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Original Article

Effect of level of farm mechanization early in life on bone later in life

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Abstract

Objective: To determine whether an active rural lifestyle during childhood and adolescence, defined as low farm mechanization, was associated with bone measures later in life. **Methods:** DXA bone data from total body, hip and spine, and pQCT data from 4% and 20% distal radius were obtained on 330 individuals (157 women) aged 20-66 years who farmed at least 75% of their lives. Primary bone outcomes included areal bone mineral density (aBMD), aBMD Z-scores, cortical and trabecular volumetric BMD, cortical thickness and periosteal circumference. Relationship between bone and recall of level of farm mechanization as a child was determined after stratifying by sex and controlling for covariates. **Results:** Controlling for covariates, females from low mechanized farms had higher femoral neck (FN) bone area (p=0.03) than those on high or moderate mechanized farms. No group differences in pQCT ulna measurements or z-scores were found in either gender. **Conclusion:** A low farm mechanization level (high physical activity) prior to 20 years of age is associated with greater FN bone area in females. Future research that includes type and amount of physical activity performed will contribute to growing knowledge of how and when regular physical activity during childhood and adolescence affects adult bone health.

Keywords: DXA, pQCT, Rural, Physical Activity, Children

Introduction

Osteoporosis and related fractures are major health concerns and lead to billions of dollars in health care costs[1]. A 2005 meta-analysis of the relationship between bone mineral density (BMD) and fracture risk indicates that at age 65, for each standard deviation decrease in femoral neck areal BMD (aBMD), the risk ratio for hip fracture is increased by 2.94 in men and 2.88 in women[2]. BMD is affected by both genetic and environmental factors[3], so it is important to maximize the effects of positive environmental variables, such as physical activity. Increasing bone mass during childhood through physical activity could possibly reduce osteoporosis and related fractures later in life.

Physical activity is associated with bone outcomes, and this is apparent in both male and female children and adolescents[4,5]. Research in both elite and non-elite child and adolescent athletes also shows that those who participate in high impact loading sports have higher aBMD at a number of sites, as well as higher spine BMC than controls and athletes in low impact loading sports[6-14]. Regarding racquet sports, marked bone asymmetry between the dominant and non-dominant arms was seen in pre- and early pubertal children who played tennis[15,16], further indicating physical activity affects bone. Some research suggests that the benefits accrued from participating in high impact sports during childhood and adolescence may be retained into adulthood, even though adult activity levels and intensity decreased[15-20], while others suggest increases are lost when activity ceases[21-23]. Similarly, exercise interventions have demonstrated that BMD in children and adolescents can be increased above that of controls[24-26]. In addition to high-impact and weight-bearing activity interventions, interventions specifically using jumping activities have been assessed for their effect on bone in children and adolescents and yield similar results as other exercise-based intervention studies[27-31].

Less is known about the effect of regular activity levels during childhood and adolescence on adult bone, and research on the topic provides mixed results – in part because of different

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definitions of physical activity and differences in the methods used to assess bone. Moderate levels of historical leisure time activity have been associated with spine and proximal femur aBMD[32] and bone area in postmenopaual women[33]. Conversely, other studies in men and women have shown no association between lifetime leisure and occupational activities and BMD[34,35]. In South Africans, studies have shown weak significant associations between occupational physical activity during adolescence and BMD[36] and associations between impact loading activities during adolescence and BMD later in life[37]. Although some studies longitudinally examine the relationship between physical activity and bone density, they do not draw associations between previous physical activity and current bone density[38-40].

The purpose of this study was to determine whether an active rural lifestyle during childhood and adolescence, defined as low farm mechanization, is associated with bone measurements later in life. Based on previous findings we hypothesized that if increased physical activity prior to 20 years of age leads to bone differences in adulthood, rural participants who lived on farms with low mechanization during childhood and adolescence would have higher aBMD at one or more sites, and greater trabecular vBMD, cortical thickness and periosteal circumference than rural participants who lived on farms with moderate or high mechanization during childhood. We also investigated differences in other bone measurements such as BMC and bone area.

Subjects and Procedures

Subjects

The South Dakota Rural Bone Health Study (SDRBHS) is a longitudinal study of 1,271 healthy adults aged 20 to 66 years[41]. Of the 1,271 participants enrolled between 2001 and 2004, 585 were Hutterite Brethren, 350 were classified as rural non-Hutterites, and 336 were classified as non-rural, non-Hutterites. These populations are described in detail elsewhere[41]. The current study includes only the 350 individuals (166 females) classified as rural, non-Hutterites. Briefly, to be considered as rural the subject had to have spent 75% or more of his or her life on a working farm while working less than 1,040 h/year off the farm. Rural participants were recruited by calling all individuals who owned land zoned agricultural in 8 counties in eastern South Dakota. Individuals with uncontrolled type I diabetes, parathyroid disease, or chronic regular use (>6 months) of oral steroids, anticonvulsants, or immunosuppressants were not eligible for the study, and none of the participants were taking bisphosphonates. Since estrogen status is a potential covariate for females, we categorized women as either replete (N=114; pre-menopausal or post-menopausal and receiving hormone replacement therapy (HRT)) or deplete (N=43; post-menopausal and no HRT) based on self-reported information. There were 5 women who stated that they had a menstrual cycle in the past 12 months but self-reported themselves as menopausal. These women were included in the estrogen-replete group. Two women were excluded from analysis due to possible effects of lactation, and 11 men and 7 women were excluded because they did not answer the farm mechanization level question. Following these exclusions, data from 157 female and 173 male rural non-Hutterites were analyzed.

Procedures

Data collected at baseline included anthropometric and grip strength measurements, a 24-hour diet recall, and a 7-day activity recall. Body composition outcomes, bone measurements and corresponding Z-scores of the total body, spine and hip were measured using a Hologic QDR 4500A (Waltham, MA, USA). Two-dimensional measures of areal BMD (aBMD, g/cm^2), bone mineral content (BMC, g) and bone area (cm^2) were determined, and sex-specific T- and Z-scores were obtained from the Hologic reference data sets. The coefficients of variation (CV) at our institution for total body, spine and hip aBMD measured by QDR 4500A in adults are 1.3% or less. Peripheral quantitative computed tomography (pQCT; Norland-Stratec XCT 2000) measurements of cortical area (mm^2), cortical volumetric BMD (vBMD, mg/ccm), periosteal circumference (PeriC, mm), and cortical thickness (mm) at the 20% distal radius, and total cross-sectional area (CSA, mm^2) and trabecular vBMD(mg/ccm) at the 4% distal radius of the left arm were obtained. Arm length was measured once from the elbow to the ulna styloid process. A scout view was taken and a reference line was set to identify the endplate of the radius. Slice views were taken at 4 and 20% of the measured arm length from the reference line. Slices were obtained using a voxel size of 0.4 mm and scan speed of 30 mm/second with a 1-block rotation. The slices were analyzed using ContMode2, PeelMode 2 and a threshold of 400 mg/cm^3 for trabecular bone (4% site only). Cortical bone was identified using CortMode 1 with a density threshold of 710 mg/cm^3 at the 20% site. The circular ring model was used for both periosteal circumference and cortical thickness measurements. CV's in our laboratory for trabecular bone measures are 4% or less and CV's for cortical bone measures are 1% or less based on duplicate scans with repositioning in 11 adults.

Height without shoes and weight with light clothing were determined with a portable stadiometer (SECA) and digital scale (SECA, Model 770). Height measurements, recorded to the nearest 0.5 cm, were taken in duplicate and repeated if they differed by more than 0.5 cm. Weight was recorded to the nearest 0.1 kg. Grip strength measurements, which have been shown to be significantly associated with pQCT bone measurements[41], were made on each participant as both a measure of arm strength and as an indicator of overall fitness level. Grip strength was measured using a digital GRIP-D grip strength dynamometer (Takei Scientific Instruments Co., Ltd., Tokyo, Japan). The dynamometer was fit to the hand size of the participant. While standing, the participant held the dynamometer in his or her dominant hand, with the arm relaxed and extended downward, and was instructed to squeeze the instrument as hard as possible for 1 second. Each measurement was made in triplicate and the highest value recorded.

A twenty-four-hour dietary recall interview was obtained.

	Mechanization Level			
	Low	**Moderate**	**High**	**p value**[1]
Females (N)	47	96	14	
Age (years)	51±11	47±14	42±16	**0.05**[3]
Number of live births	3.1±1.6	2.8±1.9	1.9±2.1	NS
Age at first menses (y)	13.1±1.6	13.0±1.4	13.2±1.2	NS
Estrogen Status (Replete/Deplete)	32/15	71/25	11/3	NS[4]
Anthropometrics				
Weight (kg)	78.5±15.3^{a}	73.2±14.6	68.0±11.2^{a}	**0.03**
Height (cm)	164.5±6.1	164.3±5.9	164.1±6.6	NS
Total body % fat	37±6	35±6	33±6	NS
Lean Mass (kg)	48±6^{a}	45±6	42±6^{a}	**0.01**
Fat Mass (kg)	30±10^{a}	26±10	23±7^{a}	**0.02**
Grip Strength (kg)	32±6^{a}	30±6	28±5^{a}	**0.03**
% Time moderate+vigorous activity	28±15	24±12	29±12	NS
Sleep/Weekday (hours)	7.4±1.2	7.4±1.0	7.0±1.0	NS
Years Farming	47±12	43±14	38±16	NS
Calcium intake (mg/day)	1260±812	1037±756	1024±477	NS
Vitamin D intake (IU/day)	328±293	293±278	343±290	NS
Males (N)	34	121	18	
Age (years)	48±14^{a}	45±13	38±16^{a}	**0.02**
Anthropometrics				
Weight (kg)	102.7±22.5^{a}	93.0±15.3^{a}	91.3±18.2	**0.01**
Height (cm)	178.3±7.9	178.7±7.4	178.2±7.8	NS
Total body % fat	26±6^{a}	23±6^{a}	24±7	**0.03**
Lean Mass (kg)	71±8	68±8	67±8	NS
Fat Mass (kg)	27±11^{a}	22±8^{a}	23±12	**0.02**
Grip Strength (kg)	49±9	52±9	50±9	NS
% Time moderate+vigorous activity	23±13	26±13	21±13	NS
Sleep/Weekday (hours)	7.0±1.3	7.1±1.0	6.8±1.2	NS
Years Farming	46±14^{a}	43±13	35±16^{a}	**0.02**
Calcium intake (mg/day)	1112±760	1202±753	1499±856	NS
Vitamin D intake (IU/day)	265±281	262±241	282±261	NS

[1] *p value determined by one-way ANOVA*

[2] *Means with similar superscripts are different at $p<0.05$ (Tukey HSD for multiple comparisons).*

[3] *No difference among groups using Tukey HSD*

[4] *Chi-square*

Table 1. Characteristics of study populations by sex. Data are mean ± SD[2].

Nutrient intakes, including vitamin and mineral supplements, were determined using the Nutritionist V software (First DataBank, San Bruno, CA). Calcium (mg/d) and vitamin D (IU/d) intakes were the main outcomes obtained from the dietary recall. Current activity levels were measured using a Seven-Day Physical Activity Recall (SDPAR)[42], which was modified to include examples consistent with a rural lifestyle. The SDPAR requires the participant to determine the average amount of time spent per day sleeping, sitting, or in vigorous or moderate activity during the previous week. The remaining time was classified as light activity. Vigorous activity was considered as any activity that leads to an increase in heart rate or heavy breathing and included such activities as running, brisk walking and shoveling. Moderate activity was considered as an activity that required significant movement but did not noticeably increase heart rate or result in heavy breathing. Activity patterns for both week days and weekend days were included, and the number of days per week considered weekend days also was obtained. The average daily percent of time spent in moderate plus vigorous activity was then calculated.

Farm mechanization level was assessed using a questionnaire developed by SDRBHS staff. The questionnaire addressed primary agricultural operations at 0-20 years of age, 21-40 years of age, and 41-current years of age. The participant was asked to subjectively categorize the operation as low, moderate or high mechanization for each of the age groups relative to other farms located near them. A highly mechanized operation means most of the work is done with machines, while a low mechanization level means there is little use of farm machinery. Finally, the participant answered ‘Yes’ or ‘No’

	Mechanization Level			
	Low	**Moderate**	**High**	**p value**
Females		**BMC (g)**		
Femoral Neck	4.09±0.08	4.14±0.05	3.92±0.14	NS
Total Hip	33.0±0.58	32.8±0.40	31.8±1.09	NS
Spine	64.9±1.6	66.8±1.2	67.3±2.8	NS
		Bone Area (cm^2)		
Femoral Neck	5.09±0.05^{a}	5.07±0.04^{b}	4.81±0.09^{ab}	0.03
Total Hip	33.8±0.4	33.4±0.3	32.4±0.7	NS
Spine	59.8±0.7	60.0±0.5	59.5±1.2	NS
		Areal BMD (g/cm^2)		
Femoral Neck	0.81±0.02	0.81±0.01	0.82±0.03	NS
Total Hip	0.95±0.02	0.95±0.01	0.94±0.03	NS
Spine	1.03±0.02	1.05±0.01	1.06±0.04	NS
Femoral Neck Z-Score	0.45±0.14	0.52±0.09	0.53±0.26	NS
Total Hip Z-Score	0.66±0.13	0.68±0.09	0.57±0.24	NS
Spine Z-Score	0.72±0.16	0.96±0.11	1.04±0.32	NS
Males		**BMC (g)**		
Femoral Neck	5.12±0.12	5.12±0.07	5.10±0.16	NS
Total Hip	49.1±1.1	47.1±0.7	47.5±1.5	NS
Spine	79.1±2.3	76.7±1.2	76.9±3.3	NS
		Bone Area (cm^2)		
Femoral Neck	5.90±0.06	5.89±0.03	5.98±0.08	NS
Total Hip	46.5±0.6	45.7±0.3	46.1±0.8	NS
Spine	72.2±0.8	70.5±0.4	70.9±1.2	NS
		Areal BMD (g/cm^2)		
Femoral Neck	0.88±0.02	0.88±0.01	0.86±0.02	NS
Total Hip	1.07±0.02	1.04±0.01	1.03±0.03	NS
Spine	1.11±0.02	1.08±0.01	1.10±0.04	NS
Femoral Neck Z-Score	0.24±0.13	0.21±0.08	0.13±0.18	NS
Total Hip Z-Score	0.48±0.13	0.30±0.08	0.26±0.18	NS
Spine Z-Score	0.10±0.26	-0.11±0.15	0.03±0.35	NS

[1] *Least square means +/- SEM after adjusting for age, height, lean mass, fat mass, grip strength, number of hours of sleep and estrogen status in women. Means with similar superscripts are different from each other at p<0.05, using Tukey HSD.*

Table 2. Bone differences among farm mechanization level groups by sex[1].

to being currently involved in farming for the majority of the year (>20 hours per week on average).

Written informed consent was obtained from all participants, and the study was approved by South Dakota State University Institutional Review Board.

Statistical analysis

Statistical analyses were carried out using the JMP software package (Version 8.0.2, SAS Institute, Inc., Cary, NC). Group differences among low, moderate and high mechanization level in demographic, anthropometric and bone characteristics were tested using one-way ANOVA after stratifying by sex. Group differences in bone measurements were further assessed by general linear models after including the following covariates: age, height, lean mass, fat mass, grip strength and number of hours of sleep per week night. Estrogen status (replete vs. deplete) was also included for women. These covariates are ones thought, or have been previously shown, to influence bone measurements[41]. Tukey Honestly Significant Difference (HSD) was used to determine which groups differed at $p<0.05$. Results are presented as mean or least square mean ± standard error of the mean (sem) unless otherwise stated.

Additional variables were screened as potential covariates (the quadratic term for age (age + age^2), dietary intakes of calcium and vitamin D, currently farming (yes/no), percent time in moderate plus vigorous activity, age of first menstrual period and number of live births) and were considered significant and included in a screening model if they influenced the bone

	Mechanization Level			
	Low	**Moderate**	**High**	**p value**
Females	**BMC (g)**			
	20% Distal Radius			
Cortical Thickness (mm)	2.60±0.05	2.59±0.04	2.59±0.09	NS
Cortical vBMD (mg/ccm)	1218±5	1215±4	1221±8	NS
Cortical Area (mm^2)	74.3±1.2	74.7±0.8	72.9±2.2	NS
Periosteal Circumference (mm)	37.3±0.4	37.3±0.2	37.0±0.7	NS
pSSI (mm^3)	247±7	245±6	243±13	NS
	4% Distal Radius			
Trabecular vBMD (mg/ccm)	201±5	201±3	216±9	NS
Total Area (mm^2)	282±6	283±4	285±10	NS
Males	**BMC (g)**			
	20% Distal Radius			
Cortical Thickness (mm)	3.13±0.05	3.00±0.03	3.07±0.07	NS
Cortical vBMD (mg/ccm)	1204±5	1197±3	1194±6	NS
Cortical Area (mm^2)	109.6±1.8	109.3±0.9	110.4±2.5	NS
Periosteal Circumference (mm)	45.6±0.5	46.4±0.3	46.2±0.7	NS
pSSI (mm^3)	387±12	400±7	407±17	NS
	4% Distal Radius			
Trabecular vBMD (mg/ccm)	232±5	224±3	221±7	NS
Total Area (mm^2)	387±9	392±5	396±12	NS

[1] Least square means +/- SEM after adjusting for age, height, lean mass, fat mass, grip strength, number of hours of sleep and estrogen status in women.

Table 3. Differences in pQCT measures between farm mechanization level groups by sex[1].

measurement at a value <0.10, but were dropped from the model if they were not significant at a level ≤0.05. Mechanization level was added last to the model. Results from these models containing only significant covariates did not differ from those models previously mentioned.

Results

General characteristics of the study population are given in Table 1. In females, the low mechanization group was slightly (not significantly) older, currently heavier, and had higher grip strength than the high mechanization group. Lean mass and fat mass were significantly higher in the low mechanization group compared to the high group. No other characteristics differed among groups. In males, the low mechanization group was significantly older and had been farming for more years than the high mechanization group. Also, the low mechanization group was heavier and had a greater percent body fat than the moderate mechanization group. Fat mass was significantly higher in the low mechanization group compared to the moderate group. No other characteristics differed among groups.

Controlling for covariates, females who grew up on farms with low or moderate mechanization had higher femoral neck bone area than females who grew up on farms with high mechanization (p=0.03). No other bone measures, including Z-scores, differed among low, moderate or high mechanization groups after controlling for covariates (Table 2). In men, there were no significant differences in bone outcomes, including Z-scores, among the mechanization groups after controlling for covariates (Table 2).

Table 3 shows pQCT measures among mechanization levels. There were no significant differences among farm mechanization groups in males or females after controlling for covariates. Differences in farming operations by sex and mechanization level are shown in Table 4.

Discussion

Based on previous research, we hypothesized that if increased physical activity prior to 20 years of age leads to bone differences in adulthood, rural participants who lived on farms with low mechanization during childhood and adolescence would have higher aBMD at one or more sites, and greater trabecular vBMD, cortical thickness and periosteal circumference than rural participants who lived on farms with moderate or high mechanization during childhood. We found that a low farm mechanization level, indicating high physical activity, prior to 20 years of age is associated with greater FN bone area in females.

	Mechanization Level		
	Low	Moderate	High
Females (N)	47	96	14
Livestock or Dairy	7	8	1
Crop	3	11	0
Crop & Livestock	25	55	13
Crop & Dairy	8	19	0
Other	4	3	0
Males (N)	34	121	18
Livestock or Dairy	6	15	0
Crop	2	8	5
Crop & Livestock	21	76	10
Crop & Dairy	4	19	0
Other	1	2	3

Table 4. Differences in farming operations by mechanization level and sex.

Our finding of greater bone area in females with low farm mechanization compared to those with high mechanization is consistent with results from Kriska and colleagues who found bone area in postmenopausal women was significantly related to increased historical physical activity levels at age 14-21, although they were measuring the dominant radius using computerized tomography[33]. It is possible that we did not see the same site-specific results because we measured the left arm, which is not necessarily the dominant arm. In fact, 90% of the study population was right-handed, while only 10% was left-handed. This also may explain why differences were found in femoral neck bone area, but there were no differences in pQCT findings. Bone differences were expected due to differences in physical activity as a child. Activity is likely to have a greater influence on loaded, rather than non-loaded bones, as demonstrated in tennis players who started playing during pre- or early puberty and displayed a marked bone asymmetry between the dominant and non-dominant radii at the ultradistal region as adults[15]. We speculate that pQCT differences by farm mechanization group may be more apparent in the tibia or in the loaded forearm.

We based our hypothesis on evidence that exercise during growth affects certain bone parameters both in the short- and long-term (see reviews of pediatric exercise trials[43-45]). Many studies on the effect of exercise during bone growth have been done in individuals who participated in competitive sports as a child[6-12], some of which were elite athletes, and additional studies have pointed toward the potential for long-term benefits of this physical activity on bone[15-20,46]. It is conceivable that in our study population, duration and intensity of physical activity were less than that of an elite athlete, so group differences in aBMD would not been seen. Additionally, there were marked differences in body composition measures in both males and females. It is possible that differences in socioeconomic status among the mechanization levels are driving the differences in body composition, however this was not assessed. It is also possible that those who worked on low mechanization farms prior to 20 years of age transitioned to more mechanized operations later in life, thereby going from an active lifestyle to an inactive lifestyle and decreasing their physical activity. Being older, they would have more time to accrue additional weight. Controlling for these factors eliminated differences seen in all but one bone outcome.

Overall, little is known about the effect of regular activity levels during childhood and adolescence on adult bone, and research on the topic provides mixed results – in part because of different definitions of physical activity, examining lifetime physical activity versus physical activity during various age groups and differences in methods for assessing bone. Rideout and colleagues examined historical leisure time activity in postmenopausal women and found a positive association between spine and proximal femur aBMD and leisure physical activity at 12-18 years[32]. These findings were not supported by our results; however the type of physical activity being performed as part of the different levels of mechanization was not assessed. Perhaps the types of physical activity being performed in the low mechanization group were not of adequate intensity and duration to confer benefits into adulthood, or perhaps individuals in the moderate and high mechanization groups were participating in physical activity not related to working on a farm, making it difficult to discern differences among groups attributable to lifestyle. Additionally, Micklesfield and colleagues found that physical activity for transport (walking and biking) at ages 14-21 was associated with proximal femur BMD in South African women, as was total peak bone strain score and spine BMD during the same time frame[37]. Other studies have examined the effects of lifetime occupational and leisure activity on bone measurements (using different assessment methods) in different populations and have found mixed results[34-36]. Although some longitudinal studies examine the relationship between physical activity and bone density, they do not draw associations between previous physical activity and current bone density[38-40]. Examining mechanization level as a proxy for physical activity before age 20 and its relationship between adult bone outcomes is a strength of this study, providing insight into how lifestyle at a young age may affect bone later in life, however it does not capture information all types and amounts of physical activity, which could ultimately contribute to our lack of findings.

There are studies that suggest that "rural" vs. "urban" adult populations have higher BMD or BMC and lower fracture risk[47-49], but the rural/urban classification was based on geographic location (living in a city vs. living outside of a city) and not on actually living a rural lifestyle. To our knowledge, there are no studies that have looked at how everyday activities of rural children and adolescents living a rural or farming lifestyle affect adult bone. We looked at the specific lifestyle the individual lived, and not the type of geographical area they were from, and found that simply living a less-mechanized rural lifestyle led to a difference in the femoral neck among adult women in our groups. Our findings suggest that participating in daily activities associated with a farming lifestyle is associated with at least one long-term adult bone measure in females. The fact that farm mechanization level prior to 20 years of age, and not current farming activity, was a significant predictor of this bone measurement later in life leads us to believe that some benefits to bone derived from lifestyle-related physical activity early in life are important and can be maintained into adulthood. However, these long-term benefits are not seen at all bone sites and are sex-specific.

There are several limitations to the current study. First, the mean ages were different between the low and high mechanization groups for the males. We did, however, include age as a potential covariate in all analyses, and given the similarity in the age ranges of the different mechanization groups, this should control for the influence of age on the bone outcomes. Second, data collected from the farming questionnaire was self-reported and based on individual perception. Third, the amount of time actually spent doing physical tasks as a child was never asked. A person may have lived on a farm with low mechanization but did very little, or perhaps sporadic physical work. We also did not take into account other physical activities that were done during childhood and adolescence outside of farm duties. Finally, the number of individuals in the low and high mechanization groups was relatively small, which may have limited findings. Future studies on how a farming lifestyle influences bone development in children and adolescents should address hours per week of activity and the types of activities that are performed. Despite these limitations, we still observed a bone difference by level of farm mechanization in females.

Our hypothesis that individuals raised on farms with low mechanization would have higher aBMD, trabecular vBMD and differences in bone size compared to individuals raised on farms with high mechanization was based on the assumption that individuals raised on farms with low mechanization would have greater activity levels during childhood and adolescence. We found that a low farm mechanization level, which we speculate would lead to a high physical activity level, prior to 20 years of age, is associated with greater femoral neck bone area in females. Further confirmation, and additional information that includes the type and amount of physical activity performed, will contribute to the growing knowledge base of how and when regular physical activity during childhood and adolescence affects adult bone health.

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