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Research article

PHYSIOLOGICAL CHANGES IN SIXTH GRADERS WHO TRAINED TO WALK THE BOSTON MARATHON

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ABSTRACT
The purpose of this study was to assess if supervised, low intensity training would improve aerobic capacity and body composition in sixth graders. Twelve sixth graders walk-trained at approximately 50% of their maximal heart rate, four to five days/week for 12 weeks; beginning with an average of 10 miles/week and increasing to about 27 miles/week (Experimental group [E]). Six subjects of similar age volunteered to be controls (Control group [C]). Baseline and post-training measurements included: height (cm), body weight (kg), sum of skinfolds at six sites (mm), and maximal oxygen consumption (VO_2max; $ml·kg^{-1}·min^{-1}$). Three-day dietary records were also collected at pre-, mid-, and post-training to assess dietary changes that may have occurred during the study. There were significant increases ($p < 0.05$) from baseline to post-training in both groups in height and body weight. There was a significant interaction in the sum of skinfolds: E decreased 10.3% ($p < 0.05$) and C increased 2.3% ($p > 0.05$). There were no significant differences between groups in relative VO_2max ($ml·kg^{-1}·min^{-1}$) from baseline to post-training. C consumed significantly more total kilojoules (11,577±3883 [C]; 7431±2523 [E]) and more total grams of carbohydrate (392±403 [C]; 227±48 [E]) and fat (93±97 [C]; 62±29 [E]) than E, post-training. C also consumed significantly more total grams of protein than E pre-training (95±99 [C]; 74±21 [E]). In conclusion, walk-training elicited a significant decrease in sum of skinfolds with no change in relative VO_2max. Furthermore, no dietary changes were observed in the experimental group as a result of the training.

KEY WORDS: Children, low intensity exercise, walk-training.

BOSTON MARATNUNU YÜRÜMEK İÇİN ANRENMAN YAPAN 6.SINIF ÖĞRENCİLERDE FİZYOLOJİK DEĞİŞİKLİKLER

ÖZET
Bu çalışma ile 6.sınıf öğrencilerde danışman gözetiminde yapılan düşük şiddetli antrenmanın aerobik kapasite ve vücut kompozisyonu geliştirebileceğini ölçmek amaçlandı. 12 6.sınıf öğrencisi yaklaşık maksimal kalp atım sayılarının %50'sinde, haftada 4-5 gün, 12 hafta, haftada 10 mil ile başlayan ve yaklaşık haftada 27 mil'e artan yürüme antrenmanı yaptı (deneysel grup, E). Benzer yaştaki 6 denek kontrol grubu (kontrol grup, C) olmaya gönüllü oldu. Başlangıç ve antrenman sonu ölçümler; boy (cm), vücut ağırlığı (kg), 6 bölgenin der altı kalınlık toplamı (mm) ve maksimal oksijen tüketimi (VO_2maks; $ml·kg^{-1}·min^{-1}$) içermekteydi. Çalışma sırasında oluşan beslenme değişikliklerini değerlendirmek için antrenman öncesi, ortası ve sonrasında 3 günlük beslenme kayıtları toplandı. Her iki grupta boy ve vücut ağırlığında başlangıçtan antrenman sonuna anlamlı ($p < 0.05$) artış vardı. Deri altı kalınlık toplamında anlamlı etkileşim vardı: E % 10.3 düştü ($p < 0.05$) ve C %2.3 arttı ($p > 0.05$). Başlangıçtan antrenman sonuna gruplar arasında VO_2maks ($ml·kg^{-1}·min^{-1}$) açısından anlamlı fark yoktu. C toplam kalori (kilojoul) (11,577±3883 [C]; 7431±2523 [E]), toplam gr karbonhidrat (392±403 [C]; 227±48 [E]) ve yağ tüketimi (93±97 [C]; 62±29 [E]) antrenman sonrası E'den anlamlı fazlaydı. C'nin toplam gr protein tüketimi de antrenman öncesi E'den anlamlı fazlaydı (95±99 [C]; 74±21 [E]). Sonuç olarak yürüme

antrenmanı VO_2maks'da anlamlı bir değişikliğe neden olmadan toplam deri kalınlığında anlamlı bir düşüşe neden oldu. Ayrıca antrenmanın bir sonucu olarak deney grubunda beslenme değişikliği gözlemlenmedi.

ANAHTAR KELİMELER: Çocuklar, düşük şiddetli egzersiz, yürüme-antrenmanı.

INTRODUCTION

Despite current knowledge, there is still a large percentage of the young population who do not participate in regular physical activity (SGRPAH, 1996; USDHHS, 2000). Only one-half of individuals between the ages of 12 to 21 years participate in frequent, vigorous physical activity, and one-fourth of this population reported that they did not participate in any physical activity (SGRPAH, 1996). The U.S. Department of Health and Human Services reported that only 65% of adolescents engaged in the recommended amounts of physical activity in 1999.

The American Heart Association (1992) has listed a sedentary lifestyle as a modifiable risk factor for coronary heart disease. Because the atherosclerotic process is initiated early in life (Rowland, 2001), it is important that proper dietary and exercise habits are implemented at a young age. It has been reported that physically fit children have lower blood pressures and better serum lipoprotein levels than children who do not exercise (Sallis et al., 1988). Physical activity is also important in managing obesity in children (Becque et al., 1988; Epstein et al., 1985a; 1985b).

Exercise programs that are of low intensity (50% to 60% of predicted maximal heart rate [220-age]) are becoming more popular for all individuals and are included as recommendations from two consensus conferences (NIH, 1996; Sallis and Patrick, 1994). People tend to enjoy lower intensity aerobic activities, and they seem to be more compliant to these types of programs as opposed to programs of higher intensity. Furthermore, the rate of injury may be reduced in low intensity activities. However, most training studies have focused on adults (Malina, 1995), and there are limited data on the effects of low intensity exercise on physiological changes in children (Rowland et al., 1991).

A low intensity activity, such as walking, may be appealing to the younger population as a regular physical activity. If children are encouraged to walk with specific achievements as outcomes (e.g., walking 10 miles), children may not perceive the activity as a chore. This type of physical activity may result in children maintaining an active lifestyle into adulthood. Therefore, the purpose of this study was to assess the physiological changes in sixth graders (11 to 12 years of age) who performed a low intensity, high-mileage walk-training program with the goal of walking the Boston Marathon course over a two-day period.

METHODS

Subjects

Prior to subject participation in the study, permission was obtained from the University of Massachusetts Human Subjects Review Committee. Parents and children were required to sign an informed consent form (children assented) and medical clearance was obtained from each child's physician. Subjects were volunteers (11.3 ± 0.5 years of age [exercise group, E] and 11.5 ± 0.55 years of age [control group, C]) from two elementary schools in Amherst, Massachusetts. The experimental group was comprised of students from one elementary school and the control group was from a different elementary school in Amherst, Massachusetts. This was because the teacher at the experimental elementary school was the person who implemented this walk-training program. There were seven females and five males in the experimental group, and three males and three females in the control group. All subjects were Caucasian. Although the control group did not train for the Boston Marathon walk, they were relatively active in other sports, as were those in the experimental group. Thus, both groups had similar physically activity levels at baseline. Both groups were instructed not to change their activity during the study, in order to minimize any confounding effects of other activity on the outcome of the study (aside from the major change of training for the Boston Marathon [experimental group only]). Discussion of continuing with normal activities (aside from the walk-training in the experimental group) occurred with both the children and their parents.

Training Regimen

The study was conducted over a 12-week period. Training began in January and the Boston Marathon walk occurred in April of the same year. The physical education teacher at one of the local elementary schools trained the subjects. Subjects' training regimen was specific and was carefully pre-planned and monitored by the physical education teacher (Table 1). This particular training regimen was selected because the physical education teacher used a similar training protocol previously, in children of the same age group, and children were able to complete the Boston Marathon course in a two-day period.

Table 1. Training protocol of children who trained to walk the Boston Marathon.

Week	Miles/Week	4 Days/Week† (miles.day^{-1})	5 Days/Week† (miles.day^{-1})
1 to 2	10	2.5	2
3 to 4	12	3	2.4
5 to 7	16	4	3.2
8	17	4.3	3.4
9	22	5.5	4.4
10 to 11	27	6.8	5.4
12	19*	4.8	3.8

† Days/week trained was weather dependent
* Tapered in training the week before the Boston Marathon

Heart Rate and Activity Measurements

One day per week, one of the technicians involved in the study would measure heart rate and activity levels during the training session. Although several different technicians assessed heart rate and activity levels during the training sessions each week, all were trained by the lead investigator on how to properly assess these variables and they each practiced in the laboratory prior to measurement in the field. Heart rate was measured periodically (typically three times) during each training session using 10-second radial palpation. The average heart rate was calculated for each training session as the training heart rate for that day.

Activity level was estimated using the CALTRAC™ accelerometer (Hemokinetics, Inc., Madison, WI). The CALTRAC™ has been highly correlated with oxygen consumption (r = 0.68 to 0.74) and seems “well suited for studies of activity level of groups” (Pambianco et al., 1990). This instrument was attached to each child's pants/shorts and worn over the right hip. This measurement was obtained once per week to quantify the amount of activity performed by the experimental group during the training sessions. All subjects (experimental and control) also wore the CALTRAC™ for one week at baseline to establish average activity levels for each child. Children were required to wear the CALTRAC’s™ all day, except when they showered, swam, and slept.

Anthropometric Measurements

All dependent measures were obtained at baseline and after the 12-week walk-training program. Body weight was measured to the nearest 0.5 kg on a calibrated scale (Continental Scale Corporation, Bridgeview, IL). Height was measured to the nearest 0.005 m using a stadiometer. Skinfolds were measured using Lange calipers (10 g mm constant pressure; Cambridge Scientific Industries, Inc., Cambridge, MD) by the same trained technicians at the following sites, all obtained on the right side of the body: triceps, subscapula, suprailiac, abdomen, thigh, and calf. The mean of three measurements at each site was used to represent the total sum of skinfolds.

Maximal Oxygen Consumption

Maximal oxygen consumption (VO_2max) was measured using a continuous, incremental walking test on a motorized treadmill. Each subject was first familiarized on how to properly use the treadmill and instructed on the appropriate use of hand signals. Each subject was also taught how to use the Borg's Rating of Perceived Exertion (RPE) scale (6 to 20 scale). It has been reported that the RPE scale is a useful reference for children’s perceived exertion during exercise (Williams et al., 1991). The subjects were each given a 10-minute warm-up period on the treadmill. During the warm-up period, subjects were asked to choose a speed at which he/she could continue to walk for approximately 15 minutes. The same treadmill speed was used for the post-training evaluation. Subjects were instructed to walk until exhaustion. The test began at a level grade, and was increased 2.5% every two minutes until the subject gave the signal to end the test. Oxygen consumption was measured directly every 30 seconds using computer interfaced Ametek oxygen and carbon dioxide analyzers (Ametek Division, Pittsburgh, PA) and a Rayfield dry gas meter (Chicago, IL). A computer program (VO_2 Plus, Exeter Research, Brentwood, NH) calculated VO_2 and respiratory exchange ratio (RER). Heart rate was monitored each minute of the test using a Vantage Performance Monitor (Polar Electro Company, Finland).

Criteria for achieving VO_2max were as follows: a leveling of VO_2 despite an increase in workload; a RER greater than 1.0; or the subject could not continue to exercise. If one or more of these criteria were achieved, it was considered a valid test. When VO_2max was achieved, the mouthpiece was removed, and the subject cooled-down at a slower speed until his/her heart rate was below 120 beats per minute.

Three-day Dietary Records

Three-day dietary records were collected pre-, mid-, and post-training in order to assess any possible dietary changes that may have occurred with training. Children and parents were instructed to write down all foods, beverages, and supplements they consumed for two weekdays and one weekend day. Completed dietary records were reviewed with each subject at every time point so that the researchers were certain that every item listed was understandable to read. Dietary analyses were conducted using Nutritionist III computer program (Version 5.0, released 1987; N-squared Computing Analytic Software, Silverton, Oregon).

Statistical Analyses
Repeated measures analysis of variance (ANOVA) was used to assess changes over time in all variables, using one within-subject factor (pre- vs. post-training), and two between-subject factors (gender and training group) (Statistical Program for the Social Sciences [SPSS] version 9.0 for Windows statistical software). Tukey's post hoc analysis was used to locate specific pairwise differences. The level of significance was set *a priori* at 0.05. All data are expressed as means ± standard deviation (SD).

RESULTS

Heart Rate and Activity Measurements
There were no significant differences in average kilojoules (kJ)/day expended for each group prior to training as assessed by the CALTRAC™ (experimental group = 1962±439 kJ/day [469±105 kilocalories {kcals}/day]; control group = 2209±96 kJ/day [528±23 kcals/day]). However, these results are from only 7 of the 12 subjects in the experimental group and 4 of the 6 subjects in the control group who properly used the CALTRAC™ for the full seven days prior to the study. The low kJ expenditure could have been due to two things: 1) the entire sample did not provide us with these results, and 2) although the subjects were taught to wear the CALTRACS™ for the entire day during the baseline week, they may have only wore them during certain parts of the day.

Average estimated daily kJ expended by the children in the experimental group during each walk-training session, as assessed by the CALTRAC™, was 1063±218 kJ (254±52 kcals). The range was 678 kJ (162 kcals) (training week 4) to 1322 kJ (316 kcals) (training week 6) per day.

The children's average activity heart rate was 105±8 beats per minute, with a range of 94 (training week 2) to 115 (training week 4) beats per minute. Thus, the average training intensity was approximately 50% of the children's maximal heart rate, confirming that this was a low intensity training program.

Anthropometric Measurements
Height and body weight changes are presented in Table 2. Although there were no significant pre-training differences between groups in any of the variables measured, both groups showed a significant ($p < 0.05$) increase pre- to post-training in height and body weight. There was a significant interaction ($p < 0.05$) in the sum of skinfolds measure (Table 2). Post hoc analysis revealed that the experimental group had a significant decrease (10.5%) ($p < 0.05$) in sum of skinfolds; whereas, the control group showed a non-significant increase (2.3%) in sum of skinfolds.

Table 2. Height, body weight, body mass index (BMI), and sum of skinfolds for the exercise and control groups. Data are mean (SD).

	Height (m)	**Body Weight (kg)**	**BMI ($kg.m^{-2}$)**	**Skinfolds* (mm)**
Exercise Group				
Pre-training	1.5 (0.05)	44.0 (5.7)	19.4 (2.0)	83.2 (22.7)
Post-training	1.5 (0.06)**	45.2 (6.0)**	19.5 (2.0)	74.6 (21.4) †
Control Group				
Pre-training	1.5 (0.08)	39.5 (6.7)	17.4 (1.7)	60.0 (15.8)
Post-training	1.5 (0.08)**	40.0 (7.3)**	17.4 (1.7)	61.4 (16.7)

Note: "Pre-training" and "Post-training" were used for both groups to indicate pre- and post-testing; however, the control group did not walk-train. Due to rounding of numbers, although height appears to be similar, there were significant changes over time.
* Total sum of skinfolds (right triceps, subscapula, suprailiac, abdomen, right thigh, and right calf).
** $p < 0.05$ compared with pre-training for both groups combined.
† $p < 0.05$ compared with pre-training values.

Exercise Testing Data
Total treadmill time, maximal heart rate, RPE, respiratory exchange ratio (RER), and VO_2max are listed in Table 3. All subjects achieved at least two of the three established VO_2max criteria. Although the control group had a significantly greater relative VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) at pre-training, no significant differences were observed between groups over time in relative VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) ($p = 0.12$). Boys had a significantly greater pre- ($p =$

0.0011) and post-training ($p = 0.00045$) relative VO_2max than the girls. Furthermore, at pre-training, the girls in the control group had a significantly greater relative VO_2max than the girls in the experimental group ($p = 0.028$). Nonetheless, the experimental group had a significant increase in treadmill time pre- to post-training, but the control group did not. However, this significant increase could have been simply due to the greater number of subjects in the experimental group, because both groups increased total treadmill time by a similar amount. In addition, RPE was significantly lower at pre- and post-training in the experimental group compared with the control group, implying that the training had a positive effect, which was not directly indicated by oxygen consumption. Furthermore, no significant differences were observed between average meters per second ($m \cdot s^{-1}$) on the treadmill between the two groups or over time (4184 and 4249 $m \cdot s^{-1}$ [2.60 and 2.64 mph] for control and experimental groups, respectively). Finally, although not an outcome measure of this study, the children in the experimental group did complete the entire Boston Marathon course of 26.2 miles in two days (which was their goal).

Table 3. Treadmill time, maximal heart rate, RPE, and RER for the exercise and control groups. Data are mean (SD).

	Treadmill Time (min)	**Maximal Heart Rate (bpm)**	**RPE**	**RER**	**VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$)**
Exercise Group					
Pre-training	12.4 (2.4)	200 (10)	17 (2) †	1.10 (0.05)	45.2 (4.6)
Post-training	13.6 (2.4) *	200 (8)	16 (2) †	1.10 (0.05)	47.6 (5.7)
Control Group					
Pre-training	13.5 (2.0)	193 (12)	19 (1)	1.10 (0.04)	49.0 (2.6)
Post-training	14.5 (1.2)	192 (9)	18 (1)	1.10 (0.04)	48.5 (3.9)

bpm = beats per minute; RPE = (Borg's) Rating of Perceived Exertion (6 to 20 scale); RER = Respiratory Exchange Ratio.
Note: "Pre-training" and "Post-training" were used for both groups to indicate pre- and post-testing; however, the control group did not walk-train.
* $p < 0.05$ compared with pre-training.
† $p < 0.05$ compared with the control group at each time point.

Dietary Intake

The results of the dietary analyses are presented in Table 4. All subjects were unable to complete dietary records for all three time points during the course of the study. Dietary records indicated that the control group consumed significantly more total kJ, and total grams of carbohydrate and fat than the exercise group, post-training. The control group also consumed significantly more total grams of protein than the exercise group, pre-training.

DISCUSSION

The present study was conducted to assess if children who train at a low intensity to walk long distances would exhibit a training effect. The increases that occurred in height and body weight in all subjects would most likely be attributed to growth. However, the exercise group may have increased lean body mass, whereas the control group may have gained body weight by increasing body fat. We suggest this possibility because the sum of skinfolds showed significant decreases, which may be attributed to positive body composition changes. In addition, because the children had similar activity levels at baseline and there were no significant changes in dietary intake over time in the experimental group, the changes in sum of skinfolds were more than likely due to the exercise program. Nonetheless, more sophisticated assessment of body composition would need to be conducted in order to confirm this change in sum of skinfolds in the experimental group.

One of the goals of *Healthy People 2010* is to "Reduce the proportion of children and adolescents who are overweight or obese" (USDHHS, 2000). Because obesity is a risk factor predisposing a number of diseases, including coronary heart disease, diabetes mellitus, hypertension, and some cancers, the reduction we reported in the sum of skinfolds is important, because exercise at a younger age may prevent obesity in adulthood, and thus, reduce chronic disease in the United States. Obesity during adolescence is correlated with adult obesity (Schlicker et al., 1994) and "...there is no question that obesity during adulthood carries a significantly increased morbidity and mortality risk" (Rippe et al., 1992). Exercise has been shown to prevent weight regain in adults (NIH, 1998); thus, beginning an exercise program early in life may result in less weight gain during adolescence and adulthood, reducing the incidence of obesity.

Table 4. Dietary intakes for the exercise and control groups. Data are mean (SD).

	Total KJ (KCALS)	**Total CHO (g)**	**Total Protein (g)**	**Total Fat (g)**
Exercise Group				
Pre-training (n = 10)	8 213 (1 870) [1963 (447)]	270 (51)	74 (21)	67 (24)
Mid-training (n = 7)	7 874 (3 552) [1 882 (849)]	246 (114)	80 (44)	69 (35)
Post-training (n = 7)	7 431 (2 523) [1 776 (603)]	227 (48)	82 (53)	62 (29)
Control Group				
Pre-training (n = 6)	9 844 (2 975) [2 353 (711)]	297 (282)	95 (99)*†	91 (91)
Mid-training (n = 3)	9 929 (2 870) [2 373 (686)]	349 (335)	84 (91)	76 (80)
Post-training (n = 5)	11 577 (3 883) [2 767 (928)]*	392 (403)†	99 (100) †	93 (97)†

KJ = kilojoules; KCALS = kilocalories; CHO = carbohydrate.
Note: sample size is different at each time point, because not all subjects completed three-day dietary records for each time point
* $p < 0.05$ compared with exercise group at that time point
† $p < 0.05$ compared with mid-training protein consumption

Children who partake in aerobic exercise have higher VO_2 values than their sedentary counterparts (Kwee and Wilmore, 1990). Atomi et al. (1986) concluded that the intensity and duration of daily physical activity corresponding to 60% of VO_2max in pre-adolescent children may contribute to increased aerobic power. Tell and Vellar (1988) also reported increased aerobic capacity in girls and boys, 10 to 14 years of age, who exercised two to three times per week, about 30 minutes per session. Rowland and colleagues (Rowland and Boyajian, 1995; Rowland et al., 1991) have reported improvements in VO_2max in both obese teenagers and non-obese children and adolescents who trained three days per week for 11 to 12 weeks. Although we did not report a significant change in aerobic capacity in our study, the experimental group did show a slight increase in VO_2max, whereas the control group showed a slight decline; however these were not statistically significant changes. Because our training program was designed to be of low intensity, a significant increase in VO_2max was less likely to occur, but may have occurred if the exercise training was of longer duration. Nonetheless, total treadmill time increased significantly in the experimental group, indicating that an improvement in endurance was occurring, but was not yet evident in VO_2max. Furthermore, the experimental group had a large increase in their energy expenditure over time due to the walk-training. The increased energy expenditure would result in the prevention of obesity if exercise were continued for a life time.

Walking is a simple, enjoyable exercise in which the entire family can participate, requires little skill, and is a low-injury activity. If children are positively influenced about exercise, they will more than likely adopt a healthier lifestyle, and their risk of coronary heart disease may decrease. Furthermore, they may be more likely to continue exercising throughout their lives if the exercise is enjoyable to them. It is extremely important that children are not forced to exercise, however, because this can lead to a negative attitude towards exercise, and hence, a sedentary lifestyle in adulthood (Taylor et al., 1999).

Morrow and Freedson (1994) have proposed several recommendations in their review on physical activity and aerobic fitness in children and adolescents. First, they concluded that little research has been conducted which identifies the minimal dose of physical activity required for aerobic fitness in children and adolescents. They recommend that more research should be conducted in this particular area. Furthermore, they suggest that the total "volume" of physical activity throughout the day may be the key in determining youth fitness. Malina (1995) cautions that we do not treat children as "miniature adults". He states, "It is important that physical education and activity programs for children and youth consider what is best for their overall physical and behavioral development as opposed to what we think will best prepare them for adulthood or treating them as if they were adults" (Malina, 1995).

Finally, with respect to dietary intake, C had a greater energy intake than E pre- and post-training. This may be due to the fact that C was slightly, but not significantly more active than E at pre-training. However, E was significantly more active than C post-training, which would not explain the significantly greater energy intake by C post-training. Although dietary records give a general indication of energy intake, they are not always accurate, thus, it could be that C and/or E did not accurately estimate their energy intake. Furthermore, not all subjects completed dietary records at each time point, which could have also affected the results.

CONCLUSION

From the results of this study, we conclude that a low intensity program of endurance walking may improve body composition in children between 11 and 12 years of age. These changes were independent of any height or body weight increases because both groups showed increases in these variables. Furthermore, total treadmill time significantly increased in the exercise group. More research is required to assess the effects of structured exercise programs in children. In particular, follow-up studies are required to evaluate if these children continue to exercise as they get older.

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