AN ABSTRACT OF THE THESIS OF

Courtney Lovemark for the degree of Honors Baccalaureate of Science in Exercise and Sport Science presented on June 1, 2009. Title: Factors Contributing to the Development of Body Fat In Growing Boys and Girls.

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The prevalence of overweight and obesity in children and adolescents continues to rise and is considered a major public health problem. The aim of this investigation was to evaluate the contributions of sport participation, and calcium intake (controlling for mean energy intake, sex, and maturation status) on the development of fat mass in children. This is a secondary analysis from a longitudinal study that examined skeletal development in children. 127 boys and 123 girls were included in the final analysis and were evaluated annually over 5 ± 2.2 y, with a baseline age of 8.5 ± 1 y. Sport participation, average energy intake (kcal/day), and calcium intake (mg/day) were assessed by questionnaires. Years from peak height velocity (PHV) was calculated from anthropometric measures. Body composition was measured by DXA. Analysis of co-variance was used to evaluate contributions. Calcium intake, energy intake, and sport participation, values were averaged over the number of occasions participants had data. We found that attainment of PHV marks a change in the trajectory of fat mass development between genders. Children who participated in sport at all occasions were 4% leaner than non-sport participants. Trends suggest that lower calcium and lower energy intakes may play a role in fat mass development. *Supported by NIH NIAMS AR045655-09 and Oregon State University, College of Health and Human Sciences Pilot Grant Program.*

Key Words: fat mass; children; calcium; energy intake; sport participation; maturation.

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Factors Contributing to the Development of Body Fat

In Growing Boys and Girls

by

Courtney Lovemark

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Chair, Department of Nutrition and Exercise Sciences

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I understand that my project will become part of the permanent collection of Oregon State University, University Honors College. My signature below authorizes release of my project to any reader upon request.

Courtney Lovemark, Author

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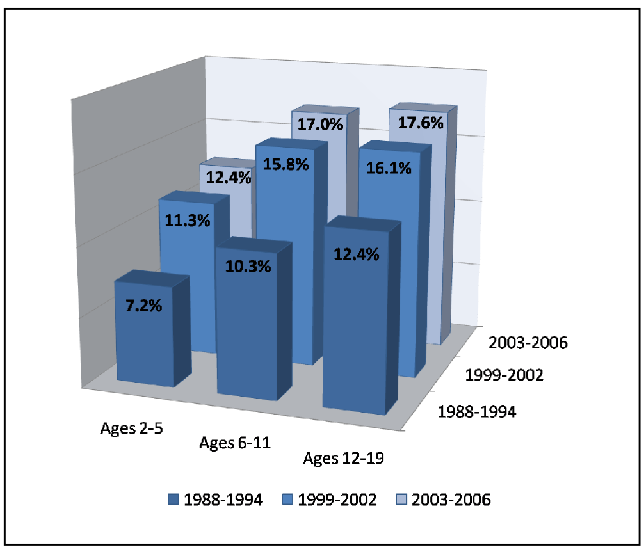
Introduction

The prevalence of overweight and obesity in children and adolescents continues to rise and is considered a major public health problem. Data from the 2003-2006 National Health and Nutrition Examination Survey show that over 17% of children aged 6-19 are obese up from approximately 6% in the late 1970s (Ogden, Carroll, & Flegal, 2008). More recently, data indicate that preschoolers are also at substantial risk with one study reporting that the prevalence of obesity among four year old children is as high as 18.4% (Anderson & Whitaker, 2009). The rise in the prevalence of obesity across ages 2-19 inclusively is depicted in Figure 1 (CDC, 2009).

Figure 1: *Prevalence of Obesity in U.S. Children and Adolescents.*



The importance of studies on childhood obesity is supported by the need to reduce the risk for lifelong chronic disease. Overweight and obese children are at increased risk for numerous health problems such as diabetes, stroke, metabolic syndrome, hypertension, coronary heart disease, dyslipidemia, cardiovascular disease, sleep apnea, liver disease and gallbladder disease compared to children of healthy weight (Dietz, 1998; Ebbeling, Pawlak, & Ludwig, 2002; Freedman, Mei, Srinivasan, Berenson, &Dietz, 2007; Maffeis & Tato, 2001; Power, Lake, & Cole, 1997). Clearly the effects of childhood overweight and obesity are far reaching and have the potential to impinge on every body system.

In children, obesity is defined as having a body mass index (BMI, kg/m^2) above the ninety-fifth percentile for age and gender (Barlow, 2007). Overweight is defined as a BMI that falls between the 85th and 95th percentiles (Barlow et al., 2007). BMI is non-invasive and calculated based on height and weight, which are easily accessible variables in most settings and identifies the fattest individuals correctly, with good accuracy at the 85^{th} and 95^{th} percentiles for age and gender (Krebs et al., 2007). While BMI is generally related to body fat, it does not directly measure fat (Field et al., 2003). Thus if we are interested in factors associated with increased body fat other methods may be more appropriate. There are several methods that directly assess body fat including dual energy x-ray absorptiometry (DXA). This strategy provides information about the total body fat and fat distribution which BMI does not do. However, limitations associated with using DXA to assess body fat include accessibility, radiation exposure and cost and it is not widely used for this purpose.

It is imperative to understand the factors contributing to this epidemic in order to combat the rising trend of childhood obesity and relieve the associated physical and psychological health-related consequences that may result in lifelong problems (Must & Strauss, 1999).

Factors Contributing to the Development of Body Fat In Children

Childhood obesity is a complex issue resulting from an imbalance between energy consumed and energy expended. However there are many factors that influence what children eat and how they move including genetic, psychosocial, and environmental factors. For this thesis project, we examined the interactions between energy expenditure with a particular focus on sport participation, dietary factors such as calcium and energy intakes, and maturation.

Physical Activity

Physical activity impacts health and optimum body composition, with physically active children having healthier body weights, lower BMI, and stronger bones compared to less active peers (Berkey, Rockett, Gillman, & Colditz, 2003; Eisenmann, Bartee, & Wang, 2002; Harrell, McMurray, Gansky, Bangdiwala, & Bradley 1999; Janz et al., 2008; Strong et al., 2005). Therefore, as obesity rates in children rises, it is logical to look at physical activity trends with respect to both age and gender to better understand how lack of physical activity behavior contributes to the rise in obesity.

Research shows that daily moderate and vigorous activity decrease with an increased grade level and chronological age (Caspersen & Merritt, 1995; Lowry, Brener, Lee, Epping, Fulton, & Eaton, 2004; Pate, Dowda, O'Neil, & Ward, 2007; Trost et al. 2002). Studies also indicate that physical activity decreases with age and maturation status in both genders (Pate et al., 2007). Recent data from the Youth Risk Behavior Surveillance Survey indicate less than 30% of high school students are getting the recommended levels of physical activity (Eaton et al., 2006). Girls may be at a particular risk as physical activity behaviors drop more drastically among girls compared to boys (Thompson et al., 2005).

Additionally, it is important to look at trends in the intensity of physical activity because more vigorous activity has a stronger association with optimal body composition than moderate physical activity (Wittmeier, Mollard, & Krielaars, 2008). Trost et al. (2002) measured physical activity and minutes spent in moderate to vigorous physical activity (MVPA) and vigorous physical activity (VPA), in students in grades 1-12. The daily MVPA and VPA levels exhibited a significant inverse relationship with grade level. The study also showed that boys were more active than girls, but that they also participated in more vigorous activity compared to girls.

Gender also appears to play a role in the level of VPA in children. Research shows that boys participate in nearly twice as much VPA when compared to girls (Hussey et al., 2007). This difference between girls and boys in physical activity participation may contribute to the increased development of excess body fat with age in girls compared to boys. This is supported by the work of Baxter-Jones et al. (2008) who found that physical activity had a significant effect on lean mass accrual of the total body and the relationship was stronger for boys compared to girls (Baxter-Jones, Eisenmann, Mirwald, Faulkner, & Bailey, 2008). Thus it appears that both the amount and the intensity of the physical activity are important considerations in the development of obesity among growing children. The involvement of children in physical activity is also crucial because it has been demonstrated that active children are more likely to become active adults (Barnekow-Bergvist, Hedberg, Janlert, & Jansson, 1998). This has implications for lifelong health.

Sport Participation

While much has been reported about physical activity generally, less has been reported about the effects of sport participation on the development of overweight and obesity. As such it may be valuable to consider the relationship between sports participation and obesity separately from general physical activity. The intensity of activity during many sports is commonly greater than general physical activity, and sport participation is one type of physical activity where children are generally active for sustained periods of time and at a greater intensity (Bailey et al. 1995).

Studies that have explored the relationship of sport participation to overweight and obesity show that young boys (pre-pubertal) who participate in sport at least three hours per week have lower whole body fat mass and lower body fat percent compared to peers who do not participate in sports (Ara et al. 2004*)*. For example, Storey et al. (2003) found that children who participated in team/organized sports have lower BMI compared to children who do not participate in team/organized sports (Storey, Forshee, Weaver, & Sansalone, 2003). Specifically, the authors found that for each team sport/organized physical activity that a child participated there was a decrease in BMI of 0.47 kg/m^2 (Storey et al., 2003). Another study showed that overweight children who participated 3-4 days per week in a soccer program for 6 months with physical activity lasting 75 minutes at each session, decreased BMI, likely through a significant increase in total daily, moderate, and vigorous physical activity (Weintraub et al., 2008*)*. Additionally, children who participate in sports are more likely to become active adolescents (Pate et al., 2007) and remain physically active as adults (Alfano, Klesges, Murray, Beech, & McClanahan, 2002; Taylor, Blair, Cummings, Wun, & Malina, 1999). This is particularly important as both present and past sport participation is related to BMI in adults. Specifically, higher levels of past sport participation are associated with a lower BMI (Alfano et al., 2002). This may be because children who participate in sports tend to remain active as adults and have lower adult obesity compared to children who do not participate in sport (Alfano et al., 2002*)*.

Maturation

The process of sexual maturation is associated with numerous physiological changes including changes in body size and fatness. The timing of maturation varies quite a bit from individual to individual. However differences between boys and girls are more systematic with girls maturing earlier than boys (Wells, 2007). There are a number of qualitative and quantitative approaches to measuring maturation. Peak height velocity (PHV) is a commonly used biological measure and the only sexual maturation landmark that occurs in both boys and girls (Baxter-Jones, Eisenmann, & Sherar, 2005). Most studies that measured PHV show girls reaching PHV between 11–12 y and boys slightly later between 13 and 14 years of age (Baxter-Jones, Mirwald, McKay, & Bailey, 2003; Bouchard, Leblanc, Malina, & Hollmann, 1978).

The effect of maturation on body composition in boys and girls is well understood. Generally, prior to puberty (pre-PHV) boys have higher body fat than those who have reached sexual maturation (post PHV); whereas in girls there is an opposite observation *(*Loomba-Albrecht & Styne, 2009; Maynard et al., 2001; Mota et al., 2002,). In a recent study examining change in body fat among boys 10 to 18 years old, body fat percentage decreased at an average rate of 1.73% per year (Marques-Vidal et al., 2008). Among girls 10 to 18 years old, body fat percentage also declined, but considerable slower at a rate of 0.48% per year (Marques-Vidal, Marcelino, Ravasco, Camilo, & Oliveira, 2008). For females, that experience puberty earlier than others they tend to have higher levels of body fat as adults (Pierce & Leon, 2005). However this may be related to increased body fat to begin with. Lee et al. (2007) found that girls with a higher BMI at 36 months and a higher increase in BMI between 36 months and 1st grade had earlier onset of puberty. This only highlights the importance of identifying factors contributing to childhood overweight and obesity as early puberty carries its own set of risks such as increased risky behaviors and increased risk of certain cancers (Lee, 2007).

Sexual dimorphism is most evident during puberty; however, there is typically a difference in the body composition of males and females (Wells, 2007). At birth, males have a similar fat mass to females but are longer and have greater lean mass (Wells, 2007). These sex differences are still evident during childhood. For both sexes, during early puberty the amount of lean body mass increases (Wheeler, 1991); however, males gain larger amounts of fat free mass and skeletal mass, and females gain significantly more fat mass (Loomba-Albrecht & Styne, 2009; Maynard et al., 2001). By adulthood, the percentage fat for males averages 10-15% and for females averages 20-30% (Norgan, 1990). Maturation may also contribute indirectly to increases in body fat as recent studies show that pubertal development is associated with decreases in physical activity behavior (Thompson, Baxter-Jones, Mirwald, & Bailey, 2003) and that early-maturing girls have lower physical activity levels relative to their peers who mature later (Baker, Birch, Trost,

& Davison, 2007). Thus factors related to the timing of maturation are important considerations in the development of childhood overweight and obesity.

Energy Intake

The influence of total energy intake in children remains unclear and studies report conflicting results. For example Ball et al. (2001) found an increase in children's energy intake was associated with a greater increase in BMI (Ball et al., 2001,). This is consistent with the findings of Tucker et al. (1997) who found that high energy intakes were associated with increased body fat (Tucker et al., 1997) among children aged 9.8 ± 0.5 y. However, these authors indicate that high energy diets are also often high in fat, therefore it is difficult to decipher if the total energy intake or specific components (such as fat) are contributing to increased body fat (Tucker et al., 1997). Others have found no association between energy intake and BMI (Maffeis, Talamini, & Tato, 1998; Scaglioni et al., 2000) and some researchers believe that body fat may be less dependent on energy consumption in children than adults (Skinner, Bounds, Carruth, & Ziegler, 2003). Either way, it is still an important consideration in understanding the factors that contribute to increases in body fat during childhood.

Calcium

Calcium is another dietary factor that has been considered as a potential contributor to the development of overweight, and obesity (Schrager et al., 2005). Epidemiological data in adult populations suggest that body fat is lower among individuals with greater calcium intakes (Zemel et al., 2002; Teegarden et al., 2005). Data also show that women with low dairy intake have higher BMI values (Varenna,Binelli, Casari, Zucchi, & Sinigaglia, 2007).

In adult populations it is thought that calcium may act to reduce the amount of fat which is stored in the body by inhibition of various enzymes involved in the process of storing fat (Ahyayauch et al., 2009). Calcium influences hormones such as parathyroid hormone and vitamin D, which in turn influence fat storage and production. High dietary calcium decreases levels of intracellular calcium inhibiting fat production and storage while low dietary calcium has the opposite effect (Zemel, 2002).

The same mechanisms that calcium affects to contribute to lower body fat in adults may be active in children (Carruth & Skinner, 2001). In a report studying young children (age: 24-60 months) regression models showed that higher mean longitudinal calcium intakes and more serving per day of dairy products were associated with lower body fat (P=0.0003) (Weaver & Boushey, 2003). In older children, ages 5-8 y, studies have shown that dietary calcium is inversely related to body fat (Carruth et al., 2001; Ogden et al., 2002*)*. In a longitudinal study of kids aged 2 months to 8 years old, 5%-9% of the variability in body fat was explained by dietary calcium (Skinner et al., 2003). A gender difference in calcium intakes between boys and girls has also been observed. Specifically, boys 9-13 years old on average consume more calcium than girls who may subsequently have an increased risk for obesity (Galloway, 2007*)*. Additionally, girls 9-18 years old consume less calcium with increased age (Affenito et al., 2007). Among school aged children it has been found that many girls have calcium consumption below adequate intake (Affenito et al., 2007; Suitor & Gleason, 2002). However, boys generally have increased total energy intakes compared to girls and it is unclear whether the differences in calcium intakes observed were independent of differences in total energy consumed. Thus, calcium intakes may be of interest when studying dietary factors that lead to an increase in body fatness.

There are numerous factors that interact and contribute to the development of body fat in growing children and adolescents. To explore them all would require an enormous sample of children and many years of follow-up. For the purposes of this study, we chose to examine the relationships between sport participation, calcium consumption and body fat in children. Specifically, we addressed the following specific aim:

Specific Aim

The aim of this investigation was to evaluate the relative contribution of sport participation and calcium intake, controlling for total energy intake, maturation and sex on the development of whole body percent fat mass in children as measured by DXA.

Hypothesis

We hypothesized that after controlling for maturation, sex, and total energy intake that sport participation and calcium intake would be significant, independent predictors of whole body percent fat in growing children.

MATERIAL AND METHODS

Study Design and Sample

The participants and data for this report were drawn from the *Building the Growing Skeletons in Youth* (BUGSY) study. BUGSY was a mixed longitudinal study of bone development in growing children beginning in fall of 1997 with new cohorts recruited in 1998 and 2002. Data were collected annually through spring 2007 on 262 participants.

Participant Identification and Recruitment

BUGSY is a longitudinal study examining the effects of a randomized, controlled exercise intervention on bone mass accrual during growth that recruited participants from elementary schools in Corvallis, Oregon. Three cohorts of children participated in three separate, but identical school-based exercise interventions. Studies were initiated in the fall of 1997 (pilot, n=33), in the fall of 1998 (n=89), and in the fall of 2002 (n=205). The exercise interventions lasted a single school year, with a sub-sample of participants agreeing to long-term follow-up (N=262; n=133 boys, n=129 girls). Those agreeing to long-term follow-up constitute the participants in the *BUGSY* study. Each child provided their assent to participate and each child's parent provided informed consent. Children ranged in age from 6-9 y at baseline and 13-18 y at the last follow-up visit.

Procedures

Children were assessed at baseline, 7 and 19-months, and then annually thereafter through spring 2007. Each parent and child pair completed health history, food frequency and physical activity questionnaires at each measurement interval from 1997-2006. Anthropometric measures (standing height, sitting height, weight) and maturity assessments were also taken at each visit. In the first four years (1997-2000), body composition data were determined by skinfold and beginning in 2002, body composition data were obtained from whole body DXA scans. Following the last visit, participants were contacted once more via phone and email to obtain additional information about birth weight and breast feeding behaviors. These procedures were approved by the Oregon State University Institutional Review Board.

Anthropometric Measures

Standing height, sitting height and weight were assessed at each visit. Standing and sitting height were measured to the nearest 0.2 cm using a wall-mounted stadiometer. Weight was measured to the nearest 0.1 kg using an electronic weighing scale (model #770, Seca). Measurements were taken twice unless there was a discrepancy greater than 0.4 cm or 0.4 kg, depending on type of measurement, then a third measurement was taken. Recorded values were the average of the two measurements or the median of the three. Body height (cm) and leg length (cm) were calculated from standing and sitting height variables. These data were used in the prediction of biological maturity.

Whole Body Percent Fat

Whole body percent fat was evaluated using dual energy x-ray absorptiometry (DXA) (Hologic QDR 4500A; Hologic Inc., Waltham, MA, USA). DXA is reported to be a valid and reliable assessment of body fat among children and adolescents (Gutin et al., 1996). Trained and qualified technicians performed all scans over the 9-year follow-up period. For ethical reasons, we did not perform repeat measurements of whole body scans and are not able to report precision. However, in-house estimates of hip and spine bone mass on 10 adults measured twice with repositioning resulted in CVs between 1% and 1.5% (data not shown).

Biological Maturity

Peak height velocity (PHV) is a commonly used biological parameter in growth studies, which allows subjects to be aligned at comparable biological rather than chronological ages. Bone measurements are considered in terms of time before and after PHV (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). Briefly this gender-specific multiple regression equation includes standing height, sitting height, leg length, and chronological age (y). The prediction is applied at each measurement occasion. As subjects approach and enter puberty, the prediction increases in accuracy. Thus, for this analysis age of PHV was predicted at the subject's last measurement occasion. The predicted years from PHV was combined with the chronological age at each measurement occasion to provide a predicted age of PHV. As a result, each participant had both a chronological age and a biological/maturity age associated with each test occasion. Participants whose chronological age was equal to or older than their predicted age of PHV were classified as having reached sexual maturity (post PHV).

For this analysis, the variable of interest was whether participants were pre or post PHV at the last measurement occasion (where pre PHV =0 and post PHV=1).

Sport Participation

Physical activity was assessed at each measurement occasion by parent and child using a self-reported physical activity questionnaire developed for children and adolescents; see Appendix A for questionnaire. Physical activity information is partitioned by general activity and participation in organized sports. Sport activities were recorded at each measurement occasion as a categorical variable (where no sport activities, *Sport Activity =0,* and 1 or more sport activities, *Sport Activity=1).* These were then averaged across the study length and included in the present analysis as a proportion of time spent participating in sport. For example, if someone was followed for five years and participated in organized sports during each of those five years, their value would equal 1. If they never participated, their value would equal 0. If they participated in four out of five years, their value would be equal to 0.80.

Calcium and Total Energy Intakes

Dietary intake was assessed using the Harvard Medical School Youth Diet Survey developed for children and adolescents between the ages of 9-18 years. This food frequency questionnaire is designed to be self-administered; however, to improve accuracy, the questionnaire was filled out by parent and child together. A researcher familiar with the diet survey was available to answer questions regarding the classification of foods and serving sizes. Visual aids were also available to help participants and their parents determine appropriate responses. Completed food surveys were sent to Harvard Medical School for analysis. Average calcium (from supplements and dietary sources, mg/day) and energy intakes (kcal/day) were obtained and summarized over the number of occasions for which data was available. As this was a self-report measure summarizing dietary habits over an entire year, values were truncated to the nearest whole number for inclusion in analyses. Participants reporting mean energy intake values 25% or more below the recommended energy intake for their age were excluded from analysis.

Statistical Methods

Descriptive analyses were performed using SPSS software version 15.0 for Windows (SPSS Inc., Chicago IL). Values are reported as means (± SD). Correlational analyses were performed to evaluate the relationship between percent body fat measured by DXA and BMI (kg/m^2) within the sample in order to relate an accepted marker of overweight and obesity to our outcome of interest (body fat percent). To summarize calcium and energy intakes, and sport participation over time, each participant's values were averaged over the number of occasions data were available. Participants with chronically low energy intakes (mean intakes below 1050 kcals/day) were excluded from analysis. The question of whether calcium intake (mg/day) and sport participation over the years of observation predicted whole body percent fat mass at the end of the study, controlling for maturation, sex, and average energy intake was evaluated using analysis of -covariance in SPSS 19.0 for Windows. In this analysis, BF% is considered with respect to maturation as time before and after PHV. This variable is included in the model as pre- or post-PHV at the last visit (post=0 is pre- PHV; post=1 is post PHV).

Results

Sample Characteristics

Complete data on the variables of interest in this report were available on 258 of 262 participants (98.5%). Eight additional participants were excluded from analyses based on insufficient mean energy intakes (<1050 kcals). Of the total participants 85.8% were Caucasian, 8.4% Biracial or American Indian, 4.2% Asian, and 1.1% African American. The final analysis included 127 boys and 123 girls; mean age=8.5 $\pm$ 1 yr. at baseline, who were evaluated annually over 5 $\pm$ 2.2 yrs. Table 1 shows descriptive data of the study sample.

***Table 1**: Sample Descriptives.*

	Boys (n=127)	**Girls (n=123)**	**Total**
Baseline Age (y)	8.4 ± 0.1	8.5 ± 1.0	8.5 ± 1.0
PHV at Baseline (Pre, Post)	100% ,0%	100%, 0%	100%, 0%
Follow-up Age (y)	12.9 $\pm$ 2.2	12.2 $\pm$ 2.2	12.7 $\pm$ 2.1
PHV At Last Visit (Pre, Post)	51%, 49%	25%, 75%	39%, 61%
Average predicted age of PHV (y)	13.5 ± 0.86	11.7 ± 0.83	12.6 ± 1.23
BF at last visit (%)	22.4 ± 9.6	28.3 ± 7.9	25.3 ± 9.3
BMI at last visit (kg/m^2)	20.8 $\pm$ 4.4	20.2 $\pm$ 3.9	20.5 $\pm$ 4.1
Means			
Energy Intake (kcal/day)	2182 ± 440	1955 ± 423	2040 ± 536
Calcium Intake (mg/day)	1323 ± 345	1223 ± 378	1253 ± 445
Sport Participation (Never, Sometimes, Always)	10%, 32%, 58%	19%, 39%, 42%	15% , 35%, 50%

Whole Body Percent Fat and Body Mass Index

There were no differences between boys and girls in BMI at the last visit (p=0.37; Table 1). However, girls had significantly greater whole body percent fat compared to boys at the last visit (p<0.001; Table 1). Body mass index and body fat were positively correlated in both boys (r=0.52, p<0.001) and girls (r=0.77, p<0.001), as was age in both boys (r=0.37, p<0.001) and girls (r=0.22, p=0.002). Body fat was negatively correlated with age in boys (r=-0.32, p<0.001).There was no association between body fat and age among the girls in this sample (r=0.02, p=0.865). Among boys, approximately 25% were classified as overweight or obese according to the Centers for Disease Control and Prevention (CDC) BMI criteria. The mean body fat for this subsample of boys was 33.2% ± 9.4 with body fat values ranging from 12.9% – 51.9%. Among girls approximately 18% were classified as overweight or obese according to the CDC BMI criteria. The mean body fat for this subsample of girls was 39.6 ± 5.2 %, with values ranging from 24.5% to 49.9%.

Model and Variable Significance

The question of whether sport participation and average calcium intakes over the observation period predicted whole body percent fat were addressed using analysis of co-variance. Maturation (post= 0 for pre PHV or 1 for post PHV) and sex (girl = 0 for boys or 1 for girls) were fixed factors and the covariates were entered in the following order; sport participation, mean energy intake (kcal/day), mean calcium intake (mg/day). Each model was significant (p<0.001). In each model, maturation, sex and sport participation demonstrated a significant association with whole body percent fat. When calcium was added to the model including sex, maturation and sport participation, the effect of the other variables was unchanged and calcium was significantly associated with whole body percent fat (p=0.001; Table 2). Once calcium intake was adjusted for total energy intake, by including mean energy intake into the model, the effect of calcium was no longer significant (p=0.086; Table 3).

Table 2: *ANCOVA Table for Model Including Maturation, Sex, Sport Participation, and Calcium Intake.*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5330.710[a]	5	1066.142	16.686	.000
Intercept	17411.983	1	17411.983	272.512	.000
Sex	1078.631	1	1078.631	16.881	.000
PHV	412.723	1	412.723	6.459	.012
Sport	528.432	1	528.432	8.270	.004
Calcium	729.298	1	729.298	11.414	.001
Sex*PHV	930.296	1	930.296	14.560	.000
Error	15590.222	244	63.894		
Total	178267.850	250			
Corrected Total	20920.932	249			

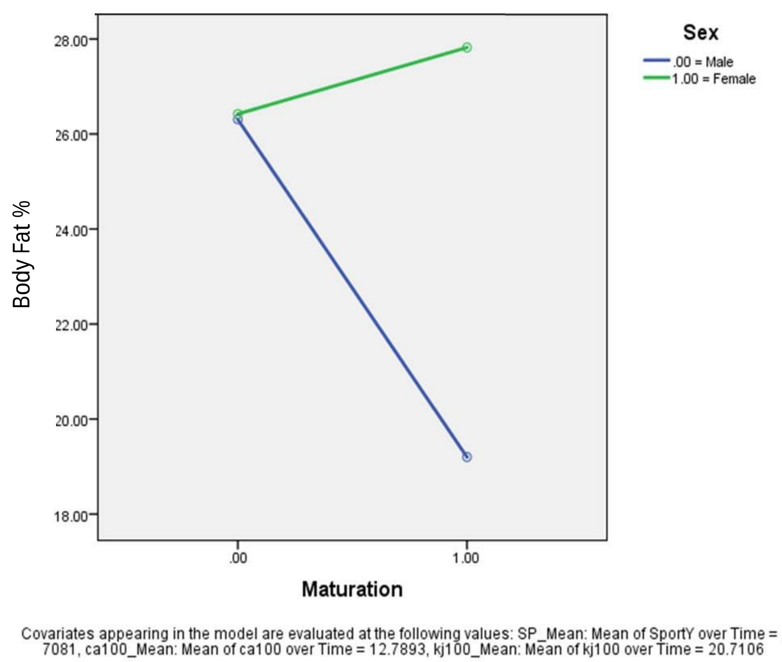
Table 3: *ANCOVA Table for Model Including Maturation, Sex, Sport Participation, Calcium Intake, and Energy Intake.*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5429.819[a]	6	904.970	14.196	.000
Intercept	12186.886	1	12186.886	191.169	.000
Sex	935.500	1	935.500	14.675	.000
PHV	430.130	1	430.130	6.747	.010
Sport	493.136	1	493.136	7.736	.006
Calcium	188.931	1	188.931	2.964	.086
Energy Intake	99.109	1	99.109	1.555	.214
Sex*PHV	942.730	1	942.730	14.788	.000
Error	15491.113	243	63.749		
Total	178267.850	250			
Corrected Total	20920.932	249			

The model also included an interaction term (Sex*PHV) to evaluate the influence of sex and maturation taken together on whole body percent fat. Figure 2 shows that at the attainment of PHV (PHV), an indicator of biological maturity, there was a significant change in the development of body fat by sex (p<0.001) whereby girls who were post PHV had 8% higher body fat than boys who were post PHV. There were no differences in BF% between boys and girls who had not reached PHV by the last visit.

The full model including maturation, sex, sport participation, mean calcium intake, mean energy intake explained approximately 24% of the variance in body fat percent (adjusted r-squared = 0.241; p<0.001).

Figure 2: *Biological Maturity and Body Fat %.*



Parameter Estimates

The coefficients in Table 4 tell us that, on average children who are post-PHV (PHV) have 1.4% more whole body percent fat than those pre-PHV and that girls have 8.6% more body fat than boys (Sex). However when exploring the interaction between sex and maturation (Sex*PHV), it is apparent that prior to achieving PHV there is no difference in whole body percent fat between boys and girls, but after PHV boys have 8.5% less body fat than girls (Figure 2; $p<0.001$). While there is no significant difference in whole body percent fat between girls who are pre- PHV and girls who are post PHV ($p=0.548$), boys who are pre-PHV have 6.7% more body fat than boys who are post PHV ($p<0.001$).

The coefficients related to sport participation (Sport) indicate that children who always participate in sports have approximately 4% less whole-body percent fat than those who never participated in organized sports. With respect to calcium, the model indicates that for every 100 more mg of average calcium intake, a child can be expect to have 0.33% less whole-body percent fat. However the relationship between calcium and whole body percent fat is not significant when average energy intakes are included in the model ($p=0.086$).

Table 4: *Regression Model Parameter Estimates.*

Dependent Variable: Whole Body Percent Fat

Parameter	**B**	**Std. Error**	**T**	**Sig.**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
Intercept	38.828	2.562	15.153	.000	33.781	43.876
Sex	-8.620	1.337	-6.448	.000	-11.254	-5.987
PHV	-1.398	1.679	-.832	.406	-4.706	1.910
Sport	-3.897	1.401	-2.781	.006	-6.658	-1.137
Calcium	-.327	.190	-1.722	.086	-.701	.047
Energy Intake	-.196	.158	-1.247	.214	-.507	.114
Sex*PHV	8.503	2.211	3.846	.000	4.148	12.859

Discussion

Our aim was to explore relationships between sport participation and calcium intakes on the development of body fat in children. We found that the interaction of sex and maturation explain nearly 6% of the variation in whole body percent fat and sport participation accounts for about 3% of the variation in body fat. In particular we found that the attainment of PHV marks a critical change in the trajectory of fat mass development between boys and girls. Boys who are post-PHV have nearly 7% less whole body percent fat than those who are pre-PHV. This effect is not apparent in girls for whom there is no significant change in body fat from pre to post PHV. We also observed that children who consistently participate in organized sports have 4% less whole body percent fat than those who never do. We also observed the influence of calcium on whole body percent fat is negligible when adjusted for total energy intakes. However trends suggest that when examined independently lower calcium and lower energy intakes are associated with higher whole body percent fat and should be explored in a dedicated study design.

Strengths of the Study

This study has several strengths. First, this was a longitudinal study spanning nine years and though not all participants made it to every visit over this time period, the average length of follow-up for participants was over five years. Secondly, of the 262 participants who agreed to long-term follow-up, 98.5% had sufficient data on all the variables of interest to this report.

Finally the use of DXA for body composition allowed us to quantify whole body percent fat directly. The majority of studies examining factors that contribute to obesity in children examine BMI as the obesity outcome, an indirect measure requiring numerous assumptions that does not distinguish between lean and fat mass. Dual energy x-ray absorptiometry (DXA) provides more accurate estimates of body fat, and also provides information about the distribution of fat mass, and estimates of lean and bone mass, all of which may be important to understanding the development of obesity and associated health outcomes. Though we did not examine the distribution of body fat, or the contributions of lean mass specifically in this study, we were able to quantify a direct measure of body fat and relate that to specific components of energy expenditure (sport participation) and energy intake (calcium intake).

Limitations of the Study

Several limitations of the study must be acknowledged. As this was a secondary analysis of an existing data set, the study design posed limitations for our questions. These include using questionnaires to measure physical activity and dietary habits. This required participants to recall average food intake and physical activity from the previous year. Recall is a limitation because reported values are influenced by dietary and physical activity habits at the time the questionnaire is completed (Chen & Wang, 2009). Further, because there are no well accepted classifications of obesity in children based on body fat percent alone, we are unable to relate our outcomes specifically to obesity. However we did explore the relationships between body fat percent and BMI, which is the current standard for categorizing children as it relates to their risk of overweight and obesity. These analyses provide context with regard to the proportion of participants in our sample who were classified as overweight or obese based on their BMI, and the broad range of body fat values that are associated with that classification in our sample.

Consistent with the literature, we found that sexual maturation marks an important time point in body fat accrual (Marques-Vidal et al., 2008; Maynard et al., 2001; Wells, 2007; Wheeler, 1991). However, contrary to the majority of studies that report increases in body fat with puberty among girls (Loomba-Albrecht et al. 2009; Maynard et al., 2001), we found no significant change in body fat among our sample of girls following the attainment of PHV. To our knowledge, only Marques-Vidal et al. (2008) reported declines in body fat among girls with puberty, with a decrease of approximately 0.47% per year. However this was a cross-sectional study and there was no description of the sample other than age and sex to provide context for these outcomes. Our findings related to the boys are consistent with other reports in the literature. We found that boys who were post pubertal (post PHV) at follow up had significantly lower percent body fat compared to boys who had not achieved PHV. This is consistent with others who report decreased body fat in post pubertal boys compared to boys who have reached sexual maturity (Marques-Vidal et al., 2008; Norgan et al., 1990).

We were initially surprised to find no significant difference in percent body fat among the pre and post pubertal girls in our study. We expected that girls who were post PHV would have higher percent body fat compared to girls who had not reached PHV. One explanation may be the high level of sports participation among girls in our sample. Aside from the interaction between sex and maturation, sport participation explained the most variability in body fat percent in our models. Over 40% of the girls participated in team sports for the entire duration of follow-up with nearly 40% more reporting having participated in organized sports over the past year on at least two measurement occasions. Most studies report that physical activity decreases with age and that males are more physically active than females (Trost et al., 2002). However, in our study most of the girls who were participating in sport at the beginning of the study were still involved at the completion of the study. Thus our results indicate that sport participation may be an important consideration in the development of programs to reduce overweight and obesity. More specifically, interventionists should consider promoting early involvement in organized sports, particularly among girls.

The influence of calcium and energy intake on body fat was minimal. Entered independently into the model, lower mean energy and calcium intakes were associated with increased body fat but this effect was not evident when both calcium and energy intake were entered together. Calcium exhibited a trend toward significance (p=0.086) with lower calcium intakes associated with higher percent body fat. This finding is in agreement with adult data that suggests body fat is lower in individuals with greater calcium intakes and low dairy intake is associated with a greater BMI (Teegarden, 2005; Varenna, 2007; Zemel, 2002). In our sample, lower calcium intakes are associated with lower energy intakes. One limitation of using is a self report measure of dietary intake is that individuals tend to under report their intakes. Thus, it is possible that total energy and calcium intakes were under reported in this study. However, as these same relationships have been observed in the adult literature with more rigorous study designs, we believe it is worth exploring the influence of calcium intakes on body fat among children in a dedicated study.

Conclusions

This study identified sport participation as a significant contributor to whole body percent fat in growing children. In addition we found a significant sex by maturation effect in that boys who are post PHV have significantly lower body fat than girls who are post PHV. Trends suggest that low calcium intakes may be associated with increased body fat, and that low calcium may be the result of lower energy intakes. However this needs to be explored in a dedicated experimental design before conclusions can be drawn. Overall these findings suggest that interventions to reduce the risk of childhood obesity should promote sport participation and that early involvement in organized sports may be particularly beneficial for girls. Finally, while our results are weak in support of calcium as a contributor to increased body fat, adequate calcium intakes are essential to muscle and skeletal development and should be promoted generally. These findings can be used to formulate successful interventions to reduce the rising tide of childhood obesity and lead to a healthier future for the next generation.

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Appendix A: Physical Activity Questionnaire

Child's Name (Last, First) ____________________ **Today's Date** __________

OREGON STATE UNIVERSITY BONE RESEARCH LABORATORY
PHYSICAL ACTIVITY QUESTIONNAIRE

QUESTIONS PERTAIN TO THE LAST YEAR ONLY.

1. How do you get to school? ____

2. How many hours per day do you do indoor, quiet activities (i.e., TV, videogames, computer, reading, homework) (Do NOT include time at school)
   a. School Days: _______________
   b. Non School Days:_______________

Research Staff Use Only:

Total hrs/wk indoor activity:________

3. How many hours do you sleep each night?
   a. School Nights: _______________
   b. Non School Nights:_____________

4. List the time <u>(in minutes)</u> that you spend <u>each week</u> doing the following activities (**NOT** an organized team sport: TEAM SPORTS on BACK). Specify if the activity is season specific (i.e. swimming lessons 3 times per week for 30 minutes during June-August).

Include PE at High School (i.e. softball 40 min 2x/wk for 4 weeks)

Baseball__________________________________ Basketball______________________

Dance/Ballet_______________________________ Football________________________

Gymnastics________________________________ Hiking__________________________

Hockey___________________________________ In-line Skating___________________

Karate____________________________________ Running/Running Games____________

Skateboard________________________________ Skiing__________________________

Snowboard________________________________ Tennis__________________________

Weight Lifting_____________________________ Other (name activity)______________

Biking ___________________________________

Horse Riding_______________________________

Swimming_________________________________

Research Staff Use Only

WBmin/wk:___________

5. Do you participate in team sports (yes / no)? If yes, go to question 6.

6. Details for team sports participation

Sport #1**________________________________**

practices/week:__________________________

weeks in season:_________________________

years participation:_______________________

Sport #2**________________________________**

practices/week:__________________________

weeks in season:_________________________

years participation:_______________________

Sport #3**________________________________**

practices/week:__________________________

weeks in season:_________________________

years participation:_______________________

Sport #4**________________________________**

practices/week:__________________________

weeks in season:_________________________

years participation:_______________________

Sport #5**________________________________**

practices/week:__________________________

weeks in season:_________________________

years participation:_______________________

Appendix B: Abstract from *Medicine & Science in Sports & Exercise*

Factors Contributing To The Development Of Overweight And Obesity In Growing Boys And Girls

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Abstract: The prevalence of overweight and obesity in children and adolescents continues to rise and is considered a major public health problem. While low physical activity is an accepted contributor to the development of obesity, dietary risk factors have been difficult to isolate. The relationship of calcium intake on the development of fat mass in children has received little attention. **PURPOSE:** The aim of this investigation was to evaluate the relative contribution of physical activity, caloric intake, and calcium intake on the development of fat mass in children. **METHODS:** This is a secondary analysis from a study that examined skeletal development in children. 135 boys and 127 girls; mean age=8.5 $\pm$ 1 yr. at baseline, were evaluated annually over 5 $\pm$ 2.2 yrs. Sport participation, average energy intake (Kcal/day), and calcium intake (mg/day) were assessed by questionnaires. Years from peak height velocity (PHV), an indicator of biological maturity, was calculated from anthropometric measures. Body composition was measured by DXA. Analysis of variance was used to determine if sport participation, average calcium intake, and average calorie intake predicted whole body percent fat mass (BF%) at the last visit. The model included gender and maturation (pre or post PHV at last visit). To summarize calcium intake, calorie intake, and sport participation over time, each participant's values were averaged over the number of occasions they had data.

RESULTS: The model explained 24% of the variance in BF% ($p<0.001$). Children who participated in sport at all occasions were 4% leaner than non-sport participants ($p=0.007$). Lower calcium intakes were associated with increased BF% ($p=0.05$); the effect diminished ($p=0.096$) when average calorie intake was in the model. There was a significant gender by maturation effect ($p<0.001$). Boys and girls who had not reached PHV by the last visit had no differences in BF%. Among those who were post PHV at last visit, girls had 8% higher body fat than boys ($p<0.001$). **CONCLUSIONS:** The attainment of PHV marks a critical change in the trajectory of fat mass development between genders. Trends suggest that lower calcium and lower calorie intakes may play a role and should be explored. *Supported by NIH NIAMS AR045655-09 and Oregon State University, College of Health and Human Sciences Pilot Grant Program.*

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