Patterns of physical activity and ultrasound attenuation by heel bone among Norfolk cohort of European Prospective Investigation of Cancer (EPIC Norfolk): population based study

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Abstract

Objectives To study associations between patterns of physical activity and ultrasound attenuation by the heel bone in men and women.

Design Cross sectional, population based study.

Setting Norfolk.

Participants 2296 men and 2914 women aged 45-74 registered with general practices participating in European Prospective Investigation into Cancer (EPIC Norfolk).

Results Self reported time spent in high impact physical activity was strongly and positively associated with ultrasound attenuation by the heel bone, independently of age, weight, and other confounding factors. Men who reported participating in ≥2 hours/week of high impact activity had 8.44 dB/MHz (95% confidence interval 4.49 to 12.40) or 9.5%, higher ultrasound attenuation than men who reported no activity of this type. In women, the difference in ultrasound attenuation between those reporting any high impact activity and those reporting none was 2.41 dB/MHz (0.45 to 4.37) or 3.4% higher. In women this effect was similar in size to that of an age difference of four years. Moderate impact activity had no effect. However, climbing stairs was strongly independently associated with ultrasound attenuation in women (0.64 dB/MHz (0.19 to 1.09) for each additional five flights of stairs). There was a significant negative association in women between time spent watching television or video and heel bone ultrasound attenuation, which decreased by 0.08 dB/MHz (0.02 to 0.14) for each additional hour of viewing a week.

Conclusions High impact physical activity is independently associated with ultrasound attenuation by the heel bone in men and women. As low ultrasound attenuation has been shown to predict increased risk of hip fracture, interventions to promote participation in high impact activities may help preserve bone density and reduce the risk of fracture. However, in older people such interventions may be inappropriate as they could increase the likelihood of falls.

Introduction

Physical activity has been shown to be associated with bone density,[1–4] but it is uncertain how the different aspects of this complex and multidimensional activity affect achievement of peak bone mass or its rate of decline in later life. Identifying the components of physical activity that are beneficial for a particular outcome is essential when designing preventive interventions, but the process is complicated by the difficulty of measuring the subdimensions of activity in epidemiological studies.[5–7] Interventions aimed at increasing activity may not produce the benefits predicted from observational studies if they focus on the wrong type of physical activity. We studied the cross sectional association between patterns of physical activity in an adult population and ultrasound attenuation by the heel bone. Low ultrasound attenuation by heel bone, which is associated with low bone mineral density, has been shown to be a predictor of higher risk of hip fracture.[8]

Participants and methods

The European Prospective Investigation of Cancer (EPIC) study is a prospective cohort study designed to investigate the aetiology of major chronic diseases. The Norfolk cohort was recruited between 1993 and 1997 and comprised 25 633 men and women aged 45 to 74 years identified from participating general practice lists. The recruitment and study methods for the EPIC Norfolk study have been described in detail.[9] From January 1998 we invited the cohort for a second health check; 15 786 people had attended by September 2000, and the study group for this analysis is all participants who had complete data entry by May 1999. Tests at the second check included ultrasound measurements of the calcaneus. Attenuation of broadband ultrasound (dB/MHz) and speed of sound (m/s) were measured at least twice on each foot with a CUBA clinical instrument (McCue Ultrasonics, Winchester). We used the mean ultrasound measurements (left and right) for analysis. Four CUBA machines were used, and each was calibrated daily with a physical phantom.

A roving physical phantom was used monthly to check calibration between machines.

Volunteers also completed the EPIC physical activity questionnaire (EPAQ2), which is a self completed questionnaire that collects self reported physical activity behaviours in a disaggregated way such that the information can be reaggregated according to the dimension of physical activity that is of interest. The recreational section is derived from the previously validated Minnesota leisure time activity questionnaire,[10] with activities ordered according to their frequency in the United Kingdom population.[11] For this analysis the reported recreational activities were classified beforehand into four groups according to the level of impact (box). Three month repeatability of the questionnaire was assessed in a random sample of 402 participants. Correlation coefficients for the activity indices used in this study ranged from 0.7 to 0.95. The EPIC Norfolk study was approved by the Norfolk local research ethics committee.

Statistical methods

Time spent participating in physical activity was calculated for the four recreational activity groups by multiplying frequency and usual time spent per episode in hours per week. Frequency of climbing stairs was calculated from self reported figures on weekdays and at weekends. A flight was defined as about 10 steps. Inactivity, measured by time spent watching television and video, was calculated by summing responses to hours watched before and after 6 pm separately for weekdays and weekends. As ultrasound attenuation and speed of sound are highly correlated ($r=0.7$, $P<0.0001$), we present data only for ultrasound attenuation. All analyses, stratified by sex, were performed with STATA statistical software.

Classification of recreational physical activity

No impact
Swimming (competitive or leisure)
Fishing
Snooker
Playing musical instrument

Low impact
Racing or rough terrain cycling
Cycling for pleasure
Weeding, pruning
Conditioning exercises
Floor exercises
Rowing
Horse riding
Sailing, wind surfing, boating

Moderate impact
Backpacking or mountain climbing
Walking for pleasure
Mowing lawn
Watering lawn or garden in summer
Digging, shovelling, or chopping wood
Do it yourself
Other types of aerobics
Exercises with weights
Dancing
Bowling
Table tennis
Golf
Cricket
Ice skating
Winter sports—for example, skiing
Martial arts, boxing, wrestling

High impact
High impact aerobics, step aerobics
Competitive running
Jogging
Tennis or badminton
Squash
Football, rugby, or hockey
Netball, volleyball, basketball

Table 1 Characteristics of 2143 men and 2631 women with no history of osteoporosis or fracture, 1998-9. Values are mean (SD) unless stated otherwise

	Men	Women	P value*
Age (years)	64.6 (8.3)	62.9 (8.4)	<0.0001
Height (m)	1.74 (0.07)	1.61 (0.07)	<0.0001
Weight (kg)	81.2 (11.3)	69.1 (11.7)	<0.0001
No (%) ever smoked	1396/2123 (66)	1000/2604 (38)	<0.0001
No (%) stopped menstruating	—	1891/2552 (75)	—
No (%) ever used hormone replacement therapy	—	826/2584 (32)	—
Ultrasound attenuation (dB/MHz)	89.5 (17.5)	71.4 (16.5)	<0.0001
Speed of sound (m/s)	1645 (41)	1624 (41)	<0.0001

*Test for heterogeneity between men and women by analysis of variance for means or χ^2 for proportions.

Results

A total of 2296 men and 2914 women had a heel ultrasound measurement at the second health check and had complete data entry by May 1999. Participants who had experienced any fracture (142 men, 236 women) or who reported having had osteoporosis diagnosed by their doctor (11 men, 47 women) before the second health check were excluded from subsequent analysis due to potential bias in reporting physical activity. Table 1 shows the characteristics of the remaining 2143 men and 2631 women available for analysis.

Figure 1 shows the patterns of physical activity. The mean times spent participating in recreational activity were 9.8 (SD 12.6) hours/week for men and 6.2 (7.0) hours/week for women. Moderate impact activity accounted for most time in men and women (mean 7 (11.4) and 3.4 (4.5) hours/week respectively). Mean participation in high impact activity was identical in men and women (0.2 (1.5) hours/week), although the proportion of men who participated in any high impact activity was greater (292 (13.6%) in men *v* 244 (9.3%) in women). For men, 91% of time spent in high impact activity was accounted for by tennis and badminton (50%), competitive running and jogging (29%), and squash (12%). In women, 94% of time in high impact activity was spent participating in tennis and badminton (66%), step aerobics (16%), and competitive running and jogging (12%).

Mean time spent watching television or video was 21.9 (9.9) hours/week for men and 22.6 (10.0) hours/week for women. The median category for frequency of stair climbing was 1-5 flights a day for both men and women. More women than men reported climbing more than 10 flights a day (378 (14.4%) *v* 218 (10.2%)).

Men who reported participating in high impact activity reported climbing more stairs and watching

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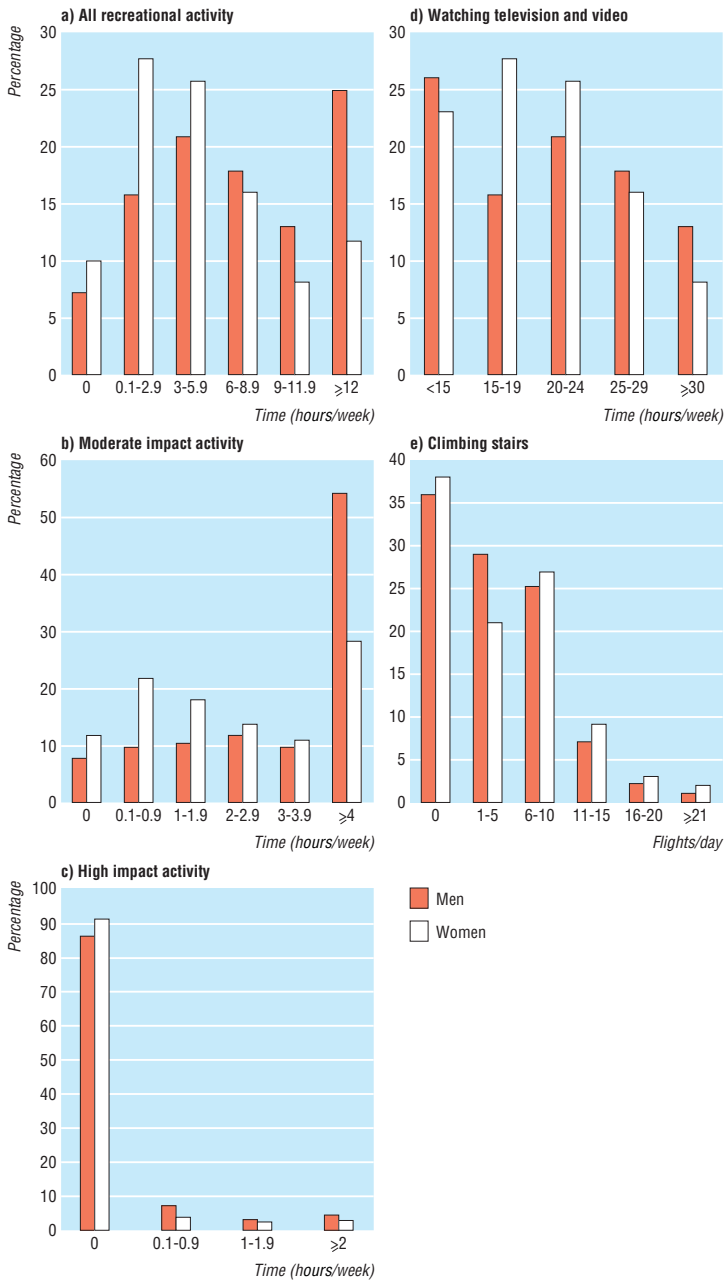

Fig 1 Self reported physical activity among men and women aged 45-74 in EPIC Norfolk cohort

less television or video than those who reported no such participation. However, there was no difference in time spent in other groups of recreational physical activity. In women, those who reported participation in high impact activities reported spending more time in total recreational activity, more time in moderate impact activities, climbing more stairs, and watching less television or video (data not shown).

Table 2 shows the linear regression coefficients for each covariate predicting ultrasound attenuation. Model 1 includes potential confounding variables (age, weight, height, and smoking status for men and women and menopausal status and use of hormone replacement therapy for women). The prediction of ultrasound attenuation for current smokers and former smokers was similar and therefore the categories were combined to form a single category "ever smoker." The only type of recreational activity positively associated with ultrasound attenuation was high impact. In men there was a significant linear relation between increasing hours of participation in high impact activity and ultrasound attenuation. In women, however, there was no dose-response relation, and the association was confined to some participation versus none. The association between high impact activity and ultrasound attenuation was unaffected by adjustment for climbing stairs and watching television or video. After people who participated in high impact activity were excluded, no association was found between time spent in moderate impact activity and ultrasound attenuation. Nor was there any association with time spent in total recreational, non-impact, or low impact activity (data not shown)

In women we found a significant negative association between the amount of time spent watching television or video and ultrasound attenuation (fig 2). The adjusted linear regression coefficient for each additional hour of television and video viewing per week was −0.08 dB/MHz (95% confidence interval −0.14 to −0.02, P=0.006). A positive and significant association was also found between number of flights of stairs climbed and ultrasound attenuation (fig 3). The regression coefficient for each additional five flights of stairs per day was 0.64 dB/MHz (0.19 to 1.09, P=0.006). The associations of ultrasound attenuation with stair climbing and television viewing were independent of each other and of participation in high impact activity. In men there was no association between time spent watching television and ultrasound attenuation (fig 2), but there was a weak association with stair climbing (fig 3). We repeated all of the analyses excluding people with prevalent rheumatoid arthritis (n=51), and the results were unchanged.

Discussion

Lower ultrasound attenuation by heel bone is associated with lower bone mineral density at the heel and at the hip.[9,10] Low ultrasound attenuation is an independent predictor of higher risk of hip fracture.[8,11] This cross sectional study supports the hypothesis that specific physical activities help maintain bone density and that physical inactivity, measured in this study by television viewing, has an adverse effect. The study design does not allow us to determine whether the relation between high impact physical activity and ultrasound attenuation reflects a higher peak bone density achieved in early adulthood or a slower rate of decline in later life. However, if our results are substantiated by prospective studies, they are likely to result in recommendations on the type of physical activity best able to slow the rate of bone loss in middle aged people. Prescribing high impact activities for older people with established osteoporosis would probably do more harm than good.

The biological basis of the association we have observed is supported by animal studies showing that activities which create diverse and unusual loading have potent osteogenic potential.[15–17] Similar studies are difficult in human populations because of the problems of measuring loading at the site of interest.

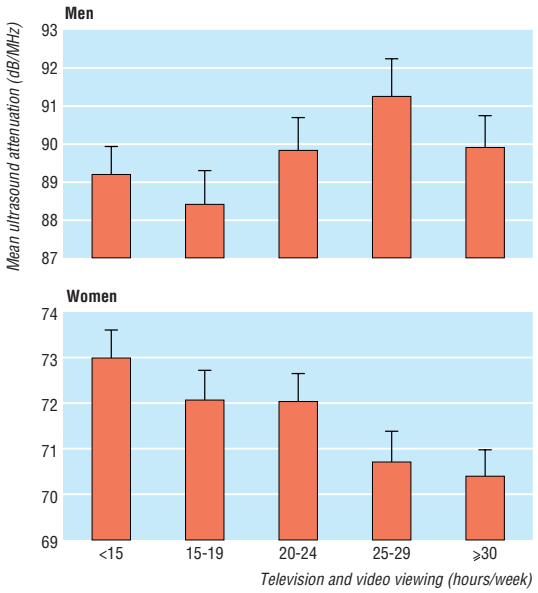

Fig 2 Mean (SE) ultrasound attenuation according to hours of television and video viewing adjusted for age, weight, smoking history, and ultrasound machine for men and women plus menopausal status and hormone replacement therapy for women

Table 2 Linear regression coefficients for ultrasound attenuation (dB/MHz) in men and women aged 45-74 for models based on covariates and time in high impact activity

	Men		Women	
	Regression coefficient (95% CI)	P value	Regression coefficient (95% CI)	P value
Model 1—confounding factors:				
Age (years)	–0.09 (–0.17 to 0.01)	0.07	–0.59 (–0.67 to –0.50)	<0.001
Weight (kg)	0.20 (0.13 to 0.27)	<0.001	0.38 (0.33 to 0.43)	<0.001
Height (m)	0.08 (–0.04 to 0.20)	0.2	0.11 (0.02 to 0.20)	0.01
Never smoker	2.46 (–0.05 to 4.97)	0.05	2.52 (0.60 to 4.44)	0.01
Stopped menstruating	—	—	–4.40 (–5.99 to –2.82)	<0.001
Never used hormone replacement therapy	—	—	–3.84 (–5.06 to –2.63)	<0.001
Constant	63.04 (41.54 to 84.53)	<0.001	76.25 (60.63 to 91.88)	<0.001
Model 2—Time in high impact recreational activity (hours/week)*:				
0.1-0.9	3.27 (0.33 to 6.20)	0.03	3.07 (0.37 to 5.78)	0.03
1-1.9	6.72 (2.26 to 11.19)	0.003	2.14 (–1.51 to 5.79)	0.3
≥2	8.40 (4.49 to 12.32)	<0.001	1.33 (–2.20 to 4.86)	0.5
Model 3—Time in high impact recreational activity (hours/week)†	2.97 (1.85 to 4.08)	<0.001	0.87 (–0.10 to 1.84)	0.08
Model 4—Participated in high impact recreational activity (yes *v* no)	5.39 (3.15 to 7.63)	<0.001	2.36 (0.42 to 4.31)	0.02

Coefficients in models 2-4 were calculated including the confounding variables in model 1. All models include adjustment for machine.
*Reference category 0 hours.
†Linear trend for ordered categories of model 2.

However, activities such as running and landing from a jump generate external loads on the body of 3-10 times body weight,[18] and such external loads have been correlated with internal forces in the femur.[19]

Potential bias

We reduced the potential for recall bias by excluding people with osteoporosis or fracture who may have recalled physical activity differently as a consequence of a disease label. Confounding has also been diminished by adjustment for age, weight, height, smoking habit, menopausal status, and use of hormone replacement therapy. Given the imprecision of the assessment of physical activity as well as ultrasound attenuation, it was surprising that we found significant relations; random measurement error is likely to underestimate the true association.

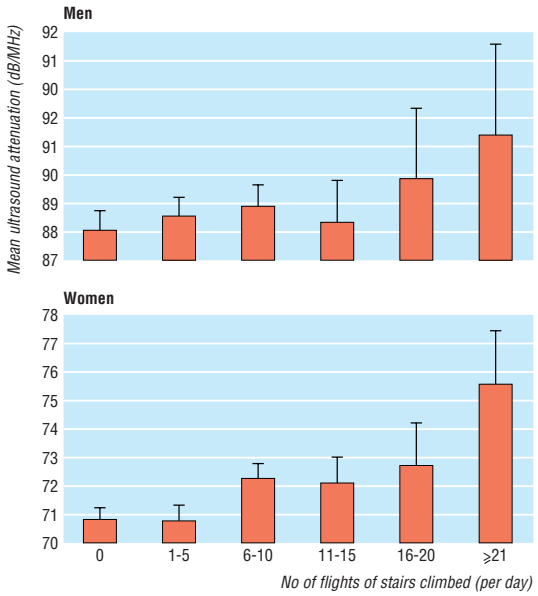

Fig 3 Mean (SE) ultrasound attenuation according to frequency of climbing stairs adjusted for age, weight, smoking history, and ultrasound machine for men and women plus menopausal status and hormone replacement therapy for women

Implications

The association that we observed was large. In men, an additional hour per week doing high impact activity had the same effect on ultrasound attenuation as an extra 3 kg in body weight. For women the effect of regular participation in high impact activity was the same as the effect of a difference in age of four years. The association is important because it may reflect the future risk of fracture. In prospective studies, 1 SD higher ultrasound attenuation by the heel bone was associated with a reduction in relative risk of future hip fracture of about a half.[8] In our study, the difference in ultrasound attenuation in men who participated in ≥2 hours per week of high impact activity compared with those who did none was 0.48 of 1 SD, which might be translated into a 33% reduction in risk of hip fracture. Among women, the difference between those who did and did not participate in high impact activity was 0.15 of 1 SD, which would translate to a relative risk reduction of 12%.

The differences in our results between men and women might be explained by differences in overall physical activity. Women who participated in high impact activity also spent more time participating in other recreational activities, whereas men who reported participation in high impact activity tended to do so more exclusively. However, among people who did no high impact activity, we were unable to demonstrate an association between moderate activity and ultrasound attenuation. The association between

What is already known on this topic

Low ultrasound attenuation at the heel is associated with low bone mineral density at the heel and the hip and is associated with a higher risk of hip fracture

Physical activity is associated with bone density, but it is unclear which aspects of this complex multidimensional exposure are most important

What this study adds

Participation in high impact recreational activity was independently associated with higher ultrasound attenuation at the heel

There was no association with moderate or low impact physical activity

Women who reported watching more television had lower ultrasound attenuation

television viewing and ultrasound attenuation was significant only in women. This may either be a manifestation of true differences between the sexes or reflect variation in how television viewing is a surrogate indicator of physical inactivity in men and women.

These results support the development of preventive physical activity interventions that have an element of airborne projection and impact. Such interventions are inappropriate in an elderly cohort because they require a level of activity that might be poorly tolerated and have detrimental health effects at a population level.[20] However, if these interventions were aimed at a population with an adequate degree of muscle strength and balance, such as younger women,[21] they could reduce the rate of bone loss.

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Contributors: K-TK, NED, and SB originated and designed the EPIC-Norfolk population study. K-TK and JR introduced ultrasound measurement of the heel bone. ND contributed to data collection and quality assurance for ultrasound measurements in collaboration with JR. NJW introduced the assessment of physical activity. SO is study coordinator and organised data collection and measurement procedures. AW contributed to data collection. RL is responsible for data management and computing overall and assisted with analyses. RWJ conceived and conducted the data analysis with NJW. RWJ wrote the paper with NJW, who is the guarantor.

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