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The effects of an aerobic arm cranking program on children with myelomeningocele

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THE EFFECTS OF AN AEROBIC ARM CRANKING PROGRAM ON CHILDREN WITH MYELOMENINGOCELE

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CHAPTER I

INTRODUCTION

The number of men and women with lower extremity disability is growing (Pollock, Miller, Linnerind, Laughridge, Coleman, and Alexander, 1974). A chief cause of this growth is an increase in the number of accidents damaging the spinal column (Pollock et al., 1974). However, many individuals are also born with these types of disabilities, and one of the causes is a disease termed spina bifida. Spina bifida occurs in about 3 per 1000 live births (Batshaw & Perret, 1981). The spine of children born with this defect is bifida and may be exposed, along with nervous tissue surrounding the area, on the surface of the body (Anderson, Clarke and Spain, 1982). This area is termed meningomyelocele and the nerves are not able to grow beyond this point (Batshaw & Perret, 1981). A cyst forms on the back where the tissue protrudes; however, if the sac contains only the tissues surrounding the nerve cord (not the cord itself) then the defect usually does not cause a handicap (Anderson et al., 1982). This is called meningocele (Anderson et al., 1982). Another form of spina bifida is termed myelomeningocele. In myelomeningocele the nerves surrounding the opening are exposed or lie near the skin's surface and the cord is abnormal (Anderson et al., 1982). A child with this form of spina bifida may need walking aids along with having disrupted bowel and bladder control (Batshaw & Perret, 1981). Another common complication of children with myelomeningocele is hydrocephalus (Batshaw & Perret, 1981). A shunt usually helps alleviate this fluid accumulation into the abnormalities are scoliosis, kyphosis, dislocated hips and limb deformities (Anderson et al., 1982). These disorders can be corrected by orthopedic surgery in the early years; however, some final corrective surgery may be done in the teens (Anderson et al., 1982).

Another mobility problem of children with handicaps is obesity (Anderson et al., 1982). Guy (1978) conducted a study of 23 physically handicapped and 23 able-bodied children to investigate the importance of appetite and activity on their growth. The children with handicaps were 68 percent overweight as a whole; however, those children with spina bifida were 100 percent overweight. Spina bifida children with hydrocephalus are more likely to put on excess weight along with having a short stature (Anderson et al., 1982). Those who are overweight may have problems walking with crutches along with putting pressure on unstable joints (Anderson et al., 1982). It is important to alter not only the activity of handicapped children but the appetite as well, to help prevent and treat obesity (Anderson et al., 1982).

Zwiren, Huberman and Bar-Or (1973) studied cardiopulmonary functions of both sedentary and highly active paraplegics. They concluded nonactive wheelchair individuals have a lower cardiovascular endurance, higher body weight and higher percent fat than the sedentary normal population. It would be beneficial if individuals with spina bifida or similar disabilities could be screened at an early age for coronary heart disease risk factors or deficiencies in physical fitness levels. From these results preventive programs could be established accordingly. The role that motor activity plays in a child's skill and perceptual, social and emotional development is vital (Morrissy, 1978). Motor activity is not only crucial in perceptual and intellectual development (Morrissy, 1978) but in physiological development as well. Hancock, Reed and Atkinson (1979) measured bone and soft tissue changes in femoral bones of 66 paraplegics by radiation. They noted paraplegics had a significantly lower bone and muscle fat ratio in soft tissue adjacent to the femoral bone than the normal population. Basset and Becker (1979) stated that the normal process of maintaining bone mass is related to muscle activity since patients exhibit a loss of calcium in bones after bed rest. Hancock et al. (1979) recommend that patients begin early mobilization to inhibit the loss of bone mass.

Guttman (1979) stated four values of sport of physical activity for the spinal cord sufferer:

1. Sport has a therapeutic value because it is the most natural form of remedial exercise,
2. Sport has a recreational value,
3. Sport assists in improving psychological readjustments of the paralyzed and,
4. Sport is a means for social integration of the paralyzed.

However, before the handicapped patient is able to reap the full benefits of sport or exercise he/she needs to participate in physical training and/or rehabilitation programs. Pollock et al. (1974) used an arm cranking ergometer to show the physiological responses to endurance training. Several studies have used arm pedaling ergometry to measure physiological training responses in paraplegics (Zwiren and Bar-Or, 1975; Hildebrandt, Voigt, Bahn, Berendes and Koger, 1970). From these studies it was concluded that paraplegics have low fitness levels and have shown improvement in their cardiorespiratory and muscular fitness levels following training.

As stated by Morrissy (1978), intensive therapy during rehabilitation needs to be incorporated into the child's environment. Therefore, exercise and recreational programs designed to aid the individual in improving his/her fitness level should be supplemented with social activity as well.

Social and emotional development of adolescents with myelomeningocele could be enhanced by participation in group exercise programs.

Ankenbrand (1981) showed significant increases in skill, self-concept and acceptance among college students with disabilities after an eight week recreational bowling program. Dalton (1981) found depression scores of men and women who were disabled decreased significantly following an eight week endurance training program. However, the individuals were also taking vitamin B-12 supplement and therefore, it was difficult to separate the effects of the vitamin on the scores from that of exercise.

Most rehabilitative programs for the handicapped are designed to deal with the health needs of the individual instead of their cardiorespiratory fitness (DiCarlo, 1982). Wicks, Oldridge, Cameron and Jones (1983) in working with spinal cord injured subjects, attested to the need for further research in this area. They stated that data on exercise responses are more widely available for cardiac and respiratory patients than the spinal cord injured.

Although previous research has dealt primarily with trying to define the cause of spina bifida, more recent attempts have been directed to bettering the lifestyles of the individuals. Any attempt that is made to improve alternatives the individual has in enhancing his/her physical and psychological growth is vital and worthwhile.

Since few studies have assessed the effect of physical activity on children with spina bifida, it was the purpose of this study to measure the physiological responses occurring in children with spina bifida (myelomeningocele form) following an eight week aerobic arm cranking training program.

CHAPTER II

PROBLEM

Purpose

The purpose of this investigation was to determine the effects of an eight week aerobic arm cranking program on the cardiorespiratory, muscular fitness and body composition of children (ages 8-15) with myelomeningocele. A secondary purpose of this study was to compare these responses to those of able-bodied children (ages 8-15 years).

Hypotheses

The .05 level of probability was used as the criterion for statistical significance.

Within Group

1. Posttraining maximal oxygen uptake (ml·kg·min) of both groups will be significantly greater than the pretraining score using arm ergometry.
2. Posttraining resting heart rate of both groups will be less than the pretraining resting heart rate.
3. Posttraining body composition of both groups will change in the following ways:

a. The posttraining weight will be significantly less than the pretraining weight.

b. The posttraining sum of skinfolds will be significantly less that the prettraining sum of skinfolds.

4. The muscular fitness in both groups will change in the following ways:

   a. The posttraining muscular endurance will be significantly greater than the pretraining muscular endurance.

   b. The posttraining muscular strength will be significantly greater than the pretraining muscular strength.

   c. The posttraining muscular power will be significantly greater than the pretraining muscular power.

5. Posttraining flexibility in both groups will be significantly greater than the pretraining flexibility.

6. Posttraining forced vital capacity will be significantly greater in both groups than the pretraining forced vital capacity.

Between Group Hypotheses

1. The able-bodied subjects will have a significantly greater pre-and posttraining maximal oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$) score than the myelomeningocele subjects.

2. The able-bodied subjects' body composition will differ from the myelomeningocele subjects' body composition in the following ways:
   a. The pre- and posttraining weight of the able-bodied group will be significantly less than that of the myelomeningocele group.
   b. The pre- and posttraining sum of skinfolds of the able-bodied group will be significantly less than the sum of skinfolds of the myelomeningocele group.
3. The able-bodied group's muscular fitness will differ from the myelomeningocele group's muscular fitness will differ from the myelomeningocele group's muscular fitness in the following ways:
   a. The able-bodied subject's pre- and posttraining muscular endurance will be significantly greater than the myelomeningocele group's muscular endurance.
   b. The able-bodied group's pre- and posttraining muscular strength will be significantly greater than the myelomeningocele group's muscular strength.
   c. The able-bodied group's pre- and posttraining muscular power will be significantly greater than the myelomeningocele group's muscular power.
4. The able-bodied subjects' pre- and posttraining flexibility of both the elbow and shoulder will be significantly greater than the flexibility of the elbow and shoulder in the myelomeningocele group.

5. The able-bodied subjects' pre- and posttraining forced vital capacity will be significantly grater than the myelomeningoceles forced vital capacity.

Delimitations

Eight male and female adolescents with myelomeningocele and ten male and female adolescents between the ages of eight and fifteen were used in this study. Subjects were obtained from St. Thomas Moore Grade School and area schools in the Omaha, Nebraska vicinity.

Limitations

The following extraneous variables may have affected the results of this study:

1. Limited local muscle endurance and strength, limited motivation or not reaching maximal exhaustion may have prevented some of the subjects from achieving true maximal oxygen consumption scores.
2. Even through the training sessions were supervised it was sometimes difficult to keep all the children motivated at all times to maintain their respective training heart rates.

3. No control groups were used because of the limited availability of children (ages 8-15 years) with myelomeningocele. Therefore, any physiological changes which occurred may have been influenced by the childs' growth cycles. Also because of the use of numerous t-tests there may be a chance of a type I error.

Definition of Terms

Spina Bifida - congential birth defect in which the spinal cord and surrounding nervous tissue may be exposed on the surface of the body. This congenital closure defect (failure to close opening) usually occurs in the lower lumbar area and can result in varying degrees of paralysis depending on the lesion cite.

Myelomeningocele - a form of spina bifida in which the nerves surrounding the opening are exposed and the spinal cord in abnormal. A child with this form of spina bifida usually requires some type of ambulatory aid and has disrupted bowel and urinary control.

Able-bodied Adolescents - are those individuals between the ages of eight and fifteen who are healthy and able to ambulate upright with no major difficulties.

Physiological Responses - the changes occurring in the subject's maximal oxygen uptake (ml·kg·min), body weight, percent fat, sum of skinfolds, muscular strength, power and endurance, flexibility, resting heart rate, and forced vital capacity following the eight week training program.

Arm Endurance Training - a form of physical training in which the subjects' train (cycle) on a modified Monarch bicycle with their arms. The exercise was classified as primarily aerobic and was performed three times per week for at least 15-20 minutes.

CHAPTER III

Review of Literature

Introduction

Numerous studies dealing with the benefits and effects of physical training have been conducted (Pechar, McArdle, Katch, Magel and DeLuca, 1974; Siegel, Gunner and Mitchel, 1970; Vokac, Bell, Bauz-Holfer and Rodahl, 1975). However, limited documented research has been completed on adolescents with lower-limb disabilities such as myelomeningocele, which documents the responses to chronic aerobic training. In addition, spinal centers do little to rehabilitate the spinal cord sufferers' cardiorespiratory systems (DiCarlo, 1982).

Due to the limited amount of literature that has been written on handicapped children and adolescents the Review of Literature was categorized as follows: acute responses of handicapped and able-bodied individuals to exercise, chronic responses of adults to arm exercise and, acute and chronic responses of handicapped and able-bodied children to exercise.

Acute Responses of Adults

Wicks et al. (1983) used 72 elite male (n=61) and female (n=11) physically disabled athletes to investigate the cardiorespiratory responses to progressive incremental arm cranking and wheelchair ergometry. Male tetraplegics' peak power during wheelchair ergometry (8.3 $\pm$ 2.3 $kpm \cdot min^{-1}$) and arm ergometry (36.9 $\pm$ 9.8 $kpm \cdot min^{-1}$) was significantly less ($p<0.001$) than paraplegics' peak power during wheelchair ergometry ergometry (39.4 $\pm$ 3.1 $kpm \cdot min^{-1}$) and arm ergometry (1.11 $\pm$ 9.3 $kpm \cdot min^{-1}$). The peak $\dot{V}O_2$ ($l \cdot min^{-1}$) for male paraplegics during wheelchair ergometry (1.92 $\pm$ 0.41) and arm ergometry (1.96 $\pm$ 0.57) was significantly greater ($p<0.001$) than tetraplegics' peak $\dot{V}O_2$ during wheel chair ergometry (0.97 $\pm$ 0.32) and arm ergometry (0.88 $\pm$ 0.21). Female paraplegic peak $\dot{V}O_2$ ($l \cdot min^{-1}$) during arm ergometry (1.24 $\pm$ 0.16) and wheelchair ergometry (1.11 $\pm$ 0.26) was significantly less ($p<0.001$) than that in males. They concluded that the differences between the performance levels of spinally injured subjects are probably due to the site of the lesion. The authors stated that cardiac and ventilatory limitations to exercise may in part be due to the degree of impairment of the neural mechanism. They indicated that an increased level of performance may be achieved if a greater degree of sympathetic neural pathways is preserved.

Glaser, Sawka, Laubach and Suryaprasad (1979) studied eighteen able-bodied male subjects who underwent progressive, discontinuous wheelchair ergometry (WERG) and bicycle ergometry (BERG) tests to examine the cardiopulmonary and metabolic responses to exercise. Heart rate (HR) and maximal oxygen consumption ($\dot{V}O_2$ max) increased linearly with power output (PO) levels (30,90 and 150 $kpm \cdot min^{-1}$ in both WERG and BERG tests. During the WERG tests, greater lactate (LA) (32.1 $\pm$ 5.0 mg.100 ml vs. 18.8 $\pm$ 2.8 mg·100 ml) values were found following exercise ($p<0.05$). Significantly greater pulmonary ventilation ($\dot{V}E$), respiratory exchange ratio (R) and ventilatory equivalent ($\dot{V}E/\dot{V}O_2$) values at each PO level were found in the WERG when compared to those resulting from BERG exercise ($p<0.05$). They stated that these results could have indicated a lower metabolic efficiency that is caused by movements of the lower limbs and trunk during wheelchair ergometry. These inefficient biomechanics do not aid in force application on the hand rims (Glaser et al., 1979). The authors however, concluded that both modes of exercise could be used to increase cardiorespiratory fitness.

Different responses of the cardiorespiratory system to submaximal and maximal arm cranking as compared to leg exercise was studied by Franklin, Vander, Wrisley and Rubonfire (1983). They developed a prediction equation and table to estimate steady-state oxygen (O_2) cost of arm ergometry when direct measurement were not available. Arm cranking during submaximal exercise elicited significantly greater ($p<0.05$) HR, $\dot{V}O_2$ ($l \cdot min^{-1}$) and VE ($l \cdot min^{-1}$) values than leg exercise at the same submaximal workloads. During maximal tests, leg exercise elicited significantly greater ($p<0.05$) values in those variables than those during arm exercise. The maximal workload achieved by arm ergometry (675 $kpm \cdot min^{-1}$) was only 55 percent of that achieved during leg exercise (1,230 $kpm \cdot min^{-1}$).

The arm $\dot{V}O_2$ max (2.54 ± 0.45 $l \cdot min^{-1}$) was only 80 percent of that achieved by leg exercise (3.17 ± 0.53 $l \cdot min^{-1}$). The differences may be explained by a low venous return to the heart (Hjeltnes, 1977) and a higher sympathetic drive during arm work as compared to leg exercise (Hjeltnes, 1977).

Two methods of body composition testing along with skinfold measurements were used to determine body density and percent fat in two female wheelchair athletes (Lussier, Knight, Bell, Lohman and Morris, 1983). Underwater weighing and potassium 40 (K40) activity by whole body scintillation counter difference between the two methods. The skinfold prediction of percent fat conflicting. The three methods of skinfold prediction used to estimate percent fat were the Sloan, Burt and Flyth (1962), Wilmore and Behnke (1970) and Katch and McArdle (1973). The percent estimates for each skinfold equation were: subject one, 17.7, 21.9, 17.7 and subject two, 21.0, 25.5, 23.5, respectively. The authors suggested that new standards of interpreting the body composition for this population be established. They also contended that individuals in wheelchairs cannot afford to have excess weight because pressure ulcers and skin and soft tissue damage may occur. They suggested that adequate muscle mass needs to be maintained in order for the individual to perform transfers and other daily activities adequately.

Kannel, Hubert and Lew (1983) used data from the Framingham study to investigate the relationship of the Forced Vital Capacity (FVC) to the development of mortality in cardiovascular disease. FVC was adjusted for height to account for differences in stature. The coefficients for regression of cardiovascular occurrence on FVC were calculated by a standardized regression model which measured the strength of the relationship between FVC and cardiovascular morbidity and mortality. The univariate, bivariate (age and FVC) and multivariate (ECG, left ventricular hypertrophy, relative weight, heart rate, systolic pressure, cigarettes, glucose intolerance and cholesterol) cases were taken into account. Analysis was done on men and women ages 45 to 74 years. FVC ranked as a high predictor among the risk factors in cardiovascular morbidity and mortality ($p<0.01$). This was shown by the standardized partial regression coefficients in the multivariate case. The univariate correlations of FVC with cardiovascular risk factors were low. The authors stated that because of the limited information that was available it was difficult to claim that FVC is one of the major risk factors. However, the strongest correlation found for FVC may be a measure of general health and overall vigor.

Serial pulmonary function results in 187 patients with systemic sclerosis were presented by Schneider, Wise, Hachberg and Wigley (1982). They compared the rate of change in various measures of pulmonary function of subjects with systemic sclerosis to that of a normal population. The mean rate of loss of vital capacity for 38 patients studied over 63 months was more than three times the expected amount of loss for the normal population. Twenty-seven patients with systemic sclerosis had a diffusing capacity that was similar to that of a normal population. The authors stated that the pulmonary involvement in systemic sclerosis is a restrictive ventilatory defect that increases gradually. However, due to the individual variability of pulmonary function tests the authors did not advocate prognostication on the basis of initial pulmonary function testing.

Chronic responses of adults

Gass, Watson, Camp, Court, McPherson and Redhead (1980) used nine subjects with high level spinal lesions to study the effects of a seven week training regimen. Subjects trained five times a week on a motorized treadmill using a progressive, discontinuous protocol. There was a significant increase in mean minute ventilation, (34 percent), wheelchair time on the treadmill and $\dot{V}O_2$ max (52 percent $l \cdot min^{-1}$ and $ml \cdot kg^{-1} \cdot min^{-1}$). The authors indicated that the percent gain in cardiorespiratory fitness would be affected by the low initial level of $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$), inadequate innervation of intercostal and abdominal muscles and the number of years each subject was inactive.

Maximal $\dot{V}O_2$ uptake ($l \cdot min^{-1}$) and muscular strength and endurance were examined following a seven week training program (Nilsson, Staff and Pruett, 1975). Twelve paraplegics (22 to 55 years) trained three times a week on a modified Monark bicycle ergometer followed by a weight training program. The weight training program concentrated on the tricep brachii muscles because they are vital for crutch walking. However, the biceps and abdominal muscles were also trained. Results showed a significant increase in $\dot{V}O_2$ max from 1.88 to 2.08 $l \cdot min^{-1}$ ($p<0.025$), workload from 612 to 804 $kpm \cdot min^{-1}$ ($p<0.005$), mean dynamic strength from 64 to 74 kg ($p<0.005$) and mean endurance values from 10 to 18 repetitions ($p<0.01$). The effects of a ten week arm cranking training program were conducted by Pollock et al. (1975) on 29 sedentary males (22 to 55 years). Two experimental groups and a control group were used. Group two, which contained 11 able-bodied subjects, showed a significantly higher $\dot{V}O_2$ max ($ml \cdot kg^{1} \cdot min^{-1}$) and $l \cdot min^{-1}$ ($p<0.01$) and ($l \cdot min^{-1}$) ($p<0.05$) than group one, which consisted of eight lower-limbed disabled subjects. The authors suggested that the difference may have been due to the ability of group two to use their legs while propelling. They believed that group two was able to use their legs for added leverage, therefore, increasing the amount of muscle mass being used. Group two and the control group (n=10) also underwent $\dot{V}O_2$ max treadmill ($ml \cdot kg^{-1} \cdot min^{1}$ and $l \cdot min^{-1}$) testing.
Group two should a greater improvement in $\dot{V}O_2$ max during arm

exercise (1.23 $l \cdot min^{-1}$ increase and 14.6 $ml \cdot kg^{-1} \cdot min^{-1}$ increase, 39 percent) than in the $\dot{V}O_2$ max treadmill test (0.65 $l \cdot min^{-1}$ increase and 8.2 $ml \cdot kg^{-1} \cdot min^{-1}$ increase, 7 percent). They attributed this to specific physiological changes occurring due to specificity of training. Several studies have indicated that cardiorespiratory responses increase to a greater extent when the subject trains specific muscle groups which are used in the activity (Fox, McKenzie and Coher, 1975; McArdle, Magel, Delio, Toner and Chase, 1978; McCafferty and Horvath, 1977). Dreisinger, Londerece, Craig, Whiting and Dalton (1979) studied the effects of wheelchair ergometric training using 12 subjects confined to a wheelchair and 16 able-bodied subjects. Subjects trained 10 minutes, three times per week over an eight week period. Training was done using a stationary WERG. Subjects trained at 65 - 80 percent of their maximum oxygen consumption value. There was a significant increase ($p<0.05$) in O_2 uptake ($ml \cdot kg^{-1} \cdot min^{-1}$) following training.

An interval training program was initiated by Glaser et al. (1978) using wheelchair subjects. Four able-bodied females were pre- and posttested on the WERG to measure $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$), respiratory quotient (R), VE and heart rate up to a 150 $kpm \cdot min^{-1}$ workload. After five weeks of training, they noticed improvements in fitness levels by mean reductions in $\dot{V}O_2$ (19 percent $ml \cdot kg^{-1} \cdot min^{-1}$), (R) (3 percent), $\dot{V}E$ (27 percent) and heart rate (19 percent) values during submaximal work. They concluded that interval training can increase fitness levels and it may be beneficial in the speed and ease of rehabilitation.

Ten healthy males were used to investigate the peripheral and central effects of physical training in a study conducted by (Rasmussen, Klausen, Clausen and Trap-Jensen, 1975). The responses to exercise of trained and untrained leg and arm muscle groups were compared by examining the specificity of training effects on a respiratory and blood gas values. Five subjects trained five times a week for five weeks using an intermittent protocol. The remaining five subjects used the same protocol except the arm muscles were exercised. Significant decreases ($p<0.05$) after training in the $\dot{V}E/\dot{V}O_2$ was seen only during exercise with trained muscle groups (arm training = arms 3.340, legs 1.357 and leg training = legs 2,395, arms 0.415). No significant changes occurred following training in the arterial values of pH and partial pressure of carbon dioxide (PCO_2) during arm and leg exercise. The only change in PCO_2 in venous blood was at the 1.5 min of light and heavy arm exercise after leg training (values were presented in figures, therefore, no numerical data were recorded) ($p<0.05$). The authors suggested that the changes that occurred were primarily due to local adaptations.

Clausen Klausen, Rasmussen and Trap-Jensen (1973) examined the central and peripheral circulatory changes occurring in the legs and arms after training for five weeks. Thirteen able-bodied male subjects were divided into an arm training group (n=5) and a leg training group (n=8). Both groups showed significant decreases in heart rate at rest and exercise at all the workloads with trained as well as untrained muscle groups. The authors suggested that the bradycardia may have been caused by central circulatory mechanism changes occurring when large muscle masses are used. It was speculated that the arms may not be accustomed to heavy rhythmic exercise and therefore there could be a greater potential for local adaptations.

The effects of aerobic arm ergometry training for five weeks on spinally injured subjects were studied by DiCarlo, Supp and Taylor (1983). Four male subjects trained three times a week for thirty minutes on an arm ergometer using a discontinuous multistage protocol. They found a significant increase in $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$) by 60.54 percent and maximal workload ($ml \cdot kg^{-1} \cdot min^{-1}$ by 64.32 percent ($p<0.05$). The authors felt there is a need for cardiovascular training in spinally injured subjects because of their increased risk of obesity, stroke and coronary heart disease.

Twenty-five healthy male (n=5) and female (n=18) subjects (x = 22 years) were used to examine the effect of increased abdominal muscle strength on forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) (Simpson, 1983). The Cybex II Isokinetic device was used to measure peak torque during a trunk curl and for the training program designed to strengthen the abdominal muscles. Subjects trained at 24 degrees/second for 12 training sessions over a three week time period, four times per week. Each subject completed three sets of eight repetitions of isokinetic curl-ups which limits the validity of the study. A significant increase ($p<0.05$) in the mean torque values (ft.· lb.) between the experimental and control group was found after training (experimental = 115 $\pm$ 30 vs. control = 92 $\pm$ 24). There was no significant difference between the mean FVC and FEV_1 ($l \cdot min^{-1}$) values of the experimental group (3.86 $\pm$ 0.78 and 3.34 $\pm$ 0.52 and 3.05 $\pm$ 0.48) following training. Both groups showed increases in FVC and FEV_1 following the program. However, the changes were not significant (experimental FVC = 0.18 $l \cdot min^{-1}$ increase and FEV_1 = 0.11 $l \cdot min^{-1}$ increase and control FVC = 0.18 $l \cdot min^{-1}$ increase and FEV_1 $l \cdot min^{-1}$ = 0.14 increase). It was concluded that the increased abdominal strength does not appear to improve respiratory fitness (FVC and FEV_1) in healthy subjects. The author did not use ANCOVA to account for any initial differences between the groups which limits the study's validity.

Acute and Chronic Responses of Children

There are limited data dealing with the effects of training on normal, handicapped or obese children (Moody, Wilmore, Girandola and Royce, 1972; Fraser, Phillips and Harris, 1983; Godfrey, Davis, Wozniak and Barnes, 1971). Several of the studies have used only physical work capacity (PWC), heart responses or respiratory responses of children to exercise in analyzing the fitness level of adolescents. Not only is the research limited regarding the physiological responses of children to exercise but it is controversial. Katch (1983) attempted to hypothesize as to why there is conflicting research on the effects of training on children. He terms his hypothesis the "trigger hypothesis" which states that any biological changes occurring in prepubescents from training are small due to the lack of hormonal stimulation. In other words, the hormones which modulate and initiate puberty and development are not fully functioning. He states that there is a critical period in children's lives ("trigger point") which happens with the onset of puberty. Katch (1983) believes that little if any changes in physical fitness from training occur prior to this level of maturation. He states that this "trigger point" is due to the increased secretion of androgens and growth hormone (GH) which institutes the onset of puberty. He suggests that during prepuberty years more emphasis should be placed on skill acquisition and not physiological conditioning.

Ekblom (1969) studied the effects of exercise during the growth period before and after puberty of 14, 11-year old boys. Training was twice a week for 45-60 minutes over a 36 month time period. After six months, the training group showed a significant increase in $\dot{V}O_2$ max by 15 percent from 2.15 to 2.48 $l \cdot min^{-1}$ and a 10 percent improvement in relative $\dot{V}O_2$ max from 53.9- to 59.4 $ml \cdot kg^{-1} \cdot min^{-1}$. No significant improvement was found in the control group to $\dot{V}O_2$ max from 2.01 to 2.07 $l \cdot min^{-1}$ or from 49.9 to 50.2 $ml \cdot kg^{-1} \cdot min^{-1}$. The author questioned if it is possible to accelerate the growth rate by increased physical activity during these years. His study showed an accelerated increase in the training group's height when compared to the growth norm values of the Karlbert-Iggbom chart (1959). This acceleration was not found in the control group.

Prepubescent children ages 8-11 years were used to investigate the effects of physical training by Lussier and Buskirk (1977). The exercise program consisted of progressive, continuous training, two times a week for 10-35 minutes over a 12 week period of 45 minutes of running games or activities also conducted two times a week. The training intensity was 80 percent of their $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$) or 92 percent of their maximal heart rate value. Subjects elicited a significant increase ($p<0.05$) in $\dot{V}O_2$ max (from 55.6 to 59.4 $ml \cdot kg^{-1} \cdot min^{-1}$) following training. The control group showed no significant increase (from 53.1 to 53.9 $ml \cdot kg^{-1} \cdot min^{-1}$) following training. Submaximal heart rates decreased significantly from 129.3 to 119.8 ($beats \cdot min^{-1}$) ($p<.05$) during walking at 40 percent $\dot{V}O_2$ max and during running at 80 percent $\dot{V}O_2$ max from 187.9 to 174.4 ($beats \cdot min^{-1}$) (0.01). An increased stroke volume (SV) and arteriovenous O_2 difference were indicated by the authors as causing the increased aerobic capacity. They suggested that a prime reason why children may not increase their aerobic capacity following training may be due to the fact that the level of activity of children is already high enough to maintain their aerobic capacity.

Thirty-four male competitive endurance runners and fifty-six ordinary boys ages 12-16 years were studied by Sundberg and Elovainio (1982). A comparison of the two groups' functional and somatic variables was conducted. Skinfold thickness of runners age 14 (18.4 ≤ mm) and 16 years (19.8 mm) was significantly less ($p<0.01$) than that of the control groups age 14 (25.9 mm) and 16 years (27.8 mm). The percent body fat of the 14 (11.2 percent) and 16 year old runners (12.3 percent) was significantly less than that of their control counterparts (15.2 percent and 16.4 percent, respectively). The resting heart rate of the 16 year old runners (62 beats$\cdot$min^{-1}) was significantly lower that the 16 year old nonrunners (85 beats$\cdot$ mm^{-1}) ($p<0.001$). The $\dot{V}O_2$ max (ml$\cdot$kg$^{-1}\cdot$ min^{-1}) of the endurance runners (12 year olds = 59.3, 14 year olds = 63.7 and 16 year olds = 66.4) was significantly higher ($p<0.01$) than that of the nonrunners (12 year olds = 51.1, 14 year olds = 56.0 and 16 year olds = 56.1). Their study indicated that young competitive endurance runners may be leaner and have increased cardiorespiratory fitness levels than that of their non-running counterparts.

Thirteen boys ages 10-12 years interval trained four times per week for eight weeks to study the effects on the cardiorespiratory system (Stewart and Gutin, 1976.). The training consisted of alternating 1-minute and 3-minute periods of running with distances of 250 yards and 600 yards, respectively. The submaximal heart rates of all the workloads decreased significantly ($p<0.05$) during cycling and treadmill testing. However, there was no significant increase in VO_2 max in the training group. They reasoned that the children may already have an initial high level of fitness and therefore no significant improvement in $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$) scores were found. In order for a child's $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$) to increase following training the intensity level during training needs to be high enough to elicit a change (Stewart and Gutin, 1976). The authors stated that the changes found in the maximal effort values may be independent of changes occurring in submaximal cardiovascular fitness since the submaximal values decreased after training. They believed that using only $\dot{V}O_2$ max values to indicate cardiorespiratory fitness may be misleading and that submaximal values should also be considered when evaluating fitness levels in children.

Parizkova, Vaneckova, Sprynarova and Vambervoa (1971) compared obese and normal boys' (x = 11.8 years) physiological responses to exercise. The obese boys showed increased body weight due to increased body weight due to increased fat along with achieving maximal O_2 uptake ($ml \cdot kg^{-1} \cdot min^{-1}$) at lower running speeds and shorter times. They concluded that excess fat may affect physical efficiency during maximal effort.

Eighteen obese boys and 15 obese girls from the study then underwent a 28 week summer therapy camp. Their diet was altered to a 1700 $kcal \cdot day^{-1}$ with restrictions on fat and carbohydrate intake. The children also engaged in various types of physical activity along with an instructional period to aid nutritional results. The results showed significant decreases ($p<0.05$) in submaximal O_2 uptake ($ml \cdot kg^{-1} \cdot min^{-1}$) (boys = 11.6 to 9.7, girls 10.2 to 9.7) and in ventilatory rate (boys = 15.74 to 13.26, girls = 15.48 to 15.0). From their study they suggested that it is imperative to accurately diagnose and prevent early stages of obesity. In order to aid child health care, body composition and functional capacity of children should be controlled (Parizkova et al., 1971).

Corbin and Pletcher (1968) studied 50 fifth grade children's caloric intake and physical activity to determine the effects of physical activity and diet on the development of obesity. There was no significant difference in the amount of calories consumed or the amount of carbohydrates, proteins or fats consumed between obese and non-obese fifth grade children. However, the obese group was significantly less active ($p<0.05$) than at lease one of the non-obese groups in all situations of activity. They suggest that further restrictions of the diet may not be necessary since there was no significant difference in caloric intake between the two groups. They also stated that inactivity may be just as important or even more important in maintenance and development of childhood obesity than excess caloric intake.

Twenty-eight obese high school girls and twelve non-obese high school girls were used to study the effects of a jogging program on body composition (Moody et al., 1972). The program lasted 15 weeks with 19 subjects electing to continue for 29 weeks. The training was four times per week and consisted of a one mile run with equal walking and jogging. Eventually the distance progressed to 3-3.5 miles with 75 percent of the distance covered while jogging and 25 percent while running. There was no alteration in diet. Body density was determined by hydrostatic measurements. Normal and obese groups decreased significantly in skinfold measurements (Σ mm Δ 23.9 and 52.5 respectively). The obese group showed significant decreases ($p < 0.05$) in relative fat (from 38.88 to 36.55) and body weight (from 71.60 to 70.52) after the 15-week program. There were also significant increases ($p < 0.05$) in body density (from 1.0125 to 1.10178) and lean body weight (from 43.76 to 44.89) in the obese group. The non-obese group showed no significant changes. The authors stated that exercise may have an effect on food intake, appetite, basal energy levels and metabolic processes. They believe these may have caused the decrease in weight and fat found in the obese group. They also stated that there is a complex relationship between exercise and body composition which may be affected by the hypothalamus and endocrine systems. Moody et al. (1972) recommended that in order for more substantial changes to occur, diet modifications may also be needed.

Seventeen adolescents with severe motor handicaps trained 30 minutes, two times a week for six weeks to determine the physiological responses to training (Ekblom and Lundberg, 1968). The training was moderate, involving continuous training 2-5 minutes of large muscle groups, i.e., wheelchair driving, throwing a medicine ball, using dumbbells, levering movements in a wheelchair and on parallel bars. Two groups were formed based on the diagnosis of their handicap. Group one consisted of seven cerebral palsy adolescents and group two was composed of ten paraplegics. The cerebral palsy group showed no significant changes possibly due to the severity of their handicap (Ekblom and Lundberg, 1986). The paraplegic group showed significantly lower 0_2 uptake at submaximal workloads after training (from 0.63 to 0.70 $l \cdot min^{-1}$) ($p<0.01$). The submaximal heart rate was also significantly lower ($p<0.01$) following training (from 157.0 to 139.2 beats$\cdot$ min^{-1}). Blood lactate decreased significantly ($p<0.01$) from 42 to 25 mg$\cdot$100 ml during submaximal testing. During maximal testing the 0_2 was unchanged while the heart rate dropped significantly ($p<0.05$) (from 187.0 to 179.3 beats$\cdot min^{-1}$) and the blood lactate also decreased significantly ($p<0.005$) (from 74.00 to 64.60 mg$\cdot$100 ml) following training. Eight of the paraplegics could perform at 40 percent greater workloads during the maximal test following training. The study indicated that cardiorespiratory responses can increase in severely handicapped adolescents following training.

Dickman, Schmidt and Gardner (1971) measured pulmonary functions in children 5-years through 19-years. A computerized on-line 13.5 liter Collins spirometer was used to collect data. There were close correlations of FVC and FEV_1 with height, age and weight (males = 0.94, 0.91 and 0.93, respectively; females = 0.91, 0.89 and 0.90, respectively). The authors concluded from the data that normally healthy children's pulmonary function is closely related to growth and development. Differences between prepubescent boys and girls were slight. Pulmonary development increased during adolescence and differences between boys and girls were found. They also stated that height is a more reliable index of the onset of puberty than age.

Rothman (1978) studied the effects of breathing exercise on the vital capacity of children with cerebral palsy. Ten children were used with five in the experimental (x = 7.2 years) and five in the control group (x = 7.5 years). The following breathing exercises were used; diaphragmatic breathing, expiratory exercise, inspiration and expansion of the thorax, stimulation inspiration and strengthening of the abdominal musculature. The first exercise was performed every day for the entire program while the other exercises were each performed five days weekly for two weeks. Each exercise increased in difficulty with each period lasting five to seven minutes a day. The entire exercise regimen lasted a total of eight weeks. The experimental group had a mean increase in vital capacity of 31 percent ($p<0.005$) following the program. The control group showed no significant improvement. The pretest values for all the children were low when compared to normal predicted values presented by Polgar (1971). After the program the vital capacity measurements of the experimental group was 1.32 liters which was 94 percent of the predicted normal values of Polgar (1971). The author suggested that breathing exercises should be a vital part of cerebral palsy therapeutic programs for children.

Summary

It appeared from the review of literature that performance of spinally injured subjects during WERG and APERG testing may be influenced by the neurological functioning level present in the subjects (Wicks et al., 1983). Leg exercise elicited higher cardiorespiratory values as compared to those achieved during arm exercise (Franklin et al., 1983). This may be partially caused by a higher sympathetic drive during arm exercise than leg as well as a small muscle mass being used (Hjeltnes, 1977).

Training studies of able-bodied adults (Rasmussen et al., 1975 and Pollock et al., 1974) and lower-limbed disabled adults (Gass et al., 1980 and Nilsson et al., 1975) indicate an improved cardiorespiratory fitness following arm ergometry exercise. Literature dealing with adolescents and their physiological responses to training are limited and inconclusive. An explanation as to why the data are conflicting may be due to hormonal changes found in children (Katch, 1983 and Ekblom, 1969). Some studies have shown increases in cardiorespiratory fitness, specifically $\acute{V}O_2$ max scores (Ekblom, 1969 and Lussier and Buskirk, 1977), while other studies have only found increases in oxygen uptake scores during submaximal testing (Stewart & Gutin 1976 and Parizkova, et al., 1971). Obese children may also show increases in fitness levels following an exercise program (Parizkova et al., 1971).

Pulmonary studies also have shown that pulmonary function measurements increase following breathing exercises in children with cerebral palsy (Rothman, 1978) and with age, height and weight increases (Dickman et al., 1971. Simpson (1983) did not find any increases in pulmonary function measurements in healthy adult males and females following abdominal strength training.

CHAPTER II

METHODS

Introduction

The following chapter is the methodology used in studying the physical characteristics of children with myelomeningocele and their physiological responses to exercise.

Subjects and Sampling Procedures

A list of prospective adolescents with myelomeningocele was obtained from the Spina Bifida Association of Nebraska. Able-bodied adolescents were obtained from St. Thomas Moore Grade School in Omaha, Nebraska. Selection of subjects was on a volunteer basis. Potential subjects with spina bifida were advised to be screened by a medical examination for physical problems which may have affected the safety of the subjects. An area physical therapist who was or had treated several of the myelomeningocele adolescents also gave a verbal indication of problems some of the subjects might have while being involved in the study. Eight adolescents (six males, two females) with myelomeningocele and ten able-bodied adolescents (seven males, three females) were used in the study. The subjects were placed into two separate experimental groups. Subjects and guardians were informed of possible risks involved in the study before signing a consent form.

Variables and Measurements

Each subject was pre- and post-training tested following an eight week arm training program. Post-testing was conducted within one week of completion of the program. The post-testing protocol for the upper body testing was identical to the pre-tests.

Flexibility

A Leighton flexometer (1955) was used to measure shoulder and elbow flexibility. The flexometer was attached to the body segment located distally to the joint being tested. The full range of motion occurring in one plane was assessed using degrees as the unit of measurement. Each subject's sides were measured, with three trials being administered. The average of the two largest measurements with the least amount of deviation between them was used for data analysis.

Body Composition

Subjects were weighed underwater to determine body volume. The Siri equation (Siri, 1956) was used to calculate percent body fat. Subjects were immersed ten times. The three greatest values with the least amount of deviation among them were averaged to determine the underwater weight. Not all subjects were able to be underwater weighed adequately. Therefore, the sum of skinfold measurements was used to show changes in subcutaneous body fat. Skinfold thickness at the following sites was taken with a Harpenden skinfold caliper with a constant pressure being applied:

1. the midportion of the right bicep, located between the acromion process and olecranon process,
2. the right tricep located at the midportion between the acromion process and olecranon process,
3. the iliac fold located one inch vertically above the anterior superior iliac spine,
4. the interior apex of the scapula and
5. the vertical fold one inch to the right of the umbilicus.

Each site was measured three times and the average of the two closest values was used for data analysis.

Muscular Strength, Power and Endurance

The Cybex II Isokinetic Dynamomenter was used to determine muscular strength, power and endurance of the shoulder and elbow during extension and flexion. Positioning and recording was conducted using Cybex II Manual Protocol (1983). A Cybex II Dual Channel Recorder and Cybex Data Reduction Computer were used to collect college data. Subjects were seated on a Cybex II Upper Extremity Testing Chair. Restraining belts were placed across the subjects' chest and legs. For consistency in data collection in the sequence of testing for the pre- and post-tests was as follows: the right shoulder, left shoulder, right elbow and left elbow. Each subject warmed up with three to four practice trials at each speed. After an one minute rest period three maximal contractions were recorded for each speed. Subjects were allowed 45-60 seconds between each test to rest. The velocity for the shoulder and elbow tests was 60 degrees/second, 180 degrees/second and 300 degrees/second. Peak torque values were measured by the Cybex II Dual Channel Recorder. The endurance test consisted of the work produced (ft.lbs) by the flexors and extensors in 25 contractions at a velocity of 180 degrees/second. The Cybex II Data Reduction Computer was used to determine the amount of work completed.

Maximal Oxygen Uptake

A modified Monark bicycle was used during the maximal arm cranking test in which maximal oxygen uptake was determined. The ergometer was braced on a table. Subjects sat behind the ergometer with the shoulders level with the pedals. Each subject began cranking at 60 revolutions per minute ($r \cdot min^{-1}$) and zero resistance for two minutes. Subjects kept pace with a metronome set at 60 beats per minute. Every two minutes the resistance increased 0.1 $kg \cdot min^{-1}$ with the revolution remaining at 60 $r \cdot min^{-1}$ throughout the test. For the older and larger subjects the cranking pace was 65 $r \cdot min^{-1}$ and the resistance increased 0.2 $kg \cdot min^{-1}$ every two minutes for the first three stages and 0.1 $kg \cdot min^{-1}$ for the remainder of the test. A two minute rest period was given between each stage in order to help decrease local muscle fatigue before a true maximal state was reached (Gass et al., 1980; DiCarlo et al., 1983). Maximal exhaustion was determined by the following criteria:

1. The subject was unable to maintain the pedaling rate for two consecutive minutes,
2. voluntary exhaustion,
3. a respiratory quotient (R) of 1.00 or more and,
4. a relative plateauing of oxygen uptake ($\dot{V}O_2$) with less than a 150 ml increase with an increase in workload.

Oxygen concentration in the expired gas was analyzed by a Polagraphic Applied Electochemistry S-3A Analyzer. A Beckman LB-2 Analyzer was used to analyze the concentration of carbon dioxide (CO_2) in the expired air. Both analyzers were calibrated before each test using standard reference gas. A Parkinson-Cowan CD-4 dry gas meter was used to measure the inspired air volume. Heart rate was monitored on a Quinton 633 model Electrocardiograph (ECG). Modified placement of the electrodes was used to decrease the amount of artifact occurring from upper body movements. Leads were placed on the right and left suspraspinous portion of the scapula. Heart rates were recorded the last 15 seconds of each workload. Due to technical problems with the analyzers the post-tests were conducted in Peru, Nebraska with the following equipment: a Beckman (MMC1) Metabolic Cart with a Beckman LB-2 CO_2 and a

Beckman OM-11 analyzer and heart rates were monitored on a Marquetter 5000 ECG machine.

Forced Vital Capacity

Forced vital capacity (FVC) was determined using a 13.5 liter Collins Spirometer. Subjects were seated with a noseclip placed on their nose. Subjects were asked to breathe normally for three to four breaths and then maximally expire and precede for forcefully inspire and expire again to determine FVC readings. The best of three trials was used for data analysis.

Training Program

Each subject was encouraged to train at approximately 70 percent of his/her maximal heart rate attained on the pretest. Table 10 indicates the respective training heart rate of each subject. Each training session began with cranking at zero resistance followed by an one minute rest. The first two weeks, the subject pedaled a total of 15 minutes using a progressive discontinuous protocol. Each workload lasted five minutes interspersed with a two minute rest period. The heart rate was monitored for six seconds using the radial artery pulse. After 2.5 minutes of exercise the subject ceased cranking to allow for the pulse to be monitored in order to insure that the subject's heart rate was at his/her specified level. The heart rate was again monitored after each five minute workload. After completion of the workout the subjects continued to crank slowly for one minute. The subject then rested for three minutes and his/her heart rate was taken for one minute. Every two weeks the training period increased by five minute increments with an exercise duration lasting 30 minutes for the final two weeks.

Data Analysis

Dependent and independent t-tests were used to analyze pre- and post data between and within the two groups. The 0.05 level of probability was used to test for significance. ANCOVA was used to test for significant t-tests between groups if the pre-test data were significantly different. The Minitab and SPSS-X statistical packages from the VAX computer system at the University of Nebraska at Omaha were used for data analysis.

Significance of the Study

The results of the study may be beneficial in determining if adolescents with myelomeningocele can improve their cardiorespiratory fitness, muscular strength, power and endurance, flexibility, body composition and forced vital capacity following an aerobic arm exercise program. Results may also aid physicians, physical therapists, physical educators, exercise scientists, parents and patients in using exercises that will efficiently improve fitness levels in myelomeningoceles.

CHAPTER V

RESULTS

Introduction

The following chapter contains the results of the physiological changes which occurred after the eight week training program. The chapter was divided into three sections: within group changes, initial differences between groups and comparison of training changes between groups.

Within Group Changes

Descriptive data are summarized in Table 1. Neither groups showed a significant change in weight, height, FVE or sum of skinfolds after training. Flexibility results for both groups are summarized in Table 2. No significant change occurred in should or elbow flexibility in either group following training.

Table 3 shows the changes which occurred following training in the peak torque and muscle endurance of the myelomeningocele group. No significant change occurred in elbow flexion/extension data at 60 deg.sec, 180 deg.sec or 300 deg.sec after training. The myelomeningocele group's elbow endurance did not change significantly following training. At 60 deg.sec no significant change was shown in should flexion/extension results following training. Significant increases ($p<0.05$) in peak torque at 180 deg.sec were found in right shoulder extension, right shoulder flexion ($p<0.01$) and left shoulder extension ($p<0.05$). Right shoulder extension ($p<0.05$), right shoulder flexion ($p<0.01$) and left shoulder flexion ($p<0.01$) peak torque values at 300 deg.sec increased significantly after training. The only significant change which occurred during the endurance test was a greater right shoulder flexion ($p<0.05$).

Table 4 indicates the changes in torque and muscle endurance of the able-bodied group. No significant changes occurred in elbow flexion/extension peak torque values at 60 deg.sec or 180 deg.second. The only significant increase following training at 300 deg.sec was in left elbow extension peak torque ($p<0.05$). In the endurance test, right elbow extension, left elbow extension, right elbow flexion and left elbow flexion all increase significantly ($p<0.05$). At 60 deg.sec no significant changes occurred in the shoulder flexion/extension peak torque values. Only shoulder extension peak torque values improved significantly ($p<0.05$) at 180 deg.second. Significant increases in right shoulder extension ($p<0.05$), left shoulder extension ($p<0.01$), right shoulder flexion ($p<0.05$) and left shoulder flexion peak torque values ($p<0.05$) occurred at 300 deg.second. Right shoulder extension and left shoulder extension endurance tests showed significant increases ($p<0.05$) following training.

Cardiorespiratory changes following maximal arm ergometry tests are summarized in Table 5 for both groups. The myelomeningocele group showed no significant change in $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$ or $l\ min^{-1}$), $\dot{V}E$ (BTPS), R or heart rate max ($beats \cdot min^{-1}$) following training. Maximal heart rate following training was the only significant increase ($p<0.05$) which occurred in the able-bodied group. No significant change occurred in the $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$ or $l \cdot min^{-1}$), $\dot{V}E$ (BTPS) and R values following training of the able-bodied group.

Initial Differences Between Groups

Between group comparison of pre-test descriptive and flexibility data are presented in Table 6. The only significant differences in the pre-test data between the two groups was a greater height ($p<0.05$) and right elbow flexibility ($p<0.05$) in the able-bodied group when compared to the myelomeningocele group.

Table 7 indicates the between group comparison of the pre-test elbow peak torque and muscle endurance. At the elbow, the only significant difference was a greater ($p<0.05$) right elbow flexion peak torque in the able-bodied group as compared to the myelomeningocele group at 180 deg.second. Table 8 indicates the between group comparison of pre-test shoulder. At 60 deg.sec, the right shoulder flexion peak torque was significantly different ($p<0.05$) while no other differences occurred. Significant differences were found in peak torque values of right shoulder flexion ($p<0.01$) and left shoulder flexion ($p<0.05$) at 180 deg.second. The only significant differences at 300 deg.sec were found in right and left shoulder flexion peak torque (both $p<0.05$). On the endurance test (180 degree/second), the differences which occurred were in the right and left shoulder flexion (both $p<0.05$).

The pre-test cardiorespiratory responses in maximal arm ergometry between group comparisons are summarized in Table 9. The only significant differences found were in the $\dot{V}O_2$ max ($l \cdot min^{-1}$) and $\dot{V}E$ (BTPS) (both $p<0.05$). In all the variables which were significantly different, the able-bodied group had greater values.

Comparison of Training Changes Between Groups

Table 10 shows the between group comparison of all variables following training. No significant differences were found in the flexibility or descriptive data. At 60 deg.sec, 180 deg.sec and 300 deg.sec no significant differences were found in peak torque in the elbow tests. Significant differences were found in the endurance tests. Right elbow extension ($p<0.05$), right elbow flexion and left elbow flexion peak torque (both $p<0.01$) were significantly different between the groups. No significant differences were found at 60 deg. sec in the shoulder flexion/extension peak torque values. Left shoulder extension peak values at 180 deg.sec were significantly different ($p<0.05$) while at 300 deg.sec no significant differences were found. The right shoulder extension was significantly different ($p < 0.05$) between the two groups on the endurance test. The only significant difference in the cardiorespiratory responses was found in the maximal heart rate value ($p < 0.05$). In all of the above comparisons, training changes of the able-bodied group were greater than the myelomeningocele group except in the endurance test of the right elbow flexors.

CHAPTER VI

DISCUSSION

Introduction

This chapter provides a comparison of the results of this study with those of similar studies which used children as well as adults as subjects. The major divisions of the chapter are: body composition and FVC, flexibility, muscular strength and endurance and cardiorespiratory changes.

Body Composition and FVC

A review of the pre-post changes occurring in height, weight, FVC and sum of skinfold data showed no significant changes in either group. A comparison of training changes between groups also showed no significant difference in height, weight, FVC or sum of skinfold data. Gass et al. (1980) also found no significant changes in height, weight, circumferences of the chest, waist and arms and total skinfold measurements of seven high lesion spinal patients. Their arm training program lasted seven weeks. They suggested that the training duration and lack of negative caloric balance as possible reasons for no significant changes. Gass et al. (1980) also found no significant pre-post changes in FEV, FVC, and FEV percent following the program. This was in agreement with the present study. The authors speculated that this could be due to the interaction of three factors: (1) chronic inactivity,

(2) heavy cigarette smoking and (3) loss of innervation to the intercostal and abdominal muscles. However, in the present study the first two factors would not be applicable since the children were fairly young and did not smoke. It is interesting that the variables did not change due to maturation alone. Other studies with children have also not shown significant changes in these physical variables after training for at least six weeks (Vaccaro and Clarke, 1978; Massicate and Ross, 1974; Fournier, Ricci, Taylor, Ferguson, Montpetit and Chartman, 1982).

Simpson (1983) found no significant increase in FEV_1 and FVC of 16 healthy male and female ($\bar{x}$ = 22 years) volunteers following a 12-session training program. The program was designed to increase abdominal strength which did increase significantly ($p < 0.05$). The author found the correlations between abdominal muscle strength and FVC and FEV_1 to be low (0.15 and 0.32 respectively). She concluded that abdominal muscle strengthening did not appear to be effective in improving FEV_1 and FVC values in healthy subjects.

The only significant difference between the pre-test data of the two groups was found in the height measurements. The height of the able-bodied groups was significantly greater ($p < 0.05$) than that of the myelomeningocele group. A study conducted by Guy (1978) also found that the physically handicapped children as group were significantly shorter

($p<0.005$) than their control group (23 normal children). After Guy (1978) analyzed the subgroups of the handicapped it was found that this difference was due to the relative shortness of the spina bifida group. Children with spina bifida tend to be shorter than normal or other physically handicapped children (Guy, 1978). This may be due to the insufficient bone growth. Bone cells need a minimum stimulation in order for continued production (Little, 1973). Since children with spina bifida are not fully ambulatory their bones may not receive adequate stress to stimulate growth. Little (1973) states that a reduction of bone growth frequently coincides with a decrease in exercise.

<u>Flexibility</u>

Shoulder and elbow flexibility of either group did not change significantly. This could have been due to the fact that the form of exercise was not designed specifically to increase flexibility. In light of the specificity concept (Fox et el., 1975; McArdle et al., 1978; McCafferty and Horvath, 1977) it does not seem likely that repetitive moving through less than a full range of motion would enhance flexibility. It would appear that aerobic arm cranking does not improve shoulder or elbow flexibility in able-bodied or myelomeningocele children (8-15 years). The initial flexibility scores for the able-bodied and myelomeningocele children fall within the normal range as compared to those found by Leighton (1955) in a group of 40 normal 16 year old boys from Oregon where the mean right and left elbow flexion/extension were 140.55 and 142.65 degrees, respectively and right and left shoulder flexion/extension, 256.75 and 257.00 degrees, respectively.

No significant differences were found when comparing the training changes between groups. However, the pre-test right elbow flexibility of the able-bodied group was significantly greater ($p<0.05$) than that of the myelomeningocele group. This may be due to the type and level of activity of the able-bodied group as compared to that to the myelomeningocele group. Able-bodied children may be more likely to be involved in throwing activities than are the myelomeningocele children. This may cause an increase in the elbow flexibility of the able-bodied group as compared to that of the myelomeningocele group.

Muscular Strength and Endurance

The pre-post changes occurring in the peak torque values of both groups were spurious. The elbow flexion/extension peak torque of both groups showed no significant improvement at any of the speeds except in left elbow extension of the able-bodied groups at 300 deg.second. Only the able-bodied group showed significant ($p<0.05$) improvement in elbow muscle endurance. This could be a result of the able-bodied group having used their lower extremities to actively oppose the arm movements while training. This may be resulted in the ability to utilize the elbow muscles to a greater extent.

Shoulder flexion/extension peak torque values of both groups significantly improved in 14 of the tests at the speeds tested but the improvements were sporadic. The able-bodied groups also elicited significantly greater pre-test peak torque values in elbow and should flexion/ extension at various speeds. These difference however, were few and mainly found in the shoulder flexion/extension data. Comparison of training changes between groups showed few significant differences. The able-bodied group did have significantly greater training changes in the elbow endurance test and peak torque values of the shoulder tests.

Nilsson et al. (1975) had seven paraplegics (22-25 years) train for seven weeks, three times a week on a Monark bicycle with their arms. Each bicycling session was followed by weight training of the triceps, biceps and abdominal muscles. Their study showed significant increases in dynamic strength (19 percent) and muscular endurance (80 percent). They concluded that significant improvement can occur in muscular strength and aerobic capacity following a weight lifting and arm cranking program.

Simpson (1983) found significant improvement in abdominal strength of 25 healthy male and female ($\bar{x}$ = 22 years) volunteers after a 12-week training session. A Cybex II isokinetic system was used to measure peak torque values during trunk curl-ups. Training was also conducted using the Isokinetic device at a speed of 24 deg.second. There was a significant increase in the mean torque values between the control and experimental groups at post-test ($p<0.05$). The study indicated that abdominal strength can increase significantly in healthy subjects following isokinetic training program.

The present study did not incorporate a weight training program but subjects trained on a Monark bicycle with the arms. However, there were improvements in various peak torque values and muscle endurance tests following aerobic arm cranking. As stated by Clausen et al. (1973) oxidative enzymatic changes may occur following training which improve the capacity of the muscle to perform activities over long time periods. However, since the muscle endurance tests involved 25 maximal repetitions, the test probably reflects anaerobic capacity primarily. Consequently, the training was chiefly aerobic in nature and therefore may not have transferred an improved capacity to an anaerobic test. Davis et al. (1981) stated that there is a need for longitudinal studies concerning strength training of handicapped subjects since shoulder and arm strength are important for wheelchair users.

Cardiorespiratory Changes

Neither groups showed significant improvement in $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$), VE and R values following training. Ekblom and Gundberg (1968) also found no significant change $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$) in 17 subjects (14-24) years) with severe motor handicaps following a six-week wheelchair training program. They stated that the subjects were probably not able to fully tax their oxygen uptake ability and anaerobic work power during maximal work following training. They suggested that the cause might be due to the inadequacy of the trunk muscles to provide adequate trunk stability which is needed during maximal work with the arms. Stewart and Gutin (1976) studied the responses of 10 healthy boys (10-12 years) to an 8-week interval training program. Their results showed no improvement in $\dot{V}O_2$max ($ml \cdot kg^{-1} \cdot min^{-1}$) scores after training. However, submaximal heart rate and VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) values decreased significantly ($p<0.05$). The authors stated that in order for a child to increase their $\dot{V}O_2$ max, the child probably needs to train at a high intensity level. They also believed that submaximal changes may be independent of changes occurring during maximal effort. The intensity of training for the myelomeningocele and able-bodied groups in this study was 79.38 percent and 76.41 percent of their maximal heart rate values, respectively.

These levels of intensity may not be high enough to elicit significant changes in maximal oxygen uptake values. Lussier and Buskirk (1977) used healthy prepubescent children (8-11 years) to investigate the effects of a 12-week progressive, continuous training program. The training intensity was 92 percent of their maximal heart rate value of 80 percent of their $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$) value. Results of their study showed not only significant decreases in submaximal heart rates but also significant increases in submaximal heart rates but also significant increases in $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$) values ($p<0.05$). They believed that a prime reason why some studies do not show increases in $\dot{V}O_2$ max scores is that the level of activity of children may be at a high enough level to maintain their aerobic activity. Another reason may be due to the amount of muscle mass used along with the type of training program. Lussier and Buskirk (1977) used a 12-week progressive, continuous training program with two times a week training for 10-35 minutes and 45-minutes of running games or activities also conducted two times a week. The present study exercised the arms with a progressive, discontinuous training program of 5-minute workbouts interspersed with a 2-minute rest period, conducted 3-times per week lasing 15-30 minutes. Gass et al., (1980) stated that the cardiovascular regulatory function may not be highly effective in high leveled spinally lesion patients because part of the sympathetic spinal control may be absent.

The only significant difference in between group comparisons of pre-test cardiorespiratory data was in the $\dot{V}O_2$ max ($l \cdot min^{-1}$) and VE values. The myelomeningocele group had a significantly lower ($p<0.05$) $\dot{V}O_2$ max ($l \cdot min^{-1}$) and VE than that of the able-bodied group. However, when weight was taken into consideration, there was no significant difference in $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$). It may be possible that minute ventilation could limit aerobic power (McArdle, Katch and Katch, 1981). If ventilation is unable to adequately keep pace with oxygen consumption then it is possible that the individual would reach an exhaustive state (McArdle et al., 1981). The significantly lower $\dot{V}E$ found in the myelomeningocele group could be a cause of their significantly lower $\dot{V}O_2$ max ($l \cdot min^{-1}$). Chemical and nonchemical stimuli, neurogenic factors (cortical influence and peripheral influence) and temperature are factors which regulate ventilation (McArdle et al., 1981). It would seem more likely that neurogenic factors, specifically peripheral, influence may be partially responsible for a lower VE value found in the myelomeningocele group. During arm exercise, it appeared that the able-bodied subjects were able to use their legs and trunk muscles to a greater extent that the myelomeningocele group. This would enable the able-bodied group to receive stimulation from tendons joints or muscles in the peripheral receptors in the lower-limbs which would cause an increase in ventilation and therefore $\dot{V}O_2$ max ($l \cdot min^{-1}$) would also increase. Also, with a constant workload, a small exercise muscle mass causes a greater rise in serum lactate than a larger muscle mass. (Astrand, Ekblom, Messin, Saltin and Stenberg, 1965; Klausen Rasmussen, Clausen and Trap-Jensen, 1974). A larger serum lactate concentration in exercising arms as compared to that of exercising legs could also be due to a more sufficient local blood flow in the leg muscles (Klausen et al., 1974). The elevated lactate inhibitors muscle function (deVries, 1980) which in turn may reduce maximal oxygen uptake.

Inadequate innervation of the intercostal and abdominal muscles may also cause lower ventilation values in the myelomeningocele group (Gass et al., 1980). Mean maximal oxygen uptake values before and after training for the myelomeningocele and able-bodied groups were 0.67 $l \cdot min^{-1}$ to 0.61 $l \cdot min^{1}$ and 1.30 $l \cdot min^{-1}$ to 1.24 $l \cdot min^{-1}$, respectively. The mean ventilation scores before and after training for the myelomeningocele and able-bodied groups were 29.99 $l \cdot min^{-1}$ to 32.06 $l \cdot min^{-1}$ and 45.90 $l \cdot min^{-1}$ to 55.7 $l \cdot min^{-1}$, respectively. Ekblom and Lundberg (1968) cited values of 1.091 $l \cdot min^{-1}$ (before) and 1.103 $l \cdot min^{-1}$ (after) for a group of seven paraplegics. The mean ventilation scores were not given. The values in the present study for the myelomeningocele group are lower than that found by Ekblom's and Lundberg's study (1968) which may be due to such factors as, (1) the activity level of the subjects, (2) the site of lesions and (3) the age of the subjects. Their subjects ranged in age from 14-24 years versus a range of 8-15 years cited in the present study. Pollock et al. (1974) found maximal uptake values of 1.88 $l \cdot min^{-1}$ before and 2.23 $l \cdot min^{-1}$ after training in eight lower-limbed disabled men ($\bar{x}$ = 38 years).

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CHAPTER VII

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

There has been an increase in interest dealing with the effects of physical training on children with handicaps. Few studies have been completed pertaining to the effects of aerobic arm cranking on body composition, muscular strength, power and endurance, flexibility and cardiorespiratory fitness of children with lower-limb disabilities. This study dealt with the effects of aerobic arm cranking on children with myelomeningocele and secondly, it compared these results to those of able-bodied children. The training program lasted eight weeks. Each child trained three times a week using a discontinuous regimen at 77 percent of their maximal heart rate value. In the first two weeks the training period lasted 15 minutes and it increased in 5 minute increments every 2 weeks with the final 2 weeks lasting 30 minutes.

The present study showed significant increases in pre-post testing of both groups in various elbow and shoulder peak torque values and muscle endurance of the elbow and shoulder.

Significant differences in pre-test values between the two groups also were found in various elbow and shoulder muscular strength and endurance tests, height, elbow flexibility and $\dot{V}O_2$ max (1 min^{-1}) and $\dot{V}E$ scores ($p<0.05$). In the comparison of training changes between the groups, the only significant differences were found in isolated muscular strength and endurance tests, and maximal heart rate values following training ($p<0.05$).

Conclusions

The following conclusions were made:

Within Group Changes

1. Arm ergometry training in the myelomeningocele or able-bodied group produced no significant change in height, weight, FVC or sum of skinfold data ($p<0.05$).
2. Arm ergometry training in the myelomeningocele group or able-bodied group produced no significant change in elbow or shoulder flexibility ($p<0.05$).
3. Arm ergometry training the myelomeningocele group produced no significant change ($p<0.05$) in muscle endurance or peak torque of the elbow at 60 deg.sec, 180 deg.sec and 300 deg.sec but changes did occur at the shoulder ($p<0.05$) at these speeds.

4. Arm ergometry training in the myelomeningocele group produced significant change ($p<0.05$) in muscle endurance and peak torque at 180 deg.sec and 300 deg.sec in the shoulder.

5. Arm ergometry training in the able-bodied group produced no significant change ($p<0.05$) at 60 deg.sec or 180 deg.sec in the elbow.

6. Arm ergometry training in the able-bodied group produced significant change ($p<0.05$) in left elbow extension peak torque ($p<0.05$) and elbow muscle endurance ($p<0.05$).

7. Arm ergometry training in the able-bodied group produced significant change ($p<0.05$) in shoulder muscle endurance and peak torque at 180 deg.sec and 300 deg.sec but not at 60 deg.sec.

8. Arm ergometry training in the myelomeningocele group produced no significant change ($p<0.05$) in $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$ or $l \cdot min^{-1}$), $\dot{V}E$, R or maximal heart rate ($beats \cdot min^{-1}$).

9. Arm ergometry training in the able-bodied group produced no significant change ($p<0.05$) in $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$ or $l \cdot min^{-1}$), $\dot{V}E$, or R values but maximal heart rate did increase significantly ($p<0.05$).

Initial Differences Between Groups

1. The able-bodied group were significantly taller, more flexible in the right elbow and had higher absolute $\dot{V}O_2$ max ($l \cdot min^{-1}$) and VE scores than the myelomeningocele group at the onset of the study.

2. The able-bodied group had significantly greater peak torque values in various elbow and shoulder tests at 60 deg.sec, 180 deg.sec and 300 deg.sec along with right shoulder flexion endurance.
3. No significant differences were found in R values, $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$), height, weight, FVC, maximal heart rate ($beats \cdot min^{-1}$) or sum of skinfolds ($p<0.05$).

Comparison of Training Changes Between Groups

1. The two groups showed no significant differences between them due to training in flexibility, height, weight, FVC, sum of skinfolds, peak torque of the elbow at 60 deg.sec, 180 deg.sec or 300 deg.sec, peak torque of the shoulder at 60 deg.sec or 300 deg.sec, $\dot{V}O_2$ max ($ml \cdot kg^{-1} \cdot min^{-1}$ or $l \cdot min^{-1}$), $\dot{V}E$ and R values.
2. The able-bodied group produced significantly grater elbow and shoulder muscle endurance, peak torque values of the shoulder at 180 deg.sec and maximal heart rate ($beats \cdot min^{-1}$) training changes than that of the myelomeningocele group.

Recommendations

The following recommendations have been suggested for further investigation:

1. Further studies investigating changes in submaximal cardiorespiratory fitness of children with lower-limbed disabilities following an aerobic arm cranking program should be done.
2. Studies on determining body composition norms of lower-limbed disabled children should be researched.
3. Research which will determine accurate prediction equations or field tests for estimating cardiorespiratory fitness and body composition should be done.
4. Further investigation of the effects of various training regimens on the fitness levels of children with lower-limbed disabilities should be conducted.
5. Longitudinal studies on the effects of physical training on the lower-limbed disabled should be investigated.

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Table 1. Summary of selected pre-post training changes for each group.

Variable	Myelomeningocele group (n=7)				Able bodied group (n=9)			
	pre	post	%	t-value	pre	post	%	t-value
Age (yrs.)								
Mean	11:25				11.44			
SD	2.82	2.82			2.75	2.75		
Range	8- 15	8- 15			8- 15	8- 15		
Weight (kg)								
Mean	36.80	37.77	2.64	-0.068	40.03	40.77	1.84	-0.123
SD	26.40	26.70			12.80	12.60		
Range	16.80- 92.30	17.70- 93.70			24.40 64.80	25.00- 65.00		
Height (cm)								
Mean	132.62	133.66	0.78	-0.106	149.53	151.16	1.09	-0.191
SD	15.40	15.50			17.40	18.70		
Range	113.60- 155.10	119.40- 158.70			127.00- 171.7	129.05- 177.70		
FVC (l·min)								
Mean	1.64	1.81	10.37	-0.303	2.39	2.61	9.21	-0.485
SD	0.98	1.08			0.91	1.02		
Range	0.76- 3.26	0.85- 3.85			1.07- 4.37	1.03- 4.73		
Sum of (mm) Skinfold								
Mean	62.67	63.89	1.95	-0.049	34.57	37.04	7.14	-0.449
SD	44.90	47.70			10.60	12.60		
Range	21.65- 154.50	22.30- 161.50			23.65- 55.70	22.65- 59.80		

Table 2. Changes in shoulder and elbow flexibility within each group (degrees).

	Myelomeningocele group (n=7)				Able bodied group (n=9)			
Variable	Pre	post	%	t-value	pre	post	%	t-value
Right Shoulder								
Mean	238.26	223.14	6.39	-1.275	241.44	239.94	0.62	0.141
SD	15.60	27.50			20.00	24.90		
Range	215.00-262.50	190.00-258.50			199.00-258.50	196.00-272.00		
Left Shoulder								
Mean	239.29	238.43	0.36	-0.040	241.78	255.78	5.79	-0.987
SD	17.40	22.80			29.60	30.50		
Range	216.00-263.00	204.00-267.50			177.00-275.00	185.00-289.50		
Right Elbow								
Mean	144.71	155.07	7.16	-1.184	162.78	155.39	4.54	1.095
SD	12.10	19.70			10.60	17.30		
Range	132.00-166.00	126.00-179.00			142.50-178.00	134.00-174.50		
Left Elbow								
Mean	141.07	151.29	7.24	-1.423	152.11	157.33	3.43	-0.713
SD	9.80	16.30			17.00	13.90		
Range	119.50-147.50	127.00 173.00			128.00-176.50	138.00-184.50		

Table 3. Summary of changes in elbow peak torque and muscle endurance in the myelomeningocele group. (ft·lbs).

	Pre			Post				
	$\bar{x}$	S.D.	Range	$\bar{x}$	S.D.	Range	%	t-value
60 deg·sec								
Right elbow extension	11.71	5.12	5.-0- 19.00	15.00	5.77	7.00- 23.00	28.10	-1.126
Left elbow extension	12.29	6.05	3.00- 21.00	15.43	3.74	10.00- 20.00	25.55	-1.170
Right elbow flexion	11.43	5.22	4.00- 17.00	14.00	4.80	8.00- 21.00	22.48	-0.959
Left elbow flexion	11.43	5.32	4.00- 19.00	13.71	4.23	8.00- 18.00	19.95	-0.890
180 deg·sec								
Right elbow extension	7.14	6.44	0.00- 18.00	11.57	5.06	6.00- 18.00	62.05	-1.430
Left elbow extension	8.57	7.39	0.00- 19.00	13.00	4.69	5.00- 17.00	75.91	-1.339
Right elbow flexion	5.86	6.20	0.00- 15.00	9.29	5.74	0.00- 15.00	58.53	-1.074
Left elbow flexion	7.57	4.50	0.-0- 14.00	10.57	4.83	4.00- 16.00	39.63	-1.202
300 deg·sec								
Right elbow extension	4.71	5.47	0.-0- 15.00	9.14	5.64	0.00- 16.00	94.41	-1.491
Left elbow extension	5.00	6.16	0.00- 17.00	10.00	5.23	0.00- 15.00	100.00	-1.637
Right elbow flexion	3.00	4.51	0.00- 12.00	6.29	5.25	0.00- 13.00	110.00	-1.256
Left elbow flexion	3.14	5.84	0.00- 15.00	5.57	5.59	0.00- 12.00		-0.794
Endurance								
Right elbow extension	281.29	269.00	6.00-684.00	392.43	181.00	109.00-607.00	39.51	-0.906
Left elbow extension	272.29	285.00	0.00-699.00	424.57	174.00	136.00-621.00	55.93	-1.207
Right elbow flexion	148.86	162.00	6.00-386.00	230.71	121.00	78.00-374.00	54.98	-1.072
Left elbow flexion	189.14	168.00	30.00-419.00	223.86	132.00	35.00-356.00	18.36	-0.429

Table 3. Summary of changes in shoulder peak torque and muscle endurance in the myelomeningocele group (ft·lbs). (continued)

	Pre			Post				
	$\bar{x}$	S.D.	Range	$\bar{x}$	S.D.	Range	%	t-value
60 deg·sec								
Right shoulder extension	16.71	7.04	7.00- 28.00	19.43	5.29	13.00- 16.00	16.28	-0.816
Left shoulder extension	16.86	5.52	9.00- 25.00	22.00	8.56	15.-0- 39.-0	30.49	-1.335
Right shoulder flexion	13.43	5.26	7.00- 19.00	17.86	5.64	12.00- 27.00	32.99	-1.520
Left shoulder flexion	13.71	4.82	7.00- 21.00	19.71	8.69	12.00- 33.00	43.76	-1.597
180 deg·sec								
Right shoulder extension	11.29	7.93	0.00- 23.00	18.71	7.18	9.00- 27.00	65.72	-1.837*
Left shoulder extension	14.71	6.95	6.00- 27.00	17.86	7.56	9.-0- 28.00	21.14	-0.810
Right shoulder flexion	5.71	5.00	0.00- 13.00	14.00	4.69	7.00- 19.00	145.00	-3.254**
Left shoulder flexion	9.43	3.91	5.00- 16.00	14.00	6.93	6.00- 26.00	48.46	-2.594*
300 deg·sec								
Right shoulder extension	5.29	6.65	6.00- 14.00	15.14	7.54	6.00- 26.00	186.20	-2.594*
Left shoulder extension	10.14	8.93	0.00- 27.00	12.43	9.29	0.00- 21.00	22.58	-0.469
Right shoulder flexion	1.71	3.15	0.00- 8.00	11.86	6.57	4.00- 23.00	593.36	-3.684**
Left shoulder flexion	2.57	2.51	0.00- 5.00	8.43	7.63	0.00- 24.00	228.02	-1.928*
Endurance								
Right shoulder extension	389.29	265.00	107.00-727.00	617.57	290.00	217.00-994.00	58.64	-1.538
Left shoulder extension	393.14	294.00	85.00-758.00	612.00	285.00	236.00-1023.00	55.67	-1.415
Right shoulder flexion	188.14	141.00	58.00-413.00	395.14	208.00	155.00-694.00	110.02	-2.179*
Left shoulder flexion	216.00	173.00	43.00-453.00	327.29	141.00	203.00-504.00	52.45	-1.317

Table 4. Summary of changes in elbow peak torque and muscle endurance in the able-bodied group. (ft·lb).

	Pre			Post				
	$\overline{x}$	S.D.	Range	$\overline{x}$	S.D.	Range	%	t-value
60 deg·sec								
Right elbow extension	13.89	5.93	4.00- 23.00	18.56	7.37	8.00- 31.00	3.62	1.481
Left elbow extension	16.67	7.00	5.00- 28.00	17.67	6.16	7.00- 27.00	6.00	-0.322
Right elbow flexion	15.22	8.58	0.00- 31.00	19.22	7.31	7.00- 32.00	26.28	-1.064
Left elbow flexion	16.22	8.20	0.00- 27.00	18.87	8.70	3.00- 35.00	15.78	-0.641
180 deg·sec								
Right elbow extension	10.00	6.40	0.00- 21.00	14.78	6.53	6.00- 26.00	38.52	-1.348
Left elbow extension	11.22	8.42	0.00- 25.00	15.33	5.79	5.00- 24.00	36.63	-1.207
Right elbow flexion	11.44	6.33	0.00- 22.00	15.33	7.71	0.00- 22.00	34.00	-1.169
Left elbow flexion	12.67	7.98	0.00- 23.00	15.11	7.49	0.00- 27.00	19.26	-0.670
300 deg·sec								
Right elbow extension	7.11	6.58	0.00- 18.00	11.56	6.78	0.00- 23.00	62.59	-1.410
Left elbow extension	6.00	7.73	0.00- 19.00	13.11	6.68	0.00- 21.00	118.50	-2.088*
Right elbow flexion	16.89	7.17	0.00- 19.00	12.00	6.87	0.-0- 24.00	28.95	-1.544
Left elbow flexion	6.33	7.66	0.00- 19.00	11.56	7.06	0.00- 24.00	82.62	-1.504
Endurance								
Right elbow extension	288.76	261.00	5.00-824.00	559.78	319.00	169.00-1228.00	93.86	-1.972*
Left elbow extension	284.22	269.00	1.00-859.00	575.89	290.00	90.00-1016.00	102.62	-2.211*
Right elbow flexion	262.33	203.00	2.00-692.00	513.78	309.00	21.00-1105.00	95.85	-2.090*
Left elbow flexion	232.56	197.00	0.00-696.00	509.44	318.00	50.00-1137.00	119.06	-2.223*

Table 4. Summary of changes in shoulder peak torque and muscle endurance in the able-bodied group. (ft·lb). (continued)

	Pre			Post				
	$\bar{x}$	S.D.	Range	$\bar{x}$	S.D,	Range	%	t-value
60 deg·sec								
Right shoulder extension	23.67	11.90	9.00- 48.00	28.44	9.73	14.00- 48.-0	20.15	-0.927
Left shoulder extension	22.22	8.81	12.00- 41.00	29.89	9.93	14.00- 18.00	34.52	-1.732
Right shoulder flexion	19.44	6.60	9.00- 30.00	24.33	7.84	13.00- 40.00	25.15	-1.431
Left shoulder flexion	18.78	7.82	9.00- 35.00	23.56	7.49	12.00- 38.00	25.45	-1.324
180 deg·sec								
Right shoulder extension	17.44	7.94	6.00- 34.00	23.67	8.66	10.00- 41.00	35.72	-1.589
Left shoulder extension	16.56	8.05	5.00- 31.00	24.78	6.79	12.00- 37.00	49.64	-2.347*
Right shoulder flexion	16.22	6.24	7.00- 26.00	21.11	8.75	8.00- 31.00	32.13	-1.364
Left shoulder flexion	15.22	6.18	7.00- 26.00	20.67	7.75	8.00- 31.00	35.81	-1.648
300 deg·sec								
Right shoulder extension	9.67	9.31	0.00- 26.00	18.22	8.79	0.00- 31.00	88.42	-2.005*
Left shoulder extension	12.00	7.09	0.00- 24.00	20.44	6.75	6.00- 32.00	70.33	-2.589**
Right shoulder flexion	7.89	8.77	0.00- 23.00	15.89	8.98	0.00- 28.00	101.39	-1.913*
Left shoulder flexion	8.11	8.31	0.00- 22.00	15.56	8.09	0.00- 26.00	91.86	-1.925*
Endurance								
Right shoulder extension	579.56	382.00	111.00-1345.00	102.57	434.00	267.00-1888.00	76.98	-2.316*
Left shoulder extension	607.78	396.00	172.00-1443.00	956.56	418.00	270.00-1285.00	57.39	-1.817*
Right shoulder flexion	635.00	452.00	38.00-1531.00	867.78	997.00	87.00-1755.00	36.66	-1.039*
Left shoulder flexion	489.11	325.00	46.00-1061.00	708.44	449.00	19.00-1590.00	44.84	-1.106*

Table 5. Cardiorespiratory responses to training within each group.

	Myelomeningocele group				Able bodied group			
Variable	pre	post	%	t-value	pre	post	%	t-value
$\dot{V}O_2$ ($ml \cdot kg^{-1}$) min^{-1})								
Mean	22.53	23.73	5.33	-0.268	30.36	27.86	8.23	0.551
SD	8.59	8.09			9.37	7.49		
Range	9.62- 33.36	13.30- 35.90			22.09- 47.94	19.60- 42.00		
$\dot{V}O_2$ ($l \cdot min^{-1}$)								
Mean	0.67	0.61	8.96	0.408	1.30	1.24	4.62	0.233
SD	0.19	0.35			0.50	0.47		
Range	0.49- 0.89	0.29- 1.31			0.57- 2.08	0.68- 2.02		
$\dot{V}E$ (BTPS)								
Mean	29.996	32.057	6.87	-0.295	45.901	55.70	21.35	-1.067
SD	16.80	15.10			15.70	18.60		
Range	15.01- 47.03	14.60 58.30			29.81 68.85	35.5- 90.0		
R value								
Mean	0.93	0.99	6.45	-0.823	0.99	1.02	3.03	-1.315
SD	0.15	0.11			0.06	0.05		
Range	0.71- 1.20	0.87- 1.18			0.96- 1.07	0.93- 1.08		
Heart rate (beats·min)								
Mean	167.57	165.00	1.53	0.256	161.56	178.67	10.59	-2.475*
SD	18.20	19.40			16.90	12.00		
Range	140- 190	130- 190			134- 185	160- 200		

Table 6. Between group comparison of selected pre-test data.

	Myelomeningocele group			Able-bodied group			
	$\bar{x}$	S.D.	Range	$\bar{x}$	S.D.	Range	t-value
Age (yrs)	11.25	2.82	8.00-15.00	11.44	2.75	8.00-15.00	
Weight (kg)	36.80	26.40	16.80-92.30	40.03	12.80	24.40-64.80	-0.297
Height (cm)	132.62	15.38	113.60-155.10	149.53	17.40	127.00-171.70	1.879*
FVC (1·min)	1.64	0.88	0.76-3.26	2.39	0.91	1.07-4.37	-1.588
Sum of skinfold (mm)	59.87	48.50	21.65-154.50	33.46	11.30	23.65-55.70	1.309
Flexibility (degrees)							
Right Shoulder	238.36	15.60	215.00-262.50	241.44	20.00	199.00-258.50	-0.347
Left shoulder	239.29	17.40	216.00-263.00	241.78	29.60	177.00-275.00	-0.210
Right Elbow	144.71	12.10	132.00-162.78	162.78	10.60	142.50-178.00	-3.121**
Left Elbow	141.07	9.80	119.50-147.50	152.11	17.00	128.00-176.50	1.628

Table 7. Between group comparison of elbow pre-test peak torque and muscle endurance data (ft·lb).

	Myelomeningocele group			Able-bodied group			
	$\bar{x}$	S.D.	Range	$\bar{x}$	S.D.	Range	t-value
60 deg·sec							
Right elbow extension	11.71	5.12	5.-0- 19.00	13.89	5.93	4.00- 23.00	-0.786
Left elbow extension	12.29	6.05	3.00- 21.00	16.67	7.00	5.00- 28.00	1.341
Right elbow flexion	11.43	5.22	4.00- 17.00	15.22	8.58	0.00- 31.00	-1.091
Left elbow flexion	11.43	5.32	4.00- 19.00	16.22	8.20	0.00- 27.00	-1.413
180 deg·sec							
Right elbow extension	7.14	6.44	0.00- 18.00	10.67	6.40	0.00- 21.00	-1.088
Left elbow extension	8.57	7.39	0.-0- 19.00	11.22	8.42	0.00- 25.00	-0.669
Right elbow flexion	5.86	6.20	0.00- 15.00	11.44	6.33	0.00- 22.0	1.772*
Left elbow flexion	7.57	4.50	0.00- 14.00	12.22	7.82	0.00- 23.00	-1.493
300 deg·sec							
Right elbow extension	4.71	5.47	0.00- 15.00	7.11	6.58	0.00- 18.00	-0.795
Left elbow extension	5.00	6.16	0.00- 17.00	6.00	7.73	0.00- 19.00	-0.288
Right elbow flexion	3.00	4.51	0.00- 14.00	16.89	7.17	0.00- 19.00	-1.325
Left elbow flexion	3.14	5.84	0.00- 15.00	6.33	7.66	0.00- 19.00	-0.945
Endurance							
Right elbow extension	281.29	269.00	6.00-684.00	288.78	261.00	5.00-824.00	-0.056
Left elbow extension	272.29	285.00	0.00-699.00	262.22	269.00	1.00-859.00	-0.085
Right elbow flexion	188.86	162.00	8.00-386.00	262.33	203.00	2.00-692.00	-1.244
Left elbow flexion	189.14	168.00	30.00-419.00	232.56	197.00	0.00-696.00	-0.475

Table 7. Between group comparison of shoulder pre-test peak torque and muscle endurance data (ft·lb). (Continued)

	Myelomeningocele group			Able-bodied group			t-value
	$\overline{x}$	S.D.	Range	$\overline{x}$	S.D.	Range	
60 deg·sec							
Right shoulder extension	16.71	7.04	7.00- 28.00	23.67	11.90	9.00- 48.00	-1.459
Left shoulder extension	16.86	5.52	9.00- 25.00	22.22	8.81	12.00- 41.00	-1.489
Right shoulder flexion	13.43	5.26	7.00- 19.00	19.44	6.60	9.00- 30.00	-2.030*
Left shoulder flexion	13.71	4.82	7.00- 21.00	18.78	7.82	9.00- 35.00	-1.592
180 deg·sec							
Right shoulder extension	11.29	7.93	0.00- 23.00	17.44	7.94	6.00- 34.00	-1.540
Left shoulder extension	14.71	6.95	6.00- 27.00	16.56	8.05	5.00- 31.00	-0.491
Right shoulder flexion	5.71	5.00	0.00- 13.00	16.22	6.24	7.00- 26.00	3.791**
Left shoulder flexion	9.43	3.91	5.00- 16.00	15.22	6.18	7.00- 26.00	2.285*
300 deg·sec							
Right shoulder extension	5.29	6.65	0.00- 14.00	9.67	9.31	0.00- 26.00	-1.097
Left shoulder extension	10.14	8.93	0.00- 27.00	12.00	7.09	0.00- 24.00	0.451
Right shoulder flexion	1.71	3.15	0.00- 8.00	7.99	8.77	0.00- 23.00	1.957*
Left shoulder flexion	2.57	2.51	0.00- 5.00	8.11	8.31	0.00- 22.00	1.892*
Endurance							
Right shoulder extension	389.29	265.00	107.00- 727.00	579.56	382.00	111.00-1345.00	1.175
Left shoulder extension	393.14	294.00	85.00-758.00	607.78	396.00	172.00-1443.00	-1.542
Right shoulder flexion	188.14	141.00	58.00-413.00	635.00	452.00	38.00-1531.00	-2.796*
Left shoulder flexion	216.00	173.00	50.00-453.00	489.11	325.00	46.00-1061.00	-2.158*

Table 8. Between group comparison of pre-test cardiorespiratory data.

	Myelomeningocele group			Able bodied group			
	$\bar{x}$	S.D.	Range	$\bar{x}$	S.D.	Range	t-value
$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	22.96	8.21	9.62-33.36	30.36	9.37	22.09-47.94	0.067
$\dot{V}O_2$ ($l \cdot min^{-1}$)	0.67	0.19	0.49-0.89	1.30	0.50	0.57-2.08	2.84*
$\dot{V}E$ (BTPS)	29.996	10.80	15.01-47.03	45.901	15.70	29.81-68.65	2.215*
R Value	0.93	0.15	0.71-1.20	0.99	0.06	0.96-1.07	0.885
Heart rate ($beats \cdot min^{-1}$)	167.57	18.20	140.00-190.00	161.56	16.90	134.00-185.00	-0.677

Table 9. Between group comparison of changes in all variables following training.

Variable	t-value	ANCOVA	Significance
Flexibility (degrees)			
Right shoulder	0.889		0.2000
Left shoulder	1.374		0.1033
Right elbow		-1.648	0.1250
Left elbow	-0.427		0.3380
Descriptive			
Weight (kg)	-0.459	0.3267	0.3289
Height (cm)	0.3463	0.736	0.3920
FVC (l·min)	0.484		0.3216
Sum of skinfolds (mm)	0.800		0.2195
Peak torque (ft·lb)			
60 deg·sec			
Right elbow extension	-1.1300		0.1082
Left elbow extension	-1.132		0.1391
Right elbow flexion	-1.106		0.1487
Left elbow flexion	-0.160		0.4378
180 deg·sec			
Right elbow extension	0.165		0.4372
Left elbow extension	0.150		0.4210
Right elbow flexion		0.2546	0.8030
Left elbow flexion			
300 deg·sec			
Right elbow extension	0.009		0.4963
Left elbow extension	0.882		0.1968
Right elbow flexion	0.956		0.1784
Left elbow flexion	1.101		0.1455
Endurance (ft·lbs)			
Right elbow extension	2.007		0.0339*
Left elbow extension	1.452		0.0861
Right elbow flexion	3.262		0.0034**
Left elbow flexion	-3.696		0.0013**

Table 9. Between group comparison of changes in all variables following training. (Continued)

Variable	t-value	ANCOVA	Signigicance
Peak torque (ft·lbs)			
60 deg·sec			
Right shoulder extension	0.958		0.1792
Left shoulder extension	1.178		0.1318
Right shoulder flexion		1.1108	0.2881
Left shoulder flexion	-0.494		0.3196
180 deg·sec			
Right shoulder extension	-0.800		0.2212
Left shoulder extension	3.239		0.0041
Right shoulder flexion		0.5320	0.6040
Left shoulder flexion		1.9101	0.0800
300 deg·sec			
Right shoulder extension	-0.521		0.3056
Left shoulder extension	1.496		0.0828
Right shoulder flexion		1.6129	0.1330
Left shoulder flexion		2.7693	0.0170
Endurance (ft·lbs)			
Right shoulder extension	1.831		0.0450*
Left shoulder extension	1.193		0.1272
Right shoulder flexion		2.056	0.0620
Left shoulder flexion		1.0154	0.3300
Cardiorespiratory responses			
$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	-1.553		0.0795
$\dot{V}O_2$ ($l \cdot min^{-1}$)		-1.4993	0.1650
$\dot{V}E$ (BTPS)		-0.63147	0.5420
R value	1.162		0.1417
Heart rate ($beats \cdot min^{-1}$)	3.892		0.0015**

Table 10. Training intensities of each subject in the myelomeningocele and able bodied groups.

	Myelomeningocele group				Able-bodied group			
Subject	Age (yrs)	Training Heart rate (beats· min^{-1})	Pre-max Heart	% max	Age (yrs)	Training Heart rate (beats· min^{-1})	Pre-max Heart rate	% max
1	8	126.68	146	86.8	8	124.5	146	85.10
2	8	125.96	142	88.7	8	119.3	147	81.10
3	10	130.65	175	74.7	8	124.6	163	76.40
4	11	129.12	167	77.3	11	126.59	176	71.93
5	13	137.80	177	77.9	11	132.26	185	71.50
6	15	148.72	190	78.3	13	122.92	160	76.80
7	15	128.06	178	71.95	14	120.55	179	67.30
8					15	135.71	164	82.75
9					15	121.14	162	74.80
Mean		132.43	167.86	79.38		125.26	164.67	76.41
SD		8.19	17.68	6.15		5.50	13.42	5.78