AN ABSTRACT OF THE DISSERTATION OF

Julie J. Downing for the degree of Doctor of Philosophy in Human Performance presented on June 4, 2002.
Title: The Effects of Training on Upper Body Power in Female Cross-Country Skiers.

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Abstract approved: ______________ Anthony Wilcox

A distinguishing feature of elite cross-country (xc) skiers is their superlative upper body power (UBP). Race points/rankings are highly correlated to UBP, thus it appears that UBP training is an integral component to the success of xc ski racers. Recently, roller board training was shown to be superior for improving UBP when compared to circuit-type resistance training, free-weight training, and specific-strength training. However, a recent innovation in UBP training has been the introduction of the wind machine, and this has gained wide usage by xc skiers. The purpose of this study was to determine if wind machine training is as effective as roller board training in increasing upper body power in female cross-country skiers.

Forty-four female xc skiers, age 23-59 years, were matched on initial absolute maximal UBP and placed into one of two experimental groups (roller board or wind machine). All subjects underwent eight weeks of UBP training.

Variable	Roller Board Pre-Test	Roller Board Post-Test	Wind Machine Pre-Test	Wind Machine Post-Test
Absolute Power, w ± SD	74.5 ± 30.9	95.9 ± 29.8 *	74.5 ± 33.5	99.3 ± 34.3 *

While both groups improved significantly in mean maximal absolute UBP, t-tests indicated that there was no significant difference ($p > .05$) between the groups in the absolute UBP improvement, indicating that the wind machine was as effective at enhancing absolute UBP as the roller board. Future research should focus on determining the ideal UBP training program, combining the use of the wind machine, roller board, and various core and body resistance exercises.

The Effects of Training on Upper Body Power in
Female Cross-Country Skiers

by
Julie J. Downing

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Julie J. Downing, Author

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DEDICATION

to my husband "JD"

who encouraged me to pursue my Ph.D., moved us to Corvallis, sacrificed, listened, and supported me while taking classes at O.S.U., moved us back to Bend, boosted my confidence and calmed me down while studying for written & oral comps in Bend and finally never let me forget that I wasn't done until the dissertation was complete. Thank you for never giving up on me. I couldn't have done this without you.

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and to Sharon Nofziger

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THE EFFECTS OF TRAINING ON UPPER BODY POWER IN FEMALE CROSS-COUNTRY SKIERS

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ABSTRACT

A distinguishing feature of elite cross-country (xc) skiers is their superlative upper body power (UBP). Race points are highly correlated to UBP, thus it appears that UBP training is an integral component to the success of xc ski racers. Recently rollerboard training was shown to be superior for improving UBP when compared to circuits, weight-training, and specific-strength training. However, a recent innovation in UBP training has been the introduction of the wind machine. **Purpose**: The purpose of this study was to determine if wind machine training was as effective as rollerboard training at increasing UBP in female xc skiers. **Methods:** Skiers were matched on UBP and randomly placed into rollerboard or wind machine 8-week training groups. **Results:** While both groups improved significantly pre-post in UBP, there was no significant difference in UBP improvement between groups. **Conclusion:** Wind machine training appears to be as effective at increasing UBP as rollerboard training.

Key Words: ROLLER BOARD, WIND MACHINE, TRAINING

INTRODUCTION

With the arrival of skate-skiing in the early 1980s, the sport of cross-country (xc) skiing changed forever. Under most conditions, skate-skiing is much faster than traditional classic skiing (34). It was soon shown that with both double-poling and the new skate-skiing, forward propulsion was achieved in large part by the upper body (14, 31, 33), much more so than with classic xc skiing. In fact, the upper body contributes over 50 percent of the force used to propel the skier forward in skate-skiing (33) and a distinct feature of elite xc skiers over lesser ability xc skiers is their superior upper body power (UBP) (24, 30). Thus, it appears that UBP training is integral to the success of xc ski racers.

Thirty studies have collected data pertaining to the upper body power (UBP) of xc skiers. Several of these studies (1, 6, 7, 8, 10, 12, 13, 15, 16, 19, 21, 22, 26, 27, 28, 32) used correlational data to investigate the relationship of upper body measures to xc ski performance. Both absolute UBP (7, 12, 13, 19, 27, 28, 32) and relative UBP (1, 7, 10, 12, 27) show high correlation to race performance ranking/points. Gaskill et al., taking a slightly different approach, showed high correlation ($r = 0.89$) between absolute UBP and race velocity (6). Also, UBP was found to be a necessary variable to be included in multiple regression equations predicting xc ski performance (6, 13, 16, 32).

Eleven of the 30 UBP studies of xc skiers failed to include women as subjects (10, 12, 17, 18, 21, 22, 23, 24, 29, 33, 36), while only two of these studies used women exclusively (11, 26). Looking specifically at training studies of UBP (3, 4, 6, 11, 13, 18, 19, 20, 23, 25, 29), three of 11 studies (18, 23, 29) failed to include women. It cannot be assumed that men and women will show the same trends in UBP. For example, male biathletes' UBP was not significantly correlated to national ranking, whereas female biathletes' UBP was ($r = 0.95$) (27). Also, it cannot be assumed that women will respond the same to UBP training as men (19, 27), and with the exception of the study conducted by Hoff and coworkers (11), the few UBP training studies that included female xc skiers suffered from small sample size or the failure to differentiate the male and female responses in the experimental groups.

Recently, roller board training has been shown to be the best way to develop UBP when compared to circuit-type resistance training, free-weight training, and specific-strength training (20); however the study did not include training using the newly developed wind machine. The wind machine originated as a portable UBP training device in Russia. A replica was built in the late 1990's by Canadian machinist, Miworth, which is now used widely by elite Canadian and American xc skiers for power training. It is imperative that its effectiveness be assessed, because skiers are assuming it will increase UBP and, thus, xc skiing performance without any scientific proof.

The purpose of this study was to determine if wind machine training is as effective as roller board training at increasing UBP in female xc skiers. Since females are not well represented in the previous research on UBP in xc skiers, the subjects in this study were exclusively female.

METHODS

The experimental design of this study was a matched groups, pre-test, post-test design. The dependent variable was absolute upper body power (UBP), while the independent variable was the type of training (2 levels – wind machine and roller board). A review and approval by the Institutional Review Board (Human Subjects Committee) at Oregon State University was obtained prior to initiating this study. Prior to data collection, subjects signed an informed consent and completed physical activity/health history questionnaires to determine study eligibility.

Forty-four local female xc skiers, age 23-59 years, participated in the study. Subjects were recruited from the local xc ski community. For inclusion, all subjects agreed to forego any other intensive UBP training for the duration of the study.

The pre-testing session consisted of the following measurements: body mass, height, upper arm circumference, skinfolds, and maximal UBP. Upper arm circumference was measured around the right arm midway between the acromion process of the scapula and the olecranon process of the ulna with the subject's arm hung freely at her side with the palm facing forward (9). Skinfold measurements were taken with a Lange caliper and body fat was estimated using the Jackson, Pollock, and Ward 7-site generalized equation for women (9).

Maximal absolute UBP was measured by a computerized arm ergometer, Freestyle model made by Ergometrx (Figure 1). Subjects stood on a large platform, holding in each hand a ski handle attached to a rope, and pulled simultaneously in a xc ski double-poling fashion. Subjects were required to maintain a pulling speed of 46 pulls per minute throughout the test, as set by a metronome. The initial test resistance was 0.95 kg, increasing by 0.2 kg every 20 seconds, until the subject could no longer maintain the pulling speed or no longer increase or maintain her maximal power output as displayed by the Extend Software (3, 27, 28). Duration was 1 - 8 minutes.

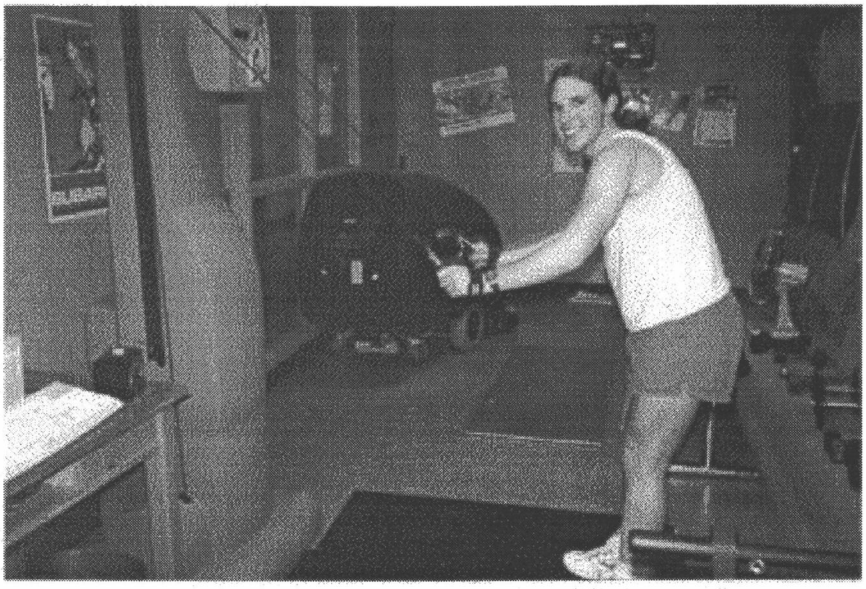

Figure 1 - Maximal UBP Testing Apparatus.

Subjects participated in two brief familiarization sessions, one before pre-testing on the arm ergometer and another on either the wind machine or roller board before their first training session. All testing and training sessions were held in the XC Ski Lab on the campus of Central Oregon Community College in Bend, Oregon. After the pre-testing, subjects were matched into either the wind machine (WM, n = 22) or roller board (RB, n = 22) experimental groups, matched on pre-test UBP results. All subjects were required to participate in three supervised training sessions per week (approximately 30 minutes each) for an eight-week period (24 sessions total) beginning the week after pre-testing.

Training sessions were composed of a five-minute aerobic warm-up, an interval session on either the RB or WM followed by 1 set of 20 repetitions of each dumbbell biceps curls and dumbbell flys, and finally a five-minute aerobic cool-down. The interval sessions gradually progressed over the 8 weeks from lower to higher resistances, more sets (range = 3-6 sets), longer rest between sets (range = 3-5 minutes) and faster speeds. Training resistances used were as follows: Low = 5% grade on RB and 2 paddles on WM. Medium = 7.5% grade on RB and 3 paddles on WM. High = 10% grade on RB and 4 paddles on the WM. For both groups, speed was defined as the following: Slow = slow & controlled, Intermediate = moderate speed, and Fast = as fast as possible. Interval durations ranged from 1-3 minutes.

All subjects used two 5 pound dumbbells at the first training session, increasing by 5 pounds per dumbbell each session until the appropriate weight for 20 repetitions was determined. When 20 repetitions became easy, the subject once again increased dumbbell weight by 5 pounds per dumbbell. Dumbbell exercises were included to work antagonistic muscle groups of those worked during the WM and RB intervals, thus avoiding possible muscular imbalance.

The roller board used in the study was a Pro Model Vasa Trainer. Resistance and grade (angle) were adjustable. The skier lies on a padded seat (at an angle with the head higher than the torso) with wheels on the bottom that roll along the two metal tracks allowing the skier to use attached ropes to pull herself up and down the apparatus in an angled xc ski double poling fashion (Figure 2).

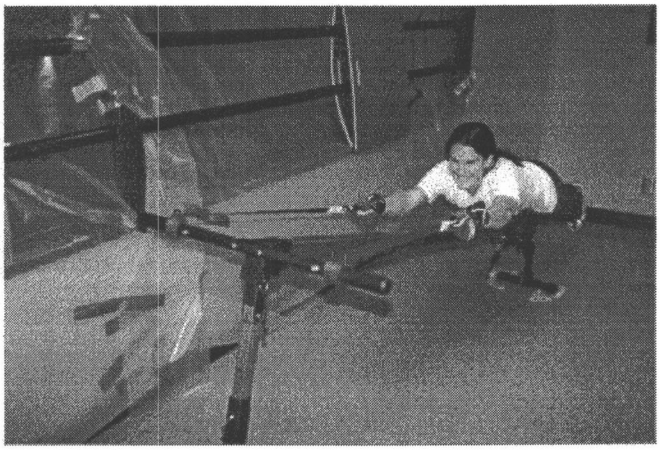

Figure 2 - Roller Board Training.

The wind machine, also known as the Miworth Specialty Machine is a modification of a Russian-designed xc ski machine (Figure 3). As the skier pulled, two flywheels turned, causing attached paddles to produce wind resistance (Figure 4). The harder the skier pulled, the greater the resistance. Higher levels of resistance were also achieved by adding paddles, one to four paddles per side.

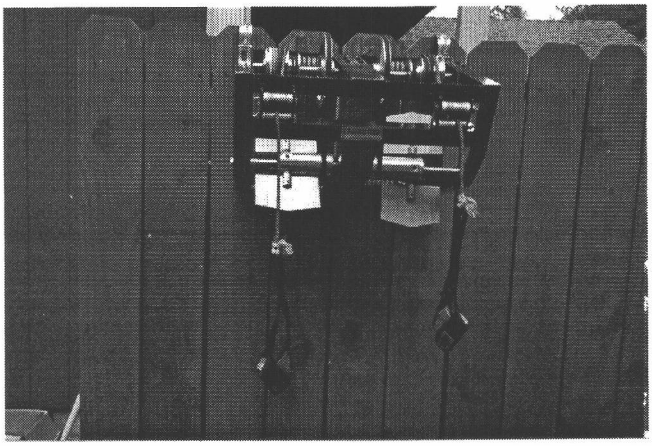

Figure 3 - Wind Machine Apparatus.

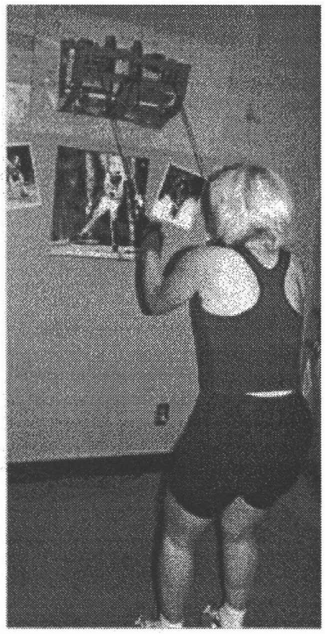

Figure 4 - Wind Machine Training.

Subjects were post-tested once during a four-day period in the week immediately following the 8th week of training, giving subjects two to three days of rest prior to the post-testing. Means and standard deviations were calculated on each measured variable for descriptive purposes as well as statistical analysis. Two-tailed independent measures t-tests were applied to the pre-post difference scores to determine significant ($p \leq 0.05$) differences between the wind machine and roller board groups. Two-tailed dependent measures, paired t-tests were used to determine significant ($p \leq 0.05$) differences pre-post within the wind machine group and within the roller board group.

RESULTS

Forty eight subjects volunteered to be a part of the study. Two subjects in the roller board treatment group dropped out during the first week of the study, one due to illness and the other due to a job conflict. The two wind machine subjects who lost their matched pair completed the study, but their data were not used in the analyses. Thus, although 46 women completed the study, 22 matched pairs (44 total subjects) were used for data analysis. All results presented exclude the two unmatched subjects.

Subject attendance/compliance

The RB and WM groups averaged 23.3 and 23.4 sessions attended, out of 24 total sessions, equaling 97.0 and 97.5 % attendance rate, respectively. The subjects received constant reminders to forego any other intensive UBP training for the duration of the study and there was no indication that any subject violated this agreement of the study.

Matching results

Although subjects were matched into the groups on maximal absolute UBP alone, t-tests comparing pre-test means across groups revealed that there were no significant differences between groups at the onset of the study in any of the measured variables (See Table 1).

Within group differences (training effect)

Pre-post mean comparisons (See Table 1) within each group showed statistically significant improvements in absolute UBP, relative UBP, Total Time to Exhaustion in the UBP test protocol, and Percent Body Fat for both WM and RB groups. There were no significant changes in mass (RB $p = .366$, WM $p = .459$) pre-post for either group, and two variables showed significant difference in the RB group but not the WM: arm circumference (RB $p = .032$, WM $p = .087$) and triceps skinfold (RB $p = .018$, WM $p = .216$). Table 2 shows percent change pre-post within each group.

Table 1. Pre and Post Testing Values (Mean ± SD) for Study Groups.

Variable	Roller Board Pre-Test	Roller Board Post-Test		Wind Machine Pre-Test	Wind Machine Post-Test	
Number of subjects	22	22		22	22	
Age, yr	39.7 ± 11.5	x		37.9 ±8.0	x	
Height, cm	164.6 ± 5.3	x		163.1 ± 4.7	x	
Body Mass, kg	59.3 ± 7.0	59.5 ± 7.1		58.2 ± 6.4	58.4 ± 6.6	
Arm Circumference, cm	25.7 ± 2.2	26.2 ± 2.3	*	25.4 ± 2.2	25.8 ± 2.2	
Body Fat, %	17.7 ± 0.1	17.0 ± 0.1	**	17.1 ± 0.1	16.0 ± 0.1	**
Absolute Power, W	74.5 ± 30.9	95.9 ± 29.8	**	74.5 ± 33.5	99.3 ± 34.3	**
Relative Power, W/kg	1.2 ± 0.5	1.6 ± 0.4	**	1.3 ± 0.5	1.7 ± 0.6	**
Total Time, min	3:03 ± 0:06	4:32 ± 0:07	**	3:04 ± 0:06	4:58 ± 0:06	**
Triceps Skinfold, mm	15.5 ± 5.41	14.45 ± 4.53	**	16.05 ± 4.50	15.72 ± 4.31	
Sessions Attended, %	x	97.0		x	97.5	

x = measured only once. * = significant difference ($p \leq .05$) pre-post within the group.
** = significant difference ($p \leq .01$) pre-post within the group.

Between group differences (group effect)

The main emphasis of the study was to determine whether or not there would be a significant difference in improvement in maximal absolute UBP between the two training groups. Results indicated that there was no significant difference in the maximal absolute UBP pre-post improvement (expressed in watts) between the roller board and wind machine training groups (RB = 21.4 ± 10.2, WM = 24.8 ± 17.0), thus the two forms of training were equally effective at enhancing maximal absolute UBP.

The only variable that differed between groups following the training was the improvement in pre-post maximal time duration on the maximal UBP test, in which the wind machine group (1.90 minutes pre-post improvement) was able to endure a longer period of time than the roller board group (1.49 minutes pre-post improvement), $p = .050$ (See Table 2).

Table 2. Pre-post Absolute Difference Scores (± SD) and Percent Change Within Each Group.

Variable	RB Absolute Change	RB Percent Change	WM Absolute Change	WM Percent Change
Body Mass, kg	0.19 (± 0.97)	+0.3	0.25 (± 1.56)	+0.4
Arm Circumference, cm	0.50 (± 1.02)	+ 2.0	0.39 (± 1.01)	+1.6
Body Fat, %	-0.62 (± 0.01)	-3.6	-1.05 (± 0.01)	-6.6
Absolute Power, W	21.41 (± 10.21)	+34.3	24.77 (± 16.99)	+42.1
Relative Power, W/kg	0.37 (± 0.19)	+40.2	0.43 (± 0.32)	+41.3
Total Time, min	1.49 (± 0.03) *	+58.4	1.90 (± 0.02) *	+75.2
Triceps Skinfold, mm	-1.05 (± 1.91)	-6.5	-0.32 (± 1.17)	-2.0

* = significant difference ($p \leq .05$) pre-post between groups

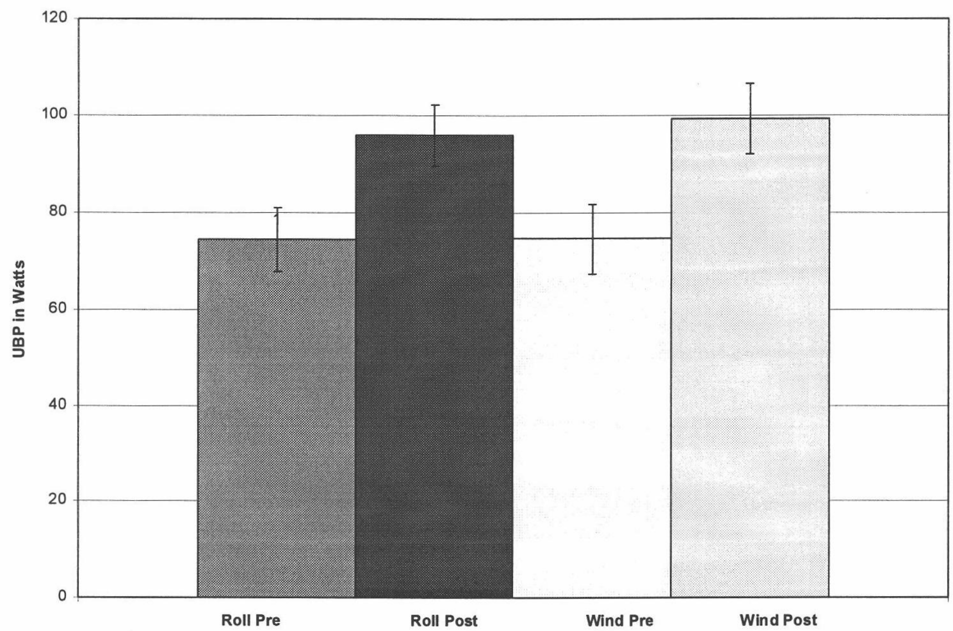

Figure 5 – Pre-Post Maximal Absolute UBP Group Means ± SE Expressed in Watts.

Test-retest results

Three subjects were post-tested twice (See Table 3), with two days between testing, on the maximal UBP test to confirm the results of the pilot testing and Bednarski's study (2) indicating high reliability of the Ergometrx UBP ergometer.

Subjects number 8, 24, and 30 were randomly selected to participate in the test-retest part of the study. No reliability statistic was run due to the inadequate number of subjects retested, however the raw data indicates good reliability. Results are presented below:

Table 3. Test-Retest Data.

Subject Number and Group	Test / Retest Absolute Power in watts	Test / Retest Relative Power in watts / kg	Test / Retest Total Time in minutes
8 RB	63 / 63	1.5 / 1.5	2:20 / 2:20
24 WM	110 / 108	2.2 / 2.2	6:00 / 6:00
30 RB	140 / 136	2.5 / 2.4	6:40 / 6:40

DISCUSSION

The purpose of this study was to compare a proven upper body power training method (roller board) with a newer, unproven upper body power training method (wind machine) in female cross-country skiers. The data of this study show that both roller board and wind machine training regimens improve maximal absolute UBP significantly over an eight-week period.

It was shown in 1997 (19) that a 4-month UBP training program (including roller board) significantly improved maximal UBP in young female xc skiers by 15 $\pm$ 5.6 watts and in young male xc skiers by 35.8 watts on average pre-post (no absolute pre, post, or percent change data were reported). Nesser and coworkers' recent study (20) reported an improvement of 18.55 $\pm$ 13.8 watts pre-post in maximal absolute UBP as a result of a 10-week roller board training study of female and male xc skiers combined, however no gender-specific data were reported. Ploetz and Rundell (25) showed a 41 watt (24%) and 47 watt (17%) increase in maximal absolute UBP in female and male xc skiers, respectively, over 4 years of UBP conditioning using various modes. Hoff (11) showed that female xc skiers improved UBP at anaerobic threshold by 7 watts (7%) over a 9-week maximal strength training period. Finally Bilodeau (3) reported maximal absolute UBP changes of 9 watts (7%) in female xc skiers and 3 watts (2%) in male xc skiers respectively over a 4-month ski season in which no power training, except what occurred while skiing, was performed.

The current study showed greater pre-post maximal absolute UBP improvement (WM = 24.8 $\pm$ 17.0 watts = 41.3% improvement and RB 21.4 $\pm$ 10.2 watts = 34.3% improvement) than any of the past studies reporting this value on xc skiers, despite the shorter training period of 8 weeks. Possible explanatory factors include near perfect attendance, highly motivated subjects, inclusion of dumbbell exercises, and on average, fairly low initial maximal absolute UBP values, as only a few of the females were elite-level skiers.

While the RB and WM groups showed similar trends in results, the RB group showed statistically significant pre-post values in two variables (upper arm circumference and triceps skinfold) that the WM group did not. The upper arm circumference increased by 0.50 cm ± 1.02 in the RB group and 0.39 cm ± 1.01 in the WM group. The triceps skinfold decreased by 1.05 mm ± 1.91 in the RB group and 0.32 mm ± 1.17 in the WM group. It is hypothesized that this increased girth was due to muscular hypertrophy, not increased fat accumulation, as the skinfold caliper results indicated that both body fat percentage and triceps skinfold had reduced significantly pre-post in the RB group. This muscular hypertrophy may have been related to the greater workload (pulling their own body weight up the roller board) used in RB training.

The only other significant difference between the groups was the WM group's pre-post total time to exhaustion improvement was significantly greater than that of the RB group, meaning the WM subjects endured a longer duration on the post-maximal UBP test than the RB subjects.

The WM group's longer time to exhaustion on the maximal UBP test may have been correlated to the faster pulling speeds achieved during the WM training and/or it may be related to the fact that the maximal UBP testing apparatus is more similar in motion to the wind machine and actual xc skiing than the roller board. Both the WM and the maximal UBP testing ergometer require the subject to stand up, allowing the use of the abdominal musculature during the crunching/flexion phase of the torso. However, in the RB exercise, the subject must lie on the padded seat, inactivating the abdominal musculature.

Although RB and WM protocols were identical in number and duration of sets and recovery, pulling speed (slow, medium, or fast), and resistance (low, medium, or high), there was no way to quantify the intensity of the training. Therefore, it is not possible to equate the amount of work performed in the two training regimens. However, both training programs were designed to closely correspond to widely used training practices with the respective devices.

It appeared that the RB subjects pulled at a slower rate at all three resistance levels (Low, Medium, and High) and all three speeds (Slow, Intermediate, and Fast) when compared to the WM subjects. This was simply due to the RB subjects having to pull their own body weight up the board with each pull, while the WM group stood and only had to overcome the resistance that the varying number of paddles created.

Since power is a function of both velocity and force (5), it is hypothesized that the RB group enhanced their power primarily by producing a greater force, while the WM group's power improved mainly by being able to achieve higher pulling speeds. Results showed a 34% and 42% pre-post absolute UBP improvement for RB and WM groups respectively. Although not significantly different statistically, it does raise the question that perhaps the greater speeds obtained in WM training are more transferable to the demands of xc skiing and therefore more effective at improving UBP in female xc skiers.

Statistical power

With two groups of 22 subjects each, statistical power was estimated, prior to data collection, to be .70, meaning that if the study were repeated 100 times, the null hypothesis would be rejected 70 times when the alternate hypothesis was true (35). Observed statistical power within groups is reported in Table 4 and between groups is reported in Table 5. Low statistical power values are seen in all but one (total time to exhaustion) of the between-group and in four of the within-group (body mass, arm circumference, body fat, and triceps skinfold) t-tests. The low observed statistical power values were due to small effect size while the higher observed statistical power values were due to larger effect sizes.

Table 4. Observed Statistical Power Within Groups.

Pre-Post Variable	Roller Board Statistical Power	Wind Machine Statistical Power
Body Mass, kg	.051	.052
Arm Circumference, cm	.111	.088
Body Fat, %	.072	.129
Absolute Power, W	.627	.659
Relative Power, W/kg	.725	.686
Total Time, min	.881	.989
Triceps Skinfold, mm	.104	.056

Table 5. Observed Statistical Power Between Groups.

Between Group Pre-Post Difference Variable	Observed Statistical Power
Body Mass, kg	.053
Arm Circumference, cm	.065
Body Fat, %	.253
Absolute Power, W	.122
Relative Power, W/kg	.115
Total Time, min	.506
Triceps Skinfold, mm	.318

Study design strengths include the following: 1) A large sample size, 44 subjects (22 subjects in each group), was used. No other UBP training study of female xc skiers has used as many subjects. 2) This was the first study to provide research on the wind machine. Other study strengths include near perfect attendance rate, low dropout rate, low injury rate, and equal groups based on initial UBP matching.

Weaknesses of the study include the lack of a control group, no quantification of training workload, similarity of wind machine and the UBP testing apparatus, and low observed statistical power values. A control group would have provided evidence that the changes seen in the study were due to the two treatments and not related to some other factor not controlled for in the study. Quantification of training loads would have provided evidence that differences between groups were not due to differences in the amount of work being performed between the groups. Observed statistical power values were lower than expected, therefore it is not a certainty that non-significant effects are real or occurred due to lower statistical power.

In summary, because high correlations between UBP and xc ski performance have been shown in several studies, it was necessary to compare the current proven method for UBP development (RB) with the newer WM. This study allowed such a comparison. With significant pre-post UBP improvements in both groups and no statistically significant difference in UBP between groups, it can be concluded that the wind machine is as effective as the roller board at improving maximal absolute UBP, and theoretically xc ski performance.

PRACTICAL APPLICATION

The results of this study justifies wide-spread use of the wind machine as a major part of an UBP development program for xc skiers. The ideal program would likely be one that includes regular use of the roller board, wind machine, a variety of body resistance exercises such as crunchers, dips, low back work, pull-ups, push-ups, sit-ups, and circuit type activities utilizing standard weight room equipment. Cross-country ski training has been shown to improve by adding variety (36, 43) and this type of combination training would enable the athlete to train all the upper body musculature used in xc skiing at varying intensities and speeds much like the varying terrain found in a typical xc ski course. Future studies of this nature should attempt to quantify work output on the various apparatuses used, obtain enough subjects to include a control group, and use combination-training methods.

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APPENDICES

Appendix A

Review of Literature

Historical Introduction of Cross-Country Skiing

Cross-country (xc) skiing has evolved from a form of transportation over 4000 years ago into a popular recreational activity and competitive sport for men and women of all ages (9). In 1921, a ski was found in Holting, Sweden that is estimated to be from around 2500 B.C. (53). A pair of skis and one pole were found in Kalvstraesk, Sweden and are estimated to be 4000 years old (27). It is believed that skiers used only one pole through the 19th century when it was determined that two poles allowed the skier to travel faster.

Cross-country skiing is first brought to our attention by pictorial representation, as seen in a petroglyph from Rodoy, Norway estimated to be from approximately 2000 B.C. (5). The first mention of women skiing was in the written word from Swedish archbishop, Olaus Magnus in the mid-1500s (3).

Skiing was not just used for transportation by Scandinavian civilians. It was common practice for Scandinavian military soldiers to train on skis, usually while carrying rifles. Once used in war, the combination of xc skiing and rifle shooting is now a sport called biathlon. The first known biathlon competition occurred in 1767 between Norwegian and Swedish border guards (18).

Two of the major xc ski races today honor war-related travel on skis. The first is the Birkebeiner held each March in Norway commemorating the epic journey of two soldiers who skied the deceased king's infant son to safety in 1206 through blizzard conditions (3). The second race is the Vasa Loppet in Sweden also held annually in March. It honors Gustav Vasa's fleeing from Mora to Saelen and then return to Mora with the people of Mora who had followed him. Upon his return he lead the Swedes to victory over Denmark in 1521 A.D. and later became King. The Vasa Loppet starts at Saelen and finishes in Mora 92 kilometers later. It is now the world's largest xc ski race with approximately 18,000 skiers each year (12).

With such history behind it, it is no surprise that xc skiing was one of the selected sports for the first Winter Olympics (men only). There is disagreement about when the first Winter Olympics were: 1924 or 1928. In 1924, a winter sports festival was planned for the city of Chamonix, in the French Alps. The Marquis de Polignac, a member of the International Olympic Committee (IOC) made a plea to the IOC that the festival be officially recognized as the Winter Olympic Games (18). However, this was not to be as Baron Pierre de Coubertin, also a Frenchman and founder of the modern Olympics, disagreed with the proposal. The end result was that the IOC agreed to let Chamonix call its festival an "Olympic Winter Carnival." The hero of the carnival was a xc skier named Thorleif Haug of Norway who won three gold medals, for 18 kilometer, 50-kilometer, and nordic combined event (xc skiing and ski jumping). Since the 1924 carnival was so well received, in1928 the IOC formally established the Winter Olympic Games to be held in St. Moritz, Switzerland (18).

Biathlon was also in the first Winter Olympics for men, removed for a few Olympics and is now back as a Winter Olympic sport since 1960. Women were allowed to compete in Olympic xc skiing in 1952, while the first women's Olympic biathlon was not until 1992 (18). The 2002 Salt Lake City Winter Olympic Games included biathlon (skate-skiing and rifle shooting) and xc skiing (classic and skate-skiing) events for both men and women, plus nordic-combined (skate-skiing and ski-jumping) for men only.

As of the year 2000, xc skiing is a general title that covers two very different techniques, so different that they require completely different equipment, snow grooming, and, arguably, training methods. The original technique is referred to as "classic" skiing where the skis remain parallel to the direction of travel at all times (15) and require a set track (two grooves approximately 4 inches wide and 8 inches apart) for the skis to glide in. Depending on the terrain and snow conditions, a classic skier uses different movements to propel themselves forward in the most efficient way. There are three primary classic movements: single-poling, also known as diagonal striding (alternate arm and leg, similar to running on skis but with a distinct glide phase), double-poling (no lower body movement just poling with both arms simultaneously), or kick double poling (a variation of the double pole where the skier kicks onto one ski before double poling).

The newer technique is referred to as "skate-skiing", "freestyle" or by most xc skiers as just "skating". It is similar to a hockey skating motion with poles (49) and is best described as a pushing off of skis that are gliding at an angle outward from the direction of travel (15). It does not use classic tracks, however it does require a fairly wide (10-20 feet), hard-packed snow surface. A skate skier would use one of five primary movements: the marathon skate (one ski in a classic track and the other ski pushing off to the side), V1 (for uphills), V2 & V2 Alternate (for flats, gradual uphills or downhills), or double poling (for starts of races, steep downhills, flats, or gradual uphills).

Before the early 1980s, only the classic technique was being used. The person credited with the first use of the skate-skiing technique in World Cup competition was Bill Koch. He had already become the first American to win an Olympic medal in xc skiing in the 1976 Games and with some refining of his new secret weapon, skate-skiing, he shocked the international xc ski community by winning the 1981 over-all World Cup title (13). None of the other competitors knew how to ski-skate with the exception of some occasional rudimentary marathon skate-skiing. Bill Koch's ingenuity revolutionized the sport of xc skiing forever, meaning that both techniques are here to stay.

Both classic and skate-skiing techniques use double poling, thus double poling is often the technique used for laboratory testing of xc skiers. Double poling requires nearly 100% of all forward propulsion to be supplied from the upper body (48). It has been shown that the average poling force in the V1 skate technique is 0.45 times the body weight which is 2-3.5 times greater than that previously reported for classic skiing (48). Skate-skiing up a gradual hill may require greater than 60% of the propulsive forces be applied through the poles via the upper body (46, 48). Specifically in the V1 skate-skiing technique, over half of the power to propel the skier forward is produced by the upper body (48). It has been shown that skate-skiing is 10-23% faster than classic skiing (50). Peak poling forces during V1 skate-skiing and

V1 roller skiing have been reported to be from 40-50% body weight compared to just 10% body weight in diagonal stride classic skiing (24). Therefore, double poling used in classic skiing and skate-skiing are very dependent on good upper body power (UBP).

Currently, national and international xc ski competitions have both classic and free-style (skate-skiing) events. Thus to be an all-around competitor, skiers must train for both techniques. Skate-skiing is strictly prohibited in the classic events, while anything goes in the free-style; however, skate-skiing is usually the fastest depending on the terrain and snow conditions.

Cross-country (xc) skiing, also referred to as nordic skiing, is often thought of as a graceful, tranquil activity where a person glides effortlessly across the sparkling snow. An elite skier can definitely make his/her sport look easy but in reality this is far from the truth, especially with skate-skiing proven to be very power-intensive (48, 50). Of all sports, xc skiing is one of the most physically demanding (13, 35).

Cross-country skiing involves repeated muscular contractions over extended periods of time. With the emergence of skate-skiing, it has become increasingly apparent that UBP as well as upper body aerobic endurance play an even more important role than previously thought. This is supported by higher levels of lactic acid production during skate-skiing than classic technique (29). In order to compete at the highest level in the sport, an athlete must possess excellent aerobic conditioning, near-perfect technique, years of sport-specific race experience, top of the line equipment for both classic and skate-skiing, tremendous mental toughness, a genetic predisposition (25), and superior power, especially UBP (1, 15, 21, 23, 33, 39, 40, 41, 45, 47). Elite ski-skaters look nothing like distance runners or even classic skiers of the past. Modern day skiers are powerful machines, carrying much more lean body mass than ever before (6).

Early Strength/Power Studies of XC Skiers

This review of literature will focus on upper body strength and UBP testing and training of xc skiers only, due to the plethora of related literature in other individual sports. Also, it will not discuss the biomechanical or kinematic aspects of the different cross-country skiing techniques, with the exception of a few propulsive force values necessary to fully explain the relevancy of UBP to xc skiing.

In xc skiing, it has been demonstrated that muscular power is more relevant to test than muscular strength; in fact, Kelly (23) reports that strength has little meaning in evaluating an athlete involved in a repetitive endurance event, such as double poling in xc skiing. Strength is defined as the peak force developed during one maximal voluntary contraction under a set of conditions, while power is defined as the rate at which mechanical work is performed or simply put: "explosive strength" (11).

In the past, the most common modes of testing strength and power were weight-lifting tests, isometric tests (strength only), isokinetic tests, and special jumping tests. One frequently used power test was developed in 1966 by Margaria et al. (28) in which subjects would run up a flight of nine steps as quickly as possible. The ascent was timed and power was calculated as the quotient of work and time. Work was defined as the product of body mass and total vertical height of the stairs, and time is defined as the period over which the steps were ascended.

Komi et al. (25) used the Margaria power test in 1977 as one of many different tests performed on xc skiers, power event athletes, runners, ski jumpers, canoeists, hockey players, alpine skiers, and nordic combined skiers. It was discovered that xc skiers had the second lowest lower body power values, with only distance runners having less. It was also discovered that female xc skiers had 22% less absolute lower body power (expressed as kilogram meters per second) than the male xc skiers but were stronger than the male long distance runners in relative measures of lower body power. It would be interesting to repeat this study now using UBP instead of lower body power, especially in xc skiers who ski-skate. Recall that in 1977, only the less power-intensive classic skiing technique was being used.

Haymes and Dickinson (16) also used the Margaria stair run to estimate maximal power in their study on the U.S. Ski Team (alpine, xc, and nordic-combined). They measured several other variables including isometric knee extension. Results showed that alpine skiers had significantly higher maximal lower body power and greater isometric knee extension strength than did xc skiers. This would seem to be expected, as alpine skiers rely primarily on the legs and torso for propulsion, using their poles only for pivoting and balance. Cross-country skiers, on the other hand, use the entire body for forward propulsion, with the poles aiding to a great extent, especially in skate-skiing. Thus, this particular study has limited application to the proposed study, as it looked only at lower body power in a non-sport specific movement.

Greater UBP in Elite XC Skiers

Since its development in the late 1960s, the Wingate power test (2) which involves pedaling a bicycle ergometer (or less commonly, arm cranking) at maximal effort for thirty seconds was often used to determine maximal watts (power). There is much published literature pertaining to Wingate testing of athletes, including alpine skiers, but only one study was found that used the Wingate test on xc skiers (37). Patton et al. (37) were the first to study the UBP of xc skiers. Subjects performed upper body (Wingate arm cranking) and lower body (Wingate bicycle ergometer pedaling) testing. The researchers compared results from a group of British Ski Federation Biathlon skiers to a control group. They found that the biathletes possessed significantly higher upper and lower body relative mean power and relative peak power, as well as a smaller decrease in power during the test than the controls (37).

The work of Patton et al. (37) has received criticism because arm cranking has a very different movement pattern and does not include all the relevant upper body muscle groups used in xc skiing (52). O'Shea reports that "the primary upper body muscles involved in poling when classic skiing or skate-skiing are the muscles that support the scapula, especially the posterior deltoids, latissimus dorsi triceps brachii, and trapezius" (35).

It soon became clear that a valid and reliable ergometer capable of measuring UBP needed to be created that was specific to the poling motion of xc skiing. Dr. Glenn Street developed such a piece of equipment that he called the Street ergometer. Modifications of this apparatus are still used today in the U.S. to measure UBP. A modified Street arm ergometer produced by Ergometrx, Inc. was used in this dissertation study and has already been used in most of the following studies reviewed.

Shorter (now Downing) et al. (45) performed a study using the Street ergometer to compare physiological variables of a group of developing (lesser ability) xc skiers to a group of elite xc skiers. The three dependent variables were lactate threshold, maximal oxygen consumption, and UBP. The only variable found to be significantly different between the two groups was UBP. This study proved to be valuable for a number of reasons. First, it used sport-specificity for all three dependent variables. The Street Arm Ergometer was used to test UBP and a single pole ski walk test was used to determine maximal oxygen consumption and lactate threshold. Secondly, it was the first study to show that sport-specific UBP did indeed differ between moderate and good skiers. It led to studies that attempted to correlate sport-specific UBP to race performances and to UBP training studies.

Correlational UBP Studies in XC Skiers

The original tests used to measure the upper body of xc skiers were not sport-specific. In fact one of the first tests was a grip strength test (34). Ng et al. discouraged the use of this test, as the forearm musculature active in gripping was found to be an invalid measure of xc skiing strength (33). Instead, he used a Cybex machine to test upper body strength. In doing so, he determined that relative upper body strength explained the largest part (r = 0.78) of the variance in a multiple regression analysis of 10-kilometer race times (33).

Mygind et al. (30) helped confirm the importance of the upper body to xc skiing. Although their subject sample size was small (n=6) and composed of male skiers only, results were still valuable. Skier VO2max was tested while running on a treadmill and then while performing a double poling motion on a specially built upper body ergometer. Only the upper body ergometer VO2max values were significantly related to race performance rankings (r = -0.80).

Hilden et al. (19) used the Ergometrx arm ergometer to find a strong correlation (r = 0.92, $p<0.001$) between United States Biathlon Association (USBA) national points and relative UBP in eleven male biathletes. The study does not however, report correlations of absolute power and USBA National points. Regardless, it was the first study to show a significant correlation between competitive rankings and relative UBP, as determined by a Street Ergometer, in men.

Using male and female biathlon skiers as subjects, Rundell and Bacharach (40) obtained results as expected for the female skiers, however not what was expected for the men. The women demonstrated that national rankings were correlated to running VO2 peak (r = 0.81) and to both absolute (r = 0.95) and relative UBP (r = 0.85). For the men, only maximal run time during the VO2max test was correlated to national rankings (r = 0.72), while neither absolute nor relative UBP were related to the rankings. This was the first study to show a significant correlation between competitive rankings and maximal oxygen consumption, absolute UBP and relative UBP in women. It also shows the need for men and women's results to be analyzed separately as trends may differ between genders.

Seven national caliber female biathletes were used as subjects to determine that treadmill running VO2peak was not highly correlated to UBP or 15 kilometer roller ski race results. However, both treadmill roller-skiing VO2peak ($r = 0.90$) and 15 kilometer roller ski race results ($r = -0.85$) were significantly related to UBP, thus emphasizing the need for sport-specificity in endurance testing as well as with UBP testing. Also of importance was the finding that times for the 15 kilometer outdoor roller skate-skiing race were related to the indoor treadmill roller ski time to exhaustion ($r = -0.78$, $p = 0.04$), providing evidence that roller ski testing in the lab is a valid substitute for field testing in xc skiers (39).

Arcilesi et al. (1) verified the 1994 findings of Rundell and Bacharach (40) by comparing ski race performance national rankings to arm VO2peak and relative UBP for U.S. female biathlon skiers ($r = -0.67$ and $r = -0.83$ respectively). The higher correlation seen with relative UBP emphasizes the significant relationship between relative UBP and racing performance.

Using the same data set as Arcilesi, absolute UBP results, instead of relative UBP results, were found to be even more strongly correlated with both national ranking ($r = 0.948$) and ski time ($r = -0.799$) (41).

Similarly, Kammermeier et al. (21) correlated several variables, including treadmill roller skiing (skate-skiing) economy to xc ski performance rank of seventeen elite male xc skiers. Performance rankings were not correlated to VO2peak from treadmill roller skiing (r = -0.08), but rankings did correlate moderately to skiing economy (r = 0.65), and strongly correlated to absolute and relative UBP (r = -0.72 and –0.82, respectively).

In 1999, Gaskill et al. (15) compared UBP of runners with that of xc skiers. Findings show that runners' mean UBP was only 46% of that of xc skiers. More importantly though was the discovery that there were strong correlations between xc skate-skiing race velocity and relative UBP (r=0.89) and absolute UBP (r = 0.83). Further, skiers were divided into slow and fast groups based on reported race velocity. From this it was determined that UBP was a good predictor of race velocity in both men and women. Results also showed that approximately 70% of the variance in xc skate-skiing velocity could be accounted for by UBP.

Staib et al. (47) reports that strong correlations exist between Federation of International Skiing (FIS) points and double pole time to exhaustion(r = -0.81), double pole VO2peak (r = -0.76), and UBP (r = -0.65) in 23 elite xc ski racers. It was calculated through multiple regression that 79% of the variance in FIS points could be accounted for by UBP and DP VO2peak. This study reports that UBP is important to performance, but suggests that perhaps double pole time to exhaustion and double pole VO2peak are more related to points than UBP. This contradicts past research such as that done by Kammermeier et al. (21) and Rundell and Bacharach (40).

In 2000, LaRoche et al. (26) used ten collegiate xc ski racers to study the relationship between a 5 kilometer xc skate-skiing race and several laboratory-determined variables. It was found via multiple regression analysis that skate-skiing VO2 peak, skate-skiing time to exhaustion, double-pole time to exhaustion, upper body VO2peak, and UBP explained 93% of the variance in the 5 kilometer xc skate-skiing race time. This differs from the 1979 calculation by Niinamaa et al. (34) for classic skiing that years of racing experience, maximal oxygen consumption, and body fat percent explain 89% of the variance. Whereas Niinamaa et al. presented data as to contribution by individual variables, LaRoche et al. did not, thus we do not know how much UBP alone contributed to the race results. The study does however reinforce that ski-specific laboratory tests are valid to use for testing purposes.

Thus, the research quite clearly points to the fact that UBP is strongly related to xc skiing performance (1, 15, 19, 21, 26, 30, 39, 40, 41, 47). The main question left unanswered is how do we best train a xc skier's UBP. The research discussed below begins to address this issue.

Training Studies of Strength/UBP in XC Skiers

The first explosive strength (power) training study published with xc skiers was quite ahead of its time back in 1991. Paavolainen et al. (36) from The University of Jyvaskyla in Finland studied the effect of a six-week training program on physical performance characteristics in fifteen male xc skiers. A control group completed a 6-week program of 85% endurance and 15% endurance type strength training, while the experimental group's program consisted of 34% explosive type strength training and 66% endurance training the first three weeks, and 42% and 58% respectively for the next three weeks. Results showed that the experimental group had significant changes in neuromuscular performance such as improvement in squat and jumping exercises, while the control group had no significant improvements in these measures. No significant changes occurred in aerobic performance characteristics for either group, suggesting that xc skiers can perform explosive strength (power) training without a decrease in aerobic capacity. These findings were important to the literature, as there had been some concern that power training would perhaps decrease aerobic endurance.

A training study (30) was performed on six male xc skiers who were required to devote 10% of their training time to strength development, although type of strength training was not specified. Researchers pre- and post-tested the subjects in September and December, respectively. Results showed improvement in maximal upper body work output by 11.8% ($p < 0.05$), but with no control group and several possible confounding factors, it is impossible to know the true reason the subjects improved upper body work output.

Bilodeau et al. (7) took the current UBP literature a step farther when they performed a study in 1994 that examined treadmill running maximal oxygen consumption and UBP at two different times during the ski season: December and April. Skiers were divided into two groups: early peakers and late peakers. Late peaking is what is desired, as the most important races are at the end of the season. Maximal oxygen consumption results showed no change from December to April in either group. Results showed that early peakers' UBP did not improve significantly from December to April; however late peakers' UBP significantly increased over the same time period. The researchers concluded that specific upper-body tests appear to be more related to xc skiing fitness level than a running maximal oxygen consumption test (7, 8). It also emphasizes that UBP is crucial to success in xc ski racing.

A 1996 study divided cross-country skiers with poor race results into two groups. One group acted as a control group undergoing the same training as the year prior. The other group (treatment group) performed a modified training program increasing high intensity training (including UBP work) from 17% to 35% while decreasing low intensity training 22%. Results show that the control group had no significant improvements from season one to season two, but the treatment group showed significant improvements in all five dependent variables: VO2 max, VO2 threshold, lactate response, competitive race results, and UBP. The authors conclude that for non-responders, a higher intensity training program, one that includes extensive UBP training may help improve race results (14).

Rusko et al. (43) assigned 25 elite male xc skiers into either a control or experimental group. The experimental group replaced part of their on-snow training with "dryland" training including ball type games, swimming, running, and circuit type strength (upper body included) training for a month. While the control group showed no significant changes in any physiological variables, the experimental group had significant improvements in maximal oxygen consumption values as well as jumping performance. The researchers conclude that xc ski training was improved by adding variety, thus avoiding musculature overworking (36, 43). This study does have some faults. First of all, by adding several dryland exercises all at once, one does not know if one exercise (such as strength/power work) contributed more than the others. Also, the oxygen consumption values were obtained from a treadmill running test which has been shown to not be as sport-specific (7, 8).

A training study was performed on young, developing xc skiers. Testing was performed before and after a four month summer training program which incorporated endurance as well as UBP training. Results reveal that the young xc skiers were more economical during a double poling test (-2.39 ± .48 ml/kg/min) on average following the training period. They also improved their absolute UBP significantly (35.8 ± 4.4 watts improvement in boys, 15 ± 5.6 watts improvement in girls (31). This study would have been more valuable had there been a larger sample size, a control group to compare with, and/or performance markers to correlate with. It does however, reemphasize the need to present UBP data separately for males and females, as it can be seen that the boys improved their absolute UBP by more than twice that of girls' UBP improvement.

Noting the continued international race improvement of U.S. biathlon team skiers, Ploetz and Rundell (38) set out to see where team members differed physiologically at that time as compared to four years ago, when they were not nearly as successful in international competition. Results for the twelve women showed that VO2peak during double poling was not different, running VO2peak was actually lower, while UBP was 20% higher. The men's results showed no change in double pole VO2peak and running VO2peak, but they too showed a 20% improvement in

UBP. The researchers speculate that the improved International performance seen may have be related to the increase in UBP.

Hoff et al. (20), used a newly designed xc ski-specific upper body ergometer to add to the current literature by investigating whether or not nine weeks of maximal strength training performed three times per week would improve work economy in fifteen female xc skiers. Subjects were randomly divided into either a low-intensity, strength-trained control group or an experimental group performing high-intensity, strength-training. The experimental group performed three sets of six repetitions at an intensity of 85% 1 repetition max on a special pulling apparatus. Results show significant improvement in double-poling economy on the ski ergometer for the experimental group ($p = 0.001$) but not for the control group. Researchers concluded that upper body maximal strength training improves work economy, thus improving double poling performance.

In 1999, Kelly et al. (23) trained the upper body of a group of teenage xc skiers for ten weeks, three times per week. The researchers used a points system similar to that used by the FIS to rank skiers by race results. The purpose of the study was to see if relationships existed between changes in race points and changes in UBP and strength measures. Points were strongly correlated to absolute UBP ($r = 0.78$) but only moderately correlated to relative UBP ($r = 0.49$). Points did not appear to be related to absolute or relative upper body strength ($r = 0.10$ and $r = 0.16$ respectively). The changes in UBP are estimated to account for 61% (r squared = 0.61) of the changes in race performance. Thus it seems that increases in UBP, not upper body strength, are significantly related to improvements in race performances (14, 23).

The most recent and one of the most meaningful studies in the area of xc ski UBP training was conducted by Nesser et al. (32). They studied the effects of four different training programs on UBP in young xc skiers (96 male and 99 female) in Minnesota. Skiers were divided into one of the following: free weight, circuit, roller board, or specific strength training groups. Most traditional xc ski training programs have focused on circuit-type resistance training with a small percentage of training time devoted to roller board and specific strength work (6, 22, 44). The supervised training duration was ten weeks with a frequency of three times per week. For roller board training, subjects performed three to four sets per session, alternating slow, steep angle (grade) work with quick, lesser angle work. Much of the sessions involved the subject performing sets to failure. Results showed that only the roller board training group improved significantly more than the control group in UBP and strength. The roller board group also improved significantly more than all other groups on the total distance as well as flat sections of the 3-kilometer roller ski time trial. Thus the researchers concluded that roller board training was the gold standard for improving both upper body strength and UBP in young skiers.

Nesser recommends that future studies of UBP in xc skiers focus on the roller board as well as upper body plyometric training exercises. He also recommends that future studies look at specifics of UBP training such as number of repetitions, sets, intensity, and rest periods, to see what combination seems to work best (32).

Reliability of UBP Ergometers

While U.S. researchers interested in UBP of xc skiers were putting together training studies using the Street (Ergometrx) arm ergometer as their UBP measurement device, two Norwegians Helgerud and Rasmussen, were engineering their own xc ski specific ergometer. With their device, the subject stands on a platform gripping two ski poles with wheels on the bottom that ran on rails connected to a motor that bring the poles back up (52).

Although the intent here was to be even more sport-specific than the Street ergometer, there are some problems: 1) the poles are heavier than normal to accommodate the necessary ball-bearings, thus fatiguing the upper body musculature quicker, and 2) the poling motion was not alterable, meaning that the subject could only pole at the set width, perhaps not allowing the most natural individually selected position and motion to occur.

Their first study using this new piece of equipment showed that for xc skiers, the ergometer was valid and reliable for testing upper body force development and VO2 at maximal and submaximal intensities. Validity was determined by comparing ergometer results to field testing (no correlation reported), while reliability was determined by test-retest correlations ($r = 0.98$, $p = 0.001$). Three tests were performed by each subject over a 14 day period (52).

Since no reliability data had been published yet on the Street (Ergometrx) ergometer used in the U.S., Bednarski et al. (4) basically followed the same procedure as Wisloff et al. (52), except he had subjects perform three tests over three days, with two of the tests done in the same day. From repeated measures ANOVA, it was determined that there was no significant difference between max watts on the three tests and correlations between the three tests were strong ($r = 0.92$). No p-value was given. Thus both the Scandinavian and American UBP ergometers appear to have excellent reliability (4, 52).

Application of the Literature

Though the literature clearly shows that UBP is important for xc skiers, the optimal UBP training protocol is not yet known. Thus, most xc ski coaches have either developed their own UBP training systems or have modified one of the protocols published by other researchers or coaches.

In the book: *Physiology of Cross-Country Ski Racing* written by Bergh (6) in 1982, it is suggested that upper body training be performed with rubber tubing. This enables the xc skier to simulate single or double poling and is still a common exercise used today by xc skiers.

In 1984, Sharkey (44) wrote a book titled: *Training For Cross-Country Ski Racing* in which he devotes an entire chapter to muscular power training. He prescribes a resistance of 30-60 % maximal strength done as fast as possible, 3 sets of 15-25 reps, performed 3 times per week. For lower body, he recommends plyometric training and for UBP development he suggests the use of a roller board, exergenie, rubber tubing, or even exercises such as dips and push-ups. The exergenie is basically a pulley with variable resistance mounted to a wall in which a rope with attached ski handles is pulled alternately with the right and left arms in a ski-poling fashion. Although the exergenie can only be used for single-poling, it was a first step towards the development of the wind machine that will be used in this proposed study.

One UBP and strength protocol frequently used by xc ski coaches is written by Torbjorn Karlsen, graduate of the Oslo Sport College and holder of Norway's highest level of coaching certification. In 1998, Karlsen and Patterson (22) published a xc ski training manual: *How to, When to, Why to: A Norwegian Model Training Guide and Programs for Cross-Country Skiers* that has become quite popular among U.S. skiers of all ages and abilities. He says that strength training should be mostly specific, similar to skiing up a hill, to develop power, or can be performed as circuit type training. Of particular value to coaches and athletes is a table in the manual describing 25 different xc ski-specific strength/power exercises. The name and purpose of each exercise is listed along with the suggested number of repetitions and a drawing of each.

The most recent book published (late 1998) on xc ski training is titled: *Fitness Cross-Country Skiing* by Gaskill (13). While the content is definitely aimed at the novice skier, it does provide valuable information regarding upper body development: weight lifting and roller board training.

Karlsen and Patterson (22) advise that total training time devoted to strength/power should be 5-15%. According to Mygind et al. (30), more than 50% of a well-coached xc skier's total training is made up of upper body training. Rusko (42) reports that xc skiers can improve strength and speed, thus power, when they increase explosive type strength training to 30-40% of the total training. Thus, there are obviously differences in opinions as to quantity of training time devoted to power.

Review of Literature Summary

To summarize, it has been shown that in both double poling and skate-skiing, the upper body plays a significant role in forward propulsion. It has also been shown that UBP is highly correlated to xc skiing rank and performance, thus separating elite from lesser-ability skiers. The question remaining is what is the best way to train the upper body of a xc skier so as to increase UBP and performance.

This dissertation looked to challenge the conclusion that roller board training is the optimal method for increasing UBP and thus performance in xc skiers. A roller board is basically two boards that run at an angle from the floor to various heights on the wall. The skier sits on a seat with four wheels on the bottom that roll along the two boards allowing the skier to use ropes attached to the wall to pull themselves up and down the boards.

A new training device (wind machine) with Russian origin being used now in the U.S. and Canada by top xc skiers will be compared to roller board training as to its effectiveness in improving UBP. The wind machine is an apparatus that attaches to the wall that has two fly wheels which move as a result of the skiers pulling on ropes. As the fly wheel turns, it causes attached paddles to produce wind resistance. Thus the harder the skier pulls, the harder the resistance. Higher levels of resistance can be achieved by adding more paddles. The reason skiers like the wind machine is because it is a simple, rather inexpensive, portable machine.

The goal of this study is not to replace roller board training with wind machine training, but to determine if it is as effective at developing UBP. It could be used to compliment roller board training and or be used in place of it when athletes are traveling.

Appendix B

OSU Institutional Review Board (IRB)

The Effects of Training on Upper Body Power in Female Cross-Country Skiers

Application for Approval of the OSU Institutional Review Board (IRB)
for the Protection of Human Subjects

1. Significance of the Project.

Like distance running or bicycling, cross-country skiing is considered an aerobic activity, but one that also requires tremendous musculature power of the entire body. The upper body has been shown to contribute over fifty percent of the propulsive force in the newest, faster form of cross-country skiing: skate-skiing. In a study looking at lactate threshold, maximal oxygen consumption, and upper body power, only upper body power differed significantly between developmental (lesser ability) and elite (accomplished) cross-country skiers. Performance in cross-country ski race results has recently been correlated to high levels of upper body power as well. It therefore appears that upper body power training is integral to the success of a cross-country ski racer. Recently roller board training has been shown to be the best form of upper body power training, however the study did not look at wind machine training. The purpose of this study is to determine if wind machine training is as effective as roller board training in increasing upper body power in female cross-country skiers.

2. Methods and Procedures.

Subjects will need to complete this consent form, health-history questionnaire, and physical activity questionnaire prior to pre-testing. This will take approximately 15 minutes. Upon completion of the prescreening, subjects may or may not be asked to participate. Subject selection criteria include: female gender, age 19-59, able upper body musculature, participant in xc skiing, have agreed to forego any other UBP training for the duration of the study, and without high-risk medical conditions (as identified by the healthy history questionnaire). If the subject is considered high risk, she will have to get a physician's approval prior to participation in the study.

Subjects will participate in a familiarization session to the computerized arm ergometer and either the wind machine or roller board. Following the familiarization session, subjects will participate in a pre-testing session lasting approximately 20 minutes which will consist of the following:

a) Body mass and height will be measured in light clothing without shoes.
b) Maximal upper arm circumference will be measured with a flexible tape measure.
c) Skinfold thicknesses will be measured with a skinfold caliper at seven sites on the right side of the body (shoulder blade, side, stomach, chest, back of the upper arm, hip, and thigh) for estimation of body fat percent.
d) Maximal upper body power will be assessed using a computerized arm ergometer. Subjects will stand on a platform, hold a ski handle in each hand attached to a rope and pull simultaneously in a cross-country ski double-poling fashion. Resistance will begin at 0.95 kilograms, increasing by 0.20 kilograms every 20 seconds with a constant pulling speed of 46 pulls per minute. Subjects will continue pulling until they can no longer increase or maintain maximal UBP output. Test duration is approximately three to five minutes. Subjects may quit this test at any time for any reason, however without a max UBP value, they will either have to perform the test again within a 48-hour period or not participate in the study.

Upon completion of the pre-testing, subjects will be matched (according to maximal UBP results) into either the wind machine or roller board group. Subjects will be required to participate in three 30-minute training sessions per week for an eight-week period. A training session consists of a five minute warm up, an interval session on either the roller board or wind machine, light dumbbell exercises for the chest and biceps, and a 5-minute cool-down.

Following the 8 week training period, all subjects will be re-measured on mass, arm circumference, skin fold measurements, and maximal UBP. All testing and training sessions throughout the study will be held upstairs in Mazama Hall.

3. Benefits and Risks.

Subjects will benefit by receiving information regarding their pre and post testing of upper arm circumference, millimeters of subcutaneous fat, percent body fat, mass, absolute upper body power, and relative upper body power. The eight weeks of training completed should help prepare the skiers physically for their upcoming ski season. They can also feel pride in contributing to the future success of female xc ski racers everywhere.

Subjects will feel an increase in heart rate and breathing rate and may feel some muscular discomfort (similar to skiing at a high intensity up a hill) during the maximal upper body power test. There may be some mild muscle soreness after the pre-testing and first few training sessions. Researchers are certified in CPR in the unlikely event that an emergency should arise, however the risks are minimal as subjects are fit and healthy. Also, subjects will feel a slight pinching sensation when the skinfold measurements are taken.

4. Subject Population.

Subjects will be local female cross-country skiers, age 19-59. They will be divided (matched upon pre-UBP testing) in to one of the two experimental groups (roller board or wind machine). It will be necessary to have 20-25 subjects per group to ensure adequate statistical power.

The subjects will be recruited by the researcher from the Athletic Club of Bend (ACB), Tumalo Langlauf Ski Club (TLC), Central Oregon Community College (COCC), and phone calling of known local female cross-country skiers. The recruiting procedure will occur by either e-mail posting, letter size poster, or telephone calling. An e-mail will be sent out to all female members of TLC. Posters will be approved and posted in all buildings on the COCC main campus and ACB. A copy of the e-mail to be sent, phone script, and poster can be found in the appendix.

Justification for using females only. Of the thirty studies found pertaining to UBP of xc skiers, eleven did not include women as subjects and three studies did not identify the gender. In fact, the numbers of male and female subjects in these studies are 484 and 273, respectively, which means that women participate only 56% as often as men. Of the 11 UBP training studies performed on xc skiers, three did not include women as subjects and one did not report subject gender. Male and female subject numbers are 111 and 86 respectively, showing women's participation at 77% which is better than the over-all percentage but still not close to equity. Only two of the 30 studies used women exclusively (no men). It cannot be assumed that men and women will show the same trends in UBP or that they will respond the same to UBP training. Of the seven UBP training studies on female xc skiers published to date, there is only one that is free of a major research flaw, thus showing the need for advancement in the area of UBP training in female xc skiers.

5. Informed Consent Document.

A copy of the informed consent for the proposed study is attached.

6. Methods by which the informed consent will be obtained.

Participants will be asked to read and sign the informed consent prior to the pre-testing. Subjects will be verbally reminded of their right to withdraw from the study at any time without prejudice. Any questions regarding the proposed study, testing procedures, or any other subject concerns, will be answered by the investigator in Bend.

7. Method by which subject confidentiality will be maintained.

Subject information will only be available to the researchers and research assistants of the proposed study. The identity of subjects will remain anonymous in the study results by the use of identification (ID) numbers, instead of names in the data entry and analysis. A computerized data bank will be used to link ID numbers with subjects' personal information such as full name, address, phone, contacts, etc. for emergency purposes as well as sending them test and study results. This link will only be accessible to the researchers and will be deleted upon distribution of final study results.

8. Questionnaires, surveys, testing instrument.

The health history questionnaire and physical activity questionnaire are attached.

9. Other approvals.

A verbal approval for this study to be conducted in Mazama Hall at COCC in Bend, OR has been given by Health & Human Performance Chairperson, Nancy Colton, June 2000.

Script for Telephone Recruitment of Subjects

- Hello. May I please speak to first and last name. Thank you.
- Hi first name. My name is Julie Downing. How are you?
- The reason I am calling is to inform you of a research study that I am conducting at COCC that you might like to participate in. For my doctoral dissertation, I am studying upper body power in female xc skiers. If you agree to participate in the study you would have to come up to Mazama Hall twice for testing, participate in 8 weeks of training (3 times per week, 30 minutes per time) and agree to do no intensive upper body training (except the study training) for the duration of the study.
- Does this sound like something you would be interested in?
- Let me give you the specifics.
- The first testing session would be during the week of **Sept. 18th - 22nd** and last about 45 minutes (15 minutes of paperwork followed by 30 minutes or so of testing. Testing would consist of measuring mass, height, arm circumference, percent body fat via skinfold calipers, and maximal upper body power. The maximal upper body power test lasts only 3-5 minutes. It involves you pulling on straps (similar to using poles in xc skiing) at a set speed, while resistance would increase every 20 seconds until you can no longer maintain or increase your upper body power output.
- For 8 weeks straight, you'd be required to come to Mazama Hall to participate in 3 x 30 min. training sessions. You will perform a five minute warm up, an interval session on either the roller board or wind machine, light dumbbell exercises for the chest and biceps, and end with a five minute cool-down. Training duration, intensity, and speed will vary throughout the 8 weeks. We will set up training sessions that are most convenient for you. When would work best for you?
- After an 8 week period, you would repeat the above testing (**Nov. 20th – 22nd**), minus the paperwork, taking only about 30 minutes this time. So, your efforts would greatly help me to accomplish my goal of obtaining my Ph.D. as well as provide you with valuable information regarding your testing and how you can apply that to improve your xc skiing this winter.
- Do you still think you are interested?
- Do you have any questions or concerns?
- IF INTERESTED: let's set up an appointment for the first testing session. If you need to contact me (Julie Downing), call 383-7764 at COCC or 317-0205 at home. I'll see you on day and date at time upstairs in Mazama Hall. Thank you so much.
- IF NOT INTERESTED OR UNSURE: Please contact me (Julie Downing) at 383-7764 by Sept. 19th, if you decide you'd like to participate. Thank you for your time.

E-Mail Posting for Recruitment of Subjects:

Hi everybody!! Most of you know me. For those who don't, I am a fellow runner and xc skier that teaches at COCC in the Health & Human Performance Dept. I am also currently working towards completing my Ph.D. from O.S.U. by writing my doctoral dissertation. My study will look at the effects of training on upper body power in female xc skiers. The bottom line is this: I NEED YOU!!!

- I am looking to recruit 40-50 local female xc skiers (ANY LEVEL – true beginner up to serious ski racer) to be divided into one of two experimental training groups. You would participate in brief pre-testing and post-testing sessions as well as participate in an 8 week (3 x week for 30 min.) training program to be held in Mazama Hall. Training sessions will be worked around your schedules so as to least inconvenience you. No intensive upper body training (except for what is done as part of the study) is allowed for the duration of the study.

- The first testing session would be during the week of **Sept. 18th - 22nd** and last about 45 minutes (15 minutes of paperwork followed by 30 minutes or so of testing. Testing would consist of measuring mass, height, arm circumference, percent body fat via skinfold calipers, and maximal upper body power. The maximal upper body power test lasts only 3-5 minutes. It involves you pulling on straps (similar to using poles in xc skiing) at a set speed, while resistance would increase every 20 seconds until you can no longer maintain or improve your maximal UBP output. Testing will be repeated (minus the paper work) between **Nov. 20 - 22nd** right before Thanksgiving.

- For 8 weeks straight, you'd be required to come to Mazama Hall to participate in 3 x 30 min. training sessions. You will perform a five minute warm up, an interval session on either the roller board or wind machine, light dumbbell exercises for the chest and biceps, and end with a five minute cool-down. Training duration, intensity, and speed will vary throughout the 8 weeks. We will set up training sessions that are most convenient for you. When would work best for you?

- I really hope you will consider being a subject. This is a unique opportunity to get involved in the kind of research that usually only takes place at big Universities. Not only will you be provided with valuable information regarding your testing and how you can apply the results to improve your xc skiing this winter but also you can feel pride that you are helping me accomplish a long-time goal.

- If you are interested and or have questions or concerns, contact Julie Downing as soon as possible (definitely before September 20th) by calling 383-7764 at COCC or 317-0205 at home or e-mailing me at jdowning@cocc.edu.

- Thank you so much. Look forward to hearing from you. Julie

SUBJECTS NEEDED!!!!!!!

Who: Female Cross-Country Skiers (any ability level), age 19-59.

What: Be a subject in a study investigating upper body power. Gain valuable training information and meet other skiers.

When:
*You will pre-test once (30 minutes) during the week of Sept. 18-22nd, 2000.
*If you are picked to be part of the training, it will last 8 weeks, 3 x week (Fall quarter, finishing right before Thanksgiving).
*You will post-test once between Nov. 20- 22nd (30 minutes).

Why: You'll have fun and feel pride in being a part of improving training for women's endurance athletics.

Where: Upstairs in Mazama Hall, COCC, Bend.

For more information, contact:

Julie Downing, M.S.
Associate Professor of HHP at COCC
Call: (541) 383-7764,
E-mail: jdowning@cocc.edu, or
Stop by: Mazama Hall Office (upstairs)

Oregon State University and Central Oregon Community College
INFORMED CONSENT FORM

A. Title of the Research Project The Effects of Training on Upper Body Power in Female Cross-Country Skiers.

B. Investigators Anthony Wilcox, Ph.D., Associate Professor, Oregon State University and Julie Downing, M.S., Associate Professor, Central Oregon Community College.

C. Purpose of the Research Project The upper body contributes over fifty percent of the force used to propel the skier forward in skate-skiing. In fact, a distinct feature of elite (accomplished) cross-country skiers over developmental (lesser ability) skiers is their superior upper body power. It appears that upper body power training is integral to the success of cross-country ski racers. Recently roller board training has been shown to be the best form of upper body power training, however the study did not look at wind machine training. The purpose of this research study is to determine if wind machine training is as effective as roller board training in increasing upper body power in female cross-country skiers.

D. Procedures **I understand that as a participant in this study the following things will happen:**

1. Pre-study Screening I will need to complete this consent form, health-history questionnaire, and physical activity questionnaire prior to pre-testing. This will take approximately 15 minutes. Upon completion of the prescreening, I may or may not be asked to participate.

2. What will I do during the study? I will participate in a familiarization session to the computerized arm ergometer and either the wind machine or roller board. Following the familiarization session, I will participate in pre-testing session lasting approximately 20 minutes which will consist of the following:

   a) Body mass and height will be measured in light clothing without shoes.
   b) Maximal upper arm circumference will be measured with a flexible tape measure.
   c) Skinfold thicknesses will be measured with a skinfold caliper at seven sites on the right side of the body (shoulder blade, stomach, side, chest, back of the upper arm, hip, and thigh) for estimation of body fat percent.

d) Maximal upper body power will be measured using a computerized arm ergometer. I will stand on a platform, hold a ski handle in each hand attached to a rope and pull simultaneously in a cross-country ski double-poling fashion. Resistance will begin at 0.95 kilograms, increasing by 0.20 kilograms every 20 seconds with a constant pulling speed of 46 pulls per minute. I will continue pulling until I can no longer increase or maintain my maximal UBP output. I will be pulling for approximately three to five minutes. I may quit this test at any time for any reason.

Upon completion of the pre-testing, I will be matched (based on pre-testing UBP results) into either the wind machine or roller board experimental group, I will be required to participate in three thirty minute training sessions per week for an eight-week period. I will perform a five minute warm up, an interval session on either the roller board or wind machine, light dumbbell exercises for the chest and biceps, and end with a five minute cool-down.

Following the 8 week training period, I will be post-tested on mass, arm circumference, skinfold measurements, and maximal UBP. All testing and training sessions throughout the study will be held upstairs in Mazama Hall. Following post-testing, my participation is complete and I will be mailed a summary of study findings.

3. **Risks and Discomforts** I will feel an increase in heart rate and breathing rate and may feel some muscular discomfort (similar to skiing at a high intensity up a hill) during the maximal upper body power test. There may be some mild muscle soreness after the pre-testing and first few training sessions. Researchers are certified in CPR in the unlikely event that an emergency should arise, however the risks are minimal as I am fit and healthy. Also, I will feel a slight pinching sensation when the skinfold measurements are taken.

4. **Benefits** I understand that I will receive information regarding my pre and post testing of upper arm circumference, millimeters of subcutaneous fat, percent body fat, mass, absolute upper body power and relative upper body power. I have contributed to the future success of female xc ski racers.

E. Confidentiality Any information obtained in connection with this study that can be identified with me will be kept confidential to the extent permitted by law. A code number will be used to identify any test results or other information I provide. Neither my name nor any information from which I might be identified will be used in any data summaries or publication.

F. Compensation for Injury I understand that neither Oregon State University nor Central Oregon Community College provide me with compensation or medical treatment in the event that I am injured as a result of participation in this research project.

G. Voluntary Participation I understand that my participation in this study is completely voluntary and that I may either refuse to participate or withdraw from the study at any time without penalty.

H. Questions? I understand that any questions I have about the research study or specific procedures should be directed to Julie Downing, HHP Dept., COCC, 2600 NW College Way, Bend, OR 97701, (541) 383-7764, jdowning@cocc.edu. If I have questions about my rights as a research subject, I should contact the IRB Coordinator, OSU Research Office, (541) 737-8008.

My signature below indicates that I have read and that I understand the procedures described above and give my informed and voluntary consent to participate in this study. I understand that I will receive a copy of this consent form.

______________________	______________________
Signature of Subject	Name of Subject
______________________	______________________
Date Signed	Subject's E-mail Address (optional)
______________________	______________________
Subject's Present Address	Subject's Phone Number
______________________	______________________
Signature of Investigator	Date Signed

Appendix C

Physical Activity Questionnaire

Name: ____________________ Date: ___/___/___ I.D. #: ______

Please answer the following questions as honestly and accurately as possible. The information you provide is important to the study and is completely confidential.

1. How many days per week do you exercise aerobically? ______
2. What are the aerobic activities you participate in most often? (Examples: xc skiing, running, swimming, kayaking/canoeing/rowing, mountain or road bicycling) List your top 4. ____________ ____________ ____________ ____________
3. If you run, what pace per mile do you run when training? _____ min./mile
4. How many hours per week do you spend aerobically exercising (on average)? ____
5. Do you perform any muscular strength or power training? YES or NO
6. If so, how many days per week do you do it? _____
7. If so, describe the strength/power training you do? (Include type, for what part of the body, reps, sets, how long it takes you)

____

____

____

8. At what age did you learn to xc ski? ________
9. Do you participate in:

	Classic skiing only	_____
	Skate skiing only	_____
	Both classic and skating	_____

10. Do you ski race? YES or NO
11. If so, how many races did you do last ski season? _____
12. If so, rate your best performance. What best describes your ability. Pick the top level for you.
    - _____ I place in the lower 1/3 of women locally (Less skilled local skier)
    - _____ I place in the middle 1/3 of women locally (Mediocre local skier)
    - _____ I place in the top 1/3 of women locally (Good local skier)
    - _____ I can compete well in the NW region (Top regional skier)
    - _____ I can compete well nationally (National caliber skier)
    - _____ I can compete well internationally (World class skier)
13. If so, list the race your best ever performance has been at. (Include year and distance and how you placed)______________________________
14. What would you say is your current aerobic fitness level?

Poor	_____	Good	_____
Medium	_____	Excellent	_____

15. What would you say is your current muscular strength or power fitness level?

Poor	_____	Good	_____
Medium	_____	Excellent	_____

16. Why do you xc ski?

____

Appendix D

Health History Questionnaire

Full Name: ______________________________ **Date:** ___/___/___

Age: _____ **Date of Birth:** ___/___/___ **I.D. #:** ________

The purpose of this questionnaire is to obtain information regarding your health necessary for the researchers in assisting you with your participation in this study. Please answer all questions to the best of your knowledge. Circle the correct answers.

1. Do you have high blood pressure? YES NO
2. Do you have high blood cholesterol? YES NO
3. Do you currently smoke? YES NO
4. Are you a former smoker? YES NO
5. If so, when did you quit? ____________
6. Have you ever had a heart attack? YES NO
7. Have you ever had chest pain (angina)? YES NO
8. Have any of your blood relatives had heart disease, heart surgery, or angina? YES NO
9. If so, what is the relation? _________ What did they have? ____________
10. Are you diabetic? YES NO
11. If so, list medications taken. ______________________________
12. Do you have any respiratory problems (Example: asthma, emphysema)? YES NO
13. If so, list them. ______________________________
14. Do you have any orthopedic problems (Example: arthritis, low back pain)? YES NO
15. If so, list them. ______________________________
16. Have you had any recent illness, hospitalization, or surgical procedures? YES NO
17. If so, list them and when? ______________________________
18. Are you currently taking any medications? YES NO
19. If so, list them. ______________________________
20. Do you have any allergies? YES NO
21. If so, list them. ______________________________
22. Do you have any other conditions or problems that may affect your ability to exercise? YES NO
23. If so, list them. ______________________________

Please provide us with emergency contact information.

Name: ____________________ **Home Phone:** ______________

Relation: ____________________ Work Phone: ______________

Appendix E

I.D. Number: ________ Date: ___ / ___ / ___

DATA RECORDING SHEET

Circle: Pre Post
Upper Arm Circumference: ____cm
Total Time: _____
Height: _____ inches = _____ cm
Abs. Power: _____
Age: _____
Weight: _____ pounds = ____ kg
Rel. Power: _____

SKINFOLDS

Abdominal: _____ mm
Axillary: _____mm
Pectoral: _____ mm
Subscapular: _____ mm
Suprailiac: _____mm
Thigh: _____ mm
Tricep: _____ mm
Sum of 7: _____ mm
Body Fat: _____ %

MAXIMAL UBP TEST

Metronome Speed: 46 pulls per minute Stage Duration: 20 seconds

Stage Number	Total Time	Resistance (Kilograms)	Resistance (Pounds)	Absolute Power (Watts)	Relative Power (Watts/kg)
1	0:20	0.95	2.1	/	/
2	0:40	1.15	2.5	/	/
3	1:00	1.35	3.0	/	/
4	1:20	1.55	3.4	/	/
5	1:40	1.75	3.9	/	/
6	2:00	1.95	4.3	/	/
7	2:20	2.15	4.7	/	/
8	2:40	2.35	5.2	/	/
9	3:00	2.55	5.6	/	/
10	3:20	2.75	6.1	/	/
11	3:40	2.95	6.5	/	/
12	4:00	3.15	7.0	/	/
13	4:20	3.35	7.4	/	/
14	4:40	3.55	7.8	/	/
15	5:00	3.75	8.3	/	/
16	5:20	3.95	8.7	/	/
17	5:40	4.15	9.2	/	/
18	6:00	4.35	9.6	/	/
19	6:20	4.55	10.0	/	/
20	6:40	4.75	10.5	/	/
21	7:00	4.95	10.9	/	/
22	7:20	5.15	11.4	/	/
23	7:40	5.35	11.8	/	/
24	8:00	5.55	12.2	/	/

Appendix F

Training Protocol for Roller Board and Wind Machine

<u>RB Resistance</u>:	L = Low (5% grade),	M = Medium (7.5% grade),	H = High (10% grade)
<u>WM Resistance</u>:	L = Low (2 paddles),	M = Medium (3 paddles),	H = High (4 paddles)
<u>Speed</u>:	F = As fast as possible,	I = Intermediate,	S = Slow and Controlled

Week	Session	Resistance	# Sets	Set Duration (Min.)	Rest Betw. Sets (Min.)	Speed	Superv. Initial	Date
1	1	L	3	1	3	I		
	2	L	3	1	3	I		
	3	M	3	1.5	3	S		
2	4	M/H	2/2	2	3	S		
	5	H/M	3/1	2/2.5	3	S		
	6	H/M	3/1	2/2.5	3	S		
3	7	H	4	2.5	3	S		
	8	M/H/M/H	1/1/1/1	1/2/1/2	3	F/S/F/S		
	9	H/M	3/1	2.5/1.5	4	S/S/F/S		
4	10	L/H/M/H	1/1/1/1	1.5/3/1.5/3	4	F/S/F/S		
	11	M/H/M/H	1/1/1/1	1.5/2.5/1.5/2.5	4	F/S/F/S		
	12	H/H/M/H	1/1/1/1	2/2/2/1	4	S/S/F/S		
5	13	L/H/M/H	1/1/1/1	1.5/1/1.5/1	4	F/S/F/S		
	14	M/H/M/H	1/1/1/1	1/2/1/2	4	F/S/F/S		
	15	H/H/M/H	1/1/1/1	2/2/.75/2	4	S/S/F/S		
6	16	M	5	1	4	F		
	17	M/H/L/H	1/1/1/1	2	5	F/S/F/S		
	18	M/H/M/L	1/1/1/1	1.5/2/1.5/2	5	F/S/F/F		
7	19	M	5	2	5	F		
	20	M/H/L/H	1/1/1/1	3/2/.75/2	5	F/S/F/S		
	21	M/M/H/L	1/1/1/1	1/1/3/.75	5	F/F/S/F		
8	22	M	6	2	5	F		
	23	M/H/L/H	1/1/1/1	1.5	5	F/S/F/S		
	24	M/M/H/L	1/1/1/1	1/1/2/1	5	F/F/S/F		

Subjects will perform the following two exercises after the WM or RB interval session and before the cool-down period. Dumbbell weight will begin at 5 pounds, increasing by 5 pounds per dumbbell each session until the appropriate weight for 20 reps is determined. If 20 reps becomes easy, the subject will once again increase dumbbell weight by 5 pounds per dumbbell.

Dumbbell Biceps Curl	1 set of 20 reps
Dumbbell Flys	1 set of 20 reps

Appendix G

Roller Board Raw Data

Subject #	Pair #	Age yrs	# Sessions attended	% Sessions attended	Height inches	Height cm
17	1	32	23	96%	65.5	166.4
27	2	48	24	100%	66	167.6
30	3	25	24	100%	65	165.1
10	4	23	18	75%	65	165.1
20	5	29	23	96%	66	167.6
0	6	34	24	100%	65	165.1
22	7	51	24	100%	63	160.0
44	8	51	22	92%	65.5	166.4
23	9	33	24	100%	64.5	163.8
39	10	52	23	96%	65.75	167.0
29	11	30	23	96%	64	162.6
2	12	40	24	100%	65.5	166.4
32	13	48	24	100%	65.75	167.0
13	14	33	24	100%	63.5	161.3
43	15	49	23	96%	67	170.2
45	16	55	23	96%	64	162.6
8	17	26	24	100%	59.5	151.1
26	18	27	24	100%	70	177.8
4	19	33	24	100%	64.5	163.8
12	20	56	23	96%	65	165.1
40	21	59	24	100%	60.5	153.7
28	22	40	23	96%	65.5	166.4
Averages		**39.7**	**23.3**	**97.0%**	**64.8**	**164.6**
Stand Dev		11.51	1.32	0.05	2.09	5.31

Roller Board Raw Data (Continued)

Pre Weight pounds	Pre Weight kg	Post Weight pounds	Post Weight kg	Difference weight kg	% diff weight
150	68.0	150	68.0	0.0	0%
140	63.5	145	65.8	2.3	4%
127	57.6	124	56.2	-1.4	-2%
130.5	59.2	133	60.3	1.1	2%
140	63.5	141	63.9	0.5	1%
126	57.1	129	58.5	1.4	2%
135	61.2	134	60.8	-0.5	-1%
141.5	64.2	143	64.9	0.7	1%
130	59.0	130	59.0	0.0	0%
139	63.0	139	63.0	0.0	0%
133	60.3	135	61.2	0.9	2%
112	50.8	112	50.8	0.0	0%
150	68.0	152	68.9	0.9	1%
131	59.4	132	59.9	0.5	1%
128	58.0	127	57.6	-0.5	-1%
113	51.2	113	51.2	0.0	0%
93	42.2	93	42.2	0.0	0%
131	59.4	132	59.9	0.5	1%
129	58.5	131.5	59.6	1.1	2%
123	55.8	123	55.8	0.0	0%
109.5	49.7	106	48.1	-1.6	-3%
165	74.8	161	73.0	-1.8	-2%
130.8	**59.3**	**131.2**	**59.5**	**0.2**	**0.3%**
15.34	6.96	15.62	7.08	0.97	0.02

Roller Board Raw Data (Continued)

Pre Arm Circumf (cm)	Post Arm Circumf (cm)	Diff Arm Circumf (cm)	% Diff Arm Circumf (cm)	Pre Ab Fold mm	Post Ab Fold mm
27	29	2.0	7%	8	8
26	26.5	0.5	2%	9	9
25	25	0.0	0%	13	10
26	25.5	-0.5	-2%	9	9
26.5	27.5	1.0	4%	11	10
26	27	1.0	4%	19	21
28	28.5	0.5	2%	25	20
29	29.5	0.5	2%	18	17
24	26.5	2.5	10%	8	11
26	27	1.0	4%	25	24
28	29	1.0	4%	15	15
23	21.5	-1.5	-7%	7	7
26	27	1.0	4%	6	7
26	25.5	-0.5	-2%	30	27
26	24.5	-1.5	-6%	15	14
23	23	0.0	0%	9	7
21	22	1.0	5%	10	9
21	22	1.0	5%	20	18
25	27	2.0	8%	17	14
27	27	0.0	0%	20	16
26	26.5	0.5	2%	19	20
29	28.5	-0.5	-2%	37	30
25.7	**26.2**	**0.50**	**2.0%**	**15.9**	**14.7**
2.18	2.34	1.02	0.04	8.11	6.78

Roller Board Raw Data (Continued)

Pre Axillary Fold mm	Post Axillary Fold mm	Pre Pec Fold mm	Post Pec Fold mm	Pre Subscap Fold mm	Post Subscap Fold mm
6	6	4	5	8	11
9	7	6	6	10	10
12	8	6	5	9	8
8	9	3	4	7	8
6	6	5	5	8	8
10	7	8	9	10	9
11	10	4	10	14	14
10	12	11	7	11	11
9	9	7	6	10	10
13	12	13	9	12	11
10	10	13	8	14	14
5	5	4	4	6	7
7	8	4	4	11	10
23	20	16	16	17	15
8	9	11	10	9	10
5	6	3	3	6	6
7	6	8	5	8	8
9	10	10	11	13	12
9	9	6	9	7	8
12	14	8	6	7	9
14	12	14	9	14	12
19	19	18	15	30	23
10.1	**9.7**	**8.3**	**7.5**	**11.0**	**10.6**
4.34	3.94	4.40	3.46	5.19	3.62

Roller Board Raw Data (Continued)

Pre Iliac Fold mm	Post Iliac Fold mm	Pre Thigh Fold mm	Post Thigh Fold mm	Pre Tricep Fold mm	Post Tricep Fold mm	Pre Sum 7 mm	Post Sum 7 mm
5	5	17	18	10	13	58	66
5	5	20	21	18	18	77	76
6	5	13	12	10	10	69	58
4	5	20	18	13	12	64	65
4	5	26	25	12	12	72	71
11	13	20	21	14	15	92	95
12	9	23	24	24	19	113	106
7	8	22	23	17	16	96	94
6	8	26	26	20	18	86	88
13	14	15	13	15	11	106	94
9	11	11	11	17	14	89	83
2	3	20	18	14	14	58	58
5	5	18	17	12	11	63	62
15	15	15	15	15	15	131	123
5	3	16	16	13	11	77	73
5	5	11	13	8	8	47	48
6	5	22	25	13	13	74	71
7	6	15	14	12	13	86	84
5	5	17	15	14	11	75	71
9	8	17	17	14	14	87	84
8	6	20	20	25	21	114	100
20	14	34	34	31	29	189	164
7.7	**7.4**	**19.0**	**18.9**	**15.5**	**14.5**	**87.4**	**83.4**
4.25	3.70	5.33	5.60	5.41	4.53	30.60	25.35

Roller Board Raw Data (Continued)

Pre Body Density	Post Body Density	Pre % Body Fat	Post % Body Fat	Pre-Abs Pow watt	Post-Abs Pow watt	% Increase Abs. Pow	# abs watt Increase
1.0675	1.0643	12.31%	13.72%	139	155	12%	16
1.0580	1.0584	16.54%	16.37%	125	138	10%	13
1.0640	1.0684	13.84%	11.91%	124	140	13%	16
1.0663	1.0659	12.86%	13.03%	113	131	16%	18
1.0624	1.0628	14.59%	14.42%	109	125	15%	16
1.0542	1.0531	18.26%	18.75%	95	105	11%	10
1.0445	1.0470	22.64%	21.53%	90	100	11%	10
1.0505	1.0513	19.90%	19.57%	83	113	36%	30
1.0565	1.0558	17.20%	17.54%	72	104	44%	32
1.0468	1.0511	21.59%	19.63%	72	102	42%	30
1.0558	1.0580	17.53%	16.52%	68	111	63%	43
1.0665	1.0665	12.76%	12.76%	64	81	27%	17
1.0635	1.0639	14.10%	13.92%	59	98	66%	39
1.0408	1.0435	24.34%	23.13%	58	67	16%	9
1.0579	1.0594	16.59%	15.90%	55	80	45%	25
1.0691	1.0687	11.62%	11.80%	54	76	41%	22
1.0620	1.0631	14.76%	14.25%	48	63	31%	15
1.0573	1.0580	16.86%	16.52%	46	84	83%	38
1.0607	1.0622	15.33%	14.64%	43	66	53%	23
1.0532	1.0543	18.70%	18.19%	42	68	62%	26
1.0432	1.0481	23.27%	21.03%	41	53	29%	12
1.0231	1.0299	32.69%	29.46%	38	49	29%	11
1.0556	**1.0570**	**17.65%**	**17.03%**	**74.5**	**95.9**	**34.3%**	**21.4**
0.01	0.01	0.05	0.04	30.91	29.81	0.21	10.21

Roller Board Raw Data (Continued)

Pre- Rel. Power	Post- Rel. Power	# rel watts increase	% Increase Rel. Power	Pre- Time	Post- Time	Min Time Increase	% Time Increase
2	2.3	0.3	15%	6:00	6:00	0:00	0%
2	2.1	0.1	5%	6:00	8:00	2:00	33%
2.2	2.5	0.3	14%	4:50	6:40	1:50	38%
1.9	2.2	0.3	16%	4:00	4:40	0:40	17%
1.7	2	0.3	18%	5:00	6:20	1:20	27%
1.7	1.8	0.1	6%	3:40	5:30	1:50	50%
1.5	1.6	0.1	7%	3:00	4:40	1:40	56%
1.3	1.7	0.4	31%	4:20	5:20	1:00	23%
1.2	1.8	0.6	50%	3:20	5:40	2:20	70%
1.1	1.6	0.5	45%	3:00	4:00	1:00	33%
1.1	1.8	0.7	64%	2:20	5:00	2:40	114%
1.3	1.6	0.3	23%	2:00	3:40	1:40	83%
0.9	1.4	0.5	56%	2:20	5:20	3:00	129%
1	1.1	0.1	10%	1:40	2:40	1:00	60%
0.9	1.4	0.5	56%	2:40	4:40	2:00	75%
1.1	1.5	0.4	36%	3:20	4:20	1:00	30%
1.1	1.5	0.4	36%	1:20	2:20	1:00	75%
0.8	1.4	0.6	75%	2:20	5:00	2:40	114%
0.7	1.1	0.4	57%	2:00	3:40	1:40	83%
0.8	1.2	0.4	50%	1:20	2:20	1:00	75%
0.4	1.1	0.7	175%	1:20	2:00	0:40	50%
0.5	0.7	0.2	40%	1:20	2:00	0:40	50%
1.24	**1.61**	**0.37**	**40.2%**	**3:03**	**4:32**	**1:29**	**58.4%**
0.50	0.44	0.19	0.37	0.06	0.07	0.03	0.33

Appendix H

Wind Machine Raw Data

Subject #	Pair #	Age yrs	# Sessions attended	% Sessions attended	Height inches	Height cm
41	1	36	22	92%	65.0	165.1
19	2	27	24	100%	65.5	166.4
31	3	30	24	100%	67.0	170.2
6	4	34	24	100%	65.5	166.4
14	5	39	24	100%	64.0	162.6
11	6	42	24	100%	62.0	157.5
9	7	23	24	100%	63.0	160.0
16	8	48	24	100%	64.0	162.6
36	9	36	22	92%	65.5	166.4
37	10	43	23	96%	65.0	165.1
24	11	34	22	92%	61.0	154.9
35	12	45	24	100%	62.5	158.8
5	13	34	24	100%	63.0	160.0
21	14	46	24	100%	63.5	161.3
42	15	29	24	100%	65.5	166.4
34	16	55	24	100%	67.5	171.5
3	17	43	24	100%	63.0	160.0
38	18	37	24	100%	64.0	162.6
18	19	33	23	96%	62.0	157.5
25	20	47	24	100%	63.0	160.0
15	21	29	23	96%	68.0	172.7
33	22	43	20	83%	63.5	161.3
Averages		**37.9**	**23.4**	**97.5%**	**64.2**	**163.1**
Stand Dev		7.95	1.05	0.04	1.84	4.67

Wind Machine Raw Data (Continued)

Pre Weight pounds	Pre Weight kg	Post Weight pounds	Post Weight kg	Difference weight kg	% diff weight
129.0	58.5	125.0	56.7	-1.8	-3%
132.0	59.9	133.0	60.3	0.5	1%
135.0	61.2	144.0	65.3	4.1	7%
146.0	66.2	143.0	64.9	-1.4	-2%
118.0	53.5	118.0	53.5	0.0	0%
121.0	54.9	124.0	56.2	1.4	2%
134.0	60.8	134.0	60.8	0.0	0%
130.0	59.0	138.0	62.6	3.6	6%
145.5	66.0	144.0	65.3	-0.7	-1%
144.0	65.3	144.5	65.5	0.2	0%
105.0	47.6	108.0	49.0	1.4	3%
128.0	58.0	129.0	58.5	0.5	1%
137.0	62.1	136.0	61.7	-0.5	-1%
119.0	54.0	115.0	52.2	-1.8	-3%
120.0	54.4	121.0	54.9	0.5	1%
130.0	59.0	129.0	58.5	-0.5	-1%
116.5	52.8	118.0	53.5	0.7	1%
126.0	57.1	122.0	55.3	-1.8	-3%
92.5	42.0	93.0	42.2	0.2	1%
140.0	63.5	141.0	63.9	0.5	1%
153.0	69.4	157.0	71.2	1.8	3%
120.0	54.4	117.0	53.1	-1.4	-2%
128.3	**58.2**	**128.8**	**58.4**	**0.2**	**0.4%**
14.02	6.36	14.57	6.61	1.56	0.03

Wind Machine Raw Data (Continued)

Pre Arm Circumf (cm)	Post Arm Circumf (cm)	Diff Arm Circumf (cm)	% Diff Arm Circumf (cm)	Pre Ab Fold mm	Post Ab Fold mm
26	26	0.0	0%	7	4
28	28	0.0	0%	9	9
26.5	27	0.5	2%	21	20
29	26.5	-2.5	-9%	14	10
25	24.5	-0.5	-2%	13	10
25.5	25.5	0.0	0%	14	15
26	27	1.0	4%	24	18
26	27	1.0	4%	25	24
26.5	27	0.5	2%	18	16
29	29.5	0.5	2%	8	7
22	23.5	1.5	7%	7	8
26	26.5	0.5	2%	7	7
27	28	1.0	4%	22	19
25	24	-1.0	-4%	15	11
23	23.5	0.5	2%	18	15
23	25	2.0	9%	20	17
23	24.5	1.5	7%	5	4
23	23.5	0.5	2%	13	9
21	20	-1.0	-5%	6	5
26	26	0.0	0%	21	19
28	29.5	1.5	5%	22	19
24	25	1.0	4%	23	16
25.4	**25.8**	**0.39**	**1.6%**	**15.1**	**12.8**
2.21	2.20	1.01	0.04	6.64	5.86

Wind Machine Raw Data (Continued)

Pre Axillary Fold mm	Post Axillary Fold mm	Pre Pec Fold mm	Post Pec Fold mm	Pre Subscap Fold mm	Post Subscap Fold mm
4	4	4	3	6	4
7	8	6	6	13	14
10	12	10	6	9	9
6	7	9	8	8	8
7	8	8	7	10	10
8	7	5	3	9	9
8	7	7	9	8	8
10	10	7	6	6	9
11	10	6	5	14	15
9	9	6	6	12	11
4	6	5	6	8	8
7	7	9	4	7	8
14	12	14	6	14	14
7	5	3	5	11	8
6	4	4	3	8	5
9	9	14	10	7	7
4	5	2	3	6	6
7	5	10	5	7	8
5	5	5	3	8	8
13	13	12	14	15	18
11	12	15	14	12	12
12	10	13	8	12	10
8.1	**8.0**	**7.9**	**6.4**	**9.5**	**9.5**
2.88	2.79	3.82	3.17	2.86	3.36

Wind Machine Raw Data (Continued)

Pre Iliac Fold mm	Post Iliac Fold mm	Pre Thigh Fold mm	Post Thigh Fold mm	Pre Tricep Fold mm	Post Tricep Fold mm	Pre Sum 7 mm	Post Sum 7 mm
4	4	10	11	7	7	42	37
5	5	14	15	15	15	69	72
9	9	24	20	16	16	99	92
7	4	18	17	12	11	74	65
7	6	22	18	17	15	84	74
7	8	19	20	17	17	79	79
8	8	20	17	14	16	89	83
8	8	27	29	20	18	103	104
8	7	31	28	17	18	105	99
5	5	25	21	24	24	89	83
4	5	12	15	15	15	55	63
5	4	22	20	19	19	76	69
10	8	18	20	18	18	110	97
9	5	17	14	14	13	76	61
7	5	18	16	15	14	76	62
5	5	28	24	15	17	98	89
3	3	12	12	10	9	42	42
6	4	20	17	16	15	79	63
2	3	9	9	8	8	43	41
13	13	26	24	20	20	120	121
14	14	30	27	26	23	130	121
11	12	25	23	18	18	114	97
7.1	**6.6**	**20.3**	**19.0**	**16.0**	**15.7**	**84.2**	**77.9**
3.06	3.14	6.36	5.39	4.50	4.31	24.76	23.45

Wind Machine Raw Data (Continued)

Pre Body Density	Post Body Density	Pre % Body Fat	Post % Body Fat	Pre-Abs Pow watt	Post-Abs Pow watt	% Increase Abs. Power	# abs watts Increase
1.0736	1.0758	9.64%	8.71%	154	197	28%	43
1.0638	1.0626	13.96%	14.48%	125	138	10%	13
1.0521	1.0547	19.17%	18.03%	119	131	10%	12
1.0609	1.0645	15.22%	13.66%	114	129	13%	15
1.0565	1.0603	17.21%	15.51%	109	112	3%	3
1.0580	1.0580	16.53%	16.53%	100	111	11%	11
1.0567	1.0589	17.13%	16.12%	94	127	35%	33
1.0484	1.0480	20.87%	21.03%	81	100	23%	19
1.0492	1.0514	20.49%	19.52%	81	87	7%	6
1.0541	1.0564	18.28%	17.27%	69	105	52%	36
1.0685	1.0653	11.88%	13.30%	65	110	69%	45
1.0588	1.0615	16.19%	14.98%	62	72	16%	10
1.0477	1.0523	21.17%	19.08%	60	90	50%	30
1.0586	1.0645	16.25%	13.63%	57	65	14%	8
1.0608	1.0663	15.28%	12.84%	55	100	82%	45
1.0493	1.0526	20.47%	18.98%	52	68	31%	16
1.0727	1.0727	10.03%	10.03%	47	108	130%	61
1.0586	1.0649	16.25%	13.47%	43	100	133%	57
1.0736	1.0745	9.65%	9.29%	42	62	48%	20
1.0427	1.0423	23.50%	23.65%	41	68	66%	27
1.0417	1.0446	23.95%	22.59%	40	67	68%	27
1.0452	1.0512	22.33%	19.60%	29	37	28%	8
1.0569	**1.0592**	**17.07%**	**16.01%**	**74.5**	**99.3**	**42.1%**	**24.8**
0.01	0.01	0.04	0.04	33.51	34.26	0.37	16.99

Wind Machine Raw Data (Continued)

Pre- Rel. Power	Post- Rel. Power	# rel watts increase	% Increase Rel. Power	Pre- Time	Post- Time	Min Time Increase	% Time Increase
2.6	3.5	0.9	35%	5:50	7:40	1:50	31%
2.1	2.3	0.2	10%	4:50	6:20	1:30	31%
1.9	2	0.1	5%	5:00	7:00	2:00	40%
1.7	2	0.3	18%	3:45	5:40	1:55	51%
2	2.1	0.1	5%	5:00	6:40	1:40	33%
1.8	2	0.2	11%	3:40	5:00	1:20	36%
1.5	2.1	0.6	40%	4:45	7:00	2:15	47%
1.3	1.6	0.3	23%	3:00	5:00	2:00	67%
1.2	1.3	0.1	8%	3:20	5:15	1:55	58%
1.1	1.6	0.5	45%	3:20	5:20	2:00	60%
1.4	2.2	0.8	57%	3:20	6:00	2:40	80%
1.1	1.2	0.1	9%	2:00	3:20	1:20	67%
1	1.5	0.5	50%	3:40	5:00	1:20	36%
1.1	1.2	0.1	9%	2:00	3:40	1:40	83%
1	1.8	0.8	80%	2:20	5:00	2:40	114%
0.9	1.2	0.3	33%	2:00	3:00	1:00	50%
0.9	2	1.1	122%	2:20	5:00	2:40	114%
0.8	1.8	1	125%	2:20	5:20	3:00	129%
1	1.5	0.5	50%	1:40	3:40	2:00	120%
0.6	1.1	0.5	83%	1:20	4:00	2:40	200%
0.6	0.9	0.3	50%	1:15	3:00	1:45	140%
0.5	0.7	0.2	40%	1:00	1:40	0:40	67%
1.28	**1.71**	**0.43**	**41.3%**	**3:04**	**4:58**	**1:54**	**75.2%**
0.54	0.60	0.32	0.35	0.06	0.06	0.02	0.44