	1.0	1.51	17.43	P<.001
Sit-ups (number of sit-ups/min.)	24.0	2.09	31.8	2.70	7.8	2.83	288.49	P<.001
Shuttle run (time taken in sec.)	15.1	0.91	14.2	0.68	0.9	0.96	34.81	P<.001
Balance Flamingo (no. of falls/min.)	2.3	1.31	1.6	0.91	0.7	1.43	9.36	P<.001
Limb Movement (no. of taps/20 sec.)	91.4	5.95	93.3	4.50	1.9	4.47	6.63	.05>P>.02
Rapid Fitness Index	64.5	6.11	75.8	7.05	11.3	6.58	112.36	P<.001
Systolic Blood Pressure (mm Hg)	117.1	3.93	116.7	4.19	0.4	2.38	1.19	.2>P>.1
Diastolic Blood Pressure (mm Hg)	76.1	4.75	75.8	4.38	0.3	2.51	0.42	.6>P>.5
Pulse count (beats/ min.)	86.1	13.01	76.8	4.29	9.3	10.45	30.20	P<.001

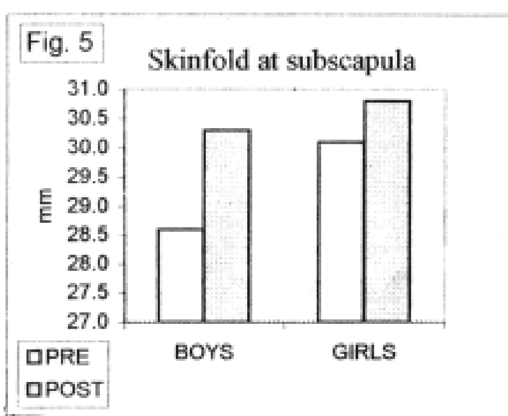
morphology in the two sexes, the effect of nutrition is also evident here. It is due to the fact that in India, especially in rural areas and smaller towns, some discrimination still exists between the rearing of the sons and the daughters. Body weight in boys decreases as a consequence of mountaineering training because their work output during training is comparatively greater than their indulgence in exercise at home, even if nutritional intake is better. On the other hand, the girls have increased body weight after training because of better nutritional intake, although their work output is similar to the regular household chores in which they indulge while at home. Upper arm circumference and calf circumference increase both in boys and girls (Table 1; Fig. 2-3) after training, though non-significantly. Recent studies on the effects of prolonged exposure to low oxygen pressure at altitude above 2000m, during real and simulated ascents to Mt. Everest on human performance capacity and muscle structure and function, suggest that body and muscle mass reduces significantly (Rose et al., 1988). This also explains the reduction in body weight in the boys after training. In contrast to these results, recent experimentation in human exercise settings at high altitudes have demonstrated that if exposure to extreme altitude condition is only present during a limited period of an endurance training session, there is a different effect on the muscle tissue. In one such study, training was found to increase muscle fibre size, capillary, myoglobin concentration and muscle oxidative capacity in individuals exposed to high altitude (Hoppeler and Desplanches, 1992). An increase in body dimensions after training in girls in the present study can be explained on this account. These findings raise the scope for further research on the control of protein metabolism in muscle tissue at high altitude in the presence or absence of training. Skinfolds at triceps, subscapula and suprailiac increases after training in both boys and girls (Figs. 4-6), but the increase is not significant statistically in any of these measurements. However, skinfold at calf decreases significantly after training both in boys and girls (Fig. 7). As the participants indulged regularly in various leg muscle exercises during training, excess body fat at calf region seem to have melted away.











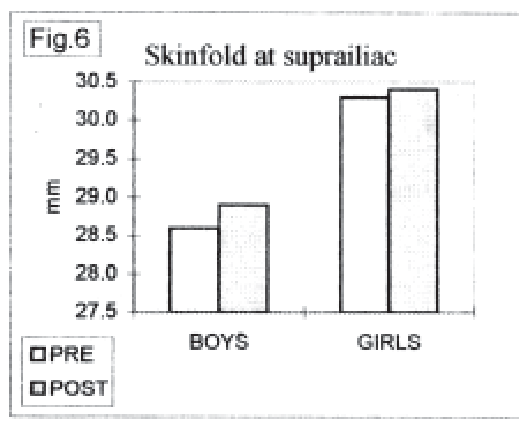


Fig. 1-6. Impact of training on Body Weight (Fig. 1), Upper Arm Circumference (Fig. 2), Calf Circumference (Fig. 3), Skinfold at triceps (Fig. 4), Skinfold at subscapula (Fig. 5), Skinfold at suprailiac (Fig. 6) in boys and girls

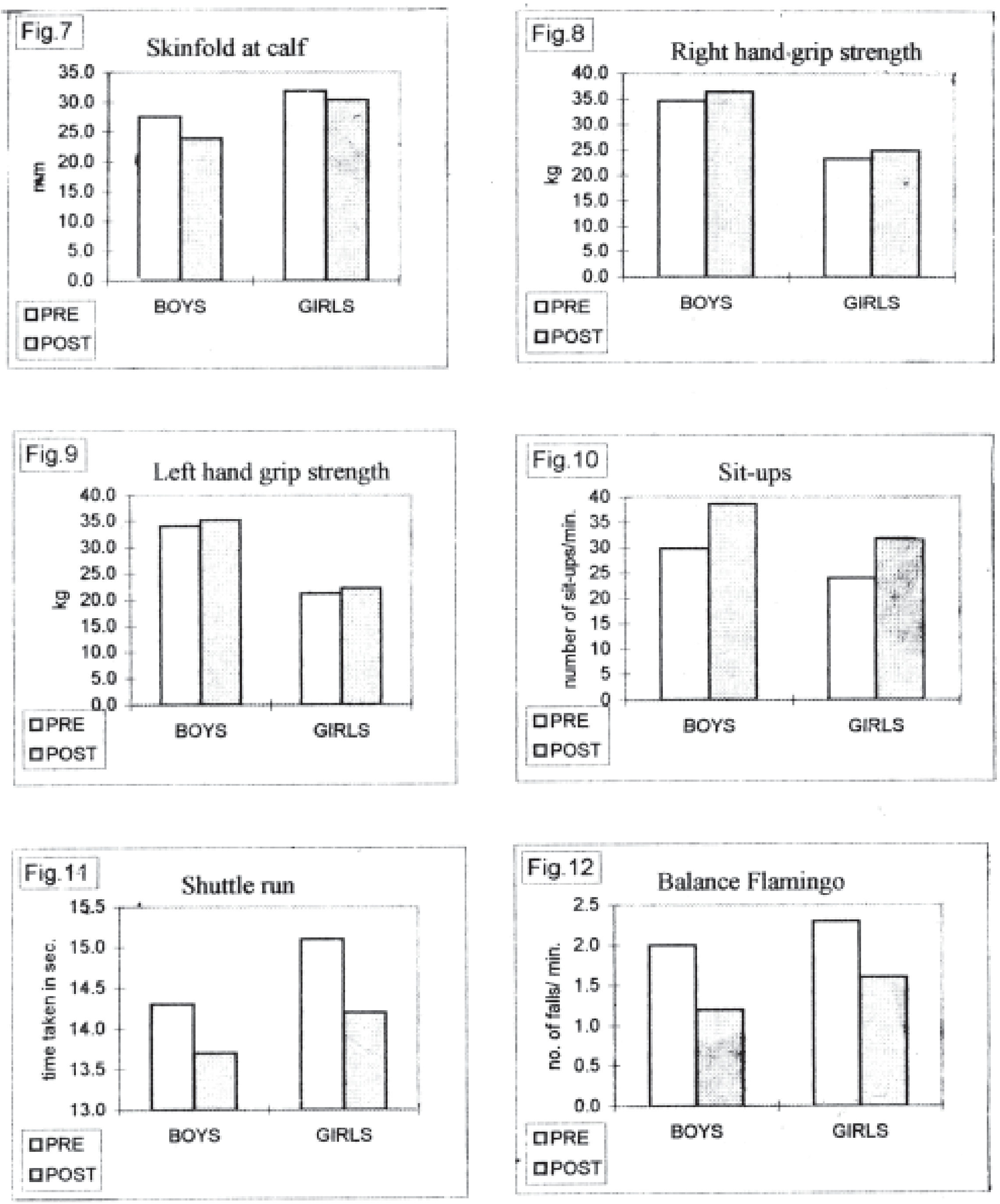


Fig. 7-12. Impact of training on Skinfold at calf (Fig. 7), Right hand grip strength (Fig. 8), Left hand grip strength (Fig. 9), Sit-ups (Fig. 10), Shuttle run (Fig. 11), Balance flamingo (Fig. 12) in boys and girls

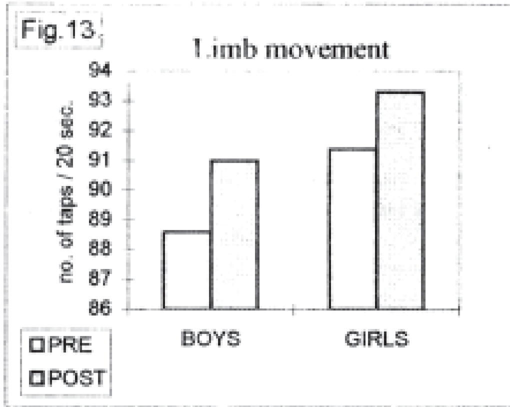
Right and left hand grip strengths (components of health related fitness) increase significantly as a result of the mountaineering training in boys and girls (Figs. 8-9). Muscular endurance at the abdominal region, as evaluated through the number of sit-ups performed per minute by the subjects, also increases significantly after mountaineering training both in boys and in girls (Fig. 10). Studies of muscle energetics during exercise and the effects of training in the same subjects at high altitudes have reported changes in muscle fibre composition, capillaries, enzyme activity, etc. (Young et al., 1982; Chance et al., 1986; Bender et al., 1989; Green et al.,1989a, 1989b; Kuno and Itai, 1992; Kuno et al., 1994). They also suggested that the effects of high altitude training on muscle energetic metabolism during exercise may have possibly been brought about by an improved oxidative capacity of mitochondria.

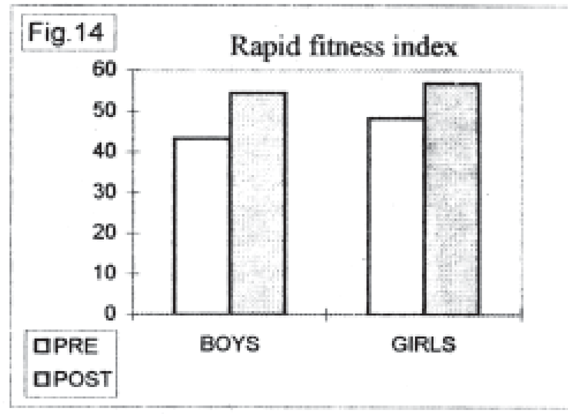
Speed of shuttle run and limb movement (components of motor fitness) show a post-training increase in boys and girls (Table 2). Balance flamingo stand results also depict an improvement after training both in boys and girls (Fig. 12), as there is a decline in the average number of falls per minute from the balance beam. As discussed earlier, physical fitness has two major components - health related fitness and motor fitness. Among these two components of physical fitness, the health related component is further divided into strength, cardio-respiratory endurance and flexibility as components. Motor fitness, on the other hand, comprises agility, speed and balance as components. Each one of these components of health related fitness and motor fitness is assessed using a combination of certain items of the physical fitness test battery. A detailed account of various tests employed to assess various components of physical fitness is provided in our earlier work (Gakhar and Malik, 1999).

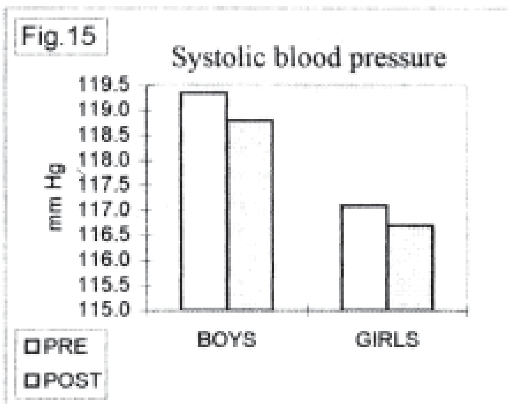
In conformity with the improvement in most of the physical fitness parameters after training, i.e., increase in strength (grip strengths of right and left hand), muscular endurance (sit-ups), agility (shuttle run and limb movement) and balance (balance flamingo), a significant increase is also observed in rapid fitness index in both boys and girls as a consequence of the mountaineering training (Fig. 14).

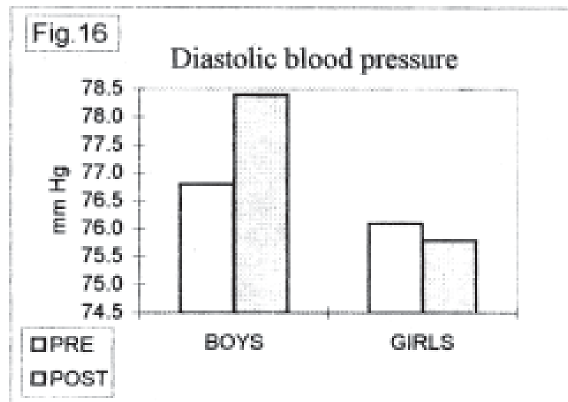
There is a significant decline in the pulse count of the subjects (both boys and girls) after training (Fig. 17). Since the main criteria for a successful adaptation to extreme environmental condition is the capacity to perform work, the characteristic and statistically significant decline in pulse count of the subjects after training ensures better adaptability. As expected changes in blood pressure are only marginal between pre-training and post-training sessions in boys and girls (Table 2). Diastolic blood pressure increases in boys and decreases in girls after training (Fig. 16). Earlier studies have shown that cardiac output at high altitude natives at rest is similar to that attained at sea level (Penaloza et al., 1963; Banchero, 1987). In humans, the low oxygen pressure of high altitude sets a mild degree of pulmonary arterial hypertension with associated alterations in the structure of the peripheral portions of the pulmonary arterial tree (Williams, 1994). Natural acclimatisation in humans is exemplified by the native Aymara or Quecha Indians of the Andes, who have not lost their hypoxic pulmonary pressor response to alveolar hypoxia (Greska et al., 1994; Beall et al., 1998). In others, changes in ventilatory sensitivity to high altitude represent one of the crucial factors of human altitude adaptation.

Physical exercise is itself known to enhance cardiac functions by reducing the effect of fatigue, for example, proper training through regular exercise reduces pulse count after exercise. Some studies have shown that there is a decrease in respiratory sensitivity in high altitude natives (Sorensen and Severinghaus, 1968; Lahiri and Edelman, 1969) and an increase in ventilatory responses of sea-level natives residing for a short time (from several days to about one month) at altitude (Read and Kellog, 1958; Forster et al., 1969; Burki, 1984; Serebrovskaya and Ivashkevich, 1992). Lower systolic but not lower diastolic blood pressure was earlier reported in humans living at high altitude compared to sea level residents (Heath, 1988; Diaz et al., 1990). Similar results are also observed in the present study, particularly in males (Table 2). Females, however, depict lower systolic and diastolic blood pressure after training. A possible









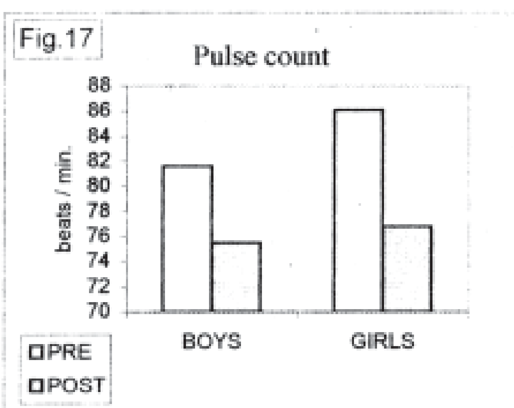


Fig. 13-17. Impact of training on Limb movement (Fig. 13), Rapid fitness index (Fig. 14), Systolic blood pressure (Fig. 15), Diastolic blood pressure (Fig. 16), Pulse count (Fig. 17) in boys and girls

explanation for this may require further research in the area.

In the present study, mountaineering training has been found to have a positive impact on the general performance of the human body, as it includes a judicial incorporation of several parameters related to promote healthy living, since it enhances grip strength, muscular endurance, cardio-respiratory endurance, agility, balance and also lays the foundation to withstand the extreme environmental stress of exposure to high altitude both among the sea-level and the native individuals.

CONCLUSION

Training individuals for a rapid ascent into high altitude, i.e., mountaineering training leads to a wide range of changes in body functions or alterations in certain physiological and physical fitness parameters. The influences which lead to these changes are those inherent in the environment of high altitude, especially the low oxygen pressure in the atmosphere. Although it has been known since long to induce changes in the bio-energetic processes in humans, reduction in oxygen demand may also result in increase of resistance to fatigue after a workout in the high terrain. This is possible due to significant decline in pulse count after mountaineering training. It is evident from the results that different body measurements respond differently to the stress of high altitude and the associated influence of mountaineering training on the subjects. Some measurements depict decline in values, while most of them show an increase after training both in boys and girls. The environmental response is, however, not uniform in all the physical fitness measurements. The differences accrue because of variation in genetical make-up, ecosensitivity, socio-cultural factors, and degree, kind and amount of stress.

A significant increase was observed in various body measurements such as, body weight, upper arm circumference, calf circumference, skinfolds at triceps, skinfold at subscapula and skinfold at suprailiac among a group of boys and girls indulged in a beginners' level training course in mountaineering. Skinfold at calf declined significantly after training both in boys and girls due to regular participation in leg muscle exercises comprising of long distance walks, climbing, running, etc. The group of trainee mountaineers also improved on various components of their physical fitness as evident from the better scores achieved by them in various physical fitness tests after training. For example, significant improvements were observed in majority of the physical fitness parameters selected for the study, *viz.*, grip strength, muscular endurance, cardio-respiratory endurance, agility and balance in both boys and girls.

Hence, it may be concluded that among the many aspects of mountaineering, *viz.* administrative, physical and mental, technical or educational and social, the physical fitness aspect is of much importance. In a mountaineering institute, different measures are taken before and after training to keep the body and mind of a mountaineer fit. Such a practice makes mountaineering one of the most interesting, useful and sought after adventure sports in India. It promotes the necessity of maintaining healthy living among the masses, while giving an impetus to adventure tourism in the country.

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