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The Physiological and Physical Effects of a Seven Week Summer Wrestling Camp on Experienced Prepubescent Wrestlers

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THE PHYSIOLOGICAL AND PHYSICAL EFFECTS OF A SEVEN WEEK SUMMER WRESTLING CAMP ON EXPERIENCED PREPUBESCENT WRESTLERS

A Thesis
Presented to the
School of Health, Physical Education and Recreation
and the
Faculty of the Graduate College

University of Nebraska at Omaha

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts in Physical Education

by

Wade Hoyt Thomson
May, 1982

School of HPER

Approval of Master's Thesis Proposal

I hereby approve the thesis posposal written by

Wade Thomson

in partial fulfillment for the requirements of the Master of Science degree in Education with a major in physical education.

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ACKNOWLEDGMENT

My sincere thanks and appreciation are extended to my committee members, Dr. Kris Berg and Dr. Ray Millimet and to my committee chair-person, Dr. Stan Sady, for their assistance and guidance. I thank Marlene Petratis and Mark Savage for assisting with the data collection and for their comments on the manuscript. Additionally, my appreciation is extended to my wife, Maggie, and Lori Ramirez, for their patience, their guidance and their typing abilities.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Participation by children in competitive sports programs has increased considerably within the past 20 years, in part because of the increased number of competitive sports programs available for children (59). Furthermore, children are becoming increasingly involved at younger ages (48). Frequently, these programs are very physical, and actively competitive with little consideration given to how the children may respond or adapt to the strenuous exercise. It is tacitly assumed that children sports participants will experience the same physiological and physical benefits as would adult participants.

The effects of exercise training on adults have been well researched (56, 57, 63, 73). The American College of Sports Medicine (1) has published guidelines for adult exercise training. Several criteria must be satisfied to achieve effective exercise training. The duration is recommended as no less than 15 minutes, the frequency no less than 3 times per week, and the intensity no less than between 60 and 70 percent of the individual's maximum heart rate. The exercise mode selected to produce the stimulus should involve large muscle groups (walking, running, swimming, and/or bicycling). Definitive information on training guidelines for children, especially prepubescent children, is not nearly as abundant.

The data available on the physiological and physical responses of prepubescent children to athletic participation are limited to ice hockey (19, 20, 21), swimming (2, 4, 7, 13, 16, 19, 29, 30, 43, 67, 69, 76), running (14, 22, 24, 25, 40, 44, 50, 66, 70, 75), bicycling (26, 27, 49), and wrestling (17, 61). The results are inconsistent with regard to the physiological and physical adaptations of the children involved.

The data relative to the aerobic responses of prepubescent children to training are inconclusive. Maximum aerobic power (max $\dot{V}O_2$) increases have been reported in some cases (14, 23, 24, 25, 26, 28, 46, 69) and no changes have been reported in others (11, 20, 22, 25, 66, 75). Maximum heart rate responses also varied showing improvements (i.e., decreases for the same work loads) (11, 66) or no change (11, 20, 24, 28, 46, 69, 75). Submaximum oxygen consumption ($\dot{V}O_2$) responses have also shown improvements (decreases for the same work load) (22), or no change (75). In those studies that reported on submaximum heart rate responses, improvements (decreases) (46, 65, 75) or no change (14) were found.

Few studies have reported data on anaerobic training in children. Athletic children were reported to have greater anaerobic power and anaerobic capacity than non-athletic children (50). Reports of studies utilizing muscle biopsy analysis indicate that substances affecting anaerobic performance capabilities, such as phosphofructokinase (PFK), adenosine triphospate (ATP), creatine phosphate (CP), and glycogen, may be increased as a result of althletic or exercise training (26, 27).

Body composition studies for the most part indicate no changes in body fat or lean mass as a result of training (16, 17, 46, 54). An exception to these results may be found in one study which indicated that even though there was a non-significant post-training weight change, lean tissue had increased and fat tissue had decreased (26).

Data on young children wrestlers are very limited. In an abstract, Clarke et al. (17) reported the physiological and physical responses of 7-9 year old boys who had participated in a 3-month wrestling program. Insignificant changes were found for body fat and max $\dot{V}O_2$. Sady et al. (61) have reported data on the body composition and physical dimensions of young, experienced children wrestlers. The wrestlers weighed less, had a lower percent body fat, and lower skinfolds than a group of comparison boys of similar age.

Fox and Mathews (31) indicate that the energy system requirements of wrestling are approximately 90% anaerobic and 10% aerobic. This means that the PFK, ATP, CP, and glycogen components of the involved musculature must be maximally developed if optimum energy supplies are to be realized. Wrestling is a tremendously strenuous individual sport and the achievement of success requires the individual's total commitment. The wrestler must learn how his body responds to training and then pursue those training methods that are successful for him.

Prior to competition, wrestlers reduce their body weight as much as possible in an effort to improve quickness. This weight loss is accomplished in 4 days or less by sweating, starvation, dehydration, and sometimes purging, and the use of diuretics. Once the athlete has officially "weighed in", he tries to regain his strength by ingesting large quantities of food and fluid. Ingestion of food and fluid results in a gain in body weight, but there is simply insufficient time for the muscle glycogen stores, which were depleted during the weight loss period, to be replenished. The result is that the wrestler actually enters into competition in a weakened condition. It is not unusual for wrestlers to lose 8-10% or more of their gross body weight in the 3 or 4 days before a match (37). This cycle is repeated for every tournament or meet participated in.

It is unknown what responses wrestling training might elicit in young prepubescent children wrestlers. Little data exists regarding the characteristics of experienced children athletes and their responses to additional intensive training. The results reported to date have investigated these qualities in swimmers (19) and ice hockey players (20, 21). The purpose of this study was to investigate the physiological and physical effects of an intensive 7-week summer wrestling camp on experienced prepubescent wrestlers. Every summer, the Explorer's Wrestling Club of Omaha conducts an intensive 7-week wrestling camp. Young, serious, experienced wrestlers from the Omaha area and the surrounding states are invited to participate. Five days a week for 8 hours a day, the wrestlers receive rigorous aerobic and anaerobic training and improve their wrestling performance capabilities by mastering new skills and perfecting existing ones.

REVIEW OF LITERATURE

The effects of exercise training on the aerobic and anaerobic capabilities of children and on their body composition are of interest for two reasons: (1) the involvement and participation of young children in competitive sports and exercise training programs is increasing, and; (2) the previous research in these areas has yielded inconclusive and/or contradictory results.

Children are frequently viewed as miniature adults with respect to the physiological and physical changes they are expected to exhibit in reponse to athletic training. As will be seen, recent research suggests that children may not respond to athletic training in the same manner as adults. Reviews of the literature concerning athletic training in adults (57, 63, 73) indicate that certain reponses may be anticipated. Aerobic training generally results in beneficial physiological and physical adaptations. Among these changes are decreased resting and submaximum heart rates, as well as increased physical working capacity and maximum aerobic power (max $\dot{V}O_2$). Concomitantly, an alteration occurs in body composition with a reduction in body fat content. Anaerobic training does not seem to affect the heart rate or body composition but it does seem to increase the capacity to perform anaerobic work.

The following literature review will examine the effects of exercise training in children using 2 basic designs: (1) cross-sectional studies which compare the characteristics of children participating in organized athletic or exercise training regimens with children who are not affiliated with such programs (the so-called "normally active children") or which compare "active" (usually determined by some sort of questionnaire) and "inactive" children, and; (2) longitudinal studies which examine the changes occuring over a period of time due to some sort of athletic or exercise training program. Additionally, certain limitations are placed on both cross-sectional and longitudinal studies due to self-selection of the subjects. Perhaps the more physiologically and physically gifted children will elect to participate in sports and exercise programs because they have previously experienced success in similar endeavors. Conversely, children lacking these physiological and physical capabilities may tend to avoid activities that rarely lead to success.

It must be made clear at the onset, that many of the studies dealing with children span a relatively wide age range. Furthermore, secondary sexual characteristics are not always used to differentiate the subjects developmentally. Many of the researchers classified their subjects by chronological age only. The onset and duration of puberty varies considerably with the result that pubescent youths may range between 8.5 and 18.5 years old (47). Puberty is a time when changing hormonal secretions result in rapidly growing bodies, and increases in muscular development, metabolism, and functional capacity (41). As much as possible, an accurate physiological development state is preferred over a simple chronological age for subject description.

Aerobic Training in Children

Athletic vs. Non-athletic Children

Various cross-sectional studies have examined boys and girls ranging in age from 6 years to the upper teens. The subjects have been variously described as active or inactive (8, 62), or as participants in sports including ice hockey (19, 20, 21), running (14, 22, 24, 25, 40, 44, 66, 70, 75), swimming (2, 4, 7, 13, 16, 19, 29, 30, 43, 52, 67, 69, 76), bicycling (26, 27, 49), field hockey and gymnastics (62).

Prepubescent children

Bailey (8) categorized young Canadian school children (100 girls and 150 boys) as active or inactive through analysis of a physical fitness questionnaire. When max $\dot{V}O_2$ was expressed relative to body weight (ml/kg/min) active children had a greater mean value at all ages. Between ages 8 and 11, the active children's mean was 58.4 ml/kg/min compared to 53.5 for inactive children. These values were estimated from graphs.

Massicotte and MacNab (49) tested 36 boys (ages 11-13) on a bicycle ergometer before and after 6 weeks of bicycle ergometer training. Three groups trained (HR:170-180, 150-160, and 130-140 beats/min, respectively) and 1 group served as a non-training comparison group. Training sessions were 3 times a week for 12 minutes a session. Submaximum (450 kpm/min) HR (mean ± S.E.) was decreased ($p<.01$) in all 3 training groups: 149.6 ± 6.37 to 133.8 ± 5.17, 163.2 ± 3.8 to 151.1 ± 4.83, and 168.7 ± 4.30 to 153.0 ± 5.20, respectively. The comparison group displayed no change. Submax $\dot{V}O_2$ (ml/kg/min) and max HR did not change ($p>.05$) for any of the groups. Max $\dot{V}O_2$ was increased only for the 170-180 HR group: 46.7 ± 2.5 to 51.8 ± 2.0, $p<.01$. Maximum work loads (kpm/min) were increased for the 3 training groups following the study: 1000 ± 43.3 to 1250 ± 55.9, 916 ± 39.1 to 1133 ± 50.7, and 833 ± 44.1 to 1017 ± 41.7.

In another study (62), active and inactive boys and girls were tested on a bicycle ergometer. The active children were involved in swimming, bicycling, field hockey, and gymnastics and had trained 1-1½ hours a session, 4-5 sessions per week, for at least one year. At every age, max $\dot{V}O_2$ (ml/kg/min) was greater for boys than for girls. Also, boys 12 years and older had a higher mean max $\dot{V}O_2$ than did younger boys. The values for active and inactive boys ranged from 42-48 ml/kg/min, considerably less than the range of means reported for similar aged children in the study by Bailey (8).

In a study of 10 year old hockey players, Cunningham et al. (21) measured physical work capacity at a HR of 170 (physical work capacity 170, or PWC_{170}) and max $\dot{V}O_2$ on a bicycle ergometer. A control group was not used, instead, the PWC_{170} results were compared with the results obtained from Canadian children of the same age (Howell and MacNab, 38) and the max $\dot{V}O_2$ values were compared with numerous studies in the literature. The PWC_{170} score was remarkably high, 14.6 $\pm$ 2.48 kgm/kg/min (79th percentile). The athletes' mean max $\dot{V}O_2$ (ml/kg/min) of 56.5 $\pm$ 1.73 was quite high for children this age.

Hamilton and Andrew (35) compared the physiological responses to bicycle ergometer work between 12 prepubescent ice hockey players and a matched (for age, height, and weight) inactive control group (n = 10). The ice hockey players had 1 or more years prior experience and had just completed a 28-week season. No differences ($p>.05$) were found between groups for HR or $\dot{V}O_2$ at 3 submaximal work loads on a mechanically braked bicycle ergometer (240, 360, and 480 kpm). The mean HR difference between groups was only three beats/min for each work load. The mean submax $\dot{V}O_2$ differences ranged from .5 to 2.4 ml/kg/min. The submax $\dot{V}O_2$ values were estimated from graphs.

Mayers and Gutin (50) determined the treadmill submaximum and maximum $\dot{V}O_2$ and HR scores of male cross-country runners (n = 8) and non-training boys (n = 8), all 8.3-11.8 years old. The runners had a greater max $\dot{V}O_2$ (56.6 vs. 45.6 ml/kg/min) than the comparison subjects ($p<.001$). At all submaximal speeds (5, 6, and 7 mph) the runners had significantly lower $\dot{V}O_2$, and HR scores (the significance levels were not indicated). The following values are mean differences at 5, 6, and 7 mph for $\dot{V}O_2$ (ml/kg/min) and HR (beats/min), respectively: 2.40, 34; 2.66, 35, and; 2.15, 33.

Krahenbuhl (44) compared 10 skilled and 10 unskilled 8 year old boy runners for max $\dot{V}O_2$, max HR, running speed, and distance covered during 5-, 7-, and 9-minute runs. Based on their performance on these runs, the boys were classified as skilled runners (above the median) or unskilled runners (below the median). There were no differences ($p>.05$) between groups for max $\dot{V}O_2$ (53.5 ± 5.80 vs. 49.4 ± 4.20 ml/kg/min) or max HR (194 ± 11.9 vs. 203 ± 9.1 beats/min).

In the only study investigating competitive wrestling, Clarke et al. (17) measured the max $\dot{V}O_2$ and HR responses in 7-9 year old boys before and after a 3-month competitive wrestling training program. A group of comparison boys of similar age continued with their pre-experimental activity levels. The wrestlers' 6.6 ml/kg/min mean increase in max $\dot{V}O_2$ was not significantly greater ($p>.05$) than the comparison boys' change. Likewise, changes in max HR were not found to differ significantly ($p>.05$) between groups. Arm endurance (as determined by bar dips and chin-ups) improved significantly in the wrestlers relative to the comparison boys ($p<.05$). These data were presented in abstract form, therefore, little detailed information was available.

Pubescent children

Åstrand (4) studied 30 girl swimmers, ages 12-16, 27 of whom had reached menarche. The swimmers' mean max $\dot{V}O_2$, (51.6 ml/kg/min, swimming, and; 48.0, bicycle ergometer) was increased 10% over non-active girls the same weight. Statistical significance was not indicated.

Cunningham and Eynon (19) used a bicycle ergometer to measure the PWC_{170} and max $\dot{V}O_2$ of male (ages 10.0-15.4 years, n = 24) and female (ages 11.8-16.0 years, n = 19) swimmers. PWC_{170} increased with age in both sexes and was greater for active children (males, 851 vs. 1285; females, 683 vs. 844 kgm/min). Although max $\dot{V}O_2$ (1/min) increased with age in both sexes, weight increases in the females were great enough to result in a decreased max $\dot{V}O_2$/body weight. Max $\dot{V}O_2$ values (ml/kg/min) for the younger and older ages were: males = 52.5 $\pm$ 1.30 vs. 56.6 $\pm$ 1.61; females = 46.2 $\pm$ 2.74 vs. 40.5 $\pm$ .95. The authors did not indicate if these differences were statisitically significant.

Hamilton and Andrew (35) compared 13 pubescent male ice hockey players with matched (these boys were chronically active in strenuous physical training and were of similar age, height, and weight, n = 6) and unmatched (n = 11) boys, all between 16 and 18 years old. The athletes had lower ($p<.01$) mean HRs at each of 3 submaximum work loads on a mechanically braked bicycle ergometer. The mean HR (beats/min) and $\dot{V}O_2$ (ml/kg/min) differences respectively between the athletes and the unmatched boys were: 300 kgm = 15 and 2.51; 600 kgm = 12 and 1.41, and; 900 kgm = 13 and 7.59. The differences between the athletes and the matched boys respectively for the 3 work loads were: 300 kgm = 20 and .79; 600 kgm = 17 and 4.22; and 900 kgm = 24 and 2.78. At any given HR, the athletes' $\dot{V}O_2$ was lower than the unmatched boys' and higher than the matched boys. The HR and $\dot{V}O_2$ data were determined from graphs. Significance was not indicated.

Bagnall and Kellett (7) examined 31 experienced potential olympic swimmers (age range for 9 males = 13.4-19.7 and for 12 females = 12.8-16.9) who trained an average of 10 km/day and compared the results with findings from the literature on similar age, inactive children. Average max $\dot{V}O_2$ (ml/kg/min) values for the males was 56.3 and for females, 46.6. The authors predicted max $\dot{V}O_2$ from the results of a bicycle ergometer PWC_{170} test. The values presented here were calculated from $\dot{V}O_2$/lean body weight scores and gross fat weight data reported by the authors.

Training Studies

The majority of the training (longitudinal) research is similar to the cross-sectional studies in that chronological ages rather than developmental stages are used to describe the subjects. In some cases, the initial age range of the subjects could easily include pubescent and prepubescent children (13, 14, 22, 23, 24, 26), while in others, the duration of the study was easily long enough for the subjects to have arrived at a new developmental level based on their age at the onset of the study (13, 14, 23, 25, 26, 27).

Prepubescent children

Ekblom (25) compared training (running and games) and non-training boys, all 11 years old at the start, at 6-month intervals over 32 months. After 6 months, treadmill max $\dot{V}O_2$ (ml/kg/min) had increased 10% in the training boys (n = 6) but was unchanged in the non-training boys (n = 7). Over the entire 32-month study, max $\dot{V}O_2$ increased 7% in both groups (n = 5 and 4 for training and non-training boys respectively), indicating that no differences in max $\dot{V}O_2$ were attributed to training. It is very possible that many, if not all, of these subjects entered pubescence during the course of this study.

Daniels and Oldridge (22) studied 6 boys (ages 10-15) over a 22 month program of running training. The intensitiy and frequency of training was not well defined. The authors found that submaximum $\dot{V}O_2$ (ml/kg/min) decreased ($p<.01$), 52.0 $\pm$ 1.22 to 45.5 $\pm$ .98, for identical submaximum running speeds. Increases in max $\dot{V}O_2$ were matched by weight changes, resulting in no changes in max $\dot{V}O_2$ per body weight. A comparison group was not utilized, instead, the results were compared with norms for midwestern boys the same age (58).

Baggley and Cumming (6) measured the PWC_{170} (kgm/kg/min) and max $\dot{V}O_2$ (ml/kg/min) of 30 Winnepeg children (16 males and 14 females, all aged 9-12 years) over one year. No changes ($p>.05$) were found for PCW_{170} (15.8 vs. 15.9) or for max $\dot{V}O_2$ (45.1 vs. 50.1).

Brown et al. (14) studied 12 female cross-country runners and 8 comparison girls (all aged 8-13 years) over a 12-week period. Max $\dot{V}O_2$

(ml/kg/min) increased 18% and 26% in the runners at 6 and 12 weeks respectively. The comparison girls had no changes in max $\dot{V}O_2$ at 6 weeks, and were not measured at 12 weeks. Both groups experienced declines in maximum and submaximum HR. After 6 weeks, mean maximum HR decreased 4.5 and 3.6 beats/min in runners and comparison girls respectively, while submaximum HR decreased 4.8 and 3.4 beats/min. After 6 weeks, the runners' maximum and submaximum HR had decreased by 5 and 6.8 beats/min relative to pre-training values. The comparison girls showed no changes at 6 weeks and were not measured at 12 weeks. The authors felt their sample size was too small to attempt a statistical analysis of the data. The mean differences reported here were calculated from individual data reported by the authors.

Eriksson (26) reported max $\dot{V}O_2$ data and attempted to correct for growth differences by expressing max $\dot{V}O_2$ per body height squared and by body weight. Increases of 14% (.82 to .92 l/m^2, $p<.001$) and 16% (41.8 to 48.5 ml/kg/min, $p<.001$) were found in 12 boys ages 9-13 years over a 16-week training period. Training consisted of an hour or more of intervals and games, 3 times a week plus a 1-week stint at a mountain camp when the boys trained 3-4 hours a day at an intensity of 70-80% of their max $\dot{V}O_2$ (estimated from pulse rate). These results were compared with measurements taken from 16 control boys. The control boys were 6.9 kg lighter, .07 m shorter, and .5 years younger than the training boys. Furthermore, the control group's max HR and max $\dot{V}O_2$ were 4 beats/min and 7.1 ml/kg/min greater than the training group's values. For the training boys, submaximum HR scores were 10-15 beats/min lower after training and max HRs were 4 beats/min lower ($p<.05$). Corresponding values for control boys were not indicated for any these indicators.

Bar-Or and Zwiren (11) examined the max $\dot{V}O_2$ and max HR responses to 9 weeks of endurance training in 9-10 year old girls and boys. Twenty-four girls and 22 boys participated in training. Comparison groups of similar size and composition (sex) played games and performed calisthenics. The training groups ran 2, 3, or 4 times a week for 40 minutes a session, increasing their distance for the first 3 or 4 weeks and then maintained the distance for the remainder of the study. Running training consisted of 145 m intervals interspersed with 1-1½ minute walks. The comparison group performed calisthenics or played games 2, 3, or 4 times a week. No changes ($p > .05$) were detected in max $\dot{V}O_2$ (ml/kg/min) for training boys (49.4 $\pm$ 4.80 vs. 50.2 $\pm$ 6.30), comparison boys (50.0 $\pm$ 6.30 vs. 49.3 $\pm$ 6.60), training girls (44.2 $\pm$ 4.60 vs. 46.1 vs. 4.20), or comparison girls (45.0 $\pm$ 5.50 vs. 43.8 $\pm$ 6.20). Max HR (beats/min) was reduced only for the training boys (206 $\pm$ 9.5 vs. 200 $\pm$ 8.4, $p < .05$).

Eriksson and Saltin (28) studied 13 boys (mean age = 11.5 years at the start) during a 5-month, 3 session per week training program. Each 60-minute session consisted of 5-10 minutes of warmup, 15-25 minutes of interval runs, and 25-40 minutes of basketball or soccer. Max $\dot{V}O_2$ (ml/kg/min) on the bicycle ergometer improved from 41.8 to 47.4 ($p < .01$). There was no significant change in max HR (196 vs. 193 beats/min, $p > .05$).

Döbeln and Eriksson (23) investigated 12, 11-13 year-old boys before and after 5 months of miscellaneous physical training. For 3 sessions a week, 60-minutes a session, the subjects performed 5-10 minutes of calisthenics, ran intervals for 15-25 minutes, and finished with basketball or soccer. The boys also skied twice daily during a one-week cross-country skiing camp. Max $\dot{V}O_2$ (ml/kg/min) increased ($p<.01$) from 42.5 to 49.1. No comparison group was utilized.

Eriksson et al. (27) examined 5 boys (mean age = 11.2 years) who trained on bicycle ergometers at 70-85% of their max $\dot{V}O_2$, 3 times a week for an average of 29.8 minutes a session for 6 weeks. An 8% increase in max $\dot{V}O_2$ (52.7 ± 4.3 vs. 56.9 ml/kg/min) was detected.

Eisenman and Golding (24) found increases in max $\dot{V}O_2$ (42.7 ± 2.16 to 49.6 ± 1.31 ml/kg/min) in 8, 12-13 year old girls. Training consisted of jogging, bench stepping, and strength and flexibility exercises for 14 weeks. A comparison group (n = 8) displayed no changes over the same period 44.5 ± 2.19 to 41.2 ± 1.38 ml/kg/min). There were no changes in either group for max HR, 201 ± 3.0 vs. 205 ± 2.1 beats/min for the runners, and 200 ± 2.6 vs. 201 ± 2.7 beats/min for the comparison girls.

Stewart and Gutin (65) reported no changes max $\dot{V}O_2$ in 10-12 year old boys following 8 weeks of training. Thirteen exercising boys had pre- and post-training max $\dot{V}O_2$ scores (ml/kg/min) of 49.8 ± .68 and 49.5 ± 1.70 compared to 48.4 ± 1.28 and 49.2 ± 1.56 for 11 non-training subjects. Runners displayed decreases in subaximum HR while cycling at 300 kpm over the course of the study (162 ± 4.9 to 149 ± 3.9 beats/min, $p<.05$) while no changes were detected for the non-training subjects (174 ± 4.5 vs. 170 ± 5.5 beats/min, $p>.05$). HRs measured during submaximum treadmill running at 3.5 mph and various grades revealed lower values for runners over the comparison subjects by 13 beats/min.

Cunningham et al. (20) measured treadmill $\dot{V}O_2$s of 66, 10 year old male ice hockey players over a 4-5 month period, approximately the middle and end of their competitive season. Data were grouped on the presence or absence of a plateau in max $\dot{V}O_2$ on 2 treadmill tests. A plateau was defined as having a $\dot{V}O_2$ change less than 2.1 ml/kg/min in successive work loads immediately prior to exhaustion. There were no changes ($p>.05$) in max $\dot{V}O_2$ from mid- to post-season testing for any of the 3 groups. Max $\dot{V}O_2$ values (ml/kg/min) for the groups were: double-plateau (achieved a plateau on both of the tests) = 56.3 $\pm$ 2.60 vs. 54.1 $\pm$ 2.20; single-plateau (only achieved a plateau on one of the two tests) = 55.9 $\pm$ 1.50 vs. 54.3 $\pm$ 1.50; and; no-plateau (did not achieve a plateau on either of the two tests) = 57.2 $\pm$ 1.10 vs 54.8 $\pm$ .90. Likewise, there were no changes over time for max HR (beats/min): double-plateau = 198 $\pm$ 2.2 vs. 200 $\pm$ 2.7; single-plateau = 195 $\pm$ 1.8 vs. 193 $\pm$ 1.4, and; non-plateau = 199 $\pm$ 1.7 vs. 197 $\pm$ 1.3. The fact that no changes in max $\dot{V}O_2$ or max HR were detected in this study may in part be attributable to the intial high conditioning level of the subjects. A comparison group was not utilized.

Lussier and Buskirk (46) divided 26 volunteer children aged 8-12 years into exercise (11 males and 5 females) and comparison (9 males and 1 female) groups for a 12-week exercise training program. All subjects were classified stage I for breast development or genitalia maturity according to Tanner's standards (68). Max $\dot{V}O_2$ was assessed on the treadmill after subjects were familiar with the procedure. Training consisted of running progressively longer distances and playing games. At the end, max $\dot{V}O_2$ (ml/kg/min) had increased in the exercise group (55.6 $\pm$ 2.07 vs. 59.4 $\pm$ 2.28, $p<.05$) but not in the comparison group (53.1 $\pm$ 1.32 vs. 53.9 $\pm$ .80, $p>.05$). There were no differences in max HR (201.3 $\pm$ 1.87 vs. 200.7 $\pm$

2.12 beats/min in exercisers, 199.8 ± 2.43 ± 203.2 ± 2.17 beats/min in comparison subjects), however, there were decreases in submaximum HR (beats/min) at 40% and 80% of max $\dot{V}O_2$. At 40%, a walking pace, the exercisers' values were 129.3 ± 1.96 vs. 119.8 ± 1.85, and for the comparison group, 126.2 ± 2.91 vs. 126.7 ± 3.00, pre- and post-training respectively ($p<.05$). At 80%, a running pace, the respective HRs were 187.9 ± 2.41 vs. 174.4 ± 2.75 for the exercisers, and 188.1 ± 2.43 vs. 188.6 for the comparison subjects ($p<.01$).

Vaccaro and Clarke (69) measured 2 male and 13 female swimmers (ages 9-11) and 3 male and 12 female comparison subjects (ages 9-11) before and after a 7-month program of swim training. PWC_{170} was assessed on a bicycle ergometer, and max $\dot{V}O_2$ was assessed on a treadmill after the subjects had familiarized themselves with the testing procedures. The actual max $\dot{V}O_2$ (ml/kg/min) values in swimmers and comparison subjects pre- to post-training were 45.7 ± 2.44 vs. 54.6 ± 1.70 and, 50.5 ± 2.87 vs. 53.3 ± 2.49. These changes were significantly different ($p<.01$). PWC_{170} scores (kgm/min) in swimmers and comparison subjects were 400 ± 23.9 vs. 480 ± 30.0, and 380 ± 20.0 vs. 410 ± 17.7. These changes were also significantly different ($p<.05$). Max HRs (beats/min) in swimmers and controls were not different ($p>.05$), 199 ± 2.8 vs. 197 ± 2.9 and, 200 ± 1.3 vs. 199 ± 1.5.

Bell and Ribisl (13) studied 31 male and female competitive swimmers ages 9-17. All swimmers had been training for at least 2 years at the time the study began. Max $\dot{V}O_2$ increased with age in both sexes. In males, max $\dot{V}O_2$ increased with age ($r = .96$) and ranged from (age in years, max $\dot{V}O_2$ in ml/kg/min): 10.3 ± .42, 51.7 ± 6.09, n = 3 to 16.2 ± .33, 62.0 ±

1.28, n = 5. For the females, max $\dot{V}O_2$ also increased with age (r = .95): 10.0 ± .48, 45.8 ± 1.89, n = 3 to 15.9 ± .37, 52.6 ± 51, n = 4. Unfortunately the sample sizes were very small.

Yoshida et al. (75) examined 57 kindergarten children over a 14 month running program. Fourteen boys and 11 girls, all 5 years old, ran 750-1500 m 5 times a week (5W), 11 boys and 10 girls ran the same distances one day a week (1W), and 5 boys and 6 girls (their school activity was limited to low intensity games) served as comparison subjects (OW). A teacher paced the children so that at least half the class could follow. Max $\dot{V}O_2$ was determined by progressive running tests on a track at various speeds. No changes were found in any of the groups pre- to post-training for submax $\dot{V}O_2$, or max HR ($p>.05$). Submaximum HR (beats/min) decreased significantly ($p<.05$) in the 5W group (190 ± 2.46 to 177.4 ± 1.96), changes in the 0W group (193.1 ± 3.62 to 185.4 ± 3.83) and the 1W group (193.5 ± 2.39 to 187.4 ± 1.94) were not significant ($p>.05$). Pre- and post-training submax $\dot{V}O_2$ scores (ml/kg/min) were not significantly lower for any of the groups (0W = 37.4 ± 1.03 vs. 36.7 ± 2.68; 1W = 38.6 ± .89 vs. 34.5 ± 1.51, and; 5W = 36.5 ± 1.12 vs. 34.3 ± .74). Post-training max HR scores (beats/min) were not significantly decreased in any of the groups (0W = 6.4, 1W = 3.9, and 5W = 9.8). Post-training max $\dot{V}O_2$ scores (ml/kg/min) also displayed non-significant changes (0W = 1.2, 1W = -1.9, and 5W = -3.2).

Clarke et al. (17) reported aerobic training results for 23, 7-9 year old boys who had participated in a 3-month wrestling program. The 6.6 ml/kg/min increase in max $\dot{V}O_2$ was not significantly greater than increases detected for a group of similar age non-training comparison boys measured before and after a 3-month period.

Pubescent children

In Bailey's study (8), active Canadian school children, as determined by child, parents, and teacher questionnaires, had greater treadmill max $\dot{V}O_2$ scores (ml/kg/min) than inactive children at all ages studied: age 12 = 58 vs. 56, age 13 = 57 vs. 53, age 14 = 60 vs. 54, and age 15 = 54 vs. 49. These values were estimated from graphs.

Stransky et al. (67) measured 30 volunteer female subjects before and after a 7-week swimming program. Sixteen girls (mean age = 15.8) trained weekly averaging 12,806 $\pm$ 1480 yards a session. The remaining 14 girls (mean age = 15.9) did not train and served as a comparison group. The swimmers' mean max $\dot{V}O_2$ score was not different from the comparison group's score, pre-training, but there was a difference post-training: swimmers = 41.6 $\pm$ 1.53 vs. 48.3 $\pm$ 1.35, $p<.01$, and comparison girls = 42.9 $\pm$ 1.29 vs. 42.9 $\pm$ 1.21, $p>.05$.

Anaerobic Training in Children

Attempts to indirectly assess anaerobic capabilities include measurements of muscle and blood lactate, ventilation ($\dot{V}E$), and performance. The determination of blood lactate is not precise because as the blood circulates throughout the body, it collects lactate from every area of the body, not just the areas primarily involved in the activity. Analysis of muscle lactate may add little precision because of the difficulty of obtaining samples directly from active muscle.

Analysis of exercise changes in 3 gas exchange variables ($\dot{V}E$, $\dot{V}O_2$, and $\dot{V}CO_2$) is sometimes employed to assess changes in energy system utilization. The departure from linearity in the $\dot{V}E$-$\dot{V}O_2$ and $\dot{V}E$-$\dot{V}CO_2$ relationships, (the inflection point) is called the level of onset of metabolic acidosis (MA) or the "anaerobic threshold."

The performance test most frequently chosen is designed to determine maximum work output and requires that the subject pedal a bicycle ergometer as rapidly as possible for 30 seconds against a resistance calculated from the subject's body weight (10). Another anaerobic power test the Margaria test, requires that the subject run up a flight of stairs after a 6 m start, ascending 3 steps at a time. Microswitches mounted on the 3rd and 9th steps determine the elapsed time (Wilmore, 73).

Direct measurements of phosphofructokinase (PFK), a rate-limiting enzyme for glycolysis, adenosine triphosphate (ATP), creatine phosphate (CP), and glycogen from analysis of muscle biopsy samples provide a better description of anaerobic capabilities than do indirect techniques. However, they are limited because of impracticality.

A major problem with the literature in this area is the inconsistent manner in which data have been collected. Some data are directly obtained measurement and others are estimated. In the studies cited, blood lactate values were determined from analysis of fingertip blood samples (4, 19) or were estimated from measurements of carbon dioxide (CO_2) in the expired air (32). Lactate analysis of blood samples are also affected by the time when the samples are taken. A series of samples taken post-exercise show that several minutes are required for peak values to occur (3). Therefore, comparison of blood lactate values may not be appropriate if the samples were not obtained in a manner designed to ascertain peak values. Very few data are available on glycogen or anaerobic muscle enzymes, PFK, ATP, and CP, primarily because muscle biopsies are required.

Athletic vs. Non-athletic Children

Prepubescent Children

Gadhoke and Jones (32) measured blood lactate in excess of resting levels in 40 school boys (n = 20, 9.5-12 years old; n = 20, 12-14.5 years old) on a bicycle ergometer at 200, 400, and 600 kgm/min. The technique estimated lactate accumulation from expired air (CO_2) concentration. No significant differences ($p>.05$) between age groups were found for excess lactate (mm/l) at 3 common workloads: 200 kgm/min = 1.0 $\pm$ 0.20 vs. 1.3 $\pm$ 0.50; 400 kgm = 2.2 $\pm$ 1.30 vs. 2.6 $\pm$ 1.00 and; 600 kgm = 4.3 $\pm$ 3.80 vs. 3.0 $\pm$ 1.40.

Cunningham and Eynon (19) reported blood lactate measurements determined from fingertip samples taken before and 2 minutes after a maximum work test on a bicycle ergometer. In general, blood lactate increased with age and was greater in males than in females. In females mean blood lactate values (mg%) ranged from 64.3 $\pm$ 8.97 (age = 12.2, n = 8) to 89.2 $\pm$ 18.87 (age = 14.9, n = 5). The males' values ranged from 81.0 $\pm$ 6.86 (age = 11.8, n = 10) to 108.6 $\pm$ 6.25 (age = 14.9, n = 10). The sample sizes were very small and probably included prepubescent and pubescent children, especially in the older groups.

Pubescent children

In Åstrand's study (4) of 30 girl swimmers ages 12-16, including beginners and world record holders, it appeared that lactic acid (LA) levels increased with age. LA (mg%) measurements were determined by analysis of 3-4 finger prick samples taken from a pre-warmed fingertip within a short time following a maximum exercise test. As was the case with other studies (19, 32), the variation was great, ranging from 45 to 135 mg%. These values, however, appeared to exceed normal values for children this age.

Training studies

Prepubescent-children

Eriksson (26) measured exercise blood (mmoles/l) and muscle lactate, ATP, CP and glycogen (mmoles/kg wet weight) concentration in young boys, age 11-13, before and after 16 weeks of mixed training (running, calisthenics, and 20-30 minutes of games). Pre- and post-training measurements of these variables were made at several work loads (kgm/min): rest, n = 8; 500, n = 7; 750, n = 6, and; maximum (pre- = 850, post- = 1014, n = 7 in both cases). At the 2 submaximum work loads, blood lactate was lower for the second test: 500 = 2.3 ± 3 to 2.1 ± 3, p>.05, and 750 = 3.7 ± .6 to 3.3 ± .7, p<.05. At max work loads, the second test producd increased lactate: 4.7 ± .20 to 5.9 ± .20, p<.01. Muscle lactate was lower at 750, 6.7 ± 1.20 to 5.6 ± 1.80, however, this difference was not significant ($p>.05$). At max exercise loads, lactate was increased at the time of the last test: 8.8 ± 1.40 to 13.7 ± 1.20, $p<.05$. Post-training, both ATP and glycogen were significantly increased, 4.3 ± .10 vs. 4.8 ± .10 ($p<.01$) and 54 ± 3.0 vs. 71 ± 3.0 ($p<.01$) respectively. Post-training CP concentrations were increased at every work load but they were significant only at rest: 14.5 ± .80 vs. 20.2 ± .8.0 ($p<.01$) and at 500 kpm/min, 9.3 ± 1.10 vs. 14.7 ± 1.90 ($p<.01$). Post-training maximum work load blood and muscle lactate values were greater than pre-training values, but unequal work loads make comparisons difficult. Resting ATP and CP levels were both improved after training ($p<.01$) and both subsequently fell to similar levels during the same absolute submaximum work loads. No data were presented for the comparison group.

In a study reported by Eriksson and Saltin (28), muscle biopsies and blood samples were taken from 13 boys to ascertain the effects of a 5-month, 3 session per week, 60-minutes per session mixed exercise training program on blood and muscle lactate. No significant post-training differences ($p>.05$) were detected for either blood or muscle lactate levels, at rest, or at 500, and 750 kgm/min work loads. At these respective work loads, muscle lactate values (mm/kg wet weight) were: 1.0, 3.0, and 6.7. At maximal work loads, 800 kgm/min pre-training, and 1000 kgm/min post-training, the values were: 8.8, and 13.7. The corresponding blood lactate values (mm/l) were: rest = 1.0, 500 kgm = 2.0, 750 kgm = 3.5, 800 kgm = 4.5 and 1000/kgm = 5.5.

The changes in PFK-activity (μmol x $[gxmn]^{-1}$) in 5 boys were assessed to determine if changes occurred as a result of 6 weeks of bicycle training (27). PFK, as discussed previously, is considered to be the enzyme determining the rate of glycolysis. Initially, the PFK-activity value was 8.4, about 30% of adult values. The 15.4 post-training value, 55% of adult values, represented an 83% increase.

Massicotte and MacNab (49) tested 11-13 year old boys (n = 36) on a bicycle ergometer before and after a 6-week training period. The boys trained on bicycle ergometers, 3 times a week for 12 minutes a session and were equally divided into 3 exercise groups (by intensity of exercise HR) and 1 comparison group. Post-training blood lactate (mg%) during submaximum work (450 kpm/min) was lowered ($p<.01$) only in the highest (HR = 170-180 beats/min) exercise intensity group: 16.8 ± 1.87 to 12.0 ± .87, $p<.01$. Lactate levels in the other 3 groups (HR = 150-160, 130-140, and control, respectively) were lowered but not significantly: 18.6 ± 2.07 to 16.2 ± 1.37, 21.4 ± 2.27 to 22.9 ± 1.50, and; 24.1 ± 2.97 to 22.9 ± 2.47. At maximum work loads, post-training lactate was increased in all groups but the change was significant ($p<.01$) only in the high intensity group: 71.7 ± 3.83 to 86.8 ± 4.37, 83.6 ± 5.77 to 94.6 ± 7.30, 84.9 ± 7.70 to 91.7 ± 5.50, and; 83.3 ± 6.20 to 87.0 ± 7.00. The maximum work loads were increased for the 3 training groups: 1000 ± 43.3 to 1250 ± 55.9, 916 ± 39.1 to 1133 ± 50.7, and 833 ± 44.1 to 1017 ± 41.7.

Mayers and Gutin (50) reported the results of a 30-second bicycle ergometer anaerobic capacity test on runners, and comparison children. Eight boys were elite cross-country runners and 8 comparison boys were not involved in any organized training, all were 8.3-11.8 years old. The subjects warmed up for 2 minutes at 300 kpm/min. The resistance was then rapidly set to 1.5 kg and all subjects pedaled as fast as possible for 30 seconds. The mean of 54 revolutions (in 30 seconds) accumulated by the runners was significantly greater than the 44 revolutions for the comparison group ($p<.01$).

Pubescent-children

Excess lactic acid values (over resting values) were assessed indirectly from expired air CO_2 content after bicycle ergometer exercise in 20 boys 12-14.5 years old (32). Generally, these measures suggest that lactic acid production increases with age for identical absolute worklads. The values (mmole/l) reported are listed for 200, 400, and 600 kgm/min work loads respectively: 1.3 ± 0.11; 2.6 ± 0.22, and; 3.9 ± 0.31. Statistical significance was not indicated.

Body Fatness in Children

Body fatness (BF), the proportion of fat and lean weight, is estimated using several indirect measurement techniques, including skinfolds, circum ferences, diameters, and underwater weighing (UWW). The body density formulas used in the UWW method of BF are based on data collected on adult cadavers, therefore, this technique may have limitations for the BF determination of children because of possible differences in total body water and bone density between children and adults (44, 55, 74). It is not unusual to find a higher fat percent in children relative to adults even though the adults have fatter outward appearances (50, 74).

Athletic vs. Non-athletic Children

Prepubescent children

Parizkova reported data on 96, 11 year old boys (54) over a 5-year period. The boys were categorized into 4 groups by activity levels according to analysis of questionnaires and sports club activity records. UWW was used to assess BC. The absolute and relative amounts of lean body mass and fat mass were not significantly different among the groups ($p>.05$). Lean and fat weight percentages respectively, beginning with the most active groups were: 84.3 ± 1.39, 15.7 ± 1.39, n = 15; 84.5 ± 0.97, 15.5 ± 0.99, n = 32; 85.3 ± 1.21, 14.7 ± 1.21, n = 28, and; 82.7 ± 17.2 ± 1.25, n = 21.

Sady et al. (61) reported data on experienced young wrestlers (mean age = 11.0 ± 0.21 years, n = 21) and normally active school children (mean age = 11.2 ± 0.24 years, n = 23). The wrestlers were 4 kg lighter, ($p<.05$), had less body fat (4.2 ± 0.24 and 7.4 ± 0.79 kg, $p<.05$), and had less percent body fat (13.3 ± 0.66 and 20.0 ± 1.13).

Pubescent children

Parizkova (54) presented data on 96, 15 year old boys. Lean and fat weight percentages are presented proceeding from the most to the least active boys: 90.1 ± 0.85, 9.9 ± 1.19, n = 15; 87.5 ± 0.74, 12.5 ± 0.72, n = 32; 86.4 ± 0.79, 13.6 ± 0.79, n = 28, and 84.1 ± 1.16, 15.9 ± 1.18, n = 21. In contrast to the first years' data when these boys were 11 years old and no differences were found among groups for either lean or fat weight percentages, the most active boys now had a greater percentage of lean body mass than the least active boys while the opposite relationship was true for the percentage of body fat. Simple inspection of the preceeding data suggest that, generally speaking, the percentage of lean tissue mass increases in direct proportion with activity levels, while an inverse relationship exists with respect to fat tissue mass.

Training studies

Prepubescent children

The 96 males in the Parizkova study (54) were measured annually for 5 years. Although physical maturity status was not assessed, 11 or 12 year old boys generally may be considered to be prepubescent. Although no statistics were presented, in general, the most active boys gained lean mass and lost fat mass 84.3 $\pm$ 1.39 to 85.9 $\pm$ 1.47 and 15.7 $\pm$ 1.39 to 14.1 $\pm$ 1.47, n = 15) while the least active boys lost lean mass and gained fat mass (82.7 $\pm$ 1.35 to 80.9 $\pm$ 1.58, and 17.2 $\pm$ 1.35 to 19.1 $\pm$ 1.31, n = 21). The general trend is for the more active boys to have greater lean mass and lesser fat mass than inactive boys.

Eriksson (26) reported a non-significant ($p>.05$) weight increase of 0.5 kg, but a significant increase ($p<.001$) in body potassium (12gm) in 12 boys, 11-13 years old after 16 weeks of mixed physical training. This corresponded to a lean tissue increase of about 5 kg or 4 kg, if the increase was predominantly muscle tissue.

Lussier and Buskirk (46) measured groups of exercising and non-exercising prepubescent children (ages 8-12) before and after 12 weeks of running training and found non-significant changes ($p>.05$) in body density (determined by UWW) and in skinfolds. The exercise subjects, 11 males and 5 females, and the comparison subjects, 9 males and 1 female, were all classified as stage I for breast development and genitalia maturity (68). Pre- and post-training measures of body density for the exercise children were, 1.053 ± .0004 vs. 1.055 ± .0004, and for the comparison children, 1.057 ± .0004 vs. 1.057 ± .0005. Skinfold measurements, for the sum of 10 skinfolds (mm) were, 88.1 ± 10.58 vs. 85.7 ± 8.35, and 86.4 ± 10.32 vs. 85.1 ± 9.94, repectively.

Vaccaro and Clarke (69) measured 15 experimental and 15 comparison subjects, ages 9-11 years, before and after a 7-month beginning competitive swimming program. Analysis of variance indicated no difference in weight, lean body weight, or percent fat between or within groups, pre- or post-training. Pre- and post-training weight (kg) and percent fat (%) measurements for experimental and comparison subjects respectively were: weight pre = 31.3 ± 1.56 vs. 33.6 ± 1.37, post = 33.2 ± 1.88 vs. 35.3 ± 1.43; percent fat pre = 19.7 ± 0.71 vs. 18.7 ± 1.02, post = 19.1 ± 0.95 vs. 18.5 ± 1.07.

Twenty-three normally active 7-9 year old boys were measured before and after a 3-month wrestling program (17). The results were compared with measurements taken on 22 normally active 7-9 year old boys not involved in any organized training. No differences ($p>.05$) were found between groups for changes in height, weight or sum of skinfolds. These results were presented in abstract form, no individual data was supplied.

Gilliam and Freedson (33) reported no changes in BC ($p>.05$) for 23, 7-9 year old boys and girls (11 experimental, and 12 comparison subjects) over a 12-week school physical fitness program. The number of boys and girls in the groups was not discussed. The experimental children participated in a special program, 25 minutes a day, 4 days a week, for 12 weeks. The predominantly aerobic activity was rated as moderately high in intensity, attendance was 42.7 ± 0.69 or about 91%. The comparison subjects participated 25 minutes once a week in their normal physical education class. Post-training values were adjusted for differences in pre-training scores (ANCOVA). The post-training measurements for body weight (kg), and percent fat (%) for experimental and comparison subjects respectively were: 33.6 ± 0.29 vs. 33.8 ± 0.28, and; 20.9 ± 0.76 vs. 21.2 ± 0.73.

<u>Pubescent children</u>

In the latter 3 years of Parizkova's study (54) the 96 boy subjects were probably of pubescent status. The fat and lean tissue percentages of active and inactive boys displayed opposite relationships. Active boys increased their percentage of lean body weight significantly more than inactive boys: 87.3 ± 1.24 to 90.1 ± 0.85, n = 15 for active boys, and 83.4 ± 1.29 to 84.1 ± 1.16, n = 21 for inactive boys. Percent body fat changes were also different, again favoring the active boys: 12.7 ± 0.38 to 9.9 ± 1.19 for active boys, and 16.6 ± 1.29 to 15.9 ± 1.18 for inactive boys. The significance level was not indicated.

Johnson (39) reported the results of a 2-year study comparing 8th graders who had participated in 2, 3, or 5 day a week physical education classes. Skinfold measurements taken before and after the study indicated the 5-day boys had significantly ($p<.05$) less body fat and more lean mass. There was no difference ($p>.05$) for the 5-day girls. Estimated fat differences for boys and girls were 2.06 and 3.61 pounds, respectively.

Stransky et al. (67) compared the estimated BC (using skinfolds) of 30 female swimmers (mean age 15.8 years for 16 experimental and 14 comparison subjects) before and after 7 weeks of training. Training consisted of 12,806 $\pm$ 1480 yards of swimming per week, and an average of 4 sessions a week. The only significant difference ($p<.05$) found was an increase in lean body weight in the experimental girls, 46.0 $\pm$ 1.30 to 46.7 $\pm$ 1.33. Comparison subjects had similar but non-significant changes: 45.2 $\pm$ 1.18 to 45.9 $\pm$ 1.20.

SUMMARY

Based on the preceeding review of literature, the following statements may be made regarding the effects of exercise/athletic training on young children.

1. The inconclusive and conflicting data regarding aerobic training in prepubescent children do not allow a definitive statement to be made concerning its effectiveness in increasing aerobic power.
   a. Maximum aerobic indicators: Active children, including those involved in exercise or athletic training programs, have greater max $\dot{V}O_2$ scores than inactive children. However, with regard to prepubescent children, studies have shown no changes (17, 33, 49, 66, 75) and increases (14, 25, 26, 27, 49) in max $\dot{V}O_2$ and no change (33, 46, 66, 69, 75) and decreases (14, 49) in max HR as a result of athletic participation or exercise training.
   b. Submaximum aerobic indicators: similar to the preceeding situation, studies have shown no change (49, 66, 75) and decreases (22) in submax $\dot{V}O_2$, and no change (49, 66, 75) and decreases (27) in submax HR as a result of athletic participation or exercise training. None of the cited studies reported slope and intercept data on $\dot{V}O_2$-HR relationships ($\dot{V}O_2$-HR lines).

2. The available evidence on anaerobic training in prepubescent children seems to suggest that more active prepubescent children display greater anaerobic capabilities (although less than adults) as determined by PFK, ATP, CP, glycogen, blood and muscle lactate, and performance tests.

   a. Metabolic acidosis (MA): no studies were found that assessed MA changes in children resulting from training or that compared MA in active and inactive children; however, some studies have investigated differences in PFK, ATP, CP, glycogen, and lactate under these conditions. All these indicators were found to increase with training (26, 27). Additionally, maximum lactate concentrations were found to be higher while submaximum lactate concentrations were found to be lower in active children compared to inactive children (26).

   b. Anaerobic power (AP): few studies have utilized the 30-second all-out bicycle test to determine AP. AP is defined as the maximum work output generated during any 1 of the 6, 5-second intervals (10). Athletic children had greater 5-second work scores than non-athletic chidren (9, 48).

   c. Anaerobic capacity (AC): few studies have utilized the all-out 30-second bicycle test for AC assessment. Active children and athletes had greater scores than non-active and non-athletic chidren (9).

3. The reported data on body fatness of prepubsecent children suggest that no changes in body fatness should be expected to occur as a result of athletic (or general physical) training.
   a. Sum of skinfolds (SSF): longitudinal or training studies have shown no changes (17, 33). Some cross-sectional studies indicate that active and athletic children have less subcutaneous fat (54, 61, 62) than inactive or non-children..
   b. Percent body fat (BF%): longitudinal or training studies have indicated no changes in BF% (17, 33). The cross-sectional data indicate decreased BF% in active children (54).

STATEMENT OF PROBLEM

As the preceeding discussion indicates, research on the aerobic, anaerobic, and body composition changes of prepubescent children in response to their participation in physical training programs has been inconclusive and oftentimes contradictory. The physiological and physical characteristics of experienced children athletes and the responses of these children to additional training have not been well researched (19, 20, 21). The present study measured the physiological and physical changes in experienced prepubescent wrestlers resulting from their participation in an intensive 7-week training program and compared the results to the changes detected in a comparison group of boys who were not involved in athletic training. This was accomplished by ascertaining the following variables in wrestlers and a comparison group before and after the 7-week camp.

1. Aerobic fitness

    a. Maximum indicators: maximum oxygen uptake (max $\dot{V}O_2$), maximum heart rate (max HR), and performance time to exhaustion.

    b. Submaximum indicators: $\dot{V}O_2$-HR lines, slopes and intercepts.

2. Anaerobic fitness

    a. Onset of metabolic acidosis (MA).

    b. Anaerobic power (AP).

    c. Anaerobic capacity (AC).

3. Body fatness

    a. Sum of skinfolds (SSF).

    b. Percent body fat (BF%).

CHAPTER II

METHODS

Subjects

All wrestlers in the camp between 7 and 12 years old were potential subjects. The comparison group, also less than 12 years old, were volunteers from a local Boy's Club. This organization provides a place where young boys may participate in group or individual activities but structured athletic training is not offered.

Informed written consent, in compliance with the policies of the Institutional Review Board for the Protection of Human Subjects of the University of Nebraska, was obtained from each boy and his parents or guardian before the boy was accepted into the study.

Determination of Prepubescence

The chronological ages of all boys ranged from 7 to 12 years of age. According to the methods of Tanner (68), prepubescence was determined by the absence of secondary sexual characteristics. For both groups, this examination was performed at the time of the final treadmill test.

Initial and Final Measurements

The following 3 measurements were performed before and after a 7 week period. The wrestlers were measured before and after the camp, and the comparison group subjects were measured 1 week later in each case.

Aerobic Fitness

Maximum Indicators

Aerobic power is generally considered to be the best single descriptor of cardiovascular fitness (5). Max $\dot{V}O_2$ was determined for each boy by analyzing the results of their performance during an incremental treadmill exercise test (15). Each test was preceeded by a 5-minute standing rest period and a 5-minute walking accommodation period after which both grade and speed were increased every 3 minutes until the boy was unable to continue. The initial stage was a slow walk, only slightly faster than the accommodation period. Subsequent stages progressed through a normal walk, a fast walk, a jog, and finally a run. Standard open-circuit spirometric techniques were used to determine $\dot{V}O_2$ (5, 51) during the last minute of each 3-minute stage.

All expired air ($\dot{V}E$) was collected using respiratory tubing and meteorlogical balloons. Expired air was analyzed for both volume and content. Beckman Model LB-2 CO_2 and Applied Electrochemistry S-3A O_2 analyzers were used to determined the percents CO_2 and O_2 of expired air samples. A gas sample from a standard medical gas cylinder was used to calibrate the analyzers. The meteorlogical balloons of expired air were evacuated into a Tissot gasometer to determine volume. Max $\dot{V}O_2$ was defined as the peak $\dot{V}O_2$ in a series of minute values. Additional criteria used were $R > 1.0$, max HR near the subject's age-predicted maximum, and subjective signs of exhaustion. The experimenters gave strong verbal encouragement to all subjects, especially during the final test stages. Additionally, one of the investigators was always stationed immediately behind the subject, straddling the treadmill, with one arm encircling but not touching the subjects' waist. This precautionary measure was taken to assure that the subjects did not fall during the exhaustive final moments of the task. This precautionary measure was also intended to assure the subjects that they would not fall and be hurt if they stumbled during the test.

Submaximum Indicators

The submaximum cardiorespiratory indicators include the slope and intercept of the $\dot{V}O_2$-HR pattern determined from the incremental treadmill test (see above). The line of best fit (determined by visual inspection) was analyzed using regression analysis.

Anaerobic Fitness

Metabolic Acidosis (MA, "anaerobic threshold")

For each child, 3 gas exchange variable were plotted against $\dot{V}O_2$ for each stage of the incremental treadmill (max $\dot{V}O_2$) test:

1. $\dot{V}E_{BTPS}$: expired air corrected to Body Temperature Pressure Saturated gas.
2. $\dot{V}CO_2$: volume of carbon dioxide produced.
3. F_EO_2: fractional concentration of oxygen in the expired air.

The determination of metabolic acidosis ($\dot{V}O_2MA$, or more simply, MA) involved the following 3 criteria (60, 71).

1. The point of departure from linearity of the $\dot{V}E$-$\dot{V}O_2$ curve.
2. The point of departure from linearity of the $\dot{V}CO_2$-$\dot{V}O_2$ curve.
3. An abrupt increase in F_EO_2.

Anaerobic power/Anaerobic capacity

An anaerobic power test (10) was also used to ascertain anaerobic fitness. The test consisted of a 30-second maximum-effort pedalling bout on a child-size stationary bicycle ergometer, and was administered at least 24 hours following the incremental treadmill test.

Anaerobic power is defined as the maximum number of pedal revolutions turned during any one of the 6, 5-second intervals during the 30-second test. Total pedal revolutions turned in a 30-second maximum effort work bout has been used to define anaeorbic capacity (AC) (10).

The flywheel resistance setting was adjusted according to body weight (66 g/kg body weight). Each subject pedaled at a low resistance (about 25% of their weight-determined resistance) for 2 minutes. The commands "ten, five, two, one, begin" signalled the subject to begin pedalling as rapidly as possible. Simultaneously, the resistance was set to the weight-determined level, a revolution counter (activated by a frame-mounted microswitch) was set to zero, and a clock were activated. Because of difficulties encountered adjusting the workload, the data for the first 5-second interval were discarded. The reliability of the AP and AC scores was determined by administering the 30-second bicycle test on 2 consecutive days during the initial testing sessions.

Body Fatness

Sum of skinfolds/Percent body fat

Body fatness was determined by densitometry (42). Underwater weight was taken as the average of the final 2-3 trials in a series of 8-10 trials and was corrected for residual lung volume. Residual lung volume measurements were determined by the oxygen dilution technique (72) prior to underwater weighing, and outside of the water in a position similar to the one assumed during the underwater weighing procedures. For a similar age group of children, reliability of residual volume scores was high ($r = .93$, with S.E. of 54 ml, unpublished data). The Siri formula (64) was used to determine percent body fat:

percent fat = (495/density - 450) X 100.

Lean body weight was determined by subtraction:

lean weight = body weight - fat weight.

Standard anthropometric techniques were performed to determine skinfolds height, and weight, (12, 34). High reliability has previously been demonstrated ($r \geq .88$, with S.E. $\leq$ 5% of the mean) for these anthropometric scores (unpublished data).

Exercise Training Regimen

The 5 day a week training routine was previously designed by the Explorer's Wrestling Club and was implemented as follows:

Morning:

1. Calisthenics and stretching.
2. 5-mile run.
3. Weight toss (10-pound plastic covered plate).
4. Jumping rope for 15 minutes.
5. 12-15 wind sprints covering a 10-yard level area and a half flight of stairs.
6. Wrestling skills practice.

Afternoon:

1. Wrestling skills practice.
2. Self-improvement talk.
3. Group meeting: motivation, discussion, diet hints.

Statistical Analysis

The reliabilities of the pre-training AP and AC scores were determined with Pearson product-moment correlation coefficients. Assessment of test-retest differences and determination of a possible differential effect of the repeated tests between groups was made using a group by test-retest factorial analysis of variance (ANOVA).

Each dependent measure was analyzed using analysis of covariance (ANCOVA). The dependent variables were: max $\dot{V}O_2$, slope, intercept, treadmill performance time to exhaustion, onset of metabolic acidosis (MA), anaerobic power (AP), anaerobic capacity (AC), sum of skinfolds (SSF), percent body fat (BF%), and body density (Bd).

CHAPTER III

RESULTS

The purpose of the present study was to ascertain the physiological effects of a 7-week summer wrestling camp on experienced prepubescent children wrestlers. Aerobic, anaerobic, and body composition variables were assessed in the wrestlers and a group of boys (comparison group) who were not involved in any organized training. Table I contains general descriptive characteristics for both groups of prepubescent boys. The wrestlers were about the same age and height as the comparison boys but the wrestlers were nearly 6 kg lighter.

TABLE I

GENERAL DESCRIPTORS (mean ± S.D.)

Variable	Wrestlers (n = 13)		Comparison boys (n = 9)		Pre-Training Analysis	
	Pre	Post	Pre	Post	t	sig
Age (yr)	11.5 ± 1.14	11.6 ± 1.14	10.8 ± 0.90	11.0 ± 0.91	1.50	N.S.
Height (cm)	142.0 ± 8.93	142.7 ± 9.35	142.2 ± 7.06	143.0 ± 6.82	.07	N.S.
Weight (kg)	34.6 ± 5.60	34.8 ± 5.64	40.6 ± 8.78	40.7 ± 8.99	1.81	N.S.

Aerobic Fitness

Aerobic power was assessed on the treadmill using the Bruce protocol (15). The unadjusted maximum and submaximum indicators of aerobic fitness for both groups, pre- and post-training, are indicated in Table II. ANCOVA was used to adjust for differences in the initial, pre-training scores before statistical comparisons (Table III) were performed. As can be seen, for the maximum indicators, performance time to exhaustion was the only variable for which changes were different between the groups. The wrestlers' time was increased ($p=.007$). There appear to be initial differences between groups for the $\dot{V}O_2$-HR curve characteristics (Figure 1, Table II). However, the adjusted data (Figure 2, Table III) indicate no differences in changes between groups for these submaximum indicators.

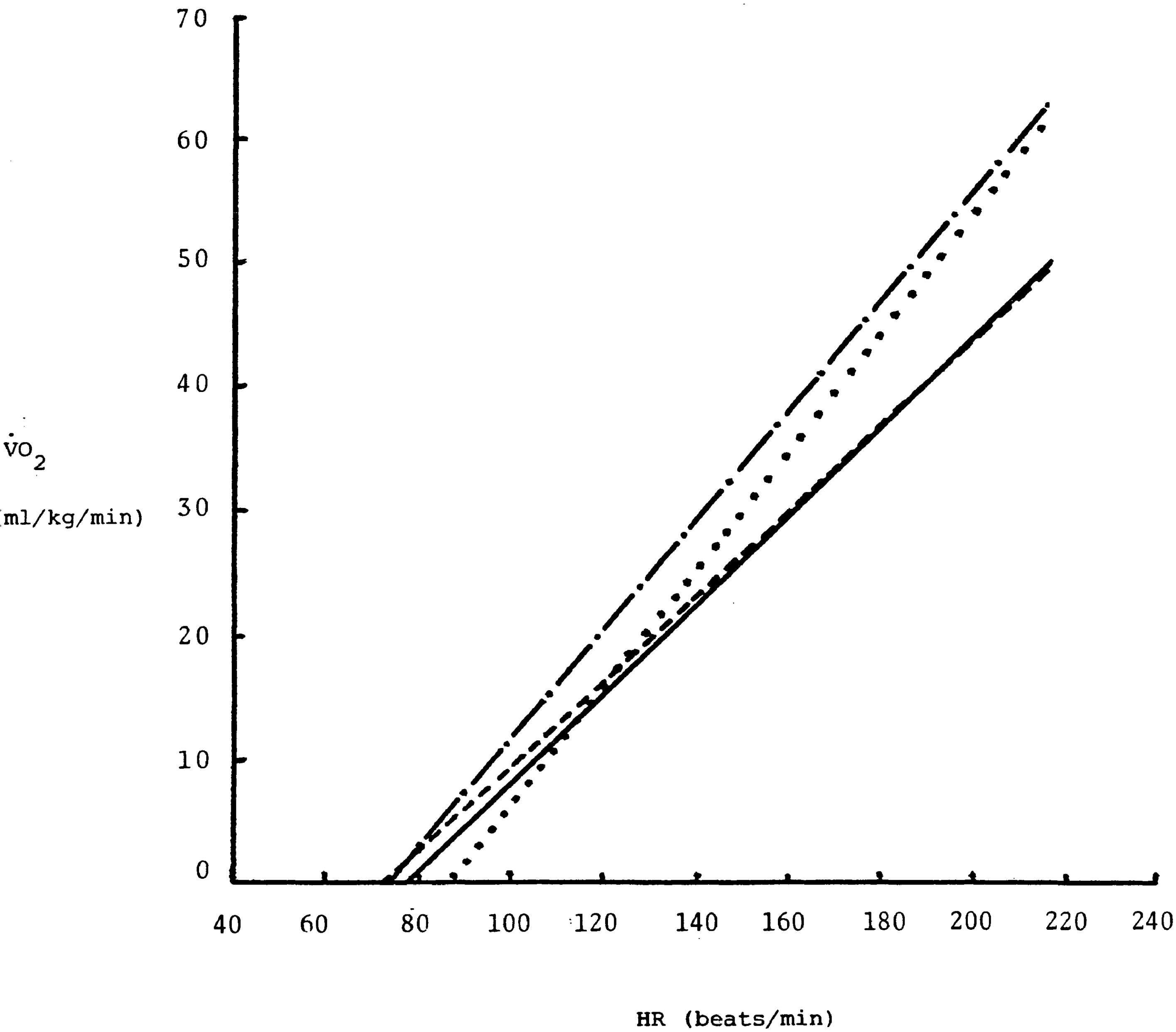
TABLE II

AEROBIC INDICATORS - UNADJUSTED (mean ± S.D.)

Variable	Wrestlers (n = 13)		Comparison boys (n = 9)	
	Pre	Post	Pre	Post
Max $\dot{V}O_2$				
(l/min)	1.90 ± .25	2.00 ± .33	1.70 ± .24	1.70 ± .17
(ml/kg/min)	54.4 ± 4.51	57.1 ± 5.76	43.1 ± 7.45	44.2 ± 7.23
Time to exhuastion				
(min)	13.1 ± .78	14.0 ± 1.11	11.3 ± 1.46	11.5 ± .89
Max HR				
(beats/min)	199 ± 7.2	196 ± 7.1	200 ± 4.7	199 ± 5.6
Max $\dot{V}E$ (l/min)	66.1 ± 8.59	70.3 ± 10.96	65.6 ± 10.93	66.8 ± 10.52
Max R	1.0 ± .05	1.1 ± .05	1.1 ± .06	1.1 ± .04
Slope	.47 ± .085	.44 ± .073	.36 ± .052	.35 ± .059
Intercept	-40.9 ± 12.19	32.1 ± 11.17	-28.0 ± 5.64	-25.1 ± 6.91

FIGURE 1

$\dot{V}O_2$-HR Lines: Unadjusted



Legend

Pre-:

Wrestlers (n=13): • • • • • •

Controls (n=9): ————

Post-:

Wrestlers (n=13): —— · —— ·

Controls (n=9): - - - - - -

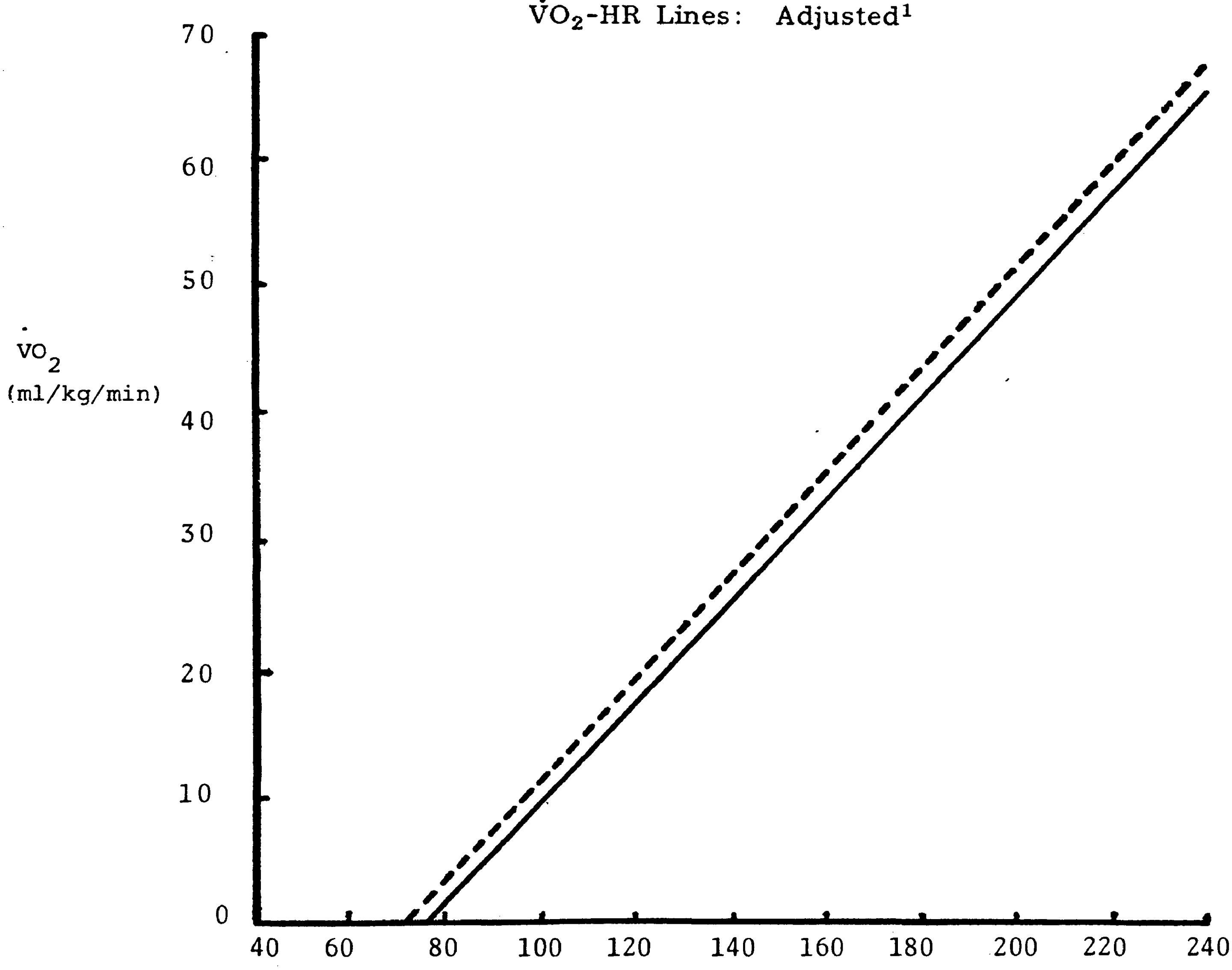
TABLE III

AEROBIC INDICATORS - ADJUSTED (mean ± S.E.)

Variable	Wrestlers (n = 13)	Comparison boys (n = 9)	Sig
Max $\dot{V}O_2$			
(l/min)	1.92 ± .049	1.83 ± .59	N.S.
(ml/kg/min)	53.8 ± 1.60	49.0 ± 2.04	N.S.
Time to exhuastion			
(min)	13.5 ± .26	12.2 ± .32	.007
Max HR			
(beats/min)	196 ± 1.3	198 ± 1.6	N.S.
Max $\dot{V}E$ (l/min)	70.1 ± 2.14	67.1 ± 2.57	N.S.
Max R	1.11 ± .013	1.13 ± .017	N.S.
Slope	.40 ± .011	.40 ± .013	N.S.
Intercept	-28.7 ± 2.19	-30.1 ± 2.72	N.S.

FIGURE 2

$\dot{V}O_2$-HR Lines: Adjusted[1]



Legend

Wrestlers (n=13): - - - - -

Controls (n=9): ———

[1] $p > .05$

Anaerobic Fitness

Anaerobic indicators were assessed by analyzing data from 2 sources: (1) the 30-second bicycle test, and; (2) the level of metabolic acidosis (MA) from the treadmill test. The test and retest AP and AC scores are presented in Table IV and Figures 3 and 4. The group by test-retest ANOVA indicated significant ($p<.05$) group differences and test-retest differences. The interaction effect is significant ($p<.05$) for the AP scores: from test 1 to test 2, scores increased for the wrestlers but were unchanged for the comparison boys. A learning effect may exist for these anaerobic tests, especially for the wrestlers. Therefore, the second test scores were used as criterion scores for pre-training

TABLE IV

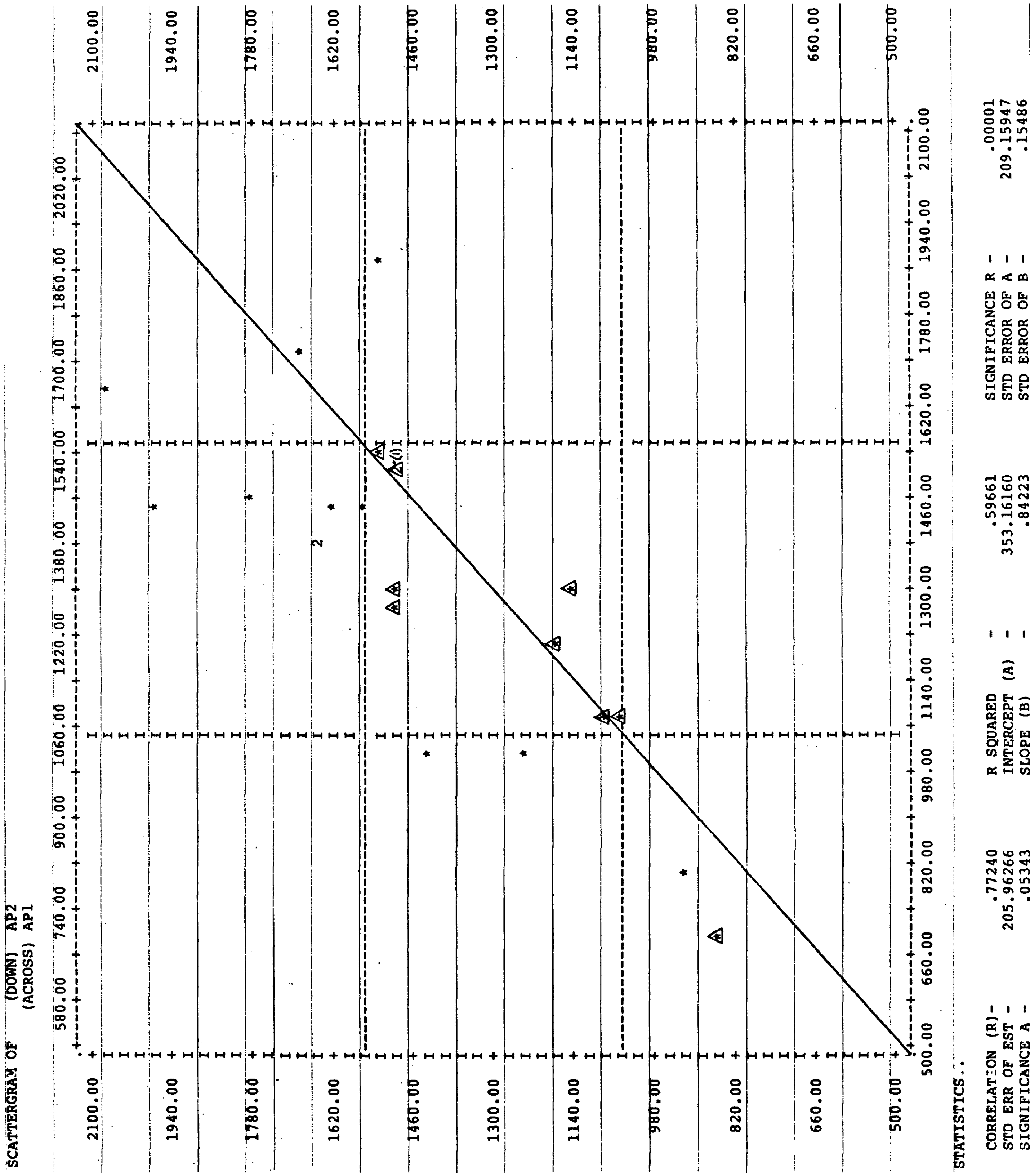
RELIABILITY DATA FOR ANAEROBIC CAPABILITY TESTS PRE-TRAINING (mean ± S.E.)

Variable	Wrestlers (n = 13)		Comparison Boys (n = 9)		ANOVA p values[1]		Test Retest Pearson r
	Test 1	Test 2	Test 1	Test 2	p	p	
AP (kgm/min)							
	1394 ± 82.8	1600 ± 80.3	1215 ± 85.8	1270 ± 84.6	.00	.04	.77
AC (kgm)							
	5826 ± 302.7	6667 ± 335.3	4564 ± 450.7	4981 ± 365.0	.00	.16	.88

[1] within and interaction p values, respectively

FIGURE 3

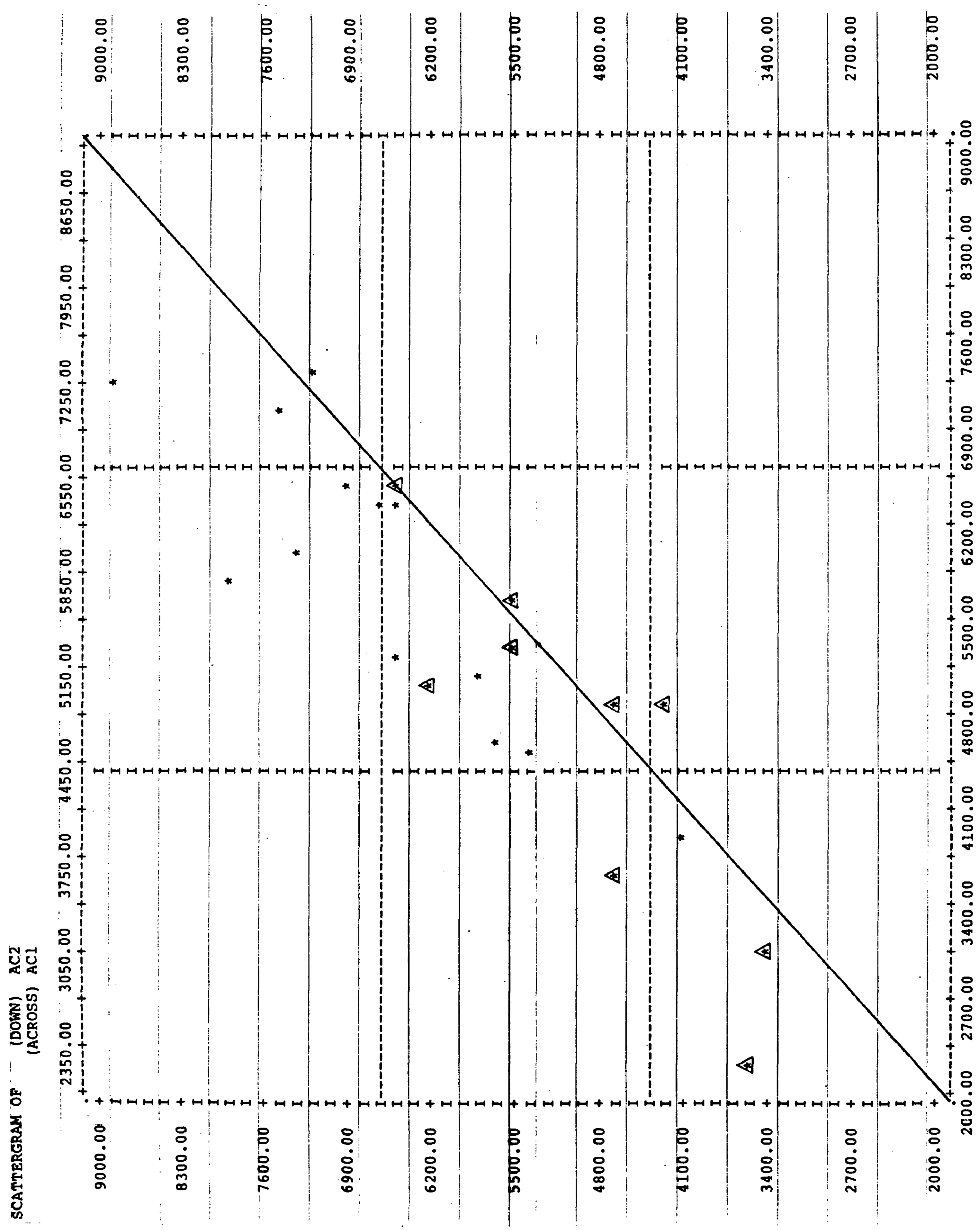
ANAEROBIC POWER: TEST-RETEST



Wrestlers : (n = 13)
Comparison boys: (n = 9) △

FIGURE 4

ANAEROBIC CAPACITY: TEST-RETEST



STATISTICS..

CORRELATION (R) -	.87657	R SQUARED -	.76838	SIGNIFICANCE R -	.00001
STD ERR OF EST -	699.48429	INTERCEPT (A) -	1029.69831	STD ERROR OF A -	625.43920
SIGNIFICANCE A -	.05766	SLOPE (B) -	.93174	STD ERROR OF B -	.11439
SIGNIFICANCE B -	.00001				

PLOTTED VALUES - 22 EXCLUDED VALUES - 0 MISSING VALUES - 0

Wrestlers : (n = 13)
Comparison boys: (n = 9) △

For the bicycle test, the unadjusted AP (maximum work output achieved in any of the 5, 5-second intervals) and AC (total work performed during the 25-second test) scores are indicated in Table V. The adjusted AP scores (Table VI) approached statistical significance ($p=.08$), while the adjusted AC scores (also Table VI) were significant ($p=.05$). For the second source of data, the onset of metabolic acidosis, (MA), scores are also given in Table V. The 4.5 ml/kg/min adjusted difference (Table VI) between groups was not significant ($p>.05$).

TABLE V

ANAEROBIC INDICATORS-UNADJUSTED (mean ± S.D.)

Variable	Wrestlers (n = 13)		Comparison boys (n = 9)	
	Pre	Post	Pre	Post
MA (ml/kg/min)	36.9 ± 5.69[1]	40.1 ± 6.74	30.3 ± 5.89	31.2 ± 6.06
AP (kgm/min)	1601 ± 289.6	1503 ± 284.0	1270 ± 253.8	1073 ± 275.3
AC (kgm)	6667 ± 1208.9	6426 ± 1171.0	4981 ± 1095.1	4256 ± 1211.7

[1]n=12

TABLE VI

ANAEROBIC INDICATORS-ADJUSTED (mean ± S.E.)

Variable	Wrestlers (n = 13)	Comparison boys (n = 9)	Sig
MA (ml/kg/min)	38.2 ± 1.72[1]	33.7 ± 2.03	N.S.
AP (kgm/min)	1396 ± 53.0	1229 ± 65.6	.08
AC (kgm)	5820 ± 190.0	5132 ± 237.1	.05

[1]n=12

Body Fatness

Initially the wrestlers had higher body densities (Bd) than the comparison boys (Table VII). The estimated body fat percents (BF%), therefore, were much lower for the wrestlers. Although the wrestlers had much lower initial BF% and sum of skinfolds (SSF) (Table VII), there were no differences ($p > .05$) in the adjusted values (Table VIII). Thus, it appears that the wrestlers' participation in this training camp did not cause their changes in body composition to differ from the changes of the comparison boys.

TABLE VII

BODY FATNESS INDICATORS - UNADJUSTED (mean ± S.D.)

Variable	Wrestlers (n = 13) Pre	Wrestlers (n = 13) Post	Comparison Boys (n = 9) Pre	Comparison Boys (n = 9) Post
BF%				
	13.2 ± 4.07	12.7 ± 3.01	25.4 ± 7.92[1]	25.0 ± 7.73[1]
SSF (mn)				
	47.6 ± 20.01	46.0 ± 18.89	112.9 ± 65.8	117.5 ± 72.36
Bd (gm/cc)				
	1.0688 ± .00935	1.0699 ± .00691	1.0414 ± .01718[1]	1.0422 ± .01689[1]
RV (1)				
	.63 ± .204	.61 ± .208	.58 ± .100	.52 ± .076[1]
VC (1)				
	2.50 ± .517	2.49 ± .518	2.46 ± .401	2.46 ± .392[1]

[1]n=8

TABLE VIII

BODY FATNESS INDICATORS - ADJUSTED (mean ± S.E.)

Variable	Wrestlers (n = 13)	Comparison Boys (n = 9)	Sig
BF%	16.6 ± .69	18.7 ± .96[1]	N.S.
SSF (mn)	74.5 ± 2.31	76.3 ± 2.89	N.S.
Bd (gm/cc)	1.0612 ± .00159	1.0564 ± .00221[1]	N.S.
RV (l)	.59 ± .019	.54 ± .024[1]	N.S.
VC (l)	2.48 ± .027	2.49 ± .034[1]	N.S.

[1]n=8

CHAPTER IV

DISCUSSION

Aerobic Fitness

Maximum Indicators

The 5 day a week running training performed by the wrestlers in the present study consisted of slow (about 4.5-5 mph), continuous (2-5 miles) jogging, and sprinting a flight of stairs (10-20 up-and-down sprints, each sprint lasted 10-12 seconds and was followed by 1-2 mintues of rest). Jogging was a low intensity stressor for the wrestlers, much less than the exercise intensity reported in studies that detected training max $\dot{V}O_2$ increases (25, 26, 27, 46), and also less than in studies that reported no change in training max $\dot{V}O_2$ (33, 65). In those studies that reported max $\dot{V}O_2$ increases, the frequency and intensity of training were both high, that is, 80-90% of max $\dot{V}O_2$ or max HR, and 3-5 times weekly (25, 26, 27, 46).

Those studies that did elaborate on the frequency and intensity of the training sessions, gave little attention to the duration of the sessions (20, 22, 75). When time was discussed, warm-up and cool-down were usually included. When sprints and intervals were used, the distance, exercise time, and rest interval time were not discussed. Because these studies lack these important training descriptors, a discussion of training quality is impossible.

In adults, the higher the initial aerobic fitness level, the less the likelihood is that aerobic training will elicit a detectable improvement in max $\dot{V}O_2$. Applying this logic to the young wrestlers in the present study, one might argue that the wrestlers' high mean initial max $\dot{V}O_2$ (54.4 $\pm$ 1.25 ml/kg/min) would decrease the possibility of finding an increase in max $\dot{V}O_2$ (relative to the non-training comparison boys) after participating in this training camp. However, the range of the initial max $\dot{V}O_2$ (ml/kg/min) scores for the studies that reported increases in max $\dot{V}O_2$ (42.7 $\pm$ 2.16 to 55.6 $\pm$ 2.07) is very similar to the range of scores for the studies that reported no changes (42.1 $\pm$ 1.04 to 56.5 $\pm$ 1.73). Although there is certainly a limit beyond which max $\dot{V}O_2$ cannot be increased, it would appear from the preceeding information that for these experienced young wrestlers, the frequency and intensity with which training is pursued will have a large influence on the likelihood of improving max $\dot{V}O_2$.

Submaximum Indicators

The scanty data available on submaximum indicators, $\dot{V}O_2$-HR line characteristics (14, 22, 46, 65, 75) do not provide a good basis with which the results of this study may be compared. Among the studies that reported on submaximum indicators, the lack of any similarity among the training variables, except for frequency, makes generalization of the results difficult at best.

The frequency of training in these studies, including the present one, was 4-5 sessions weekly. In the present study, no differences were detected between the groups for changes in the slopes and intercepts of the $\dot{V}O_2$-HR lines. This implies that submax $\dot{V}O_2$ and submax HR changes also did not differ. The training distance in this study is 2-4 times that of another study (75) that reported no submax changes for $\dot{V}O_2$ or HR. However, those subjects were much younger (5 years old) and probably ran the workout more intensively than the wrestlers (they had to try to keep pace with their teacher) . The sprints performed by the wrestlers were undoubtably very intense but they were very brief and the recovery time was great (1-2 minutes). Thus the total exercise time involved was less than that reported for studies that found decreased submax HR values (46. 65). Therefore, it appears that the duration of the wrestlers' high intensity training (80-90% of max HR) was insufficient to cause changes in their submaximum $\dot{V}O_2$ and HR that would differ from changes that the comparison boys might exhibit.

Anaerobic Fitness

Metabolic Acidosis (MA, "anaerobic threshold")

Few, if any, MA data on children have been reported. Training studies have shown that post-training lactate levels were greater than pre-training levels at maximum work loads and that post-training maximum work loads were increased (49). In the present study, even though the wrestlers were unable to achieve a greater work load on the treadmill, their adjusted post-training performance time to exhaustion was significantly increased (p=.007) compared to the change in the performance time of the comparison boys (Table III).

An inspection of Table V suggests that the wrestlers had higher initial and final MA levels than the comparison boys. After the 7-week study, however, the changes in the two groups were not found to differ, indicating that the training camp was unable to to elicite changes in the wrestlers that differed from changes detected for the comparison boys.

Anaerobic Power/Anaerobic Capacity

Performance test data (9) indicate that active (athletic) children have greater AP and AC capabilities than do inactive (non-athletic) children. Inspection of the AP and AC scores presented in Table V supports this finding.

In the present study, anaerobic capabilities were assessed using a 30-second bicycle test. The results indicated that AP and AC changes for the wrestlers were different (or nearly so) than changes detected for the comparison boys. The wrestlers' AC was increased ($p = .05$), and their AP increase approached significance ($p = .08$). The 30-second bicycle test stresses mainly the quadriceps muscle groups of the thighs, the same muscle groups that were predominantly utilized in the performance of the stair-sprint training.

It would seem logical to assume that the stair-sprint training was responsible for the wrestlers' post-training improvements in AP and AC. Extrapolating this interpretation one step further, it is suggested that the increases in AP and AC may be the reason that the wrestlers had a greater increase than the comparison boys for performance time to exhaustion.

Body Fatness

Sum of Skinfold/Percent Body Fat

Other studies have reported that active children have more lean mass and less fat mass than inactive children (54) and that no change in body composition occurred as a result of athletic or exercise training (17). The results of this study support these findings. Initial and final percent body fat and sum of skinfolds measurements (Table VII) indicate that on both occassions the wrestlers had less body fat than the comparison boys. After adjustments were made for these initial differences, there were no differences detected for changes between the groups (Table VIII), indicating that the wrestling camp was not able to produce body composition changes in the wrestlers that were different from changes that may have been found in the comparison boys.

CHAPTER V

SUMMARY

This study compared the physiological and physical changes in experienced prepubescent children wrestlers who participated in an intensive 7-week summer wrestling camp to changes that occurred in a non-training group of comparison boys over a similar time period. Wrestlers from the Omaha area and the surrounding states participated in this camp for 5 days a week, 8 hours a day. They performed rigorous aerobic and anaerobic training and improved their wrestling performance capabilities by mastering new skills and refining existing ones.

The aerobic, anaerobic, and body fatness indicators of the wrestlers were assessed prior to and immediately following the camp. A group of non-athletic comparison boys of similar age and height were measured for the same indicators before and after a 7-week period, in each case, 1 week after the wrestlers. These comparison boys were members of a local Boy's Club and were not involved in any organized athletic or exercise training program.

Differences between the groups were found only for changes in performance time to exhaustion ($p = .007$) and, AC (p=05). A near significant difference was found for the changes in AP (p=.08). No differences between the groups were noted for changes in any of the remaining variables.

CONCLUSIONS

Based on the results of this study, the following conclusions can be drawn regarding the physiological and physical effects of a seven week summer wrestling camp on experienced prepubescent wrestlers.

1. Aerobic fitness

   a. Maximum indicators

      The wrestling camp was unable to produce max $\dot{V}O_2$ changes in the wrestlers that differed from changes measured in the non-training comparison boys.

   b. Submaximum indicators

      The wrestling camp was unable to produce changes in the $\dot{V}O_2$-HR curve characteristics (slopes and intercepts) of the wrestlers' that differed from changes detected in the non-training comparison boys.

2. Anaerobic fitness

   The wrestling camp was unable to produce changes in the wrestlers' level of onset of metabolic acidosis (MA) that were different than the changes found for the non-training comparison boys. It appears, however, that the wrestling camp's stairsprint training was successful in producing changes (increases in AP and AC) in the wrestlers' AP and AC that differed from changes in the comparison boys.

3. Body fatness

The wrestling camp was unable to produce changes in the wrestlers' body composition indicators (SSF, Bd, BF%) that were different from changes that occurred in the non-training comparison boys.

PRACTICAL IMPLICATIONS

The results of this study indicate that the wrestling camp training regimen could not produce changes in the wrestlers' aerobic fitness that were different than those changes that are expected due to normal growth and development. There are 2 important points that may explain these results:

1. The wrestlers' initial aerobic power and $\dot{V}O_2$-HR line characteristics were elevated relative to the comparison boys' values and there was little margin for improvement (Table II), and;
2. The intensity and duration of the wrestlers' training were not high enough to elicit changes that were different from changes that might be found in the non-training comparison boys. If the wrestlers' aerobic fitness improvements are to exceed those associated with normal growth and development (such as those exhibited by the non-training comparison boys) then the intensity and the duration of the aerobic fitness stimulators in this camp must be increased. However, if wrestling is a predominantly anaerobic sport (90%) as was previously indicated (31), then additional aerobic conditioning would be unnecessary.

This study's finding of a difference between groups for changes in anaerobic capabilities indicates that the wrestling camps' anaerobic training stimulus operated successfully. The differences in the changes detected were a significant increase in AC ($p = .05$) and a near significant increase in AP ($p = .08$), both in favor of the wrestlers.

In view of the fact that changes in max $\dot{V}O_2$ between the groups were not different but performance time to exhaustion changes were, it seems possible that the differences in the anaerobic indicator changes may provide at least a partial explanation for the increased ($p = .007$) performance time of the wrestlers relative to the comparison boys. The increased AP and AC of the wrestlers (relative to the comparison boys) may have provided the additional energy sources necessary to increase performance time.

Relative to the comparison boys, the wrestlers have much less body fat. It is highly unlikely that any training the wrestlers receive in this camp will result in changes that differ from changes that may occur in the non-training comparison boys. Employment of methods that result in a further reduction of body fat in the wrestlers may prove harmful to their general health and well-being.

There is a need for further study of the effects of exercise training on prepubescent children. For this summer wrestling training camp the following suggestions are forwarded:

1. As accurately as possible, assess the intensity, duration, and frequency of the training procedures employed without interfering with the administration of the training. This is necessary to quantify the training for comparison with other studies.

2. Attempt to assess the anaerobic fitness of the arm and upper body musculature. The sport of wrestling requires an extensive utilization of the upper body muscle groups, perhaps more than that required of the legs. It would be useful, therefore, to determine the success of this training program in increasing the aerobic and anaerobic capabilities of the arms and upper body as well as the legs.
3. It is recommended that the wrestling training routine emphasis on aerobic conditioning be reduced for reasons previously discussed:
   a. The wrestlers' high initial aerobic fitness leaves little room for improvement, and;
   b. Wrestling is primarily an anaerobic sport and much of the time invested in aerobic training could, therefore, be better utilized for other types of training.
4. The wrestling training routine should include more anaerobic training time because of the heavy anaerobic demands of the sport. Some of the time freed by reducing the volume of aerobic training should be utilized for added anaerobic conditioning.
5. Wrestling skills may also be given additional attention when time formerly alloted to aerobic conditioning is reallocated. Wrestling skills acquisition is, after all, a primary reason most of these wrestlers attend this camp.

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APPENDIX A

Recommendations Offered to the Explorers' Wrestling Club for Conducting Future Wrestling Camps

University of
Nebraska
at Omaha

School of Health, Physical Education & Recreation
University of Nebraska at Omaha Omaha, NE 68182

February 3, 1982

Exploradories Wrestling Club, Inc.
4400½ Fontenelle Pavilion
Fontenelle Blvd.
Omaha, NE. 68104

Dear Joe:

Enclosed are duplicate copies of the data you received earlier. Two enclosures are included. "SUMMARY" is a quick overview of the body composition measurements and treadmill test results. "WRESTLER'S DAILY WORKOUT" contains suggestions for flexibility exercises, circuit weight training, and miscellaneous measures we feel would make the training routine safer from physiological and physical standpoints.

Further statistical analysis will be performed on these data and you will receive copies of the results. Please send us the "information for authors" material from the wrestling publications you receive.

Thank you again for your group's assistance.

Sincerely,

Wade Hoyt Thomson,

Stan Sady, Ph.D.

University of Nebraska at Omaha

School of Health, Physical Education & Recreation
University of Nebraska at Omaha Omaha, NE 68182

SUMMARY

Summer Wrestling Camp
1

The following tables contain cardiovascular and body composition data collected last summer. The prepubescent male subjects were wrestlers (average age = 11.5 yr., range = 9.6 to 12.9 yr.) participating an a 7 week summer wrestling camp and controls (average age = 11.0 yr., range = 9.4 to 12.1 yr.) not involved in any organized athletic training. The "pre" and "post" measurements were taken approximately 6½ weeks apart.

The cardiovascular measures are: $\dot{M}VO_2$, the maximum oxygen comsumption per kilogram of body weight per minute; MHR, the maximum heart rate in beats per minute; T, total walking and running time on the treadmill in minutes. The body composition measures are: SSF, the sum in millimeters of 7 skinfolds including triceps, chest, scapula, midaxillary, abdomen, iliac, thigh; W, weight; FW, fat weight; LW, lean weight (all 3 expressed in kilograms); and, % Fat.

Table 1 contains the pre- and post- values for all these measures (average ± standard error). Table 2 contains the difference scores (post- minus pre-training) for selected measures. No statistical differences ($p > .05$) were found between the groups for any of the scores.

It was not surprising that no significant changes occurred in the controls because they were not training athletically before or during the study; however, one might reasonably have expected the wrestlers to experience some significant improvements due to the rigorous training they performed. Their initial favorable scores on these variables indicate the wrestlers began the camp highly trained and further improvements would be difficult to elicit. This may also indicate that changes can be made, if desired, in certain aspects of their summer wrestling camp without fear of suffering a detraining effect.

Sincerely,

Wade Hoyt Thomson, B.G.S.

Stan Sady, Ph.D

University of Nebraska at Omaha University of Nebraska—Lincoln University of Nebraska Medical Center

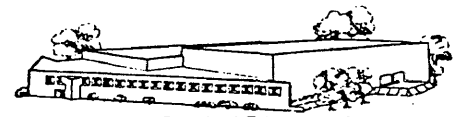
Table 1.

	Physiological Measures: Treadmill			
Variables	Wrestlers		Controls	
	Pre	Post	Pre	Post
$\dot{M}VO_2$	54.53 ± 1.3	57.77 ± 1.2	43.12 ± 2.5	42.02 ± 2.4
MHR	199.31 ± 2.0	197.15 ± 1.7	199.89 ± 1.6	198.67 ± 1.9
T	13.14 ± 0.2	13.97 ± 0.3	11.33 ± 0.5	11.51 ± 0.3
	Physical Measures: Body Composition Underwater weighing & body measurements			
W	34.59 ± 1.6	34.81 ± 1.6	40.59 ± 2.9	40.72 ± 3.0
FW	4.56	4.42	10.31	10.20
LW	30.03	30.39	30.28	30.52
SSF	47.55 ± 5.6	45.97 ± 5.2	115.13 ± 23.1	117.57 ± 24.1
% Fat	13.17 ± 1.1	12.69 ± 0.8	25.41 ± 2.8	25.05 ± 2.7

Table 2.

	Difference Scores: Change ± Standard Error	
Variables	Wrestlers	Controls
$\dot{M}VO_2$	3.24 ± 1.4	0.80 ± 1.5
MHR	-2.15 ± 1.1	-1.22 ± 1.3
T	0.83 ± 0.2	0.18 ± 0.3
SSF	-1.58 ± 1.3	2.43 ± 2.1
% Fat	-0.48 ± 0.7	-0.32 ± 0.5

University of Nebraska at Omaha



School of Health, Physical Education & Recreation
University of Nebraska at Omaha☐Omaha, NE 68182

WRESTLER'S DAILY WORKOUT

Warm-up:
1. Continuous, slow jog, 15-20 minutes.
2. Stretching: slow, sustained stretches, no bouncing.
   a. Increase range of motion (ROM).
   b. Decrease stiffness and soreness.
   c. Decrease possibility of damaging muscles, tendons, and ligaments.
3. Types of stretches:
   a. Head circles: 10 in each direction.
   b. Arm circles: begin with small circles, increasing in size for 15 repetitions, then repeat in the opposite direction.
   c. Shoulders: one arm up, the other down. Clasp the hands behind the back, or use one hand to pull the opposite elbow behind the head. Repeat on each side for 3 times, holding each stretch 8-10 seconds.
   d. Trunk rotators: begin with the feet "shoulder width" apart, knees straight, back straight, hands on hips--make 10 large, slow circles in both directions.
   e. Hip rotators: from the same starting position as above, maintain the trunk in an upright position and make large circles with the hips, 10 in each direction.
   f. Toe touchers: with the feet together, hold the ankles for 6-8 seconds, stretch as far as possible, and repeat 3 times.
   g. Wood cutter: with the feet spread wide apart and the knees straight, reach behind and between the legs as far as possible, hold for 4-5 seconds, and return to the upright position. Repeat 10 times.
   h. Groin stretches: face forward with the feet between "shoulder" and "spread width". Keep the trunk upright and one knee straight while bending the other knee to lower the body, using the hands if needed to maintain balance. Maintain the "down" position for 6-8 seconds, turn the trunk to face the bent knee, holding for 6-8 seconds. Repeat both phases 3 times on each side.
   i. Calf stretches: face a wall, one step away, with the feet together. Keep the heels on the floor, the knees straight, and lean toward the wall. If no stretch is felt, move farther from the wall until a stretch is felt on the lean. To improve the stretch during the lean, keep the heels flat and bend the knees until more stretching is felt. Hold each stage for 6-8 seconds and repeat each 3 times, moving farther from the wall each time.
   j. Bent-legged sit-ups: curl the trunk and bring one shoulder toward the opposite knee. Uncurl and repeat toward the opposite side. Perform 10 in 20 seconds, rest for 20 seconds, and repeat this cycle 3 times. As conditioning improves, the number of sets and/or repetitions may be increased, the pace may be increased, and the rest interval may be decreased.
   k. Fingertip push-ups: with the spine held straight and the hands placed directly beneath the shoulders, the elbows should be completely extended and the body lowered until the nose touches the floor. Repeat 5 times in 10 seconds, rest for 10 seconds and repeat 3 times. As conditioning improves, modify the procedure as with sit-ups.

WEIGHT TRAINING: 2-3 X WEEK

Training should immediately follow warm-up and be followed by at least one day of rest. This circuit depends on individual needs, and the equipment and area available.

Station	Exercise	Repetitions
1.	Bench press	8-10-12
2.	Sit-ups	12-16-18
3.	Chin-ups	3-5-8
4.	Stair sprints	4-6-8
5.	Curls	8-10-12
6.	Lat pulls	8-10-15
7.	Knee curls	8-10-15
8.	Bar dips	2-4-6
9.	Knee extensions	8-10-12
10.	Jog lap	1-2-3

DAILY SKILL DRILLS

Purpose: develop skill and conditioning.

1. Riding. Sets: 1-3 10 X R @ 0:10 (0:30)

   a. man on the bottom attempts to escape for 10 seconds, rests for 30 seconds, and repeats for 10 times.

   b. as conditioning improves, sets and/or repetitions may be increased, ride time may be increased gradually up to 30 seconds and rest time may be decreased gradually to 10 seconds.

2. Spinning. Sets: 1-3 10 X S @ 0:10 (0:30)

   a. man on the bottom supports top man who spins around using his legs for 10 seconds and rests for 30 seconds.

   b. as conditioning improves, modify as above.

3. Other exercises may be added as the coach sees fit.

<u>Key</u>: 10 X R @ 0:10 (0:30)

- (0:30) — length of rest, in seconds
- 0:10 — length of exercise, in seconds
- R — type of exercise (R = Riding, S = Spinning)
- 10 — number of times to repeat the exercise

MISCELLANEOUS SUGGESTIONS

1. Dummy throw. Eliminate this drill unless the wrestlers are segregated by age and by weight, and different sized dummies can be used.

2. Fluid and mineral replacement, and the prevention of heat injuries. During physical activity, the duration and strenuousness of the activity, the type and amount of clothing worn, the temperature, and the humidity all determine how much weight will be lost. Losses of from 5 to 15 pounds are not unusual. If the fluid (or fluids and minerals) are not replaced quickly and sensibly, heat illness results.

   Body weight should be recorded before and after practice to prevent injuries caused by excessive heat loss. A deficit of 3 per cent must be replaced within 24-48 hours. For example, if the pre-workout weight is 100 pounds and the post-workout is 95 pounds, the athlete must weight at least 97 pounds (within 3 per cent of the pre-workout weight) at the next pre-workout weigh-in if he is going to participate, whether it be a practice or a match. Further participation must not be allowed until the athlete returns to within the 3 per cent guideline. Athletes who lose weight in excess of 3 per cent but who come back at the next weigh-in within the 3 per cent guideline may practice or compete.

   Sweat contains much more water than salt (the amount of salt in sweat decreases as the athlete adjusts to exercise in hot and/or humid conditions). During exercise in high heat and/or high humidity, water must be replaced during and after activity to prevent high body temperatures and heat illness. Water is much more important than salt and must be drunk at frequent intervals, perhaps every 20 minutes, and certainly no less frequently than every 60 minutes. For lenghty exertions, the fluid replacement should contain both sugar and electrolytes. Gatorade is a commercial preparation designed for this purpose, although a solution of half water and half Gatorade may speed the bodies' absorption of sugar and electrolytes. Current opinions hold that if a balanced diet is seasoned slightly with salt, electrolyte replacement is not necessary. Salt tablets should not be taken unless their administration can be closely supervised. An effective fluid replacement can be made by adding 2.5 grams of sugar to 1 liter of water, or 2 1/8 teaspoons per gallon. Do not increase the amount of sugar per gallon. If additional sugar is added, it will only serve to draw more water into the stomach to dilute the sugar which slows the time needed for the system to replace the fluid it desperatley needs. The fluid is most effective when cool, not cold, but cool. Acclimatization to heat is also recommended. This may be accomplished in a week by gradually increasing the duration and intensity of activity and the amount of clothing worn. For example, on day one, schedule an easy 45 minute workout in shorts. Day two may be an hour of medium intensity in shorts and t-shirt. On day 3, go to 1¼ hours of hard work in sweat pants and the t-shirt. Day 4 may be 1½ hours of intense activity in full sweats, and day 5 may be 1 3/4 to 2 hours of intense activity in full sweats. The idea is a gradual progression. Remember the 3 per cent rule, and allow access to plenty of fluids!

3. Making weight. Wrestlers should be encouraged to reduce gradually to their desired weight. Weight loss should never exceed 2 pounds a week. Rubber sweatsuits, and special last-minute practices in closed, heated rooms without access to fluids should be discouraged or eliminated as methods of quickly losing weight. Studies on high school and college wrestlers indicate that 48 hours is not enough time to regain the water lost while making weight. Endurance is reduced in these athletes. The effects of repeated drastic water loss on growing children are unknown, but it seems wise to avoid shedding weight in this manner.