AN ABSTRACT FOR THE THESIS OF

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Katherine B. Gunter

Studies in young women show that rowing exercise is osteogenic at the spine. However, little is known regarding rowing exercise and spine bone mineral density in older women. The aim of this study was to examine differences in spine bone mineral density (BMD) and back strength between premenopausal and postmenopausal competitive female masters rowers (n=28, 45.5 $\pm$ 4.7 yrs, n=28, 56.1 $\pm$ 5.7 years, respectively) and age-matched non-rowers (n= 30, 43.3 $\pm$ 4.2 yrs; n=26, 56.8 $\pm$ 4.8 years). Competitive rowers were recruited from nine rowing clubs in the local area and compared to controls recruited from the same region who were normally active but not participating in rowing activity. Participating rowers had been engaged in competitive rowing for a minimum of one year. The average years spent rowing for the premenopausal and postmenopausal groups was 7.5 $\pm$ 6.6 yrs and 5.9 $\pm$ 6.9 yrs, respectively. BMD (g/cm^2) of the third lumbar vertebrae (L3) was measured by dual-energy x-ray absorptiometry (DXA) in both the anterior-posterior and lateral views. Back strength was assessed using a standing cable tensiometer. Subjects also completed questionnaires to assess diet, physical activity, medical history and rowing history. Differences in BMD and

back strength between groups were determined by analysis of covariance, controlling for lean mass. Compared to controls, postmenopausal rowers had 3.2% higher BMD at the anterior-posterior spine (p= .02) and 4.4% higher lateral spine BMD (p= .04). Furthermore, isometric back strength was 22.6% greater in these rowers than controls (p = .01). In contrast, controls had higher lateral BMD than rowers, with no differences in AP spine BMD or back strength between the premenopausal rowers and controls. Back strength was a significant predictor of AP spine BMD in premenopasual rowers and controls (R^2= 0.137, p= 0.004) and of lateral spine BMD in postmenopausal rowers only (R^2= 0.153, p=0.04). There were no differences in calcium intake, age, menopausal status, weight, or lean mass between rowers and controls in either the premenopausal or postmenopausal samples. Since both increased BMD and back strength are associated with reductions in vertebral fracture risk, our results suggest that rowing exercise may be an important strategy to promote bone health and reduce vertebral fracture risk in postmenopausal women. However, the forces applied in rowing may not be great enough to alter bone mass before the onset of menopause. Therefore more research is needed examining rowing exercise in these older populations.

Bone Mineral Density and Rowing Exercise in Older Women

by
Adrienne J. McNamara

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

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Adrienne J. McNamara, Author

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CONTRIBUTION OF AUTHORS

Dr. Katherine B. Gunter was instrumental in the design and planning of this research. In addition she provided great help in the editing of the two manuscripts.

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CHAPTER ONE: INTRODUCTION

BACKGROUND

Once regarded as a normal part of the aging process, osteoporosis is now considered one of the leading causes of morbidity and mortality in American society. Currently over 10 million Americans are osteoporotic, with 18 million more at risk due to low bone mass. Osteoporosis and related fractures significantly impact quality of life and carry a financial burden of over 14 billion dollars annually (NIH consensus panel, 2001). Among the consequences of osteoporosis, vertebral fractures predominate all osteoporotic fractures, occur earlier in life than hip fractures and may rival hip fractures in terms of morbidity and debilitation (Gold et al, 1999; Ross, Santura, Yates, 2001). Women are at the greatest risk of these fractures due to the accelerated bone loss of up to 5% per year in the years following menopause resulting from the cessation of estrogen production. Though it is possible to supplement estrogen through hormone replacement therapy (HRT), recent evidence has shown there are significant cardiovascular and cancer risks associated with the treatment (Humphries & Gill, 2003). Thus, fewer women are willing to use HRT, despite its effectiveness in the prevention of bone loss. Therefore a great need exists to find viable alternatives to HRT for the prevention of bone loss and subsequent fractures.

Resistance and Impact Exercise

Exercise appears to be an effective intervention for the preservation of bone mass, as long as the stimulus at the site of interest is sufficient to produce an overload (Myburgh,1993). Additionally, falls, which are a common stimulus for fracture in the elderly, can also be reduced through exercise. While impact exercises such as jumping and running seem necessary to produce changes in bone at the hip (Snow, Shaw, Winter, Witzke, 2000; Bassey, Rothwell, Littlewood, Pye, 1998; Fuchs, Bauer, Snow 2001), the spine appears to adapt to non-impact resistance exercise. For example, Kohrt, Ehsani and Birge (1997) conducted an 11 month intervention examining the effects of different types of exercise on bone. Thirty nine sedentary women (age 60-74), not taking HRT were assigned to one of three groups: a) exercises involving predominately ground reaction forces (GRF) (such as running; walking, and stairs), b) exercises consisting of predominately joint reaction forces (JRF) (such as weight lifting and rowing) or c) a no exercise control group. Both exercise groups performed specific supervised exercises 3-5 days a week for nine months, after a two month lead-in phase involving activities to increase flexibility and range of motion. Participants in the GRF group walked 30-45 minutes at 60-85% maximal heart rate (duration and intensity progressed through these ranges for the duration of the study) and were encouraged to jog as much as possible. Stair climbing was added after the third month. Participants in the JRF program spent half of each session rowing (up to three 10 minutes bouts on a rowing ergometer at 80-85% maximal heart rate) and the remainder of the session weight training (2-3 sets of standing free weight exercise at an intensity resulting in fatigue after 8-12 repetitions). Bone mineral density (BMD) of the whole body, lumbar spine, proximal femur and distal forearm were assessed at baseline and then in 3 month intervals throughout the study. The change at the spine was 1.5 $\pm$ 0.7% and 1.8 $\pm$ 0.5% in the GRF and JRF groups respectively. Changes in whole body BMD were also similar between groups. Although only the GRF group increased femoral neck BMD, increases in lower body muscle strength were greater in response to the JRF program than to the GRF program (15$\pm$ 5% vs. 9$\pm$ 4% respectively). Additionally, only the JRF group increased fat-free mass. Therefore, despite the absence of change in hip BMD, the outcomes specific to the JRF group are important factors for fall reduction and subsequent fracture prevention.

Numerous other studies have also used resistance training to elicit bone adaptations in adult populations (Kerr, Ackland, Maslen, Morton, Prince, 2001; Vincent & Braith, 2002; Pruitt, Jackson, Bartels, Lehnhard, 1992; Dornemann, McMurray, Renner, Anderson, 1997; Maddalozzo & Snow, 2000; Smidt, Lin, O'dwyer, Blandpied, 1991; Revel, Mayoux-Benhamjou, Rabourdin, Bagheri, Roux, 1993). Pruitt el al (1992) examined the effects of a nine month resistance training intervention on 17 early postmenopausal women (1-7 years since menopause onset; age 54-57) with no history of resistance training. The exercise protocol included three, one hour weight training sessions per week, where exercisers performed one set (10-12 repetitions) of each exercise designed to target either the trunk (trunk extension, hip extension, lateral flexion), lower extremities (leg press, leg ab/adduction, leg curl, leg extension), or upper extremities (biceps curl, lat pulldown, bench press, wrist roller). All exercises were performed at 60% of the subject's one repetition maximum (1-RM). The control group (n=10) was instructed to maintain their average daily activity. Bone analysis showed that the change in spine BMD of the weight trained group was significantly different from that of the control group (1.6 $\pm$ 1.2% vs. -3.6 $\pm$ 1.5% respectively), with no significant differences at any other bone site. This study shows the potential of resistance training to maintain and even increase spine BMD at a time in a woman's lifespan when rapid loss of bone mass is expected.

Similarly, in a 12-month study of 89 postmenopausal women (51-57 years of age), Revel et al (1993) had two groups of subjects perform exercises targeting either 1) the psoas muscle, or 2) the deltoid muscle groups and measured the effects on the lumbar vertebrae. The psoas exercise consisted of 60 flexions of 30° of each hip with a 5-kg sandbag on the knee whereas the deltoid exercise consisted of 60 abductions of both arms holding a 1-kg sandbag in each hand. All exercises were performed 2-3 times per day for the duration of 1 year. Bone loss at the lumbar spine in the control group (deltoid exercise) was greater than in the treatment group (psoas exercise) indicating a protective effect of site-specific weight training as well as the specificity of bone response to muscles trained. It should be noted that compliance in this study was very low, with only 55% of women completing the prescribed amount of exercise. Therefore it is likely to assume that there is potential for even greater differences in a more compliant population.

Work from our laboratory (Winters and Snow, unpublished) reinforced the site-specific adaptations of bone in premenopausal women. We examined the addition of upper body resistance exercises (using resistance tubing) to a jump plus resistance training protocol designed to overload the lower body. All exercisers (n=24) performed the lower body exercises consisting of 100 jumps and 100 repetitions of resistance exercises three times per week for 12 months. Half of the women (n=14) also performed 100 repetitions of upper body resistance exercise. Hip and spine BMD were measured by DXA at baseline and 12 months. Both exercise groups had similar significant increases in hip BMD when compared to age matched controls. However, only the group performing upper body exercises had a significant increase in lumbar spine BMD (+1.4% $\pm$ 3.9%). These results support that exercises designed to influence bone must specifically target the site of interest in order to produce bone changes.

In one of the few studies to examine both men and women, Maddalozzo and Snow (2000) compared the effects of high intensity free-weight training to moderate intensity machine-based exercises on BMD of the lumbar spine and hip. Intensity classifications were: very high: 90% of 1-RM, high: 70-80% of 1-RM and moderate: 60% 1-RM. Participants (n=54, average age was 55 $\pm$ 1 and 53 $\pm$ 1 years for men and women respectively) completed a 6 month protocol of either high or moderate intensity exercises performed for 75 minutes three days per week. Results showed that the high intensity training resulted in increases in spinal BMD in men only, with no changes at any site in women. However, due to the lack of a separate control group, one cannot conclude if the exercise was effective in diminishing the bone loss in the women which would be expected due to the low levels of estrogen typical in the early stages of menopause. It is also possible that the intervention was not long enough to see adequate changes in the female population as most studies showing an effect in this population lasted for nine months or longer (Kohrt et al,1997; Pruitt et al,1992). However, total body strength did increase in all subjects, a result beneficial to reducing fall risk and promoting overall health.

Conversely, there are also studies showing no improvement in spine BMD from resistance training in older populations (Kerr et al ,2001; Vincent & Braith, 2002; Dornemann et al, 1997; Smidt et al, 1991). For example, Kerr et al (2001) conducted a two-year intervention study testing the effect of resistance training designed for strength in comparison to the same exercises performed for aerobic fitness. Postmenopausal women (n = 126, age 60 $\pm$ 5 years) were given 600 mg/d calcium supplementation and were block randomized into one of three groups: a) strength, b) fitness, or c) non-exercise control group. Both exercise groups participated in three, one-hour exercise sessions per week where they performed: wrist curl, reverse curl, biceps curl, triceps pull-down, hip flexion, hip extension, latissimus dorsi pull-down and calf raise. The strength group performed three sets of eight repetitions per exercise at each session and progressively increased resistance on an individual basis. The fitness group performed the exercises in a circuit (40-seconds each station) with little increase in resistance during the two-year time period. Bone density of the hip, spine, radius, and whole body were taken at 6 month increments throughout the study. While there was a significant increase in hip BMD in the strength group only, no benefits to the lumbar spine were observed in any group. It should be noted, however, that of all the exercises, only the latissimus dorsi pull-down targets the lumbar spine, therefore exposure to overload at this region may have been insufficient to elicit an effect. Results from this study do stress the importance of high strain loads for osteogensis considering that only the strength training group saw any results beneficial to bone.

Likewise, Dornemann et al (1997) conducted a six-month resistance training study where sedentary, premenopausal women (age 40-45) were randomized to either a no-exercise control, or a strength training group. The exercise group (n=12) performed three one-hour sessions per week with each session varying in intensity from light (3 sets of 12-15 repetitions on core exercises), moderate (3 sets of 8-10 reps with higher weight on core exercises) and heavy (5 sets of 4-6 reps with heavy loads). Core exercises included inverted leg press, calf raises and seated overhead press. Two sets of 10 repetitions of all supplemental exercises (lat pulldown, upright row, standing front and lateral raise, standing biceps curl and triceps extension and triceps pushdown) were performed on light and moderate days with only one set of 10 reps on two of the supplemental exercises done on heavy days. The control group (n=14) maintained their normal activity patterns. At the end of the study, there were no significant increases in BMD at any site (radius, hip, or lumbar spine) in either group. However, there was a trend to a difference between groups ($p = 0.069$) in lumbar spine BMD. Considering the small number of subjects in the groups, it is likely that the power of this study was not adequate to detect a significant difference, thus explaining why only a trend toward a difference was seen. Another limitation of this study was the relatively short duration of intervention. Unlike the cardiovascular and muscular systems which have the capacity to adapt quickly, the skeletal system adapts considerably slower. In fact, one bone remodeling cycle, which is the process where older and weaker bone is replaced by newer and stronger bone through a sequence of resorption and formation, can take up to 6 months to complete (McDermott, 1998). Additionally, bone in older adults tends to adapt slower than younger bone creating the necessity for longer intervention studies when using older populations (Beck & Snow, 2003). Therefore, it is possible that in the study of Dorneman et al, a longer duration would have resulted in significant findings.

Vincent and Braith (2002) also examined the effects of intensity in producing bone adaptations by testing the current recommendation of the American College of Sports Medicine that adults over 50 should perform one set of 8-10 exercises for 10-15 repetitions. Sixty-two elderly (age 60-83) men and women were randomly assigned to groups participating in 6 months of either low intensity exercise (n = 34), high intensity exercise (n = 30) or no exercise (n = 20). The exercise protocol consisted of one set of either 8 repetitions at 80% 1-RM (high-intensity group) or 13 repetitions at 50% 1-RM (low-intensity group) of each of the following exercises: abdominal crunch, leg press, leg extension, leg curl, calf press, seated row, chest press, overhead press, biceps curl, seated dip, leg abduction, leg adduction, and lumbar extensions. Each exercise was performed three times per week at a supervised training facility. Bone mineral density of the total body, anterior-posterior (AP) and lateral views of the lumbar spine and hip was measured via DXA at the beginning and conclusion of the study. Additionally markers of bone formation (Osteocalcin (OC) and , bone-specific alkaline phosphatase (BAP)) and markers of bone resorption (serum pyridinoline cross-links (PYD)) were also measured pre and post intervention. Results indicate that the high intensity group increased femoral neck BMD by 1.96 % with no other BMD changes observed in any group or at any other site. However, the ratio of OC to PYD increased in both exercise groups and the ratio of BAP to PYD increased in the HEX group. This result is promising considering in that both OC and BAP are measures of bone formation. Therefore, increasing the ratio of either marker to PYD, which is a marker of bone resorption, indicates a tip in the remodeling scale toward bone formation and improved BMD. Once again, it is likely that the study was not long enough to realize the gains at other bone sites that may have supported these promising changes in blood chemistry. In regards to the lumbar spine, another limitation of this study is that very few of the exercises performed actually targeted the spine. Therefore, it is not surprising that changes were seen at the femoral neck where most of the stress from the exercises occurred, with no change in the spine. Regardless, this study does stress the importance of high intensity exercise for osteogenesis. Additionally, the results also indicate the importance of load frequency in that one set of few repetitions may not be adequate to elicit bone adaptations. Both load magnitude and repetitions are important considerations in the design and implementation of exercise prescription for bone health.

Finally, Smidt (1991) et al conducted a 12-month study evaluating the effects of trunk resistance training on BMD. Forty-nine postmenopausal women were randomly assigned to either a control group (n = 27, age 55$\pm$ 8) or an exercise group (n =22, age 57$\pm$ 7). The exercise group performed three sets of 10 repetitions, three to four times a week of each of the following exercises: sit-up, double leg raise, and prone trunk extension. All exercises were performed at 70 % of maximum with the intensity increasing 2-5% each month. The control group maintained their regular activity patterns. Strength assessments as well as BMD of the lumbar spine, femoral neck, Ward's triangle and trochanteric region of the hip were assessed at baseline, at 6 months, and at the conclusion of the study. Data analysis indicated no significant treatment effect in either group. However, despite the fact that bone was lost in both groups, the loss at the lumbar spine in the exercise group was minimal with losses significantly different from zero only in the fourth lumbar vertebrae during the last 6 months of the study. In contrast, losses in the entire lumbar region of the control group were significantly different from zero at the end of the one year period. While bone was not gained from this exercise protocol the results are somewhat encouraging in that exercise appeared to reduce the rate of bone loss in this population where rapid bone loss is the normality. Additionally, it should be noted that the control group in this population was very active with 23 out of 27 subjects participating in regular exercise. Therefore it is possible that the lack of significant differences between groups could be confounded by this abnormally active population. Had a sedentary control group been used it is likely that a greater difference would have been seen.

Rowing Exercise

Recent data suggest that rowing, an exercise that specifically targets the lumbar spine, offers promise as an activity to promote osteogenesis and can provide an alternative to resistance training. Morris, Smith, Payne, Galloway and Wark (2000) evaluated the bone mineral density of 14 female rowers, age 15-25 with at least 3 years rowing experience, and found the rowers to have significantly higher spine BMD than age matched controls, with no difference at any other site. In addition, rowers completed a 6 minute test to exhaustion on a rowing ergometer simulating competition, in order to estimate the shear and compressive forces experienced by the spine. Results indicate that the peak compressive force on the spine was approximately 4.6 times body weight. These loads from rowing appear to be high enough to offset low estrogen levels due to amenorrhea as seen by Wolman, Clark, McNally, Harries and Reeve (1990) who found that both amenorrheic and eumenorrheic rowers (average age 25 years) had higher BMD than non-rowing athlete controls. Thus it is possible that older women who are estrogen deplete due to menopause may also benefit from rowing exercise.

An additional study by Morris et al (1999) in young rowers showed similar results. Fourteen girls (age 14-15, experience 1-2 years) were followed over 18 months of team rowing training consisting weekly of 3-4 days of 2 hour sessions of rowing, one race row day, one general fitness session and two rowing specific weight training sessions. BMD of the total body, lumbar spine, proximal femur and femoral neck were measured at baseline, 6 months and at the conclusion of the study. Data were also collected regarding hormonal status and the girls were subsequently classified into one of two categories: ovulatory (n = 9) or anovulatory (n = 5) and analyzed separately. In addition a control group of 10 ovulatory girls was employed for data comparison. At the conclusion of the study, the rowers with normal estrogen and progesterone levels (i.e. ovulatory girls) had a 6.1% increase in lumbar spine BMD with no significant differences seen in the other groups, or at any other bone site. Consequently the authors conclude that rowing is a powerful osteogenic activity provided that sufficient estrogen is present. Should a hormone deplete environment arise, the forces generated in rowing are may not be great enough to reach the higher set point or threshold to produce bone growth. However, it should be noted that the anovulatory rowers did have a 3.9% increase in lumbar spine BMD after training but the very small sample size of 5 may not have given enough power to detect any significance. Clearly, more research needs to be done to determine the potential of rowing to offset low estrogen levels by using larger sample sizes before any generalizations of the limitations of rowing can be made. Furthermore, the forces at the spine in the young girls may have been insufficient to overcome the hormone depletion, particularly given the findings of Wolmam et al who report amenorrheic rowers had higher BMD compared to normally menstruating controls. Nevertheless, the large increase in spine BMD in the ovulatory rowers provides promise about the benefits of rowing, especially as a preventive exercise to be used before the cessation of endogenous estrogen production has occurred.

In one of the few intervention studies to look at rowing, Cohen, Millett, Mist, Laskey and Rushton (1995) trained 17 male novice rowers (average age

19.5) for seven months to examine the effects of rowing on the BMD of the hip (femoral neck, greater trochanter and Ward's triangle) and lumbar spine. The protocol included 8 hours per week of rowing plus one hour a week of both running and weight training emphasizing the muscles used in rowing. After the 7 month period, lumbar spine BMD of the rowers had increased significantly by 2.9%, with increases in BMC of 4.2%. No significant changes were seen in controls, nor were there changes in hip BMD of either group. While these results are encouraging, limitations of this study are many. First and foremost, like the Smith and Rutherford study (1993), the addition of running and weight lifting to the exercise protocol could have confounded the results, making it difficult to conclude that the bone changes came from rowing alone. Secondly, nutrition was not examined which can also be a confounding factor in that insufficient calcium may negatively affect the skeleton. Finally, assignment to groups was not random and therefore selection bias may be present. Despite these limitations however, the large changes in bone parameters after a relatively short duration of time suggest the appropriateness of pursuing rowing for future interventions.

Reinforcing the importance of high force magnitudes over repetitions LaRiviere, Robinson and Snow (2003) compared the bone response of experienced versus novice female collegiate rowers. Sixteen experienced rowers with 26 ± 10 months experience and nineteen first year rowers with less than 3 months experience were observed over the course of a 6 month competitive rowing season. Bone mineral density of the spine was assessed via DXA at baseline and at 6 months. Additionally, rowing performance was assessed at three time points via

2000- and 6000- m time trials on a Concept 2 rowing ergometer. Throughout the study, each group participated in identical training sessions that included six sessions per week of rowing (83% of total time spent in activity) and 2 sessions per week of running, weight training, and stretching. For comparison, all results were compared to a non-rowing control group (n = 14) of normally active college women. Analysis indicated that experienced rowers demonstrated a greater increase in spine BMD (2.14%) than novice rowers with no significant change between the novice and control groups. Because each athlete performed approximately the same number of load repetitions per week (6000 strokes) the observed bone response can be attributed to the ability of the experienced rowers to elicit greater force per stroke. One limitation of this study, however, is that lumbar compressive or shear forces were not directly measured, nor were the exact number of strokes actually counted. However, heights of all rowers were not significantly different therefore one can assume that each rower had a similar stroke length. Therefore, based on the similar average stroke rates and stroke lengths of the rowers on the timed tests, the faster times achieved by the experienced rowers could only have occurred through the exertion of greater forces. To substantiate these claims, the power output at the hands was estimated for all rowers. The basis from this comes from findings by Morris et al (2000) that show that spinal forces vary according to forces applied on the oar. Hand power for the time trials of the experienced rowers was 15% higher in the first testing period to 10% higher in the third testing period than the novice rowers indicating that indeed greater force was being exerted by this group.

These results seem to be in conflict of those of Cohen et al (1995) who did find increases in BMD in novice rowers. LaRiviere suggests that Cohen's cohort was stronger at baseline and therefore able to generate greater forces than the novice women. Another possibility is that the statistical power of LaRiviere et al. study was relatively low (power = 0.65) and therefore may not have been strong enough to detect a difference between the novice and control groups. However this study did control for nutrition and calcium intake, which, as previously mentioned, the lack of such control was a limitation for Cohen's study. In general, the results of this study are in accordance with those of both Vincent and Braith (2001) and Smith and Rutherford (1993) in that load magnitude, more so than load repetitions, is a very important factor in osteogenesis, and that rowing appears to offer loads that are high enough to improve the skeletal health of the spine.

Finally, kayaking, a sport mechanically similar to rowing, may also have a protective or osteogenic effect at the spine. Flodgren, Hedilin and Henriksson-Larsen (1998) cross-sectionally examined the bone health of 10 flat water sprint kayakers (mean age 19; average experience 11.5 years) compared to active controls matched for age, weight, gender and height (2 controls per subject, n=12 males, 8 females). Results measured via DXA indicated that the kayakers had significantly higher BMD of the pelvis (5.1%), humerus (10.4 and 11.7 % for left and right respectively), ribs (6.4%) and total spine (10.9%). Lumbar spine BMD was 3.3% higher in kayakers compared to controls, but this value did not reach significance. However, the very small sample size in this study, and thus low statistical power may explain the lack of significance at this site.

Back Strength and Fracture Risk

Rowing exercise has also been related to increased back strength in rowers compared to controls. This outcome is important considering that increasing back strength can greatly reduce the risk of chronic low back pain, which is the leading cause of inactivity among people under the age of 45 (Carpenter & Nelson, 1999; Alexiev, 1994). In addition, back strength seems to be positively related to BMD of the spine. For example, in a study by Halle, Smidt, O'Dwyer, and Lin (1990), 56 postmenopausal women completed testing of bone parameters as well as assessments of maximal voluntary trunk flexor and extensor torque and work using an isometric device. Forty-four percent of variability in lumbar spine BMD was explained by torque, indicating a positive relationship between trunk strength and spine BMD. The authors emphasize the importance of this magnitude of correlation in context of the vast array of factors that affect bone, such as hormone levels, race, nutrition and other lifestyle factors. Thus a single factor that contributes to nearly half of all variation in BMD can be viewed as a promising factor to promote overall bone health. Likewise a 4 year longitudinal study on 119 Japanese postmenopausal women showed similar results (Saito et al, 2002). After controlling for age, body size, and vitamin D receptor genotype, a genotype that has a potential impact on bone, researchers found a significant positive correlation between isokinetic eccentric trunk flexor torque and spine BMD at baseline ($r=.33$, $p<0.001$), as well as a significant positive correlation between annual change in BMD and torque of the trunk extensors ($r=.325$, $p<0.001$). Both of these studies suggest the importance of back strength in the health of bone, independent of other factors.

In one of the few studies to use vertebral fractures as an outcome variable, Sinaki first evaluated the effectiveness of a 2 year back strengthening program on strength and BMD of the spine, and then reexamined the subjects 8 years later to determine vertebral fracture incidence among groups (Sinaki, Wahner, Offord, Hodgson, 1989; Sinaki et al, 2002). Sixty-eight, healthy postmenopausal women (age 49-65) were randomly assigned to either an exercise or control group. Those in the exercise group performed 10 repetitions of back extensions with weighted backpacks (weight equaling 30% of maximal isometric strength), 5 days a week for 2 years, whereas controls maintained their normal activity level. No significant differences in bone loss between the two groups was seen at the end of the 2 years, despite a significant increase in back extensor strength in the exercise group.

However, in a follow up study, 50 of the subjects were re-tested for strength and BMD parameters, and vertebral fracture incidence was recorded. Results indicated that the exercise group not only maintained higher back strength compared to controls during the 8 year time period (1.6% per year loss of strength compared to 2.7% per year strength loss in controls), but they also had significantly higher lumbar spine BMD than the control group. Of greater interest, the exercise group also had 2.7 times lower incidence of vertebral fracture than the controls. The authors attribute this result to both the slower rate of bone loss achieved after the intervention, as well as to the reduction in fall risk resulting from improved strength. Another possible explanation is the decreased compressive loads on the spine due to the stronger back musculature. Overall this research shows the benefits of back strengthening in older populations and rowing can be a mechanism to improve strength and BMD in these at risk populations.

PURPOSE

To date, all of the rowing research has concentrated on young and/or elite athletic populations, and therefore results cannot be extrapolated to adults at risk of osteoporosis because of the differences in bone adaptations with age. Additionally, in all rowing studies, rowing was not the only exercise performed which may confound the observed benefits of the activity. Therefore, the goal of this study was to compile cross-sectional data of master level rowers whose primary activity is rowing, to determine whether the trends seen in younger rowers are present among older "at risk" individuals. This information will serve as pilot data suggesting the appropriateness of future interventions using rowing as the primary exercise to promote musculoskeletal health among older adults. The importance of alternative strategies to promote bone health are highlighted given recent data which suggests that HRT may be effective, but unsafe for many women. Rowing exercise has the potential to increase both BMD and strength, and thus decrease fall and subsequent fracture risk.

RESEARCH QUESTIONS AND HYPOTHESIS

The following research questions and hypothesis were addressed:

Research question 1:

Do premenopausal women who participate in rowing exercise have greater spine BMD compared to age- matched non-rowing controls?

Hypothesis 1: Premenopausal rowers will exhibit higher spine BMD than age matched controls.

Research question 2:

Do postmenopausal women who participate in rowing exercise have greater spine BMD compared to age- matched non-rowing controls?

Hypothesis 2: Postmenopausal rowers will exhibit higher spine BMD than age matched controls..

Research Question 3:

Is rowing history (years rowing) predictive of spine BMD in premenopausal female masters rowers?

Hypothesis 3*:* Number of years involved in rowing will be positively related to spine BMD.

Research Question 4:

Is rowing history (years rowing) predictive of spine BMD in postmenopausal female masters rowers?

Hypothesis 4*:* Number of years involved in rowing will be positively related to spine BMD.

Research question 5:

Is back extensor strength predictive of spine BMD in this population of premenopausal women?

Hypothesis 5: A positive relationship will exist between back extensor strength and spine BMD.

Research question 6:

Is back extensor strength predictive of spine BMD in this populations of postmenopausal women?

Hypothesis 6: A positive relationship will exist between back extensor strength and spine BMD.

COMMENTS

For the success of the study we assumed that all subjects answered truthfully on all questionnaires. In addition, for accuracy of the strength and BMD correlation, we assumed that all subjects were giving maximal effort in all strength assessments. Finally, because of the cross-sectional nature of this study, causal inferences were not made from the results, nor were the results generalized beyond the population examined. However, data from this study will be used as pilot data for future interventional studies examining rowing exercise, from which causal relationships could be determined.

CHAPTER TWO

INCREASED SPINE BONE MINERAL DENSITY IN POSTMENOPAUSAL ROWERS

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ABSTRACT

Studies in young women show that rowing exercise is osteogenic at the spine. However, little is known regarding rowing exercise and spine bone mineral density in older women. **PURPOSE:** Our aim was to examine differences in spine bone mineral density (BMD) and back strength between competitive female masters rowers (n=28, 56.1 $\pm$ 5.7 years) who had been rowing for 5.9$\pm$ 6.9 yrs and age-matched non-rowers (n=26, 56.8 $\pm$ 4.8 years). **METHODS:** Competitive rowers were recruited from nine rowing clubs in the local area and compared to controls recruited from the same region who were normally active but not participating in rowing activity. Participating rowers had been engaged in competitive rowing for a minimum of one year. BMD (g/cm^2) of the third lumbar vertebrae (L3) was measured by dual-energy x-ray absorptiometry (DXA) in both the anterior-posterior and lateral views. Back strength was assessed using a standing cable tensiometer. Subjects also completed questionnaires to assess diet, physical activity, medical history and rowing history. Differences in BMD and back strength between groups were determined by analysis of covariance, controlling for lean mass. **RESULTS:** Compared to controls, rowers had 3.2% higher BMD at the anterior-posterior spine (p= .026) and 4.5% higher lateral spine BMD (p= .04). Furthermore, isometric back strength was 22.6% greater in rowers than controls (p = .01). There were no differences in calcium intake, age, menopausal status, weight, or lean mass between groups. **CONCLUSIONS:** Since both increased BMD and back strength are associated with reductions in vertebral

fracture risk, our results suggest that rowing exercise may be an important strategy to promote bone health and reduce vertebral fracture risk in postmenopausal women.

Key Words: back strength, bone density, postmenopausal, rowing

INTRODUCTION

Osteoporosis is a condition defined as decreased bone strength and an increased risk of fracture (20). Vertebral fractures account for the majority of these fractures, and people suggest there are estimates that only one third of all incident vertebral fractures are clinically diagnosed (4). Consequences of such injuries include a dramatic decrease in quality of life leaving patients to suffer with kyphosis, height loss, and long term chronic pain that affects physical function, self-esteem, body image and psychological well-being (7). Women are at the greatest risk for fracture due to the loss of endogenous estrogen that results in an accelerated bone loss of 2-6.5% per year within the first five to eight years after menopause. Therefore, strategies to decrease the rate of bone loss during these crucial years, or to reverse osteoporosis once it has occurred, are greatly needed.

Exercise has the potential to increase bone mass in men and women of all ages, provided that the stimulus is sufficient to result in overload, and that the load is imposed to the site of interest (19). To date, resistance training has been shown to be the most effective strategy to alter spine bone mineral density (BMD) in older populations (6, 12, 14, 16, 22, 26). Protocols using resistance training have varied, but the most effective programs utilize intensities exceeding 60% of 1 repetition maximum (1 RM). Pruitt et al. (22) found a 1.6% increase at the lumbar spine in early post-menopausal women after 9 months of various resistance exercises performed at $\geq$ 60% 1RM (9). Similarly, Kohrt et al. (14) examined nine months of exercises eliciting ground reaction forces (i.e. impact exercises such as stairs, running and walking) and joint reaction forces (i.e. resistance exercises such as rowing and weight lifting) in two groups of postmenopausal women and found increases in BMD of the spine, whole body, and Ward's triangle from both types of exercise. Likewise, Maddalozzo and Snow (16) compared high intensity standing free-weight training to moderate intensity seated machine-based exercises in older men and women. The high intensity training resulted in increases in spine BMD in men only, with no changes at any site in women. However, despite the lack of BMD changes, total body strength increased in all subjects, a result beneficial to fall and subsequent fracture risk. Conversely, there are also resistance studies showing no improvement in spine BMD in older populations (6, 12, 26, 29). However, most of these studies had inadequate sample sizes, were short in duration, utilized loads of low to moderate intensity and/or did not include exercises specifically targeting the lumbar spine.

Heavy resistance strength training generally requires that individuals frequent a facility with sufficient equipment to impose the necessary loads. Furthermore, it may be detrimental to older adults with certain joint problems, and is unappealing as an exercise option to many older women. Therefore alternatives to resistance training that adequately stress the spine are greatly needed.

Rowing exercise is attractive as an osteogenic exercise because of its similarities to resistance training with respect to the large forces placed on the spine. Recent evidence has shown forces at the spine of up to four to five times body weight in experienced collegiate women rowers during maximal effort--loads that appear high enough to offset low estrogen levels due to amenorrhea (17, 30). Thus it is possible that older women who are estrogen deplete due to menopause may also benefit from rowing exercise. In addition, cross-sectional evidence suggests that male and female crew athletes have higher lumbar BMD than controls (18, 27). Limited intervention studies also support rowing as an osteogenic activity. Cohen et al (5) compared the bone mineral density of college-age male novice rowers to non-rowing controls at the beginning and end of a rowing season and found a significant increase in BMD and bone mineral content (BMC) of the spine in the rowers. Likewise, LaRiviere, Robinson and Snow (15) found increased spine BMD in experienced rowers after a six-month training season.

Because of the increased back extensor strength characteristic of rowers, rowing exercise has the potential to decrease back injuries. Additionally back extensor strength is significantly higher in individuals without back pain, when compared to those with back pain (2). Sinaki et al. (24-25) found that women who participated in a two- year back strengthening program had higher back strength compared to control subjects. Ten years later, the strength trained women had higher spine BMD and less vertebral fractures than the women who did not strength train, indicating the importance of back strength for lifetime bone health (24-25).

Very little data exist confirming the effects of rowing in older populations. To date, all cross-sectional and intervention studies examining rowing have used young and/or elite athletes as subjects. Therefore in order to determine the true potential of rowing for bone maintenance and accrual in older populations, data is needed examining this specific population. Thus, our aim was to determine whether postmenopausal master rowers have higher spine bone mineral density than non-rowing controls. Additionally, we examined whether back strength and/ or years spent performing rowing activity would be predictive of spine BMD.

METHODS

Participants

Thirty postmenopausal masters level rowers (age 56 $\pm$ 5.36 years) were recruited from nine rowing organizations across the Willamette Valley and compared to thirty postmenopausal normally active women (age 56.7 $\pm$ 4.7 years) from the Corvallis area. In order to participate, rowers were required to have been currently participating in competitive rowing for a minimum of one year. Potential subjects completed an initial medical history and screening questionnaire that supplied information on hormone status and medication use. All subjects were required to be hormone stable (i.e. not taking hormone replacement therapy (HRT) or they must have been on the same dose of HRT for at least one year) in order to participate. We determined menopausal status through the absence of the menstrual cycle for at least the previous 12 months. Any subject determined to be perimenopausal (i.e. still menstruating, but having missed periods) was excluded. Other exclusion criteria included any metabolic disorder known to affect bone (e.g. uncontrolled thyroid disorders) and use of bone altering medications (e.g. fosamax, or long-term use of corticosteroids).

All subjects were recruited either by emails to rowing organizations, flyers around the Corvallis community or by word of mouth. The Institutional Review

Board for human subjects at Oregon State University approved this study and all subjects gave written informed consent prior to participation.

Instruments, Apparatus and Procedures

Bone Density and Body Composition. Bone density (BMD, g/cm^2) of the hip, anterior-posterior (AP) and lateral spine, and whole body were assessed via dual energy x-ray absorptiometry (DXA) (Hologic QDR-4500A Elite, Waltham, MA). Whole body measurements were used to assess body composition as well as bone mass. All scans were performed and analyzed by a trained and licensed technician, according to manufacturer's directions (QDR series user's guide, 2000). Using DXA to assess BMD conforms to the World Health Organization (WHO) standard for diagnosis of osteoporosis (20) and is considered the "gold standard" in bone density measurements. The precision error of bone measurements at the Oregon State University Bone Research laboratory has been found to be approximately 1.5% at the hip and spine.

Nutritional status. Nutritional status was assessed using *The Block Brief Food Questionnaire* from which Calcium and Vitamin D intake data were extracted and controlled for in the BMD analysis. This questionnaire was self-administered to determine eating patterns and intakes and took approximately 30 minutes to complete. Furthermore, this instrument has been validated against multiple diet record methods (3).

Physical Activity level. The Aerobics Center Longitudinal Study Physical Activity Questionnaire was used to assess levels of regular exercise (13). This questionnaire has been shown to be both valid and reliable for adult populations, ages 20-80 (21). MET hrs / week were calculated using the following equation:

(sessions/wk) * (min/session) * [(1h/60 min) * (METs)]

MET values were determined using the Compendium of Physical Activities (1).

Rowing History and Spine Loading Activities. Rowers completed a survey to determine the extent of rowing activity they have been engaged in over the course of their lifespan as well as the amount of time they spend each week participating in spine loading activities (e.g. lat pull-downs, back extensions, hiking with a weighted pack, etc). Controls completed a similar questionnaire to determine time spent spine loading.

Back Strength , Leg Power and Rowing Power. Strength of the back extensors was measured using a standing back dynamometer (Baseline Back, Leg and Chest Dynamometer, White Plains, NY). Subjects stood erect with knees slightly bent and were asked to pull as hard as they could on a cable, using only their back muscles. Three trials were performed and the highest value was used in analysis. In a pilot study from our lab, the back dynamometer was found to be reliable in a similar population of postmenopausal women (Cronbach's alpha = 0.939). Leg Power was assessed using a seated leg press (Nottingham Power Rig, Nottingham, UK) where subjects pressed on a footplate as hard and as fast as possible through a distance of 0.165m, setting a flywheel in motion. The measurement was repeated until no further improvement was seen, up to a maximum of 9 pushes. The highest recorded power for each leg was used in analysis. Rowing Power was assessed using a Concept 2 rowing ergometer

(Concept 2 Inc, Morrisville, VT). After a two-minute warm up period, all subjects were asked to row as hard and as fast as they could for 15 strokes, using a damper setting of five, which corresponds to moderate resistance on a scale of one to ten. The highest achieved power of 15 strokes was recorded (9).

Height and Weight. Measures of height and weight were assessed using a stadiometer and a digital scale, respectively. Height was taken, without shoes, in centimeters and measured to the nearest 0.1 cm. Weight was assessed in kilograms and measured to the nearest 0.1 kg.

Data Analysis

Prior to analysis all variables were analyzed for normality, linearity and equal variances. Analysis of Covariance, controlling for lean mass, determined bone density differences between groups. Paired t-tests were use to determine differences in all demographic and strength variables. A regression analysis was carried out to determine the proportion of variability in BMD attributed to years of rowing exercise and back strength above and beyond age, calcium intake and lean mass. Power analyses indicate 17 subjects are sufficient for optimal power (0.80) in this group (28), therefore our sample size of 30 provided sufficient power to detect a minimum difference of 3% in spine BMD. All data was analyzed using SPSS software (version 12.0).

RESULTS

Of the sixty women tested, we were unable to obtain lateral bone measures in two rowers and four controls due to scoliosis of the lumbar spine. These women were consequently excluded from the analysis, making our final sample size 28 rowers and 26 controls. Tests of normality, linearity and equal variances indicated that there were no significant deviations from these assumptions for any variable.

Rowers (n= 26) had been participating in competitive rowing for an average 5.9 $\pm$ 6.9 years and spent an average of 5.3 $\pm$ 2.5 hours per week in rowing activity, either on the water or on a rowing ergometer. Rowers were also significantly more active than controls (115.7 $\pm$ 43.8 vs. 68.2 $\pm$ 59.4 MET hrs/ week, respectively, p= .001). Eight rowers and two controls were currently taking HRT, although each subject had been on the same drug and dose for at least one year, and were thus considered hormone stable. Both groups had less than adequate calcium intakes (740.4 $\pm$ 332.3 vs. 705.9 $\pm$ 263 mg for rowers and controls, respectively) when compared to the recommended amounts of 1000mg/day for older adults (20). However, there were no statistically significant differences between groups in this or any other demographic variable, including lean mass, BMI, years past menopause or age (Table 1).

Table 1: Subject Characteristics expressed as means ± SD

Variable	Rowers (n=28)	Controls (n= 26)
Age (years)	56.07 ± 5.69	56.70 ± 4.77
Weight (kgs)	66.49 ± 10.93	68.97 ± 10.78
Height (cm)	168.32 ± 5.01	166.17 ± 6.26
Lean mass (kg)	45.7 ± 5.32	44.42 ± 4.55
BMI (kg/m^2)	23.39 ± 3.25	25.08 ± 4.28
Calcium (mg)	740.40 ± 332.30	705.67 ± 263.26
Physical activity (MET hrs/wk)	115.73 ± 43.81*	68.22 ± 58.38

*significant at $p < 0.01$
No significant differences except physical activity

DXA measurements of the 3rd lumbar vertebrae (L3) revealed that rowers had 4.4% greater adjusted bone mineral density than controls in the lateral view (0.750 ± 0.021 vs. 0.718 ± 0.022 g/cm^2; F = 3.431, p= 0.040). Likewise rowers had 3.2% greater adjusted BMD than controls in the anterior-posterior (AP) view (1.069± 0.031 vs. 1.035 ± 0.032, respectively; F = 3.930, p = 0.026). A frequent problem during lateral scanning is obstruction of the 4th lumbar vertebra by the iliac crest thereby confounding results of total lateral spine BMD. Therefore we used only L3 in analysis. For consistency, we also analyzed L3 in the AP view. Due to the differences in HRT status between rowers and controls (n=8 vs. n=2, respectively) we re-ran the analysis controlling for hormone use. We found that lateral L3 BMD was still significantly different (p= 0.005) whereas AP BMD was no longer significant (p=0.08).

Paired t-tests showed that rowers had 22.5% greater isometric back strength than controls (81.7 ± 18.9 and 66.6 ± 421.1 kg, respectively; p = 0.011). As expected, the rowers exhibited significantly higher rowing power than controls (p<.001). However, there were no significant differences in leg power between groups.

Table 2: Bone and Performance variables expressed as means ± SE and means ± SD, respectively

Variable	Rowers	Controls
Adjusted L3 AP BMD (g/cm^2)$^+$	1.069± 0.031*	1.035 ± 0.032
Adjusted L3 lateral BMD(g/cm^2)$^+$	0.750 ± 0.021*	0.718 ± 0.022
Back strength (kgs)	81.7 ± 3.8**	66.6 ± 4.1
Leg power (Watts)	167.45 ± 6.1	162.90 ± 8.9
Rowing power (watts)	261.57 ± 9.0**	154.96 ± 12.2

** indicates significance of p < 0.01 * indicates significance of p <0.05
$^+$ Bone values adjusted for lean body mass

Of additional interest was whether back strength was predictive of spine BMD among the population as a whole, and whether years rowing was predictive of BMD among the rowers, above and beyond the variability explained by calcium status, lean mass and age. Stepwise regression analysis indicated that of all variables considered, only lean body mass was predictive of AP or lateral BMD, explaining 10.7% (F = 5.851, p = .019) and 9.5% (F = 5.152, p = .028) of total variability in bone, respectively. Back strength did not significantly contribute to this model. However, exploratory analysis examining the groups separately revealed that in stepwise regression, back strength alone was predictive of lateral

BMD in the rowing group, explaining 15.3% of variability in bone ($p = 0.048$). None of the variables entered into the model predicted AP BMD, nor was years rowing predictive of either AP or lateral spine BMD. In the control group, lean mass remained the only predictive variable, explaining 16.1% of the variability in AP BMD ($F = 4.408$, $p = 0.047$), with no variable predictive of lateral BMD in this group.

DISCUSSION

In this postmenopausal population, women involved in rowing exercise had significantly higher bone mineral density of the spine than non-rowing controls. Additionally, rowers had much higher back strength than non-rowers although neither back strength nor rowing history was predictive of bone mass in these women. However, when rowers and controls were considered separately, back strength was a significant predictor of lateral lumbar BMD in the rowers only. This trend was not evident for either the control group, or the AP bone view.

The primary strength of this study is that it is the first to examine rowing exercise and bone health in a population of postmenopausal women. Additionally we collected data on many potentially confounding variables, such as calcium status, lean body mass, age, years past menopause and BMI, and found no differences between groups on these variables, indicating the similarity of our groups on everything except rowing activity. Another strength of the study is that we were able to recruit more women in both the rowing and control groups than we initially expected, eliminating issues concerning statistical power.

The primary limitation of the study is the cross-sectional design, which eliminates the ability to generalize our results outside of this specific population and the ability to determine a causal relationship between rowing exercise and BMD. Additionally we did not have the capabilities to measure hormone status bio-chemically and therefore relied on self-report to determine menopause status. There were differences in HRT use between groups, when controlled for in the analysis, resulted in no significance in AP BMD analysis, but increased significance in lateral BMD. Although we were not able to exclude women on HRT, all women were required to be hormone stable thereby eliminating the effects on bone from new or changing hormone therapy.

Athletes that row have exhibited higher spine BMD than both non-rowers (17) and other athletes (30). Morris found that young adolescent women with 3 years rowing experience had higher spine BMD than age –matched controls. Wolman et al (30) found that both eumenorrheic and amenorrheic rowers had higher spine BMD than other non-rowing athletes, suggesting that the loads apparent in rowing may be great enough to offset the negative effects of estrogen depletion. In contrast, Morris et al (18) determined that the forces in rowing were not strong enough to promote significant bone gain in a population of anovulatory rowers and thus concluded that rowing would not benefit women in an estrogen deplete state. However, small sample size (n=5) may have hindered their ability to find significance. Our results support the notion that rowing can benefit spine

BMD even in the postmenopausal stage of life (i.e. after the cessation of endogenous estrogen production), as seen by the greater spine BMD in rowers than controls.

Intervention studies have also shown that rowing can increase spine bone mass in young populations. LaRiviere et al. (15) found that experienced female collegiate rowers increased their spine BMD after a 6-month training season, whereas novice rowers did not. Additionally, Cohen et al (5) trained seventeen male novice rowers for seven months and found a significant increase in spine bone mass. Although we found higher BMD in our rowers than in the non-rowers, causal inferences cannot be made until randomized intervention studies have been performed. Therefore more research is needed in this area to determine the ability of rowing to increase bone mass in postmenopausal women.

Our results did not confirm previous findings from the literature that back strength predicts BMD. Halle et al (8) found that maximal voluntary trunk flexor and extensor torque explained 44% of variability in lumbar spine BMD. Likewise, Iki et al (11) found that isokinetic eccentric trunk flexor torque was positively related to spine BMD at baseline and to an annual change in spine BMD. In contrast, our results did not show that maximal isometric back strength significantly predicted spine BMD when looking at the sample as a whole. However, rowers had much higher back strength than controls. Furthermore, we assessed isometric strength whereas the previous studies measured dynamic strength. Regardless, the greater back strength in the rowers compared to controls is encouraging considering the results of Sinaki et al (24) who found that women with higher back strength had 2.7 times less incidence of vertebral compression fractures during a ten-year period than women with weaker back musculature. Additionally he found that despite no difference in spine BMD after the initial two-year strength training period, the strength trained women had significantly higher spine BMD than the control group after the 8-year follow up period. Therefore, it is plausible that if we followed our rowing sample, the differences we observed in BMD and back strength might be maintained and the risk of osteoporotic fractures ultimately reduced.

In summary, postmenopausal women who participate in rowing exercise have higher spine BMD and greater back strength than non-rowing postmenopausal controls. Considering the need to prevent bone loss in this vulnerable population, rowing may be a promising alternative to more conventional resistance training and medication therapy. Future research should focus on rowing as an intervention to determine the effectiveness of this activity for maintenance of skeletal health and/or prevention of bone loss in estrogen-deplete women.

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CHAPTER 3

BONE MINERAL DENSITY AND BACK STRENGTH IN PREMENOPAUSAL ROWERS

Adrienne J. McNamara, Katherine B. Gunter, Christine M. Snow

ABSTRACT

Studies in young women show that rowing exercise is osteogenic at the spine. However, little is known regarding rowing exercise and spine bone mineral density in older women. **PURPOSE:** Our aim was to examine differences in spine bone mineral density (BMD) and back strength between competitive premenopausal female masters rowers (n=28, 45.5 $\pm$ 4.7 years) who had been rowing for 7.5 $\pm$ 6.6 yrs and age-matched non-rowers (n=30, 43.3 $\pm$ 4.2 years). **METHODS:** Competitive rowers were recruited from nine rowing clubs in the local area and compared to controls recruited from the same region who were normally active but not participating in rowing activity. Participating rowers had been engaged in competitive rowing for a minimum of one year. BMD (g/cm^2) of the third lumbar vertebrae (L3) was measured by dual-energy x-ray absorptiometry (DXA) in both the anterior-posterior and lateral views. Back strength was assessed using a standing back dynamometer. Subjects also completed questionnaires to assess diet, physical activity, medical history and rowing history. Differences in BMD and back strength between groups were determined by analysis of covariance, controlling for lean mass. The amount of variability in BMD attributed to back strength above and beyond lean body mass, age and calcium intake was determined using stepwise regression. **RESULTS:** Non-rowers had 2% higher lateral spine BMD than rowers, but there were no significant differences in AP spine BMD or back strength between rowers and controls. However, back strength predicted AP spine BMD, accounting for 13.7% of total variability in BMD ($p = 0.004$). There were no differences in calcium intake, age, menopausal status, weight, or lean mass between groups. **CONCLUSIONS:** More research is needed to determine the effects of rowing on the spine among mature, but premenopausal women. Given the positive associated between back strength and BMD in this cohort of women, any exercise, including rowing, which targets the spine, may positively influence spine BMD and thus osteoporosis risk.

Key words: Rowing, Bone density, back strength

INTRODUCTION

Osteoporosis is a condition defined as decreased bone strength and an increased risk of fracture (24). Vertebral fractures account for the majority of these fractures, and estimates suggest that only one third of all incident vertebral fractures are clinically diagnosed (7). Consequences of such injuries include a dramatic decrease in quality of life leaving patients to suffer with kyphosis, height loss, and long term chronic pain that affects physical function, self-esteem, body image and psychological well-being (9). Women are at the greatest risk for fracture due to the loss of endogenous estrogen which results in an accelerated bone loss of 2-6.5% per year within the first five to eight years after menopause. Therefore, strategies designed to decrease the rate of bone loss during these crucial years, or to maximize bone health before menopause has occurred, are greatly needed.

Exercise has shown the potential to increase bone mass in populations of all ages, provided that the stimulus is sufficient to result in overload, and that the load is imposed to the sites of interest (23). To date, resistance training has been shown to be the most effective strategy to alter spine bone mineral density (BMD) in women before and after menopause (8, 16, 18, 20, 26, 31, 35). Training protocols in studies using resistance training have varied with the most effective programs utilizing training intensities exceeding 60% of 1 repetition maximum (1 RM). Lohman et al (20) found a 1.9% increase in spine BMD in premenopausal women after 18 months of resistance training at loads between 70-80 % of 1-RM.

Pruitt et al. (26) found a 1.6% increase at the lumbar spine in early post-menopausal women after 9 months of various resistance exercises performed at ≥ 60% 1RM. Similarly, Kohrt et al. (18) examined nine months of exercises eliciting ground reaction forces (i.e. impact exercises such as stairs, running and walking) and joint reaction forces (i.e. resistance exercises such as rowing and weight lifting) in two groups of postmenopausal women and found increases in BMD of the spine, whole body, and Ward's triangle from both types of exercise. Conversely, there are also resistance studies showing no improvement of spine BMD in both premenopausal as well as older women (8, 16, 28, 31, 35). However, most of these studies had inadequate sample sizes, were short in duration, utilized loads of low to moderate intensity and/or did not include exercises specifically targeting the lumbar spine.

Heavy resistance strength training generally requires that individuals frequent a facility with sufficient equipment to impose the necessary loads. Furthermore, it may be detrimental to adults with certain joint problems, and is unappealing as an exercise option to many women. Therefore alternatives to resistance training that adequately stress the spine are greatly needed.

Rowing exercise is attractive as an osteogenic exercise because of its similarities to resistance training with respect to the large forces placed on the spine. Recent evidence has shown forces at the spine of up to four to five times body weight in experienced collegiate women rowers during maximal effort--loads that appear high enough to offset low estrogen levels due to amenorrhea (22, 36). In addition, cross-sectional evidence suggests that male and female crew athletes have higher lumbar BMD than controls (21, 32). Limited intervention studies also support rowing as an osteogenic activity. Cohen, Milett, Mist, Laskey and Rushton (5) compared the bone mineral density of college-age male novice rowers to non-rowing controls at the beginning and end of a rowing season and found a significant increase in BMD and bone mineral content (BMC) of the spine in the rowers. Likewise, LaRiviere, Robinson and Snow (19) found increased spine BMD in experienced rowers after a 6-month training season.

Because of the increased back extensor strength characteristic of rowers (36), rowing exercise has the potential to decrease back injuries, since back extensor strength is significantly higher in individuals without back pain, when compared to those with back pain (2). Additionally, back strength has been positively associated with spine BMD, with back strength explaining up to 44% of all variability in spine bone density (10). Finally, Sinaki et al. (29, 30) found that women aged 49-65 who participated in a two-year back strengthening program had higher back strength and decreased fracture incidence eight years later, compared to control subjects, the importance of back strength for lifetime bone health.

Very little data exists confirming the effects of rowing in older populations. With the exception of a recent study from our laboratory which found that postmenopausal rowers had higher spine BMD than controls, all cross-sectional and intervention studies examining rowing have used young and/or elite athletes as subjects. Therefore, in order to further understand the true potential of rowing for bone maintenance and accrual in older populations, more data is needed examining these specific populations. In this study, we examined premenopausal women over age 35 to determine if masters rowers have higher spine bone mineral density than non-rowing controls. Additionally we examined whether back strength and/ or years spent performing rowing activity would be predictive of spine bone mass.

METHODS

Participants

Thirty premenopausal masters level rowers (age 45 $\pm$ 5.36 years) were recruited from nine rowing organizations across the Willamette Valley and compared to thirty-four premenopausal normally active women (age 43.3 $\pm$ 4.23 years) from the Corvallis area. In order to participate, rowers were required to have been currently participating in competitive rowing for a minimum of one year. Potential subjects completed an initial medical history and screening questionnaire that supplied information on hormone status and medication use. All subjects were required to be over 35 years of age (corresponding to the age cutoff required for competition in masters rowing) and premenopausal. Any subject determined to be perimenopausal (i.e. still menstruating, but having missed periods) was excluded. Other exclusion criteria included any metabolic disorder known to affect bone (e.g. uncontrolled thyroid disorders) and use of bone altering medications (e.g. Fosamax, or long-term use of corticosteroids).

All subjects were recruited either by emails to rowing organizations, flyers around the Corvallis community or by word of mouth. The Institutional Review Board at Oregon State University approved this study and all subjects gave written informed consent prior to participation.

Instruments, Apparatus and Procedures

Bone Density and Body Composition. Bone density (BMD, g/cm^2) of the hip, anterior-posterior (AP) and lateral spine, and whole body were assessed via dual energy x-ray absorptiometry (DXA) (Hologic QDR-4500A Elite, Waltham, MA). Whole body measurements were used to assess body composition as well as bone mass. All scans were performed and analyzed by a trained and licensed technician, according to manufacturer's directions (Hologic QDR Series User's Guide, 2002). Using DXA to assess BMD conforms to the World Health Organization (WHO) standard for diagnosis of osteoporosis (24) and is considered the "gold standard" in bone density measurements. The precision error of bone measurements at the Oregon State University Bone Research Laboratory has been found to be approximately 1.5% for the hip and spine.

Nutritional status. Nutritional status was assessed using *The Block Brief Food Questionnaire* from which Calcium and Vitamin D intake data were extracted and controlled for in the BMD analysis. This questionnaire was self-administered to determine eating patterns and intakes and took approximately 30 minutes to complete. Furthermore, this instrument has been validated against multiple diet record methods (3).

Physical Activity level. The Aerobics Center Longitudinal Study Physical Activity Questionnaire was used to assess levels of regular exercise (17). This questionnaire has been shown to be both valid and reliable for adult populations, ages 20-80 (25). MET hrs / week were calculated using the following equation:

$$(\text{sessions/wk}) * (\text{min/session}) * [(1\text{h}/60 \text{ min}) * (\text{METs})]$$

MET values were determined using the Compendium of Physical Activities (1).

Rowing History and Spine Loading Activities. Rowers completed a survey to determine the extent of rowing activity they have been engaged in over the course of their lifespan as well as the amount of time they spend each week in spine loading activities (e.g. lat pull-downs, back extensions, hiking with a weighted pack, etc). Control subjects completed a similar questionnaire to determine time spent spine loading.

Back Strength , Leg Power and Rowing Power. Strength of the back extensors was measured using a standing back dynamometer (Baseline back leg and chest Dynamometer, White Plains, NY). Subjects stood erect with knees slightly bent and were asked to pull as hard as they could on a cable, using only their back muscles. Three trials were performed and the highest value was used in analysis. This instrument has been used in previous studies and found to be a valid measure of back strength (6, 14). In a pilot study from our lab, the back dynamometer was found to be reliable in a similar population of premenopausal women (Cronbach's alpha = 0.901). Leg power was assessed using a seated leg press (Nottingham Power Rig, Nottingham, UK) where subjects pressed on a footplate as hard and as fast as possible through a distance of 0.165m, setting a flywheel in motion. The measurement was repeated until no further improvement was seen, up to a maximum of nine pushes. The highest recorded power for each leg was used in analysis. Rowing power was assessed using a Concept 2 rowing ergometer (Concept 2 Inc, Morrisville VT). After a two-minute warm up period, all subjects were asked to row as hard and as fast as they could for 15 strokes, using a damper setting of five, which corresponds to moderate resistance on a scale of one to ten. The highest achieved power of 15 strokes was recorded (11).

Height and Weight. Measures of height and weight were assessed using a stadiometer and a digital scale, respectively. Height was taken, without shoes, in centimeters and measured to the nearest 0.1 cm. Weight was assessed in kilograms and measured to the nearest 0.1 kg.

Data Analysis

Prior to analysis all variables were analyzed for normality, linearity and equal variances. Analysis of Covariance, controlling for lean mass and height, determined bone density differences between groups. Paired t-tests were use to determine differences in all demographic and strength variables. A regression analysis was carried out to determine the proportion of variability in BMD attributed to years of rowing exercise and back strength above and beyond age, calcium intake and lean mass. Power analyses indicate 24 subjects are sufficient for optimal power (0.80) in each group (33) therefore our sample size of 30-34 provided sufficient power to detect a minimum difference of 2% in spine BMD. All data were analyzed using SPSS software (version 12.0).

RESULTS

Of the sixty-four women tested, we were unable to obtain lateral bone measures in two rowers and four controls due to scoliosis of the lumbar spine. These women were consequently excluded from the analysis, making our final sample size 28 rowers and 30 controls. Tests of normality, linearity and equal variances indicated that there were no significant deviations from these assumptions for any variable.

Rowers (n= 28) had been participating in competitive rowing for an average 7.5 $\pm$ 6.6 years and spent an average of 5.5 $\pm$ 2.6 hours per week in rowing activity, either on the water or on a rowing ergometer. Rowers were also significantly more active than controls (p= .001), this difference attributed primarily to time spent rowing. Both groups had less than adequate calcium intakes (740.4 $\pm$ 332.3 mg vs. 705.9 $\pm$ 263 mg for rowers and controls, respectively) and vitamin D intakes (143.6 $\pm$ 101.5 IU vs. 158.0 $\pm$ 99.3 IU) when compared to the recommended amounts of 1000mg/day and 400 IU / day, respectively (24). However, there were no statistically significant differences between groups is these or any other demographic variable except height, where rowers were significantly taller than controls (Table 1).

DXA analysis of the 3rd lumbar vertebrae (L3) revealed that controls had a significant 2% increase in bone mineral density compared to rowers in the lateral view (0.833 $\pm$ 0.017 g/cm^2 vs. 0.817 $\pm$ 0.018 g/cm^2 respectively, F = 3.467, p= 0.022). There were no significant differences in L3 BMD between groups for the Anterior-Posterior (AP) view (1.094 $\pm$ 0.025 g/cm^2 for rowers vs. 1.120 $\pm$ 0.024 g/cm^2 for controls, F = 1.464, p = 0.235) (table 2).

Table 1: Subject Characteristics expressed as mean ± SD

Variable	Rowers (n = 28)	Controls (n = 30)
Age (years)	45.5 ± 4.7	43.3 ± 4.2
Weight (kg)	67.0 ± 7.8	65.9 ± 11.3
Height (cm)	169.5 ± 5.7*	166.2 ± 5.8
Lean mass (kg)	48.8 ± 4.36	46.3 ± 5.8
BMI ($m \cdot kg^{-2}$)	23.4 ± 2.9	23.7± 3.5
Calcium (mg)	811.9 ± 337.2	792.4 ± 330.8
Physical activity ($MET \cdot hr \cdot wk^{-1}$)	114.7 ± 46.4**	72.1 ± 48.7

** indicates significance of $p < 0.01$ * indicates significance of $p < 0.05$

Paired t-tests showed no difference in isometric back strength between rowers and controls (83.52 ± 18.9 and 83.3 ± 22.5 kgs, respectively; $p = 0.973$). As expected, the rowers exhibited significantly higher rowing power than controls ($p<0.001$). However, there were no significant differences in leg power between groups.

Of additional interest was whether back strength was predictive of spine BMD among all participants and whether years rowing was predictive of spine BMD among rowers, above and beyond the variability explained by calcium status, lean mass and age. Stepwise regression indicated that back strength was the only variable predictive of AP BMD in the entire sample, explaining 13.7% of total BMD variability ($R^2= 0.137$, $F = 8.872$, $p = 0.004$). In contrast, only lean body mass was predictive of lateral spine BMD (R^2=0.149, F= 9.816, p= 0.003).

Years rowing was not predictive of spine BMD.

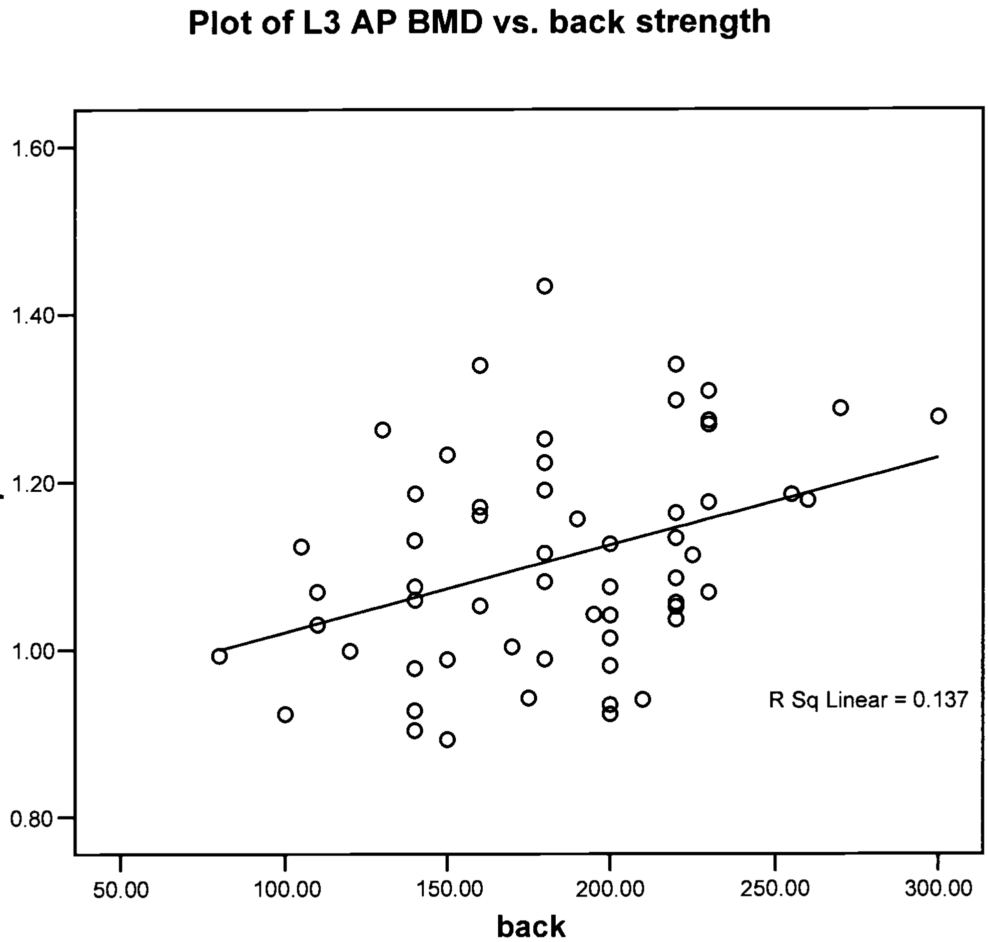
Table 2: Bone and performance results expressed as means $\pm$ SE and means $\pm$ SD, respectively

Variable	Rowers	Controls
Adjusted L3 AP BMD (g/cm^2)$^+$	1.094 $\pm$ 0. 025	1.120 $\pm$ 0.024
Adjusted L3 lateral BMD (g/cm^2)$^+$	0.817 $\pm$ 0.018*	0.833 $\pm$ 0.017
Back strength (kg)	83.52 $\pm$ 18.9	83.3 $\pm$ 22.5
Leg power (watts)	196.1 $\pm$ 34.6	181.2 $\pm$ 37.1
Rowing power (watts)	314.3 $\pm$ 72.1**	225.9 $\pm$ 10.8

** indicates significance of $p<.01$ * indicates significance of $p < 0.05$

$^+$ Bone values adjusted for lean mass and height

Figure 3.1 **AP BMD (g/cm^2) compared to isometric back strength (lbs)**



DISCUSSION

In this study we asked whether premenopausal women who row have higher spine BMD than non-rowing controls. In this premenopausal population, non-rowing controls had higher lateral spine BMD than rowers, with no differences in AP spine BMD between groups. Likewise, there were no differences in back strength between these two groups of women. However, from a group of 4 variables, isometric back strength was the only significant predictor of AP spine BMD in this population, whereas lean body mass only significantly predicted lateral spine BMD.

The primary strength of this study is that it is the first to examine rowing exercise and bone health in a population of premenopausal women over the age of 35. Additionally we collected data on many potentially confounding variables, such as calcium status, lean body mass, age, and BMI, and found no differences between groups on these variables, indicating the similarity of our groups on everything except rowing activity. Another strength of this study is that we recruited more women in both the rowing and control groups than needed based on our power analysis and thus had sufficient statistical power.

The weaknesses of the study must also be mentioned. The foremost limitation is the cross sectional study design, which renders causal inferences inappropriate. Furthermore, we did not have the capability to bio-chemically assess hormone or menopause status. Therefore it is possible that some women may have been in the early stages of menopause, even though they had not begun to miss periods. Finally we did not collect information on lifetime physical activity for the control subjects. Therefore, even though the rowers were currently more active than controls, we do not know whether lifetime involvement in spine loading activities contributed to the higher lateral BMD in the controls subjects compared to the rowers.

Our results are in contrast to those reported by other investigators. Morris et al found (21) found that young rowers (age 15-25) with an average of 3 years of rowing experience had higher spine BMD than controls. Additionally, Morris (22) found that adolescent rowers had a 6.1% increase in spine BMD over an 18 month training period, compared to no changes in control subjects. Results from our laboratory indicate that postmenopausal rowers also had significantly higher spine BMD than age-matched non-rowers. In light of our results it is possible that rowing exercise offers the greatest potential to enhance BMD in women during growth or in the estrogen deplete state of menopause. It is possible that in the mature skeleton, the stimulus provided by rowing may not be great enough to alter bone mass in the presence of estrogen, but once the production of endogenous estrogen has ceased, the forces offered by rowing may be adequate to preserve spine BMD and therefore reduce the risk of osteoporosis. This is supported, in part, by the fact that our premenopausal rowers had actually been rowing longer than our previous sample of postmenopausal rowers (7.47 ± 6.6 vs. 5.98 ± 6.8 years, respectively), suggesting that the forces from rowing may be more potent as age increases as postmenopausal women have lower initial values of BMD and thus respond better to exercise. However more research examining rowing across the lifespan is needed to confirm these findings.

Another potential explanation for the lack of differences between groups could be attributed to the lower than recommended levels of calcium and vitamin D consumed by both groups. Specker (34) performed a meta-analysis on 16 studies examining exercise and calcium intake in peri- and postmenopausal women and concluded that calcium intakes over 1000mg/day are necessary in order to see an exercise response in spine BMD. Furthermore, low levels of vitamin D can also inhibit calcium absorption. Repeating this study in populations with adequate calcium or performing intervention studies that include the supplementation of calcium are needed to confirm both of these proposed mechanisms.

Previous research has indicated that back strength is a significant predictor of spine BMD. Halle et al (10) found that maximal voluntary trunk flexor and extensor torque explained 44% of variability in lumbar spine BMD. Likewise, Iki et al (14) found that isokinetic eccentric trunk flexor torque was positively related to spine BMD at baseline and to an annual change in spine BMD. The results of the present study indicate that that back strength is positively related to AP spine BMD in premenopausal women and these findings confirm what is reported in the literature. Therefore, any activity that can increase back strength may also have a beneficial effect on spine BMD. This is confirmed by the results of Sinaki et al (27,29) who had women perform back strengthening exercises for two years and at the end of the program found that the exercising women had significantly greater back strength than controls, although there were no differences in spine BMD. Eight years later, in a follow up study, the exercising women had lost significantly less strength than the non-exercising controls as well as having significantly higher spine BMD at this point. Most importantly, these women also had 2.7 times less incidence of vertebral fractures during the follow-up period. These results support the beneficial relationship between spine BMD and back strength as well as a potential link between back strength and fracture reduction. Although there were no differences in back strength between groups in the present study, both groups had average or above average back strength when compared to static strength norms for women under 50 years old (13). Additionally, previous research has indicated that rowing can be beneficial for back strength. Wolman et al (36) found that rowers had higher cross sectional area of the psoas muscles, as well as higher peak torque in extension and flexion than non-rowers. Additionally, results from our laboratory showed that postmenopasual rowers had 22.6 % higher back strength than age-matched controls. Therefore rowing may positively influence back strength, at least in growing or in postmenopausal women. Ideally, a longitudinal study examining the effects of rowing on back strength and BMD in premenopausal women is required to determine the potential of rowing and exercise as a strategy to reduce fracture risk in this population.

In summary, rowers did not have higher spine BMD than non-rowers in this population of premenopausal women. However, back strength was predictive of AP spine BMD. Therefore any activity that increases back strength may be an important strategy in the prevention and treatment of osteoporosis.

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CHAPTER 4: CONCLUSIONS

Osteoporosis has reach crisis proportions in American society affecting more than 10 million people, with an additional 18 million at risk due to low bone mass (NIH consensus panel, 2001). Women are especially at risk of osteoporosis and related vertebral fractures due to the accelerated bone loss resulting from the cessation of estrogen production during menopause. Traditionally, hormone replacement therapy (HRT) has been used to reduce bone loss in women, however, recent evidence has shown there are significant cardiovascular and cancer risks associated with HRT (Humphries & Gill, 2003), making this an unattractive option for many women. Fortunately, exercise, particularly resistance training, has also been successful at increasing or preserving bone mineral density (BMD) in women (Revel et al, 1993, Pruitt et al, 1992). However the ideal exercise protocol to increase spine BMD remains unknown.

The aim of our study was to determine the relationship between spine BMD and rowing, an exercise that specifically targets the lumbar spine and may provide an alternative to resistance training. Research on young populations has shown that rowers have higher spine BMD than non-rowers and that rowing can actually increase spine BMD (Morris et al, 2000, Morris et al, 1999, LaRiviere et al 2002, Cohen et al 1999). Therefore we examined whether premenopausal and postmenopausal women who row have higher spine BMD than age-matched non-rowers. The results in our postmenopasual sample support the previous literature that rowers have higher spine BMD than age-matched non-rowers. In contrast, there were no differences in AP spine BMD between our premenopausal rowers and controls and the non-rowers actually had higher lateral spine BMD than rowers. The finding in the premenopausal sample is confounding but may be attributed to the low calcium and vitamin D status of these women which can dampen the effect of exercise on bone (Specker, 1996). Additionally, in light of our postmenopausal findings along with the research on young rowers, it is also possible that rowing may offer the greatest effect during growth or during the estrogen deplete state of menopause, when bone is more metabolically active. In other words, rowing may serve to preserve BMD after the onset of menopause, but may not be able to increase BMD in the presence of endogenous estrogen in the mature skeleton.

Back strength has also been positively associated with spine BMD (Sinaki et al 2000, Halle et al 1994). Therefore, a secondary aim of this study was to determine if isometric back strength predicts spine BMD in these premenopausal and postmenopausal women. Our results indicate that there were no differences in back strength between premenopausal rowers and controls although back strength significantly predicted AP spine BMD in this population. In the postmenopasual group, back strength was 22.6% higher in rowers than controls, but strength predicted lateral spine BMD in the rowers only. Considering that increased back strength has been related to a decrease in vertebral fracture incidence (Sinaki et al, 2000), any activity that increases back strength may be an important strategy in the treatment and prevention of osteoporosis.

In summary, postmenopausal women who row have greater back strength and spine BMD than non-rowing postmenopasual controls, although this finding was not replicated between premenopausal rowers and controls. Considering the need to prevent bone loss in postmenopasual women, rowing may be good alternative to other exercise and medication therapies once menopause has occurred. Intervention studies that span the years prior to and after menopause are needed to truly determine the potential of rowing for the maintenance of skeletal health and reduction of osteoporosis related vertebral fractures in these populations.

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APPENDICIES

APPENDIX A:

INFORMED CONSENT DOCUMENT

DEPARTMENT OF
EXERCISE AND
SPORT SCIENCE

OREGON
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Informed Consent

Title: Relationship between Bone Mineral Density and Rowing Activity in Older Women

Investigators: Katherine B. Gunter, Ph.D., Faculty research associate, 737-9432
Adrienne McNamara, M.S. Student, 737-6795

Purpose: This is a research study. The purpose of this study is to evaluate the relationship between spine bone mineral density and rowing exercise in women over 35 years of age. Vertebral fractures are the most common type of osteoporosis-related fracture and have a significant effect on quality of life and mortality. In young athletes, rowing appears to positively affect bone mass of the spine, however no data exists showing this trend in older populations. The information obtained from you about your bone mineral density, as well as information about your strength and leg power will help us determine whether rowing exercise may be a possible strategy to prevent osteoporosis- related fractures.

We are inviting you to participate in this research study because you are a normally active woman (not a competitive athlete) over 35 years of age or because you are a woman over 35 and have been engaged in rowing exercise continuously for at least the past year. Because of the effects of menopause on bone mineral density, subjects' data will be separated into premenopausal and postmenopausal groups for comparative purposes. In total, we are hoping to enroll 55 normally active women and 55 active rowers in this research study.

Testing Procedures: If you agree to participate, your involvement will last for approximately 2 hours. All testing will be conducted in the Bone Research Laboratory (Oregon State University, Women's Building, Room 13) and will include the following assessments:

1. **Bone Mineral Density Assessment**: Four x-ray scans will be conducted evaluating the bone mineral density of your spine, hip and whole body. Two spine scans and one hip scan will be used to determine bone health, whereas the whole body scan will be used to determine your body composition (fat and lean mass). There is a relationship between lean mass and bone mineral density and the whole body scan helps us to establish this relationship. During the scans you will be asked to lie still on an open table while the machine arm moves above you and beside you. The bone scans will take approximately 20 minutes to complete.

2. **Physical Activity and Nutrition:** You will be asked to fill out a physical activity questionnaire that will be used to assess your

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activity level including your rowing history (if you are a rower).You will also fill out a nutrition questionnaire that will assess eating patterns and nutrient intake. It will take approximately 30 minutes to fill out the questionnaires.

3. **Health History questionnaire:** You will be asked to complete a health history questionnaire in order to assess lifestyle and medical factors that may affect bone, such as certain diseases, habits, or medicine use. This information will be used in the final analysis.

4. **Leg Power and Back Strength:** The power of your legs will be measured with a seated leg press machine, where you will be asked to push on a pedal giving a maximal effort, one leg at a time for a maximum of 10 presses on each leg. The strength of your back will be measured by performing two isometric back extensions using a back dynamometer.

5. **Rowing Power**: Rowing power will be assessed using a rowing ergometer where you will be asked to perform 10 maximum strokes after a 2 minute warm-up.

Benefits: Evaluation of bone mineral density is used for diagnosis of osteoporosis, and will provide you with an accurate measure of your bone mass. Any questions concerning the results of such tests should be addressed with your physician who has the authority to make the appropriate diagnosis. We will be happy to provide you a copy of your scan as well as copies of all questionnaires and tests, or send them to your physician upon your request.

Risks: The risks involved with participation in the study are minimal. There is a risk of radiation exposure from the bone scans. You may not receive a bone scan if you are pregnant or suspect you may be pregnant. If you are pre-menopausal and not currently using an oral contraceptive, the bone scan must be performed within the first 10 days of the beginning of your last menstrual period. This will reduce the risk of performing a scan on a developing embryo. You must inform the researchers if there is a chance that you may be pregnant. If you have irregular or erratic cycles you may be asked to take a pregnancy test before the bone scan will be performed. The hip spine and whole body scans together deliver a total effective dose equivalent (0.585 mrem) which is less than the radiation exposure from a chest x-ray (5.0 mrem) or a flight across the country (4.0 mrem). In addition, you may experience mild fatigue and/or soreness from the strength assessments, but this will completely resolve within 1-2 days. You are free to rest or stop testing at any time.

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University

The investigators will minimize all risks by providing safe equipment and adequate instruction of the strength assessments.

Costs and Compensation: There are no costs associated with your participation in this research project. You will not be compensated for participating in this research project.

Confidentiality: Records of participation in this research project will be kept confidential to the extent permitted by law. All records will be kept in a secure location to which only the research team has access. However, federal government regulatory agencies and the Oregon State University Institutional Review Board (a committee that reviews and approves research studies involving human subjects) may inspect and copy records pertaining to this research. It is possible that these records could contain information that personally identifies you. The investigators will assign your data to a number which will be used in all analysis. The results of this study may be published in scientific literature, however, these data will be reported in a summarized manner in such a way that you cannot be identified.

Research Related Injury: In the event of a research related injury, compensation and medical treatment are not provided by Oregon State University.

Voluntary Participation: Taking part in this research study is voluntary. You may choose not to take part at all. If you agree to participate in the study, you may stop participating at any time. For all questionnaires, you may skip any questions that you prefer not to answer. If you decide not to take part, or if you stop participating at any time, your decision will not result in any penalty or loss of benefits to which you may otherwise be entitled. You will receive your nutrition analysis, bone scan, and body composition results if you have completed these at the time of withdrawal. Data collected prior to withdrawal may be used in the study results.

Questions: Questions are encouraged. If you have any questions concerning this research project, please contact Dr. Kathy Gunter at 541-737-9432, 13 Women's Building, Oregon State University, or Adrienne McNamara, 541-737-6795, Langton Hall 121E , Oregon State University. Any questions that you may have regarding your rights as a research subject should be directed to the Oregon State University Institutional Review Board (IRB) Human Protections Administrator at (541) 737-3437 or IRB@oregonstate.edu.

Your signature below indicates that you have read and that you understand the procedures, risks and benefits described above and that you give your informed and voluntary consent to participate in the study. You understand that you will receive a signed copy of this form.

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Subject Signature
_________________________________Date_______________

Subject name (please print)
____

I, the investigator, certify that I have explained to the above individual the nature and purpose, the potential benefits, and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature.

I have provided the participant a copy of this signed consent document.

Investigator
signature_______________________________________Date_________

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APPENDIX B:

HEALTH HISTORY QUESTIONNIARE

Last Name, First ____________ Date ____________ ID # ______

Medical History Questionnaire
Rowing and Bone Health Study

Last Name ______ First Name ______ MI ______ Age ______ Date of Birth ______

Address ______ City, State, Zip ______

Phone (land line) ______ Work/Cell phone ______ E-mail Address ______

How do you prefer to be contacted regarding this study?

- ❑ Email
- ❑ Phone
- ❑ Other ____________________

Which describes your ethnic category?

- ❑ **Not Hispanic or Latino**
- ❑ **Hispanic or Latino**: *A person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin, regardless of race. The term "Spanish origin" can be used in addition to "Hispanic or Latino"*
- ❑ **Decline to respond**

Which describes your ethnic category?

- ❑ **White:** *a person having origins in any of the original peoples of Europe, North Africa, or the Middle East.*
- ❑ **Asian:** *A person having origins in any of the original peoples of the Far East, Southern Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.*
- ❑ **Black or African American:** *A person having origins in any of the black racial groups of Africa. Terms such as "Haitian" or "Negro" can be used in addition to "Black or African American".*
- ❑ **Native Hawaiian or Other Pacific Islander:** *A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.*
- ❑ **American Indian or Alaska Native:** *A person having origins in any of the original peoples of North, Central, or South America and maintains tribal affiliation or community.*
- ❑ **Decline to respond**

Past History: Do you have or have you ever had? (Check if yes)

- ☐ High blood pressure
- ☐ Heart trouble
- ☐ Disease of the arteries
- ☐ Lung disease
- ☐ Orthopedic operations
- ☐ Epilepsy
- ☐ Diabetes
- ☐ Musculoskeletal injury
- ☐ Rheumatic fever
- ☐ Back injury
- ☐ Cancer
- ☐ Stroke
- ☐ Broken bones
- ☐ High or low thyroid
- ☐ High cholesterol
- ☐ Lactase deficiency
- ☐ Other operations
- ☐ Other illness/disease

If yes to any of the above, please explain: ______________________________

____

____

____

Present Symptoms: Have you had in the past six months? (Check if yes)

- ☐ Chest pain
- ☐ Shortness of breath
- ☐ Heart palpitations
- ☐ Painful, stiff or swollen joints
- ☐ Back pain
- ☐ Coughing blood
- ☐ Coughing with physical exertion
- ☐ Other illness/disease

If yes to any of the above, please explain: ______________________________

____

____

____

Questions Regarding Hormone Status:

1. Please check the response that reflects your current hormone status.

☐ **Premenopausal**: *experiencing normal menstrual cycles with no symptoms of menopause such as hot flashes, vaginal dryness, sleeplessness, or mood swings*

☐ **Perimenopausal:** *changes in normal menstrual function (e.g. missed period, shorter menstrual cycles, lighter or heavier bleeding than usual, light bleeding throughout the month-and/or symptoms such as hot flashes, vaginal dryness, sleeplessness or mood swings.*

☐ **Postmenopausal:** *no menstrual cycle for (at least) the last 12 months.*

2. If in question #1 you indicated that you are postmenopausal, please specify how many years post menopause. ________________

3. If in question #1 you indicated that you are perimenopausal, please list symptoms and indicate how many menstrual cycles you have missed in the last 12 months. ________________

____

____

4. Please list the name, type and dose of any hormones or medications specific to bone, menopause, or reproduction that you are currently taking (e.g. HRT (**hormone replacement therapy**), Fosomax, oral contraceptives) and indicate how long you have been taking each medication.

____

____

____

____

General Questions:

1. Please indicate your approximate height (feet, inches) ________ and weight (lbs) ________
2. Do you drink alcohol? YES or NO
3. Do you drink two or more drinks per day? YES or NO
4. Do you currently smoke tobacco? YES or NO
5. Do you smoke more than 10 tobacco cigarettes a day? YES or NO
6. Were you a tobacco smoker in the past? YES or NO

    If you have quit, when did you quit? ________

    For how long did you smoke tobacco? ________

    Did you smoke more than 10 tobacco cigarettes a day? YES or NO

Question about Supplements and Medications:

1. Do you take a multivitamin? YES or NO

    If so, what type and how often? ________________

2. Do you take a calcium supplement? YES or NO

    If so, what type and how often? ________________

3. Are you taking any prescription medications other than those prescribed for bone, menopause or birth control? YES or NO

If so, please list present medications and dosages: ____________________

____

____

____

____

Thank you for you participation in this study! If you are interested in being contacted about future studies for which you may be eligible to participate, please check here ☐

APPENDIX C:

AEROBICS CENTER LONGITUDINAL PHYSICAL ACTIVITY QUESTIONNAIRE

In this section we would like to ask you about your current physical activity and exercise habits that you perform regularly, at least once a week. Please answer as accurately as possible. Circle your answer or supply a specific number when asked.

EXERCISE/PHYSICAL ACTIVITY

1. For the last **three months**, which of the following moderate or vigorous activities have you performed **regularly?** *(Please circle YES for all that apply and NO if you do not perform the activity; provide an estimate of the amount of activity for all marked YES. Be as complete as possible.)*

Walking
NO YES ➡ How many sessions per week? _____
How many miles (or fractions) per session? _____
Average duration per session? _____ (minutes)

What is your usual pace of walking? *(Please circle one)*

CASUAL or STROLLING (< 2 mph)	AVERAGE or NORMAL (2 to 3 mph)	FAIRLY BRISK (3 to 4 mph)	BRISK or STRIDING (4 mph or faster)

Stair Climbing
NO YES ➡ How many flights of stairs do you climb UP each day? _____
(1 flight = 10 steps)

Jogging or Running
NO YES ➡ How many sessions per week? _____
How many miles (or fractions) per session? _____
Average duration per session? _____ (minutes)

Treadmill
NO YES ➡ How many sessions per week? _____
Average duration per session? _____ (minutes)
Speed? _____ (mph) Grade? _____ (%)

Bicycling
NO YES ➡ How many sessions per week? _____
How many miles per session? _____
Average duration per session? _____ (minutes)

Swimming Laps
NO YES ➡ How many sessions per week? _____
How many miles per session?
(880 yds = 0.5 miles) _____
Average duration per session? _____ (minutes)

Aerobic Dance/Calisthenics/Floor Exercise
NO YES ➡ How many sessions per week? ______
Average duration per session? ______(minutes)

Moderate Sports
(e.g. Leisure volleyball, golf (not riding), social dancing, doubles tennis)
NO YES ➡ How many sessions per week? ______
Average duration per session? ______(minutes)

Vigorous Racquet Sports
(e.g. Racquetball, singles tennis)
NO YES ➡ How many sessions per week? ______
Average duration per session? ______(minutes)

Other Vigorous Sports or Exercise Involving Running (e.g. Basketball, soccer)
NO YES ➡ Please specify:______________________
How many sessions per week? ______
Average duration per session? ______(minutes)

Other Activities
NO YES ➡ Please specify:______________________
How many sessions per week? ______
Average duration per session? ______(minutes)

Weight Training
(Machines, free weights)
NO YES ➡ How many sessions per week? ______
Average duration per session? ______(minutes)

Household Activities (Sweeping, vacuuming, washing clothes, scrubbing floors)
NO YES ➡ How many hours per week? ______

Lawn Work and Gardening
NO YES ➡ How many hours per week? ______

2. How many times a week do you engage in vigorous physical activity long enough to work up a sweat? ______ *(times per week)*

APPENDIX D:

FOOD FREQUENCY QUESTIONNIARE

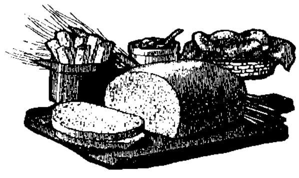
BRIEF FOOD QUESTIONNAIRE

RESPONDENT ID NUMBER

0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9

TODAY'S DATE

	DAY		YEAR
○ Jan			
○ Feb			
○ Mar	0	0	2000 ○
○ Apr	1	1	2001 ○
○ May	2	2	2002 ○
○ Jun	3	3	2003 ○
○ Jul		4	2004 ○
○ Aug		5	2005 ○
○ Sep		6	2006 ○
○ Oct		7	2007 ○
○ Nov		8	2008 ○
○ Dec		9	2009 ○



This form is about the foods you usually eat.
It will take about 15 - 25 minutes to complete.

- **Please answer each question as best you can. Estimate if you aren't sure.**
- **Use only a No. 2 pencil.**
- **Fill in the circles completely, and erase completely if you make any changes.**

Please print your name in this box.

SEX
○ Male
○ Female

If female, are you pregnant or breast feeding?
○ No
○ Yes
○ Not female

AGE		WEIGHT pounds			HEIGHT ft. in.	
0	0	0	0	0		00
1	1	1	1	1		01
2	2	2	2	2		02
3	3	3	3	3	3	03
4	4	4	4	4	4	04
5	5		5	5	5	05
6	6		6	6	6	06
7	7		7	7		07
8	8		8	8		08
9	9		9	9		09
						10
						11

This form is about your usual eating habits in the past year or so. This includes all meals or snacks, at home or in a restaurant or carry-out. There are two kinds of questions for each food.

HOW OFTEN, on average, did you eat the food during the past year?
*Please DO NOT SKIP any foods. Mark "Never" if you didn't eat it.

HOW MUCH did you usually eat of the food?
*Sometimes we ask how many you eat, such as 1 egg, 2 eggs, etc., ON THE DAYS YOU EAT IT.
*Sometimes we ask "how much" as A, B, C or D. LOOK AT THE ENCLOSED PICTURES. For each food, pick the picture (bowls or plates) that looks the most like the serving size you usually eat. (If you don't have pictures: A=1/4 cup, B=1/2 cup, C=1 cup, D= 2 cups.)

EXAMPLE: This person drank apple juice twice a week, and had one glass each time. Once a week he ate a "C"-sized serving of rice (about 1 cup).

TYPE OF FOOD	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH EACH TIME SEE PORTION SIZE PICTURES FOR A-B-C-D				
Apple juice	○	○	○	○	○	●	○	○	○	How many glasses each time	● 1	○ 2	○ 3	○ 4
Rice	○	○	○	○	●	○	○	○	○	How much each time	○ A	○ B	● C	○ D

PLEASE DO NOT WRITE IN THIS AREA

45366

TYPE OF FOOD	HOW OFTEN IN THE PAST YEAR: NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH EACH TIME SEE PORTION SIZE PICTURES FOR A-B-C-D				
How often do you eat each of the following foods all year round?														
Eggs, including egg biscuits or Egg McMuffins (Not egg substitutes)	○	○	○	○	○	○	○	○	○	How many eggs each time	○ 1	○ 2	○ 3	○ 4
Bacon or breakfast sausage, including sausage biscuit	○	○	○	○	○	○	○	○	○	How many pieces	○ 1	○ 2	○ 3	○ 4
Cooked cereals like oatmeal, cream of wheat or grits	○	○	○	○	○	○	○	○	○	Which bowl		○ B	○ C	○ D
Cold cereals like Corn Flakes, Cheerios, Special K, fiber cereals	○	○	○	○	○	○	○	○	○	Which bowl		○ B	○ C	○ D
Which cereal do you eat most often? **MARK ONLY ONE:** ○ Product 19, Just Right, Total ○ Bran Buds, Raisin Bran, Fruit-n-Fiber, other fiber cereals ○ Other cold cereal, like Corn Flakes, Cheerios, Special K														
Cheese, sliced cheese or cheese spread, including on sandwiches.	○	○	○	○	○	○	○	○	○	How many slices	○ 1	○ 2	○ 3	○ 4
Yogurt (not frozen yogurt)	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
How often do you eat each of the following fruits?														
Bananas	○	○	○	○	○	○	○	○	○	How many each time	○ 1/2	○ 1	○ 2	○ 3
Apples or pears	○	○	○	○	○	○	○	○	○	How many	○ 1/2	○ 1	○ 2	○ 3
Oranges, tangerines, not including juice	○	○	○	○	○	○	○	○	○	How many	○ 1/2	○ 1	○ 2	○ 3
Applesauce, fruit cocktail, or any canned fruit	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Any other fruit, like grapes, melon, strawberries, peaches, applesauce	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D

TYPE OF FOOD	HOW OFTEN IN THE PAST YEAR									HOW MUCH EACH TIME SEE PORTION SIZE PICTURES FOR A-B-C-D				
	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY					
How often do you eat each of the following vegetables, including fresh, frozen, canned or in stir fry, at home or in a restaurant?														
French fries, fried potatoes or hash browns	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
White potatoes not fried, incl. boiled, baked, mashed & potato salad	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Sweet potatoes, yams, or sweet potato pie	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Rice, or dishes made with rice	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Baked beans, chili with beans, pintos, any other dried beans	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Refried beans	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Green beans or green peas	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Broccoli	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Carrots, or stews or mixed vegetables containing carrots	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Spinach, or greens like collards	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Cole slaw, cabbage	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Green salad	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Raw tomatoes, including in salad	○	○	○	○	○	○	○	○	○	How much	○ 1/4	○ 1/2	○ 1	○ 2
Catsup, salsa or chile peppers	○	○	○	○	○	○	○	○	○	How many TBSP.	○ 1	○ 2	○ 3	○ 4
Salad dressing or mayonnaise (Not lowfat)	○	○	○	○	○	○	○	○	○	How many TBSP.	○ 1	○ 2	○ 3	○ 4
Any other vegetable, like corn, squash, okra, cooked green peppers, cooked onions	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Vegetable soup, vegetable beef, chicken vegetable, or tomato soup	○	○	○	○	○	○	○	○	○	Which bowl		○ B	○ C	○ D

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TYPE OF FOOD	HOW OFTEN IN THE PAST YEAR: NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH EACH TIME (SEE PORTION SIZE PICTURES FOR A-B-C-D)				
MEATS														
Do you ever eat chicken, meat or fish? ○ Yes ○ No IF NO, SKIP TO NEXT PAGE														
Hamburgers, cheeseburgers, meat loaf, at home or in a restaurant	○	○	○	○	○	○	○	○	○	How much meat	○ 1/8 lb.	○ 1/4 lb.	○ 1/2 lb.	○ 3/4 lb.
Tacos, burritos, enchiladas, tamales	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Beef steaks, roasts, pot roast, or in frozen dinners or sandwiches	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Pork, including chops, roasts, or dinner ham	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
When you eat beef or pork, do you ○ Avoid eating the fat ○ Sometimes eat the fat ○ Often eat the fat ○ I don't eat meat														
Mixed dishes with meat or chicken, like stew, corned beef hash, chicken & dumplings, or in frozen meals	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Fried chicken, at home or in a restaurant	○	○	○	○	○	○	○	○	○	# medium pieces	○ 1	○ 2	○ 3	○ 4
Chicken or turkey not fried, such as baked, grilled, or on sandwiches	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
When you eat chicken, do you ○ Avoid eating the skin ○ Sometimes eat the skin ○ Often eat the skin ○ N/A														
Fried fish or fish sandwich, at home or in a restaurant	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Any other fish or shellfish not fried, including tuna	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Hot dogs, or sausage like Polish, Italian or Chorizo	○	○	○	○	○	○	○	○	○	How many	○ 1	○ 2	○ 3	○ 4
Boloney, sliced ham, turkey lunch meat, other lunch meat	○	○	○	○	○	○	○	○	○	How many slices	○ 1	○ 2	○ 3	○ 4
When you eat lunch meats, are they ○ Usually low-fat ○ Sometimes ○ Rarely low-fat ○ N/A														

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PLEASE DO NOT WRITE IN THIS AREA

TYPE OF FOOD	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH EACH TIME SEE PORTION SIZE PICTURES FOR A-B-C-D				
Pasta, breads, spreads, snacks														
Spaghetti, lasagna, or other pasta with tomato sauce	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Cheese dishes without tomato sauce, like macaroni and cheese	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Pizza, including carry-out	○	○	○	○	○	○	○	○	○	How many slices	○ 1	○ 2	○ 3	○ 4
Biscuits, muffins	○	○	○	○	○	○	○	○	○	How many each time	○ 1	○ 2	○ 3	○ 4
Rolls, hamburger buns, English muffins, bagels	○	○	○	○	○	○	○	○	○	How many each time	○ 1/2	○ 1	○ 2	○ 3
White bread or toast, including French, Italian, or in sandwiches	○	○	○	○	○	○	○	○	○	How many slices	○ 1	○ 2	○ 3	○ 4
Dark bread like rye or whole wheat, including in sandwiches	○	○	○	○	○	○	○	○	○	How many slices	○ 1	○ 2	○ 3	○ 4
Tortillas	○	○	○	○	○	○	○	○	○	How many each time	○ 1	○ 2	○ 3	○ 4
Margarine on bread, potatoes or vegetables	○	○	○	○	○	○	○	○	○	How many pats (Tsp.)	○ 1	○ 2	○ 3	○ 4
Butter on bread, potatoes or vegetables	○	○	○	○	○	○	○	○	○	How many pats (Tsp.)	○ 1	○ 2	○ 3	○ 4
Peanuts or peanut butter	○	○	○	○	○	○	○	○	○	How many TBSP.	○ 1	○ 2	○ 3	○ 4
Snacks like potato chips, corn chips, popcorn (Not pretzels)	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Doughnuts, cake, pastry, pie	○	○	○	○	○	○	○	○	○	How many pieces	○ 1	○ 2	○ 3	○ 4
Cookies (Not lowfat)	○	○	○	○	○	○	○	○	○	How many	○ 1-2	○ 3-5	○ 6-7	○ 8+
Ice cream, frozen yogurt, ice cream bars	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
When you eat ice cream or frozen yogurt, is it	○ Usually low-fat		○ Sometimes			○ Rarely low-fat			○ N/A					
Chocolate candy, candy bars	○	○	○	○	○	○	○	○	○	How many bars	① small	① medium	① large	② large

TYPE OF BEVERAGE	HOW OFTEN IN THE PAST YEAR: NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH EACH TIME SEE PORTION SIZE PICTURES FOR A-B-C-D				
How often do you drink the following beverages?														
Real orange or grapefruit juice, Welch's grape juice, Minutemaid juices, Juicy Juice	○	○	○	○	○	○	○	○	○	How many glasses each time	○ 1	○ 2	○ 3	○ 4
Hawaiian Punch, Sunny Delight, Hi-C, Tang, or Ocean Spray juices	○	○	○	○	○	○	○	○	○	How many glasses each time	○ 1	○ 2	○ 3	○ 4
Kool Aid, Capri Sun or Knudsen juices	○	○	○	○	○	○	○	○	○	How many glasses each time	○ 1	○ 2	○ 3	○ 4
Instant breakfast milkshakes like Carnation, diet shakes like Slimfast, or liquid supplements like Ensure	○	○	○	○	○	○	○	○	○	How many glasses or cans	○ 1	○ 2	○ 3	○ 4
Glasses of milk (any kind)	○	○	○	○	○	○	○	○	○	How many glasses	○ 1	○ 2	○ 3	○ 4

When you drink glasses of milk what kind do you usually drink? **MARK ONLY ONE:**

- ○ Whole milk
- ○ Reduced fat 2% milk
- ○ Low-fat 1% milk
- ○ Non-fat milk
- ○ Rice milk
- ○ Soy milk
- ○ I don't drink milk or soy milk

TYPE OF BEVERAGE	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH EACH TIME				
Cream, Half-and-Half or non-dairy creamer in coffee or tea	○	○	○	○	○	○	○	○	○	Total TBSP. on those days	○ 1	○ 2	○ 3-4	○ 5+
Regular soft drinks, or bottled drinks like Snapple (Not diet drinks)	○	○	○	○	○	○	○	○	○	How many bottles or cans	○ 1	○ 2	○ 3-4	○ 5+
Beer	○	○	○	○	○	○	○	○	○	How many bottles or cans	○ 1	○ 2	○ 3-4	○ 5+
Wine or wine coolers	○	○	○	○	○	○	○	○	○	How many glasses	○ 1	○ 2	○ 3-4	○ 5+
Liquor or mixed drinks	○	○	○	○	○	○	○	○	○	How many drinks	○ 1	○ 2	○ 3-4	○ 5+

During the past year, have you taken any vitamins or minerals regularly, at least once a month?
○ No, not regularly ○ Yes, fairly regularly

(IF YES) WHAT DID YOU TAKE FAIRLY REGULARLY?

VITAMIN TYPE	HOW OFTEN					FOR HOW MANY YEARS?					
	DIDN'T TAKE	A FEW DAYS per MONTH	1-3 DAYS per WEEK	4-6 DAYS per WEEK	EVERY DAY	LESS THAN 1 YR.	1 YEAR	2 YEARS	3-4 YEARS	5-9 YEARS	10+ YEARS
Multiple Vitamins. Did you take...											
Regular Once-A-Day, Centrum, or Thera type	○	○	○	○	○	○	○	○	○	○	○
Stress-tabs or B-Complex type	○	○	○	○	○	○	○	○	○	○	○
Antioxidant combination type	○	○	○	○	○	○	○	○	○	○	○
Single Vitamins (not part of multiple vitamins)											
Vitamin A (not beta-carotene)	○	○	○	○	○	○	○	○	○	○	○
Beta-carotene	○	○	○	○	○	○	○	○	○	○	○
Vitamin C	○	○	○	○	○	○	○	○	○	○	○
Vitamin E	○	○	○	○	○	○	○	○	○	○	○
Folic acid, folate	○	○	○	○	○	○	○	○	○	○	○
Calcium or Tums, alone or combined with vit. D or magnesium	○	○	○	○	○	○	○	○	○	○	○
Zinc	○	○	○	○	○	○	○	○	○	○	○
Iron	○	○	○	○	○	○	○	○	○	○	○
Selenium	○	○	○	○	○	○	○	○	○	○	○
Vitamin D, alone or combined with calcium	○	○	○	○	○	○	○	○	○	○	○

If you took vitamin C or vitamin E:

How many milligrams of **vitamin C** did you usually take, on the days you took it?
○ 100 ○ 250 ○ 500 ○ 750 ○ 1000 ○ 1500 ○ 2000 ○ 3000+ ○ don't know

How many IUs of **vitamin E** did you usually take, on the days you took it?
○ 100 ○ 200 ○ 300 ○ 400 ○ 600 ○ 800 ○ 1000 ○ 2000+ ○ don't know

How often do you use fat or oil in cooking?
○ Less than once per week ○ A few times per week ○ Once a day ○ Twice a day ○ 3+ per day

What kinds of fat or oil do you usually use in cooking? MARK ONLY ONE OR TWO
○ Don't know, or Pam
○ Stick margarine
○ Soft tub margarine
○ Butter
○ Butter/margarine blend
○ Low-fat margarine
○ Corn oil, vegetable oil
○ Olive oil or canola oil
○ Lard, fatback, bacon fat
○ Crisco

Did you ever drink more beer, wine or liquor than you do now? ○ Yes ○ No

Do you smoke cigarettes now? ○ Yes ○ No
IF YES, On the average about how many cigarettes a day do you smoke now?
○ 1-5 ○ 6-14 ○ 15-24 ○ 25-34 ○ 35 or more

What is your ethnic group? (MARK ONE OR MORE)
○ Hispanic or Latino
○ White, not Hispanic
○ Black or African American
○ Asian
○ American Indian or Alaska Native
○ Native Hawaiian or Other Pacific Islander

Thank you very much for filling out this questionnaire. Please take a minute to go back and fill in anything you may have skipped.

PLEASE DO NOT WRITE IN THIS AREA

APPENDIX E:

ROWING HISTORY SELF REPORT SHEET

Rowing Activity Self Report Sheet

1. How many years have you been engaged in rowing exercise? (your response to this question should include TOTAL years rowing. For example, if you rowed through 4 years of college, then stopped for 10 years and have been rowing continuously for 2 years, your response to this question will be 6 years.

    ____________ total years engaged in rowing activity

2. How many years have you been rowing continuously counting backwards from today? For example, if you were a competitive rower in through 4 years of college, stopped for 10 years and started rowing again 2 years ago, your response to this question would be 2 years.

    ____________ years of continuous rowing counting back from today

3. How many hours per week do you spend rowing (on the water, or erg training)?

    ______________________ hours per week rowing activity

4. How many hours per week do you spend doing wt. training activities that load the spine? (e.g. squats, back extension, weighted seated rows, lat pulls)

    ____________ hours per week of weight-training

4. List the spine loading exercises you do and the approximate intensity and duration

EXERCISE	INTENSITY	SETS	REPETITIONS	FREQUENCY
e.g. lat pulls	*60-80 lbs*	*3*	*10*	*1 x per week*

5. How many hours of **non-rowing**, weight-bearing aerobic activity do you do each week? Please itemize the type of activity and the approximate time spent doing the activity.

ACTIVITY	TIME	FREQUENCY
e.g. running/jogging	*1-2 hours continuously*	*3x week*

___ ______ Total hours spent in non-rowing weight bearing activity

APPENDIX F:

SPINE LOADING SELF REPORT SHEET

Spine loading Activity Self Report Sheet

1. How many hours per week do you spend doing wt. training activities that load the spine? (e.g. squats, back extension, weighted seated rows, lat pulls)

_____________ hours per week of weight-training

2. List the spine loading exercises you do and the approximate intensity and duration

EXERCISE	INTENSITY	SETS	REPETITIONS	FREQUENCY
e.g. lat pulls	*60-80 lbs*	*3*	*10*	*1 x per week*

3. How many hours of weight-bearing aerobic activity do you do each week? Please itemize the type of activity and the approximate time spent doing the activity.

ACTIVITY	TIME	FREQUENCY
e.g. running/jogging	*1-2 hours continuously*	*3x week*

___________ Total hours spent in non-rowing weight bearing activity

4. Do you regularly participate in rowing activity either on the water, or using a rowing machine?
Circle one: YES NO

If yes, how many hours per week?

_________________________ hours per week spent in rowing activity