A pilot investigation of load-carrying on the head and bone mineral density in premenopausal, black African women

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ABSTRACT

Although the influence of weight bearing activity on bone mass has been widely investigated in white women, few studies have been conducted in black, African populations. We investigated bone mineral density (BMD) in black South African women, with and without a history of load-carrying on the head. We also investigated whether load carrying may offer protection against low BMD in users of injectable progestin contraception (IPC). Participants were 32 black, South African women (22.4±3.2 yrs). Load carrying history was determined by questionnaire and interview and participants were grouped as load carriers (LC; n=18) or non load carriers (NLC; n=14). Ten women were using IPC and 6 were load-carriers. Total body (TB), lumbar spine (LS) and total hip (H) BMD were measured by dual energy X-ray absorptiometry. There were no differences in BMD between LC and NLC, and after controlling for age and BMI using two-tailed partial correlations. IPC users had lower BMD at all sites compared to non IPC users ($p<0.05$) and there were no associations between load carrying and BMD in this group. When IPC users were excluded from analysis, LC had higher LS BMD than NLC ($p<0.005$). Correlations were found between the weight of load carried and LS BMD ($r=0.743$, $p<0.005$), and between years of load carrying and LS and TB BMD ($r=0.563$, $r=0.538$ respectively; both $p<0.05$). Load carrying on the head may offer osteogenic benefits to the spine but these benefits did not appear in women using IPC.

Key words Bone density ˙ Spine ˙ Weight-bearing activity ˙ Contraception ˙ Premenopausal women

Introduction

Loading of the skeleton through weight-bearing activity, is widely recognised as a major and modifiable prophylaxis against osteoporosis with positive outcomes for both peak bone mass and the preservation of bone mass [1-6]. There have been numerous studies which have investigated the effects of loading activities (primarily physical activity and exercise) on bone mass, predominantly in white populations [2-6]. There is less information available concerning the effects of loading on bone for those living in developing countries such as South Africa. Interestingly, based on the limited information available, fracture incidence appears to be lower in black compared to white South Africans [7, 8]. There have also been reports of higher BMD in black compared to white South Africans [9], in addition to superior bone architecture such as increased cortical thickness [10, 11].

Bone adapts functionally to loading, and effects are site-specific [12]. Evidence that weight-bearing activity can have a positive effect on bone health in children and adults has accumulated from cross sectional, retrospective, prospective and intervention studies [2-6]. Amongst Caucasians, there are reports of higher bone mass in athletes than non athletes [2, 3], greater increases in the bone mass of active individuals compared to those who are less active [4] and increases in bone mass in response to targeted exercise interventions [5, 6]. To date and as far as we are aware, few studies have investigated the effect of physical activity on bone in black African groups [13-16]. These studies have found lower levels of physical activity in black South Africans [15, 16] and only negligible [14] or no associations with BMD [16].

Vertebral fractures are a common consequence of osteoporosis, because of the higher trabecular bone content. However, the spine can be problematic to target through conventional weight-bearing physical activities. Load carrying on the head is a traditional lifestyle activity carried out by many black South African women, and provides downward, vertical loading to the spine. No study has yet investigated the effects of long term load carrying on BMD in black African women, but to do so could offer valuable insights into the effect of targeted loading on the spine. Therefore, the primary aim of this study was to investigate BMD in premenopausal, black South African women of Xhosa origin, who were load carriers or non-load carriers. Secondly, the use of progesterone-only containing contraception is wide spread in South Africa, and is associated with detrimental effects on bone metabolism and BMD at several anatomic sites in white, black and mixed race young women [17, 18]. In longitudinal studies, BMD generally decreases more over time among depot medroxyprogesterone acetate (DMPA) users than among nonusers [19]. For this reason, we also investigated whether load carrying on the head could offer protection against injectable progestin contraception (IPC) induced bone loss.

Methods

Design

We conducted a retrospective study in 32 premenopausal black women of Xhosa origin in South Africa, to investigate the association between load carrying on the head and BMD. We also investigated the effect of load carrying on BMD in women using IPC. The two main grouping variables were load carrying on the head and use of IPC.

Participants

Participants were recruited by notices which were displayed around the campus of the Cape Peninsula University of Technology. The majority of head load carriers were recruited by word of mouth from friends at the University, and lived in Khayelitsha, a large township on the outskirts of Cape Town. The women were aged between 18 and 31 years and of Xhosa origin. Pregnant women were excluded from the study. Women using IPC were included in the study to enable investigation of the potential protective effects of load carrying against IPC-related low BMD. The mean duration of concurrent use of IPC was 4.6 ±1.9 years. The study was approved by the University of Abertay Dundee Research Ethics Committee and the Cape Peninsula University of Technology Research Ethics Committee and all participants signed informed consent.

Load carrying history assessment

All women completed both a questionnaire in addition to an interview with an interpreter present to determine load carrying history, and detailed information on load carrying on the head throughout life was recorded. Load carriers were defined as women who had been carrying loads of at least 5kg on their head, for at least 5 consecutive years.

Eighteen women were defined as head load carriers. Thirteen women currently carried loads of up to 30kg on their heads, and the remaining 5 women had stopped carrying loads over the preceding 4 years (1-4 years). These women were included in the study because they had been carrying loads of between 5 and 30 kg during childhood, adolescence and into young adulthood, and weight bearing activity at this time is associated with particularly beneficial effects for the accumulation of peak bone mass [20]. Nine of the 13 women who still carried loads had reduced the frequency of their load carrying over recent years, to load carrying in school holidays which accounts for 3 months of the year. Again these women were included in the study because of their load carriage history during childhood and adolescence, carrying loads around 2-4 times per day (2 times per week to daily). The majority of women had started load carrying on the head by the age of 10 years (n=15, 5 – 10 years). One woman had started load carrying at the age of 14 years and one at the age of 15 years.

A piloted questionnaire (not published), was used to obtain information on medical history (including use of medications, menstruation, contraception, and fracture incidence), current physical activity (in addition to head load carrying and walking for transport) and average dietary intake of milk (number of servings of 100ml milk per week). All women reported daily walking for transport. Ten women reported using IPC (depot medroxyprogesterone acetate or norethisterone oenanthate).

Anthropometrical and bone mineral density testing

Physical measurements were made with subjects wearing a hospital gown and all metal artefacts removed. Total body, anteroposterior lumbar spine (L2 to L4) and total hip BMD were measured using dual energy X-ray absorptiometry (DXA) (Discovery W, Hologic Inc. US), at the University of Cape Town/MRC Research Unit for Exercise and Sports Medicine, South Africa. Machine calibration checks were carried out on a daily basis. All scanning and analyses were made by a trained operator and intra-observer variation was 0.87% at the hip and 0.98% at the lumbar spine. Absolute BMD values were used in the analysis, and were also converted to T-scores, and in accordance with the International Society Clinical

Densitometry Position Stand [21] we use the term low BMD for a T-score < -1.0. Independently of which classification system is used the T-score gives an indication of future fracture risk. Percent body fat and fat-free soft tissue mass (kg) (FFM) was derived using DXA of the total body. Height was measured and recorded to the nearest millimetre (Scales 2000, South Africa). Body mass was measured and recorded in kg to the nearest 0.1 kg (Scales 200, South Africa). Body mass index (BMI) was calculated as body mass / (height) ^{2} (kg m^{-2}).

Statistical analysis

Statistical analysis was performed using SPSS, version 16.0 (LEAD Technologies Inc©). The Kolmogorov-Smirnov test showed that all data were normally distributed. Descriptive results are presented as the mean and standard deviation (SD). Participants were grouped according to load carrying and use of IPC as follows: *all women, load carriers v non load carriers; IPC users v non-IPC users, non IPC users- load carriers v non load carriers*. Comparisons between two groups were made using independent samples t-tests. Further analysis of groups by weight of load carried utilised a one-way analysis of variance (ANOVA), followed by Tukey's HSD post-hoc test. Due to the size of the subject sample, it was not valid to compute 2-way ANOVA. To test for correlations between variables, Pearson's product moment correlations were used, and the variables were age, body mass, BMI, FFM, age at menarche, level of and years of load carrying on the head, and years of concurrent use of IPC. These correlations were performed for the total group and according to load carrying on the head (grouped yes or no) and use of IPC (grouped yes or no). To control for age and BMI, two-tailed partial correlations were computed using SPSS, between BMD and other variables. Probability values less than 0.05 were considered significant.

Results

The demographic results for all women are shown in Table I. The women were aged between 18 and 31 years and mean age of menarche was 13.6 ±2.0 years. Seventeen women (53%) had low lumbar spine BMD (T-score <-1.0), 10 women (31%) had low total body BMD and 4 women (13%) had low hip BMD (T-score <-1.0). Only 2 participants reported taking part in physical activity other than load carrying, at least twice per week.

BMD and other variables in load carriers and non load carriers (all women)

Table 1 shows the differences in variables between load carriers and non load carriers, for all women (including IPC users). In load carriers, the mean ±SD number of years of load carrying was 9.42 ± 5.5 years. Load carriers and non load carriers were similar in age, BMI and FFM. There were no significant differences in BMD between load carriers and non load carriers. Women who reported carrying the heaviest loads (20kg to 30 kg) (n=14) had greater total body BMD and T-scores than non load carriers (1.101 *v* 1.007, p=0.03; 0.0 *v* -0.4, p=0.04).

Table 1. Descriptive results for all women, head load carriers and non head load carriers mean ±SD

	All women (n=32)	**Load carriers (n=18)**	**Non load carriers (n=14)**
Age (yrs)	22.4 ±3.2	22.9 ±2.9	21.8 ±3.5

BMI (kg.m^{-2})	26.1 ±5.4	25.4 ±5.1	26.9 ±5.7
Fat-free soft tissue mass (kg)	37.1 ±4.7	36.8 ±4.6	37.6 ±5.1
Total body T-score	-0.4 ±1.0	-0.1 ±0.9	-0.6 ±1.2
Total body BMD (g.cm^{-2})	1.074 ±0.09	1.10 ±0.09	1.05 ±0.10
Lumbar spine T-score	-0.9 ±0.9	-0.7 ±0.9	-1.2 ±0.9
Lumbar spine BMD (g.cm^{-2})	0.986 ±0.09	1.005 ±0.10	0.958 ±0.09
Total hip T-score	0.1 ±0.8	0.15 ±0.8	0.06 ±0.8
Total hip BMD (g.cm^{-2})	0.957 ±0.10	0.963 ±0.09	0.950 ±0.10

There were no significant differences in variables between groups, p>0.05

BMD and load carrying in IPC use

Results for participants who were using IPC were computed in separate analyses. IPC users had been using injectable progesterone-only contraception for 4.6 ±1.9 years and 6 IPC users were grouped as load carriers. There were no differences in age, BMI, or fat free soft tissue (p>0.05). Similarly, there were no differences in BMD between IPC load carriers and non load carriers, at the total body (1.103 *v* 1.102 g cm^{-2}), lumbar spine (1.040 *v* 1.006 g cm^{-2}) and hip (0.981 *v* 1.008 g cm^{-2}) (all p>0.05).

IPC users and non-IPC users were similar in age, BMI and FFM. BMD was lower in IPC users compared to non IPC users at the total body (1.033 *v* 1.131 g cm^{-2}; p<0.05), lumbar spine (0.929 *v* 1.050 g cm^{-2}; p<0.005) and hip (0.892 *v* 1.021 g cm^{-2}; p<0.05).

Differences in variables for non IPC users: load carriers v non load carriers

In order to remove the confounding influence of IPC on BMD, differences in variables between head load carriers and non carriers were computed in women after excluding those who used IPC (Table 2). There were no differences between load carriers and non load carriers in age, BMI or FFM. Lumbar spine BMD was significantly greater in load carriers compared to non load carriers ($p<0.001$).

Table 2. Differences in variables for non IPC users (n=22): load carriers *v* non load carriers, mean ±SD

	Load carriers (n=12)	**Non load carriers (n=10)**
Age (yrs)	22.5 ±1.8	20.5±2.5
BMI (kg.m-2)	26.5 ±6.1	28.0 ±5.0
Fat free soft tissue (kg)	37.2 ±4.7	37.5 ±4.4
Total body T-score	0.3 ±0.8	-0.4 ±0.9
Total body BMD (g cm^{-2})	1.071 ±0.07	1.126 ±0.08
Lumbar spine T-score	0.0 ±0.5	-1.1 ±0.5 *
Lumbar spine BMD (g cm^{-2})	1.079 ±0.06	0.962 ±0.05 *
Total hip T-score	0.2 ±0.7	0.5 ±0.8

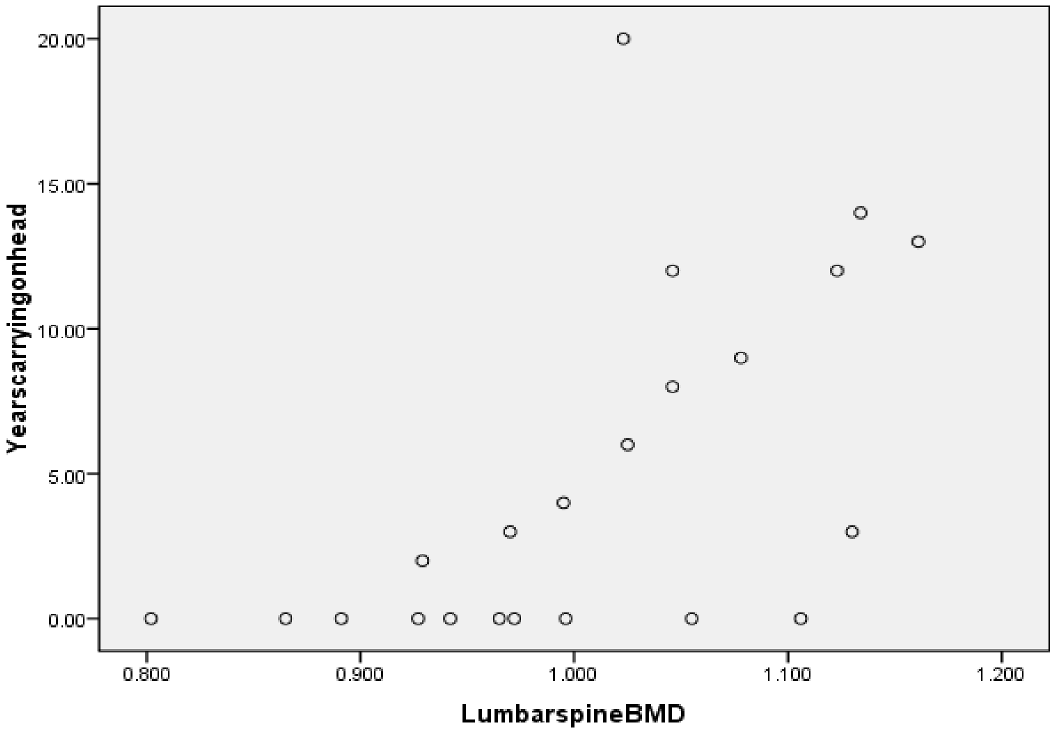
Total hip BMD (g cm^{-2})	0.969 ±0.09	1.005 ±0.09

**p<0.001*

Relationships between dependent and independent variables

Bivariate tests computed for all participants indicated a positive relationship between BMI and hip BMD (r =0.375, p<0.05) but not spine or total body BMD. There were no correlations between other independent variables including weight of load and years of load carriage and BMD. There were negative correlations between the total number of years using IPC and lumbar spine BMD (r = -0.460, p<0.05) and hip BMD (r = -0.632, p<0.005). There were no correlations observed between the weight of load carried on the head and BMD in women who used IPC.

Figure 1: Bivariate plot illustrating the association between years of load carrying on the head and lumbar spine bone mineral density (BMD, g cm^{-2}) in women who did not use injectable progestin contraception



r = 0.564, p<0.05

Following exclusion of women who used IPC from the analyses, significant positive correlations were detected between the weight of load carrying on the head and lumbar spine BMD (*r*=0.743, p<0.005), and between years of load carrying on the head and total body BMD (*r* =0.637, p<0.05) and lumbar spine BMD (*r* =0.564, p<0.05) (Figure 1), but not hip BMD.

Discussion

To our knowledge, this is the first study which has investigated associations between load carrying on the head and BMD in premenopausal black, African women. We found significantly greater BMD at the spine in load carriers compared to non load carriers, but only following the exclusion of IPC users from the analysis.

A significant association between load carrying on the head and BMD was found at the spine which may reflect a site-specific, osteogenic response to loading. Load carrying on the head is a weight-bearing activity which produces downward, vertical forces through the spine. The lack of correlation between load carrying and hip BMD suggests that the loading generated does not provide the optimum stimulus for an osteogenic response at that site. It is likely that the hip would be more responsive to loads generated from upward vertical forces from activities such as jumping. The low lumbar spine BMD found in non load carriers (T-score -1.1), despite not using IPC, did not extend to the hip. Mean hip BMD for non ICP users who were load carriers and non-load carriers was normal (T-score 0.2 and 0.5 respectively), and this may reflect a beneficial influence from daily walking, which was performed by all women.

The magnitude of loading is an important determinant of the skeletal response to loading [20, 22]. We found greater total body BMD in women who reported carrying the heaviest loads of 20-30 kg, although this did include the majority of the load carriers (n=14). The greater number of years of load carrying on the head was associated with higher BMD at the total body and spine, supporting findings elsewhere that weight bearing activity should be continued in order to provide continual bone anabolic effects [23]. However, new evidence also suggests that bone mass gains from just 7 months of high impact weight-bearing exercise in children is maintained up to 8 years following cessation of the exercise [24]. Weight-bearing activity during growth has been shown to be particularly beneficial to the attainment of peak bone mass [5, 6, 19]. In this study, all but 2 load carriers reported carrying loads on the head from a young age (<10 years), throughout childhood and adolescence.

Weight-bearing activity is a modifiable factor which can positively influence bone health, and it is universally recommended as an effective strategy to optimise peak bone mass accrual and the maintenance of bone mass in later life. Whilst load carrying on the head was a functional weight-bearing activity performed by 18 women in this study, the majority of women had in recent years reduced the frequency of load carrying to school/college holidays. Furthermore, from our preliminary investigation, reported levels of recreational physical activity were low. Only 2 women reported taking part in regular physical activity (aerobics and surfing) other than load carrying and walking for transport. Findings elsewhere suggest that recreational physical activity levels are lower in black South African populations [13, 15, 16]. Further retrospective and prospective research is required to characterise and quantify levels of physical activity in young, black African women, and investigate relations with bone health.

The use of IPC is widespread in South Africa, and in this study, 10 women (31% of the total sample) reported using IPC. The primary action of progesterone-only contraception is the prevention of ovulation through the reduced pulse frequency of gonadotropin-releasing hormone, and the consequential reduction in secretion of follicle-stimulating hormone (FSH) and lutenising hormone (LH). The decrease in FSH prevents an increase in oestradiol, and this can disrupt bone metabolism leading to bone loss. Our findings appear to confirm the negative association between use of IPC and BMD [17]. Whilst it is established that IPC has negative consequences for bone, the potential for weight-bearing activity to protect against IPC-related skeletal deficit had not been previously examined. Our preliminary observations indicate that load carrying on the head was not sufficient to counteract the hormonal influence of IPC which can adversely affect bone. Factorial randomised trials of load carrying on the head and contraception are required to definitely answer this question.

This study reports cross sectional and retrospective data from black South African women of Xhosa origin, and may not be applicable to other populations and is reliant upon the information provided by the participants. As this was a pilot study, the number of participants was small (n=32), and further research using larger sample sizes would be warranted to expand knowledge in this area of bone health.

To conclude, this study has found that load carrying on the head, practised by many black South African women, may offer osteogenic benefits to the spine. However, these benefits may not extend to women using IPC, suggesting that the loading generated is insufficient to counteract hormonal influences on bone. Further research using larger sample sizes, and of prospective or interventional design, is required in black, African populations.

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