Menstrual state and exercise as determinants of spinal trabecular bone density in female athletes

Roger L Wolman, Peter Clark, Eugene McNally, Mark Harries, Jonathan Reeve

Abstract

***Objective*—To study the effects of amenorrhoea and intensive back exercise on the bone mineral density of the lumbar spine in female athletes.**

***Design*—Cross sectional study comparing amenorrhoeic with eumenorrhoeic athletes and rowers with non-rowers.**

***Setting*—The British Olympic Medical Centre, Northwick Park Hospital.**

***Patients*—46 Elite female athletes comprising 19 rowers, 18 runners, and nine dancers, of whom 25 were amenorrhoeic and 21 eumenorrhoeic.**

***Main outcome measure*—Trabecular bone mineral density of the lumbar spine measured by computed tomography.**

***Results*—Mean trabecular bone mineral density was 42 mg/cm³ (95% confidence interval 22 to 62 mg/cm³) lower in the amenorrhoeic than the eumenorrhoeic athletes; this difference was highly significant (p=0·0002). Mean trabecular bone mineral density was 21 mg/cm³ (1 to 41 mg/cm³) lower in the non-rowers than the rowers; this was also significant (p=0·05). There was no interaction between these two effects (p=0·28).**

***Conclusion*—The effect of intensive exercise on the lumbar spine partially compensates for the adverse effect of amenorrhoea on spinal trabecular bone density.**

Introduction

Physical activity increases bone strength both in animals[1 2] and in humans.[3] In élite athletes studies have shown that bone density is increased in the wrist of the playing arm of tennis players[4 5] and in the os calcis of runners,[6] suggesting that exercise exerts its effect mainly on the bones at sites of maximum stress. Intense endurance training in female subjects may lead to amenorrhoea, which in turn reduces the trabecular bone mineral density, especially in the lumbar spine.[7] Previous studies, however, have tended to focus on athletes who concentrate mainly on exercising the lower body.

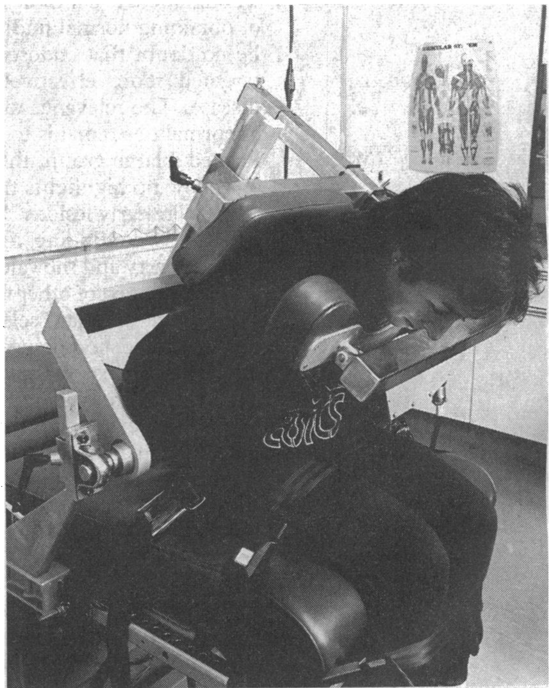
Rowing entails considerable back exercise. There is also a high incidence of amenorrhoea among competitors at lightweight (who must weigh 59 kg or less at the time of competition). There has been one previous study of lightweight female rowers,[8] but the cohort was small and the results were difficult to interpret. We studied a larger group of élite lightweight women rowers and compared them with a group of élite female athletes who exercised predominantly the lower body; about half of the subjects in each group had amenorrhoea.

Subjects and methods

Twenty six members of the national squad of lightweight women rowers, 24 élite endurance runners (either in the national squad or marathon runners with a best time of under three hours), and 14 professional ballet dancers agreed to participate in the study. Amenorrhoea was defined as no more than one period, and eumenorrhoea as regular periods with a gap of less than 35 days between the start of consecutive periods, in the six months preceding the study. On the basis of these criteria 10 of the rowers and 15 of the non-rowers had amenorrhoea and nine of the rowers and 12 of the non-rowers had eumenorrhoea; we excluded from the study all the athletes with other menstrual patterns and those taking an oral contraceptive.

Trabecular bone mineral density of the lumbar spine (mg/cm³) was measured by quantitative computed tomography (General Electric CT 9000 scanner). Based on the technique used by Cann and Genant,[9] measurements were made in a 5 mm slice at the centre of the L2, L3, and L4 and an average value was calculated. A circular area of trabecular bone exceeding 200 mm² was measured in each vertebra with reference to a calibration phantom scanned simultaneously. The results were expressed in mg of potassium phosphate equivalent/cm³. The coefficient of variation of the technique is about 3% and the absorbed radiation dose about 3 mSv in the abdominal region.

Back strength was assessed by estimating the size of the psoas muscles and by isokinetic dynamometry. The cross sectional area of the psoas muscles at the level of L3 was measured by computed tomography: the borders of both muscles were outlined and their cross sectional areas measured with the scanner software. The results were expressed as the average value in mm². Isokinetic back strength was measured with an isokinetic dynamometer (Lido). With the subject seated and the legs strapped firmly to the base, flexion-extension movements were tested with the pivot point at the hip joint (figure). Torques were recorded at a



Isokinetic dynamometer (Lido) set up to measure flexion and extension movements of back with pivot point at hip joint

British Olympic Medical Centre, Northwick Park Hospital, Harrow, Middlesex HA1 3UJ
Roger L Wolman, MRCP, *research registrar*
Mark G Harries, MD, *honorary director*

Clinical Research Centre, Harrow, Middlesex HA1 3UJ
Peter Clark, MSC, *statistician, section of medical statistics*
Jonathan Reeve, DM, *head of bone disease research group*

Department of Radiology, Northwick Park Hospital, Harrow, Middlesex HA1 3UJ
Eugene McNally, MRCPI, *senior registrar*

Correspondence to: Dr Wolman.

Br Med J 1990;301:516-8

constant velocity of 80°/s. Peak torques were expressed in N.m.

STATISTICAL METHODS

Statistical analysis consisted of fitting a linear model[10] to assess the effects of sport (rowers *v* non-rowers) and menstrual state (amenorrhoea *v* eumenorrhoea) on the bone mineral density of the lumbar spine of the athletes. Height, weight, and age were also considered in case they too exerted any significant effect.

The first stage was to determine which of the five variables on their own best explained the differences in the spinal bone density. This variable was incorporated into the model. Then each of the remaining variables was added to the model to assess which explained the greatest additional variability (that is, which had the largest F ratio). That variable was then also incorporated into the model. This procedure was repeated until all remaining variables had a p value (inversely related to the F ratio) for entering the model of greater than 0·05 (that is, no significant additional effect on bone density). Finally, the residuals were tested for normality with Shapiro Wilk's W test[11] and for equal variances in categories defined by sport and menstrual state with the Schweder test.[12] Ninety five per cent confidence intervals for the sports and menstrual states were constructed by using the residual variance from the final model fitted.

Back strengths in the sports were compared by using one way analysis of variance after checking for normality and equal variances as above.

TABLE I—*Mean (SD) demographic variables and variables of back strength in dancers and runners*

	Dancers (n=9)	Runners (n=18)	p Value
Age (years)	22·7 (3·8)	25·9 (2·7)	0·017
Weight (kg)	51·1 (4·5)	50·8 (5·9)	0·90
Height (cm)	164 (3·5)	163 (5·4)	0·66
Cross sectional area of psoas muscles at L3 (mm^2)	856 (209)	742 (140)	0·10
Peak torque in flexion (N.m)	103 (16)	107 (22)	0·63
Peak torque in extension (N.m)	173 (45)	175 (42)	0·92

TABLE II—*Mean (SD) demographic variables by sports group and menstrual state*

	Sports group			Menstrual group		
	Non-rowers (n=27)	Lightweight rowers (n=19)	p Value	Amenorrhoea (n=25)	Eumenorrhoea (n=21)	p Value
Age (years)	24·9 (3·4)	25·1 (3·5)	0·86	24·2 (3·5)	25·7 (3·2)	0·14
Weight (kg)	51·3 (5·4)	59·8 (4·2)	<0·0001	52·6 (6·4)	56·0 (6·1)	0·02
Height (cm)	164 (4·8)	169 (4·3)	0·001	165 (5·7)	167 (4·2)	0·24

TABLE III—*Mean (95% confidence interval) bone mineral density (mg/cm³) by sport and menstrual state*

	Non-rowers	Lightweight rowers	Difference between sports
Amenorrhoea	156 (139 to 173)	186 (170 to 202)	30 (3 to 57)
Eumenorrhoea	206 (187 to 226)	215 (199 to 231)	9 (−3 to 21)
Difference between menstrual states	50 (25 to 76)	29 (−2 to 60)	

TABLE IV—*Result of multiple regression analysis of bone mineral density*

Variable	Stage 1 ($F_{1,44}$)	Stage 2 ($F_{1,43}$)	Stage 3 ($F_{1,42}$)
Age	0·98	0·05	0·04
Height	2·18	0·97	0·01
Weight	4·70	1·22	0·13
Sport	3·31	*4·06* (p=0·05)	
Menstrual state	*17·08* (p=0·0002)		
Sport×menstrual state (interaction)			1·20 (p=0·28)

F Ratios test whether the entry of each variable would significantly improve the model at each stage of the analysis. The best additional variable at each stage is given in italics.

TABLE V—*Mean (SD) measurements of back strength by sport*

	Non-rowers	Lightweight rowers	Difference between groups (95% confidence interval)	p Value
Cross sectional area of psoas muscles at L3 (mm^2)	780 (171)	928 (167)	148 (47 to 249)	0·006
Peak torque in flexion (N.m)	106 (20)	137 (24)	31 (18 to 45)	<0·0001
Peak torque in extension (N.m)	174 (42)	214 (52)	40 (11 to 68)	0·007

Results

There were no significant differences between the dancers and the runners in any of the variables investigated except for age (table I). We therefore considered them to be similar enough to be grouped together as non-rowers. Table II gives details of the demographic variables by sport and menstrual state. The rowers were taller and heavier than the non-rowers but their ages were similar. The eumenorrhoeic athletes were heavier than the amenorrhoeic athletes but their ages and heights were similar.

The mean bone mineral density was 210 mg/cm³ in the eumenorrhoeic athletes but only 168 mg/cm³ in the amenorrhoeic athletes (difference=42 mg/cm³; confidence interval 22 to 62 mg/cm³; p=0·0002). The mean bone mineral density was 199 mg/cm³ in the rowers compared with 178 mg/cm³ in the non-rowers (21 mg/cm³; 1 to 41 mg/cm³; p=0·05). Within each menstrual group spinal bone density in the rowers was greater than that in the non-rowers (table III)

Table IV shows the results of the model fitting for spinal bone density. Stage 1 shows the highly significant effect of menstrual state (F=17·08; p=0·0002) and the lesser effects of weight (F=4·70) and sport (F=3·31). When menstrual state was taken into account (stage 2), however, weight no longer exerted an effect on bone mineral density (F=1·22; p=0·28) and only sport had any significant effect (F=4·06; p=0·05). When both sport and menstrual state were incorporated into the model (stage 3) no other variable had a significant effect. There was no significant interaction between the effects of sport and menstrual state (F=1·20; p=0·28) on bone mineral density (stage 3). This suggested that the effects of sport and menstrual state acted independently of each other.

The cross sectional area of the psoas muscles at L3 and the isokinetic peak torques for both flexion and extension were significantly higher in the rowers than the non-rowers (table V).

Discussion

Physical activity increases bone mineral density at the sites where the skeleton is maximally stressed.[4-6] Female rowers not only have an increased risk of developing amenorrhoea but also exercise the lumbar spine, which is sensitive to the effects of low oestrogen state.[7] Our results confirm those of previous studies, which have concentrated mainly on runners and have shown that the bone mineral density of the lumbar spine is lower in amenorrhoeic athletes than their eumenorrhoeic counterparts.[7 13 14] We found, however, that this effect was partially offset in the rowers whom we studied. Model fitting suggested that the type of activity performed by the rowers rather than their increased weight and height accounted for their higher bone mineral density.

Using dual photon absorptiometry, Snyder *et al* found similar bone mineral contents of the lumbar spine in four amenorrhoeic and seven eumenorrhoeic rowers and nine eumenorrhoeic controls.[8] These findings are surprising because if exercise does compensate for bone loss due to amenorrhoea rowers with eumenorrhoea should have a higher lumbar bone density than eumenorrhoeic controls. Dual photon absorptiometry measures both trabecular and cortical bone with vertebral bone trabeculae contributing only 35-50% of the total.[15] This and the small size of the cohort investigated may explain why Snyder *et al* were unable to detect differences between the three groups.

The factors that contribute to attaining peak bone mass in the mid-30s are not known. Physical activity tends to increase peak bone mass and may reduce the risk of osteoporosis in later life. Our results show that intensive exercise directed at a specific location in the skeleton (that is, to the spine in rowing) confers additional benefit to bone mineralisation at that site and confirm that if the intensity of exercise is so high that it leads to amenorrhoea these benefits can be lost.

We thank Yiannis Koutedakis and Dr David Katz for their advice and Adrienne McQueen for supervising the measurements of bone mineral density. RLW is supported by a grant from Glaxo Pharmaceuticals (UK).

1 Lanyon LE. Bone loading, exercise, and the control of bone mass: the physiological basis for the prevention of osteoporosis. *Bone* 1989;**6**:19-21.
2 Rubin CT, Lanyon LE. Regulation of bone formation by applied dynamic loads. *J Bone Joint Surg [Br]* 1984;**66**:397-402.
3 Nilsson BE, Westlin NE. Bone density in athletes. *Clin Orthop* 1971;**77**:179-82.
4 Huddleston AL, Rochwell D, Kulund DN, Harrison RB. Bone mass in lifetime tennis players. *JAMA* 1980;**244**:1107-9.
5 Pirnay F, Bodeux M, Crielaard JM, Franchimont P. Bone mineral content and physical activity. *Int J Sports Med* 1987;**8**:331-5.
6 Williams JA, Wagner J, Wasnich R, Heilbrun L. The effect of long-distance running upon appendicular bone mineral content. *Med Sci Sports Exerc* 1984;**16**:223-7.
7 Drinkwater BL, Nilson K, Chesnut CH, Bremner WJ, Shainholtz S, Southworth MB. Bone mineral content of amenorrheic and eumenorrheic athletes. *N Engl J Med* 1984;**311**:277-81.
8 Snyder AC, Wenderoth MP, Johnston CC, Hui SL. Bone mineral content of elite lightweight amenorrheic oarswomen. *Hum Biol* 1986;**58**:863-9.
9 Cann CE, Genant HK. Precis̆ measurement of vertebral mineral content using computed tomography. *J Comput Assist Tomogr* 1980;**4**:493-500.
10 McCullagh P, Nelder JA. *Generalised linear models.* London: Chapman and Hall, 1983.
11 Royston JP. An extension of Shapiro and Wilks W test for normality to large samples. *Applied Statistics* 1982;**31**:115-24.
12 Schweder T. A simple test for a set of sums of squares. *Applied Statistics* 1981;**30**:16-21.
13 Lindberg JS, Fears WB, Hunt MM, Powell MR, Boll D, Wade CE. Exercise-induced amenorrhea and bone density. *Ann Intern Med* 1984;**101**:647-8.
14 Marcus R, Cann C, Madvig P, *et al.* Menstrual function and bone mass in elite women distance runners. *Ann Intern Med* 1985;**102**:158-63.
15 Nottestad SY, Baumel JJ, Kimmel DB, Recker RR, Heaney RP. The proportion of trabecular bone in human vertebrae. *Journal of Bone and Mineral Research* 1987;**2**:221-9.

(Accepted 26 June 1990)

Prevalence of HIV antibody and pregnancy in Tayside, 1984-9: background to screening

Robert Smith, Naren B Patel, George E D Urquhart, Peter McFaul, Patrick Neven, Peter W Howie

Departments of Obstetrics and Gynaecology and Microbiology, Ninewells Hospital and Medical School, Dundee DD1 9SY
Robert Smith, FRCOG, *consultant obstetrician and gynaecologist*
Naren B Patel, FRCOG, *consultant obstetrician and gynaecologist*
George E D Urquhart, FRCPATH, *consultant virologist*
Peter McFaul, MD, *lecturer in obstetrics and gynaecology*
Patrick Neven, MD, *visiting registrar*
Peter W Howie, MD, *professor of obstetrics and gynaecology*

Correspondence to: Dr R Smith, Ward 37/38, Ninewells Hospital and Medical School, Dundee, Scotland DD1 9SY.

Br Med J 1990;301:518-21

Abstract

***Objective*—To determine age specific prevalence of HIV antibody, incidence of pregnancy, and likelihood of detection and correct assignment to risk category by antenatal screening of women known to be positive for HIV antibody, from 1984 to 1989.**

***Design*—Retrospective analysis of reproductive history and risk behaviour of women positive for HIV antibody and prediction of detection by screening on the basis of blood group samples, Guthrie tests, and rubella tests.**

***Setting*—City of Dundee, where the prevalence of HIV is high, since the appearance of HIV in 1984, predominantly among heterosexual intravenous drug users.**

***Patients*—All (61) women known to be positive for HIV antibody who had had clinically indicated tests, for whom case notes were available for 60.**

***Main outcome measures*—Risk assessment according to case notes and reported to the laboratory, incidence of infection, geographical location, age, date of positive test result, and reproductive history.**

***Results*—With 61 infected women the overall minimum prevalence among women within the city of Dundee was 0·67/1000 and 2·9/1000 among women in their third decade. Of the 60 women whose reproductive history was available, 35 had 57 pregnancies, 36 of which occurred after seroconversion was known to have taken place, representing 8·7% of the total number of affected pregnancies reported for the United Kingdom. If antenatal screening for HIV had been performed between 1984 and 1989 it could not have detected positivity for HIV antibody in 25 (42%) women who had no pregnancies during this time. Among the remaining 35 women, screening samples taken for blood grouping could have identified a maximum of 34 (57%), samples taken to check rubella susceptibility a maximum of 22 (37%), and blood spots on Guthrie cards a maximum of 19 (32%). Retesting would have occurred in 14 women 33 times with samples taken for blood grouping, but three and four women would have been tested twice using samples taken for rubella testing and Guthrie cards respectively. Anonymous screening would have been unable to determine risk category as a history of intravenous drug use was known in 47 (79%) women before testing but this was increased by a further 5 (8%) who admitted to it after the test result was known.**

***Conclusion*—Interpreting the results of antenatal screening programmes will be complex and will underestimate overall prevalence of HIV antibody among women; this will be exaggerated by strategies based on anonymous testing with Guthrie cards or on samples taken for rubella testing, which do not include women who have had an earlier loss of pregnancy. Only open testing with consent will permit satisfactory attribution to risk category and eliminate problems of retesting. Monitoring areas with a high prevalence of HIV infection may warn of increasing heterosexual spread.**

Introduction

HIV type I arrived in Tayside during late 1983 or early 1984,[1] as determined by retrospective analysis of stored blood samples. The virus spread rapidly among the population using intravenous drugs, with only seven of 231 positive test results among adults being attributed to homosexual or bisexual behaviour; 205 (89%) were attributed to intravenous drug use and 61 (26%) to women (Tayside Health Board. Communicable Diseases in Tayside No 12/89). This pattern of spread is similar to that in Lothian[2] but differs from that in the rest of Scotland. The reason for this difference is an estimated HIV infection rate of 50% among intravenous drug users in Edinburgh and 40% in Dundee, compared with only 2-5% in Glasgow, where the largest proportion of the Scottish population