Journal of Strength and Conditioning Research, 1994, 8(4), 219-224

A Comparison of the Cardiovascular Effects of Running and Weight Training

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Reference Data

Goldberg, L., D.L. Elliot, and K.S. Kuehl. A comparison of the cardiovascular effects of running and weight training. *J. Strength and Cond. Res. 8(4):219-224. 1994.*

ABSTRACT

Weight training is believed to result in little cardiovascular benefit compared to aerobic conditioning. In this study, heart rate and blood pressure changes in previously sedentary men were observed at rest and during simulated daily physical activities before and after a controlled 16-week conditioning program of either weight training or running. Body composition, peak oxygen uptake ($\dot{V}O_2$peak), and strength were assessed before and after the study. At rest, during isometric exertion, and while performing two levels of treadmill walking, runners and weight trainers had lower estimates of myocardial oxygen consumption compared to controls. After training, both runners and weight trainers decreased their percent body fat. $\dot{V}O_2$peak was increased among runners, while only the weight trainers increased strength. These effects are comparable to aerobic exercise during isometric and mixed isometric and dynamic activities, and can occur without enhancement of peak oxygen uptake.

Key Words: jogging, resistance exercise, myocardial oxygen consumption

Introduction

Cardiovascular adaptations to exercise may be unique to the type of training and not evident during other forms of physical exertion. Endurance or aerobic conditioning, such as running, results in increased maximal oxygen consumption with a lower heart rate at given workloads during dynamic testing (5, 11). However, strength conditioning (weight training, resistance exercise) has shown little cardiovascular benefit when assessed by dynamic testing procedures alone (1, 6, 20). Since daily physical activities are not exclusively dynamic, and often are static (isometric) or a mixture of dynamic and static effort (10, 14), adaptations during these common exercise modes should be evaluated as well. The apparent failure of weight training to result in beneficial cardiovascular changes may have been due to observations during endurance testing protocols that emphasize maximal oxygen uptake.

We prospectively observed the conditioning effects of running as compared to weight training on heart rate, blood pressure, and cardiopulmonary parameters during various forms of exertion before and after training. Predicted myocardial oxygen demand (MVO_2) was assessed by observing the heart rate × systolic blood pressure (rate pressure product) at rest, during isometric exercise, and while engaged in mixed static and dynamic exertion. In addition, peak oxygen consumption ($\dot{V}O_2$peak), body composition, and strength were assessed before and after the training period.

Methods

Thirty men (age 37 ± 4 yrs) volunteered, signed informed consent, and completed the research protocol. All were free of medical conditions that would contraindicate rigorous exertion. None took medication, smoked tobacco, or had engaged in endurance training, weight training, or other regular exercise during the preceding 6 months. Individuals were randomized to one of three groups: control, running, or weight training. The groups consisted of 7 men who remained sedentary, 10 who jogged, and 13 who lifted weights.

Testing protocols were identical before and after the training period. Data were collected while standing at rest, during isometric exertion and two stages of isometric and dynamic (mixed) exercise, and during maximal dynamic exercise. Before exercise testing, each subject was familiarized with the experimental protocol and informed consent was obtained. During all exercise modes, oxygen consumption was assessed while subjects performed isometric weight holding and both stages of mixed exercise. It remained unchanged during pre- and posttraining test procedures, ensuring comparable workloads.

Initially the participants were supine for 10 min while electrocardiography was performed. After 5 min of upright posture, blood pressure and heart rate were determined by sphygmomanometry and continuous 12-lead electrocardiographic recording, respectively. During all exercise tests the subjects breathed through a Hans-Rudolph two-way respiratory valve as expired air was collected in a mixing chamber and analyzed for oxygen consumption by a Gould 9000 metabolic cart.

A practice session was performed approximately 10 min before actual testing for isometric and mixed exercise familiarization. Following this session, participants were given a 9.07-kg weight which they held down at the side, elbow extended, in the right hand for 3 min while standing (isometric testing). They continued to hold the weight during two subsequent 3-min periods (Stages 1 and 2) of treadmill exercise at 10% grade and 1.7 mph, followed by 12% grade and 2.5 mph (mixed isometric and dynamic exercise). Heart rate and blood pressure were determined near the end of each 3-min exercise period while the participant was still exercising.

After a minimum of 5 min rest during which the heart rate returned to within 5 bpm of the initial resting rate, participants performed maximal cycle ergometry, with incremental increases of 30 watts every 2 min until volitional exhaustion (a pedal frequency below 50 rpm). Oxygen uptake was continuously assessed.

Body fat % was calculated from body density, obtained by averaging the last two of four hydrostatic weighing measurements and performed by the same technician throughout the study (3). Residual volume was predicted by vital capacity measurement (24). As an index of lower extremity strength, right knee extension was done with Cybex II isokinetic dynamometry (19). This was assessed in ft lbs at an angle speed and setting of 60°/sec and 150°, respectively. For each variable, differences among groups at baseline and after training were determined by one-way ANOVA. If significance was found, Newman-Keuls tests were used to make individual comparisons between the control and both experimental groups.

Training Program

Weight Training

Subjects in this group participated in 16 weeks of progressive weight training using Universal Gym equipment (Centurion Model), exercising three times a week on nonconsecutive days for 45 to 60 min. They trained with light resistance for the first three sessions to familiarize themselves with the conditioning procedure. Following this, weight training consisted of three sets of repetitions for each of eight exercises—bench press, seated rowing, latissimus pull, military press, leg press, leg extension, leg curl, and forearm curl—in random order after initial bench press exercise. No less than 3 nor more than 8 reps were allowed for each training set. All exercise sets were performed until exhaustion. If a subject could lift a training weight eight consecutive times for each of the three sets, he increased the resistance by one level (10 to 15 lbs). A rest period of at least 2 min occurred between sets. Those engaged in weight training did not perform other types of exercise.

Running

Subjects in this group trained three times a week at 70 to 85% of maximal heart rate as determined by the pretraining maximal graded cycle ergometry. All began running for 20 min during the first three training sessions, increasing to a minimum of 45 min three times a week from Weeks 3 through 16. During the first 4 weeks of training each session was supervised. Thereafter, exercise was monitored weekly by checking exercise logs. Runners did not report participating in other forms of regular physical exercise.

Results

Resting Values

Prior to training (Table 1) there were no differences in resting heart rate, blood pressure, or rate pressure product ± *SEM* × 10^3 (Figure 1) within or between groups. After respective conditioning programs, heart rate (Table 2) and rate pressure products (Figure 1) were lower among weight trainers ($p < 0.05$) and runners ($p < 0.05$) as compared to controls.

Isometric Exercise

After 3 min of holding the 9.07-kg weight prior to training, the rate pressure product ±*SEM* × 10^3 among all three groups was similar (Figure 2). Following 16 weeks of conditioning, rate pressure product for both exercise groups was significantly lower ($p < 0.01$) than for the control subjects during weight holding.

Table 1
Pretraining Hemodynamics, Oxygen Uptake, and Body Composition Parameters

	Control (n = 7)		Weight trng (n = 13)		Running (n = 10)	
Parameter	*M*	*SEM*	*M*	*SEM*	*M*	*SEM*
Resting HR (bpm)	80	5	80	3	85	3
Resting SBP (mm Hg)	118	4	122	4	121	4
Isometric; HR	92	7	95	4	101	3
Isometric; SBP	127	6	125	5	128	4
Mixed I; HR	122	7	120	5	127	4
Mixed I; SBP	153	7	156	7	158	7
Mixed II; HR	146	7	145	6	149	5
Mixed II; SBP	173	7	174	7	182	8
Max HR	184	3	185	3	186	3
Max SBP	183	10	188	8	195	7
Max RPP × 10^3	33.3	1.7	34.7	1.4	36.2	1.4
$\dot{V}O_2$ (ml · kg FFM^{-1} · min^{-1})	44.9	3.3	44.5	2.2	43.9	1.6
Body weight (kg)	80.2	4.9	79.8	3.6	84.6	3.4
LBM (kg)	65.0	1.3	64.1	0.7	67.3	0.6
% Body fat	18.9	0.5	20.0	0.5	20.0	0.5

Note. SBP = systolic blood pressure; Mixed = mixed isometric and dynamic exercise; Max = maximal value obtained during cycle ergometry to volitional exhaustion.

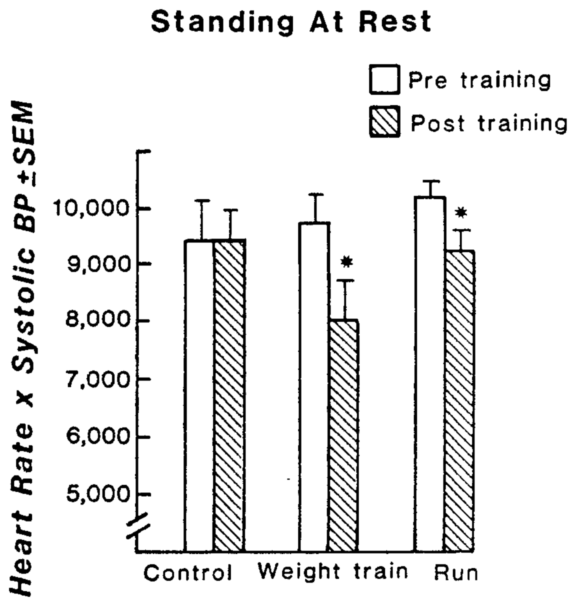

Figure 1. Resting rate pressure product ±*SEM* before and after 16 weeks among the 3 groups. *$p \le 0.05$

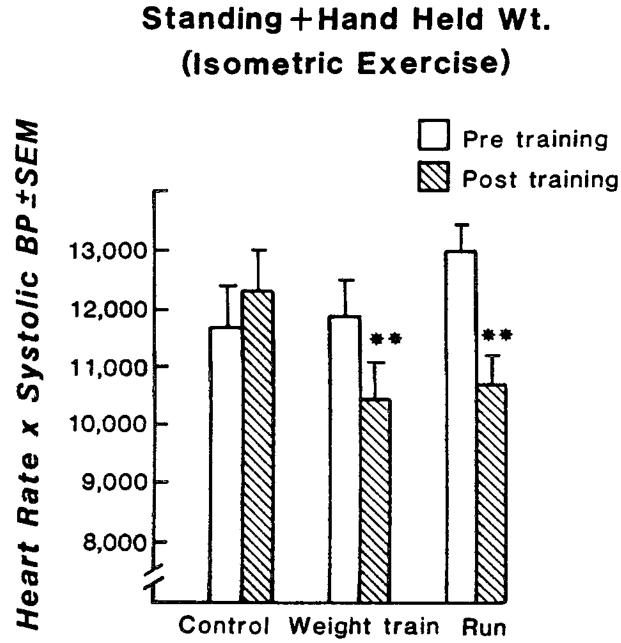

Figure 2. Rate pressure product ±*SEM* during isometric exertion (standing while holding a 9.07-kg weight) before and after 16 weeks among the 3 groups. **$p \le 0.01$

Table 2
Posttraining Hemodynamics, Oxygen Uptake, and Body Composition Parameters

Parameter	Control (n = 7) *M*	*SEM*	Weight trng (n = 13) *M*	*SEM*	Running (n = 10) *M*	*SEM*
Resting HR (bpm)	81	3	72	4*	72	3*
Resting SBP (mm Hg)	117	8	116	3	119	3
Isometric HR	99	4	87	3*	87	3**
Isometric SBP	125	9	121	4	122	3
Mixed I; HR	122	6	108	4**	104	3**
Mixed I; SBP	155	13	142	5	142	5
Mixed II; HR	145	5	133	3*	128	5**
Mixed II; SBP	173	14	161	7	162	5*
Max HR	188	3	186	3	180	3
Max SBP	190	15	186	6	201	7
Max RPP × 10^3	35.6	2.7	34.5	1.0	36.3	1.7
$\dot{V}O_2$ (ml · kg FFM^{-1} · min^{-1})	41.1	0.9	46.7	0.6	50.2	0.5**
Body weight (kg)	80.3	5.1	81.2	3.2	82.7	3.4
LBM (kg)	64.4	1.4	66.6	0.7**	67.4	0.6
% Body fat	19.7	0.5	18.0	0.5*	18.5	0.66**

Note. As compared to controls, *$p < 0.05$; **$p < 0.01$.

Pre- and posttraining values are shown in Tables 1 and 2, respectively. Heart rate and blood pressure ±*SEM* were similar between groups prior to conditioning. After training, heart rate was reduced among weight trainers ($p < 0.05$) and runners ($p < 0.01$). No differences in systolic blood pressure were observed between exercisers and sedentary controls, either before or after training.

Mixed Exercise

At the end of Stage 1 treadmill walking (1.7 mph at 10% grade) with a 9.01-kg handheld weight, double product was similar to that among all groups prior to training. After conditioning, the rate pressure product was lower among both weight trainers ($p < 0.01$) and runners ($p < 0.01$) (Figure 3). Heart rate was also significantly lower for both exercise groups ($p < 0.01$) compared to controls. Systolic blood pressure did not differ among groups before or after the training period (Tables 1 and 2).

At the end of Stage 2 treadmill walking (2.5 mph at 12% grade) and continued weight carrying (Figure 4), rate pressure product, heart rate, and blood pressure were similar to baseline values for all three groups. After training, rate pressure product was significantly lower for runners ($p < 0.01$) and weight trainers ($p < 0.05$), with no significant differences between both groups. Heart rate was also lower for weight trainers ($p < 0.05$) and runners ($p < 0.01$) postconditioning as compared to sedentary controls. Systolic blood pressure was lower only among runners ($p < 0.05$) after training.

Other Training Results

Graded Cycle Ergometry

As a nonspecific test for changes in aerobic endurance, a cycle ergometer was used to assess the conditioning effect. To adjust for body composition changes, oxygen consumption was determined by observing oxygen consumption of fat-free mass per minute. Prior to conditioning, $\dot{V}O_2$peak was similar between groups. After

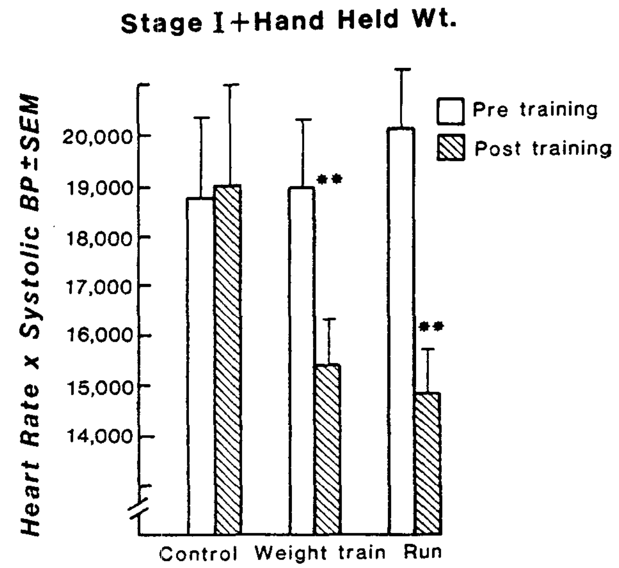

Figure 3. Rate pressure product ±*SEM* during mixed exercise (treadmill walking at 1.7 mph at 10% grade) while carrying a 9.07-kg weight before and after 16 weeks among the 3 groups. $^{**}p < 0.01$

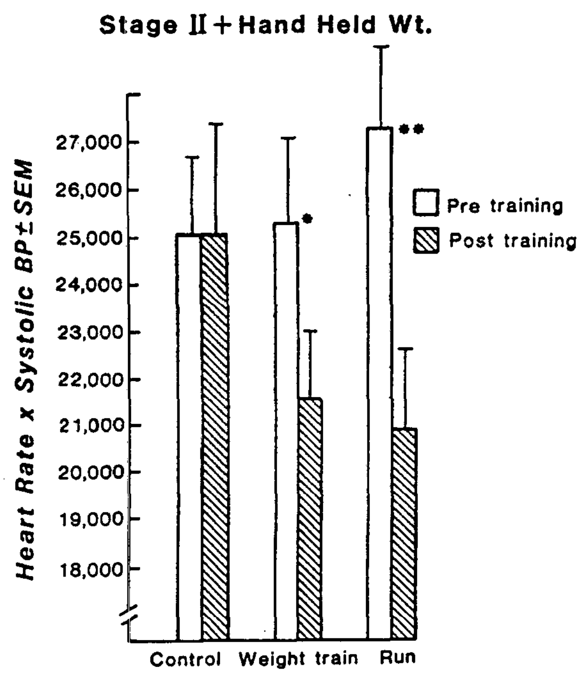

Figure 4. Rate pressure product ±*SEM* during mixed exercise (treadmill walking at 2.5 mph at 12% grade) while carrying a 9.07-kg weight before and after 16 weeks among the 3 groups. $^{*}p < 0.05$; $^{**}p < 0.01$

training, runners had higher peak oxygen uptake ($p < 0.01$) during cycle ergometry to volitional exhaustion when compared to controls. $\dot{V}O_2$peak increased 4.9% (n.s.) for weight trainers and decreased 8.5% (n.s.) among controls. Maximal heart rate, systolic blood pressure, and peak rate pressure product were similar for all three groups before and after the training period.

Body Composition

Characteristics for body weight, % body fat, and lean body mass (fat-free weight) before and after training were observed (Tables 1 and 2). Body weight did not differ between groups at either time. After conditioning, runners ($p < 0.01$) and weight trainers ($p < 0.05$) lowered their % body fat as compared to controls. Although lean body mass was similar among controls and runners after training, weight trainers gained fat-free weight ($p < 0.01$).

Strength Differences

Isokinetic dynamometry was used as a nonspecific test of strength changes. Right quadriceps strength as assessed by peak torque (in ft lbs) with Cybex II isokinetic dynamometry (19) was significantly greater for weight trainers by approximately 12.5% ($p < 0.05$) at the end of the study (Figure 5).

Discussion

Systolic blood pressure, heart rate, and their product were followed during different types of exertion to shed light on the cardiovascular adaptations of running and weight training. Because clinical measurements of the heart rate × blood pressure product correlate well with invasive measurements of myocardial oxygen consumption and demand (MVO_2) during isometric and dynamic exercise and a combination of both, we could evaluate the effect of both types of conditioning based on this parameter (15, 22). Although mechanisms underlying these changes are addressed, this was a descriptive investigation and the specific reasons for the adaptive responses were not sought but do warrant further study.

Different exercise modes produce differences in muscle length and tension. Isometric (static) exertion is a continuous activity resulting in muscle tension change without alteration of muscle length (e.g., holding an object in a fixed position, pushing against an immovable object) (2, 18). Endurance or aerobic exercises are repetitive activities, usually performed with modest resistance, resulting in muscle length change and small increases in muscular tension (e.g., jogging and cycling) (17). Weight training usually combines changes in muscle length with greater levels of tension development. Unlike a sustained isometric contraction, weight training is dynamic and repetitive, interrupted by periods of relaxation (2). There are two general forms of weight training programs: low resistance/high repetition, and high resistance/low repetition training. The weight training employed during this study is considered moderately high to high resistance training (7).

Static (isometric) exercise causes a continuous increase in systolic and diastolic blood pressure in proportion to the percent of maximal voluntary contraction (MVC) of the exercising muscle group; progressive aerobic activity results in increased systolic

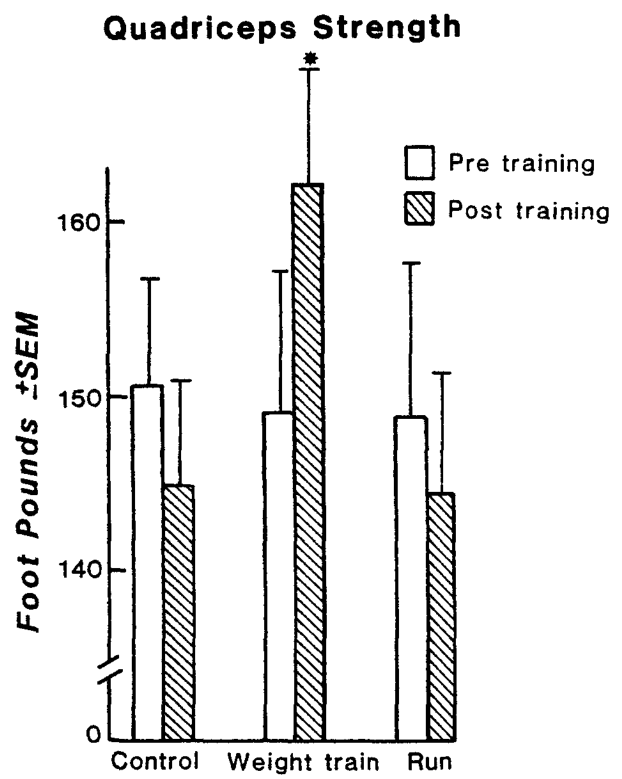

Figure 5. Right quadriceps strength in ft lbs ±*SEM* as assessed by isokinetic dynamometry (60°/sec, peak torque) before and after 16 weeks among the 3 groups. $^{*}p < 0.05$

blood pressure while diastolic pressure is reduced (2, 18, 21). Differences in heart rate and blood pressure occur during various exercise modes, with endurance exercise resulting in a greater heart rate response than for isometric exertion (11, 13, 14, 18). The responses to adding dynamic exertion (treadmill exercise) to an isometric contraction result in increased heart rate and blood pressure beyond the effect of either exercise alone (13).

Blood pressure and heart rate were evaluated during isometric and mixed isometric and dynamic exercise because they are common forms of exertion during daily activities (10, 14). The changes in predicted MVO_2 observed for weight trainers in this study during isometric and both stages of mixed exercise were comparable to those observed among the runners after their conditioning regimens. A previous prospective weight training protocol also showed that rate pressure product was reduced during mixed exercise after weight training (8); however, no control group was used and weight trainers were not compared to aerobically conditioned individuals.

The lower rate pressure product during isometric and mixed exercise among weight trainers might be explained by upper extremity strength increases (9). The weight trainers regularly performed upper body training. As expected, they increased fat-free mass (Table 2) and strength, as indexed by isokinetic dynamometry (Figure 5). Although no direct assessment of strength was performed for the right shoulder and arm, a similar weight training protocol was found to increase upper body strength among participants (8).

It is likely that similar strength gains also were present among our participants. The 9.07-kg load for the strength trained participants may have represented a reduced percentage of MVC after training, resulting in a lowered heart rate response to the given workload. Although a central cardiovascular or neural effect cannot be ruled out, it is possible that an increase in strength reduced the relative % MVC exerted during the experiment, accounting for the observed reduction of heart rate and rate pressure product during this exercise.

Among the runners, reduced heart rate and blood pressure during mixed exercise after training may be due to the improved aerobic capacity ($\dot{V}O_2$peak), with the dynamic component of the exertion representing a lower relative intensity (11). Runners had an increase in $\dot{V}O_2$peak · kg FFM^{-1} · min^{-1}. Oxygen uptake FFM was used to disassociate body composition changes (alterations in fat or lean mass) in order to observe changes in oxidative capacity of muscles.

It is not clear why the runners' rate pressure product was lower during isometric exertion. Despite the lack of upper extremity training in this group, alterations induced by endurance conditioning appeared to transfer to the static exercise mode. In other studies, endurance training effects have not always transferred to untrained limbs during aerobic work (4, 23). Thus it was thought that peripheral changes rather than central or cardiac training occur after endurance exercise (3, 5, 11, 12, 16). Our findings suggest that the endurance conditioned group may have achieved a possible central adaptation for isometric exertion.

The runners and weight trainers both had lower body fat after 16 weeks of conditioning as compared to controls. For runners, this was primarily due to fat mass loss; for weight trainers, the change in body composition was due in part to the gain in fat-free mass. In summary, after 16 weeks of exercise, improved $\dot{V}O_2$peak was found in runners while increased strength occurred in weight trainers. Both weight training and running exercise reduced % body fat, but only the weight trainers increased fat-free mass. However, both exercise groups had similar beneficial cardiovascular changes, with lower rate pressure product at rest and during simulated daily activities of isometric and mixed isometric and dynamic exertion.

Practical Applications

Weight training can have cardiovascular benefits similar to aerobic exercise that are unrelated to oxygen uptake. The lowering of heart rate × blood pressure product during various activities, such as holding a weighted object (e.g., suitcase, briefcase) or walking while performing isometric exertion, will result in less myocardial oxygen demand after either strength conditioning or jogging for 16 weeks. This effect may also provide the basis for functional improvements observed in those with coronary heart disease after participating in weight training programs. The results support the use of strength training and the beneficial adaptation to this type of exercise.

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Acknowledgments

Supported in part by DHHS Grant 1 D28 PE10057-01. The authors thank Darlene J. Coffey and Sue Simmons for their assistance in preparing this manuscript.