Original Research Article

Fertility, Body Size, and Shape: An Empirical Test of the Covert Maternal Depletion Hypothesis

ILONA NENKO AND GRAZYNA JASIENSKA
Department of Epidemiology and Population Studies, Institute of Public Health, Jagiellonian University, 31-531 Krakow, Poland

ABSTRACT In populations with limited resources, high-reproductive effort may lead to poor nutritional status of the mother (the maternal depletion syndrome), whereas in well-nourished populations woman's body weight tends to increase after each pregnancy. However, in affluent populations, women's body shape may change due to mobilization of polyunsaturated fatty acids (PUFAs) from the lower parts of their bodies to meet the needs of the developing child (the "covert maternal depletion"). We studied relationships between reproductive history traits and body size and shape for 296 rural, parous women in good nutritional status (mean body mass index, BMI = 27.9, SD = 5.94), aged 22–85 (mean 47.8, SD = 16.34) from southern Poland. Body mass adjusted for age, age of menarche, body height, and similarly adjusted BMI were each positively related to the number of children born by a woman (R = 0.13, P = 0.02 and R = 0.13, P = 0.02, respectively). Waist and hip circumferences, adjusted for confounders, did not show statistically significant relationships with the number of children. Moreover, groups with low and high parity did not significantly differ in hip/BMI and waist/BMI ratios, which were proposed to be indicators of covert form of maternal depletion (after controlling for overall body fatness and age). In conclusion, parity caused a slightly higher body mass and BMI later in life. However, parity did not lead to covert maternal depletion, perhaps because women in this population have relatively high-dietary intake of PUFAs. Am. J. Hum. Biol. 21:520–523, 2009.

In populations with limited access to resources high-reproductive effort may lead to poor nutritional status of the mother (the, so-called, maternal depletion syndrome) (Jelliffe and Maddocks, 1964; Khan et al., 1998; Shell-Duncan and Yung, 2004; Tracer, 2002). By contrast, in well-nourished populations, women's body weight tends to increase with each pregnancy (Harris et al., 1997a), which suggests a lack of maternal depletion. However, a recent study by Lassek and Gaulin (2006) showed that in the United States women increasing parity is associated with a decrease in hip and thigh circumferences, even though each pregnancy is associated with an increase in body weight and fat. These authors suggested that mobilization of body fat from hips and thighs is necessary in pregnant and lactating women, because developing fetal and infant brain requires polyunsaturated fatty acids (PUFAs) (Hornstra, 2000; Lassek and Gaulin, 2006). These fatty acids are stored in maternal lower body regions and are usually not used until late pregnancy and lactation. Once mobilization of fatty acids occurs, it leads to a shift in the relative fat distribution. This phenomenon was referred to as covert maternal depletion.

This study examined the potential occurrence of covert maternal depletion in population with traditional, rural, agricultural lifestyle, good nutritional status, and relatively high fertility.

MATERIALS AND METHODS

We examined 296 rural, parous women aged 22–85 (mean 47.8, SD = 16.34) from The Mogielica Human Ecology Study Site (for description of study site, see Jasienska and Ellison 2004). Body height, body weight and percentage of body fat (by bioimpedance) were measured by trained assistants. A general questionnaire was used to collect information about reproductive health and family history. Women had between 1 and 12 children (mean 3.97, SD = 2.12) and were well nourished (mean BMI = 27.9, SD = 5.94) (Table 1). We excluded from the analysis four nulliparous women and women who were pregnant or breastfeeding during the study.

Statistical analysis

The relationship between the mother's current body weight as the dependent variable and the number of her children was tested by multiple regression analysis. The model included the potential-confounding variables characterizing the mother, such as her age, age of menarche, and body height. We also performed a similar analysis with body mass index (BMI) as the dependent variable instead of body weight (body height was not used as a variable in any analysis that included the BMI).

Following the method of Lassek and Gaulin (2006), we calculated the ratios of the waist and hip circumferences to BMI. These ratios were proposed to indicate the relative proportion of fat stored in these regions of the body. To test the occurrence of covert maternal depletion, women were divided into two groups based on the median number of children (low parity, three children or fewer vs.

This paper is presented at the seminar on trade-offs in female life histories: Raising new questions in an integrative framework, Bristol, United Kingdom, July 23–25, 2008.

Contract grant sponsors: Center for Human and Primate Reproductive Ecology (CHaPRE), Wenner-Gren Foundation (to IN), and Polish State Committee for Scientific Research (to GJ).

*Correspondence to: Ilona Nenko, Department of Epidemiology and Population Studies, Institute of Public Health, Jagiellonian University, Grzegorzecka 20, 31-531 Krakow, Poland. E-mail: ilona.nenko@uj.edu.pl

Received 30 October 2008; Accepted 5 March 2009

DOI 10.1002/ajhb.20938

Published online 28 April 2009 in Wiley InterScience (www.interscience.wiley.com).

TABLE 1. Characteristics of the participants

	All women				Low parity (≤3 children)				High parity (> 3 children)			
	N	Mean	SD	Range	*N*	Mean	SD	Range	*N*	Mean	SD	Range
Age (years)	294	47.8	16.34	22–85	157	41.0	14.46	22–84	137	55.5	14.90	25–85
Age of menarche (years)	274	14.59	1.46	10–18	151	14.44	1.38	10–18	123	14.78	1.54	11–18
No. of children	296	3.97	2.12	1–12	158	2.37	0.69	1–3	137	5.77	1.68	4–12
Body fat percentage	279	33.24	7.67	12.5–51.0	148	31.87	7.88	12.5–51.0	131	34.79	7.14	17.0–49.1
Body weight (kg)	292	70.70	14.95	37.9–119.1	155	68.14	14.42	37.9–119.1	137	73.60	15.07	38.4–114.4
Body height (cm)	292	159.33	6.29	138.2–175.0	155	160.46	6.11	138.2–175.0	137	158.05	6.26	143.8–173.5
Body mass index (kg/m^2)	292	27.90	5.94	16.6–49.3	155	26.51	5.68	16.59–49.34	137	29.47	5.85	17.84–48.85
Waist circumference (cm)	291	89.99	14.85	63.0–130.0	154	85.50	13.94	63.0–130.0	137	95.03	14.26	68.4–128.5
Hip circumference (cm)	292	105.70	11.74	82.3–147.5	155	103.05	11.06	82.3–147.5	137	108.71	11.81	87.6–145.7
Waist-to-hip ratio	291	0.85	0.08	0.69–1.12	154	0.83	0.07	0.69–1.12	137	0.87	0.07	0.72–1.06
Hip/BMI ratio	291	3.87	0.44	2.91–5.31	155	3.97	0.44	2.95–5.31	136	3.76	0.40	2.91–4.98
Waist/BMI ratio	290	3.27	0.30	2.54–4.25	154	3.27	0.28	2.54–3.96	136	3.26	0.33	2.63–4.25

TABLE 2. Body mass and body mass index in relation to parity

	Body mass (kg)		BMI (kg/m^2)	
	$N = 271$; $R^2 = 0.22$; $P < 0.001$		$N = 271$; $R^2 = 0.23$; $P < 0.001$	
	R^a	P	R	P
No. of children	0.13	0.02	0.13	0.02
Age (years)	0.31	<0.001	0.34	<0.001
Age of menarche (years)	−0.15	0.007	−0.15	0.007
Body height (cm)	0.33	<0.001	–	–

[a]Values of semipartial correlation.

TABLE 3. Hip circumference in relation to parity

	Hip circumference (cm)					
	Model 1a $N = 289$; $R^2 = 0.88$; $P < 0.001$		Model 2a $N = 288$; $R^2 = 0.89$; $P < 0.001$		Model 3a $N = 275$; $R^2 = 0.81$; $P < 0.001$	
	R^a	P	R	P	R	P
No. of children	0.04	0.07	0.03	0.09	0.03	0.21
Age (years)	−0.03	0.12	−0.06	0.005	−0.08	0.002
Body mass index (kg/m^2)	0.85	<0.001	0.35	<0.001	–	–
Waist circumference (cm)	–	–	0.06	0.002	0.34	<0.001
Body fat percentage	–	–	–	–	0.17	<0.001
Body height (cm)	–	–	–	–	0.03	0.33

[a]Values of semipartial correlation.

TABLE 4. Waist circumference in relation to parity

	Waist circumference (cm)					
	Model 1b $N = 288$; $R^2 = 0.85$; $P < 0.001$		Model 2b $N = 288$; $R^2 = 0.86$; $P < 0.001$		Model 3b $N = 275$; $R^2 = 0.84$; $P < 0.001$	
	R^a	P	R	P	R	P
No. of children	0.02	0.46	0.01	0.65	0.03	0.23
Age (years)	0.19	<0.001	0.19	<0.001	0.16	<0.001
Body mass index (kg/m^2)	0.72	<0.001	0.20	<0.001	–	–
Hip circumference (cm)	–	–	0.07	0.002	0.31	<0.001
Body fat percentage	–	–	–	–	0.15	<0.001
Body height (cm)	–	–	–	–	−0.01	0.84

[a]Values of semipartial correlation.

high parity, more than three children), and the analyses of covariance were used to test the differences among the two groups in waist circumference, hip circumference, waist-to-hip-ratio (WHR), hip/BMI ratio and waist/BMI ratio, while controlling for the percentage of body fat and age (covariates).

In order to further test if parity leads to changes in the relative fat distribution, but to avoid potential statistical problems associated with the use of ratios (Jasienski and Bazzaz, 1999), we run six different multiple regression analyses. First, we tested if hip and waist circumference is affected by parity controlling for age and BMI as potential confounders. Second, we tested the relationship between hip circumference and parity, while controlling for age, BMI, and waist circumference. We repeated this analysis replacing BMI with the body fat and body height. We also tested the relationship between waist circumference and parity, when adjusting for age, BMI, and hip circumference, and finally we repeated this analysis replacing BMI with the body fat and body height. Analyses were performed with Statistica analysis package version 7.0 for Windows.

RESULTS

Body mass adjusted for age, age of menarche, and body height and the similarly (with the exception of body height) adjusted BMI were positively related to the number of children born by a woman ($R = 0.13$, $P = 0.02$; $R = 0.13$, $P = 0.02$, respectively; Table 2).

None of the results suggested that covert maternal depletion occurs in the studied population. Hip circumference (Table 3) was not related to the number of children, while controlling for age and BMI ($R = 0.04$, $P = 0.07$; Model 1a). Moreover, adding waist circumference as additional potential covariate did not change the results ($R = 0.03$, $P = 0.09$; Model 2a). Similarly, hip circumference did not depend on the number of children, when instead of BMI, body fat, and body height were included in the model ($R = 0.03$, $P = 0.21$; Model 3a). Waist circumference (Table 4) was not dependent on the number of children born by a woman, when adjusted for age and BMI ($R = 0.02$, $P = 0.46$; Model 1b) or age, BMI, and hip circumference ($R = 0.01$, $P = 0.65$; Model 2b). Including body fat and body height instead of BMI did not change the statistical significance of the relationship ($R = 0.03$,

TABLE 5. Comparison between groups of women with low and high parity[a]

	Low parity (≤3 children) (N = 146[b])	High parity (>3 children) (N = 129)	P for trend
Waist circumference (cm)	87.58[c] (86.08–89.09)	90.30 (88.87–91.74)	0.13
Waist/BMI ratio	3.25 (3.20–3.31)	3.24 (3.19–3.29)	0.56
Hip circumference (cm)	103.95 (102.61–105.28)	105.99 (104.72–107.27)	0.16
Hip/BMI ratio	3.88 (3.83–3.94)	3.82 (3.76–3.87)	0.53
Waist-to-hip ratio	0.84 (0.83–0.85)	0.85 (0.84–0.86)	0.69

[a]Differences between groups were tested by analyses of covariance with age and percentage of body fat as covariates.
[b]In hip circumference and hip/BMI ratio analysis N = 147.
[c]Values given as means with confidence intervals in parentheses.

$P = 0.23$; Model 3b). Repeating analyses for a restricted sample of women younger than 50 years of age did not reveal any significant relationships between parity and waist or hip circumference (results not shown).

Groups of women with low and high parity did not differ significantly in mean hip and waist circumferences, controlling for the percentage of body fat and age ($F_{1,268}$ = 1.98, P = 0.16, and $F_{1,267}$ = 2.27, P = 0.13, respectively, Table 5). In addition, while controlling for the percentage of body fat, WHR was significantly higher in the group of women with more than three children ($F_{1,273}$ = 8.98, P = 0.003); however, after including age of the woman as an additional covariate, the model was no longer statistically significant ($F_{1,267}$ = 0.16, P = 0.69, Table 5).

Women with more than three children had lower hip/BMI ratio than women with less than three children, controlling for the overall body fatness ($F_{1,274}$ = 5.35, P = 0.02). However, after adjustment for body fat and age, the difference between groups became statistically nonsignificant ($F_{1,268}$ = 0.39, P = 0.53) (Table 5). Furthermore, there was no difference in waist/BMI ratio between groups with low and high parity, while controlling for percentage of body fat and age ($F_{1,267}$ = 0.34, P = 0.56) (Table 5). Repeated analyses for women under 50 years of age did not show statistically significant differences between the two parity groups (results not shown).

DISCUSSION

Reproduction is costly and in women high parity is often associated with poor health in older age (Humphries et al., 2001; Kvåle et al., 1994; Lawlor et al., 2003; Ness et al., 1993) and even the reduced lifespan (Dribe, 2004; Gagnon et al., in press; Jasienska et al., 2006; Smith et al., 2002). In women with good nutritional status, body mass often increases with the number of produced children (Cederlöf and Kaij, 1970; Harris and Ellison, 1997; Harris et al., 1997a,b; Rodrigues and Da Costa, 2001; Wolfe et al., 1997). In the studied Polish rural population, women followed that pattern: body mass and BMI were positively related to the number of children born by a woman. The more children the woman had the higher were her body mass and BMI, although parity explained only a small fraction of variation in these indices of nutritional status. In affluent populations, where women have access to sufficient resources, maternal depletion syndrome (Winkvist et al., 1992), defined as reduction in body weight and fat with parity, is not expected to occur.

However, Lassek and Gaulin (2006) showed that affluent women might pay price for reproduction in a different way. In women from the United States, high parity was associated with relatively less fat stored in lower body parts (as expressed by lower hip/BMI ratio). Lassek and Gaulin (2006) pointed out that the developing human brain has high requirements for PUFAs, but mothers usually do not have enough of these fatty acids in their diets. That is why during late pregnancy and lactation, fatty acids for the developing child must come from the maternal organism. PUFAs are stored mostly in lower body parts, on hips and thighs (Phinney et al., 1994). Therefore, covert maternal depletion, which is depletion of fat from hip and thighs, leading to changes in body shape, can be expected even in women of good nutritional status (Lassek and Gaulin, 2006). Decrease in hip and thigh circumference by 0.5 cm and increase in waist circumference by the same amount was observed with each live birth. Researchers suggested that fat stored at lower parts of the women's body is protected from mobilization until pregnancy and lactation. A special function played by fat stored at lower parts of the body was previously suggested by a Swedish study in which, during the 6 postpartum months, women mobilized fat stored on thighs, but still retained some fat around their waists (Sohlström and Forsum, 1995). In another study, a reduction in hip circumference was observed in women who breast-fed exclusively, but not among formula-feeding mothers and those who used both formula and breastfeed (Kramer et al., 1993). This result suggests that breastfeeding mothers used fat from the lower body for needs of their newborns. Moreover, in Brazilian women, an increase in parity was related to having more fat around their waists, in relation to fat stored in lower body parts (Rodrigues and Da Costa, 2001). Additionally, women with gynoid fat distribution reported the lowest number of birth and women with android fat distribution the highest (Kirchengast et al., 1999). Lassek and Gaulin (2006) showed that WHR was associated with parity after adjusting for age and BMI. This relationship was reported previously in Hispanic (Ness, 1995), Dutch (Tonkelaar et al., 1990) and the US women, where African-American women demonstrated greater changes in adiposity than did white women (Smith et al., 1994). Population variation in female body shape may be expected in relation to environmental conditions (Cashdan, 2008). In particular, in populations experiencing nutritional stress, accumulation of fat in abdominal region (higher WHR) should be more common than in populations where resources are abundant. In our study, while women with high parity seemed to have higher WHR (R^2 = 0.11, P < 0.001), this relationship was not longer statistically significant after adjusting to age and BMI. It seems that women had more fat around their waist due to aging (Cashdan, 2008) and not to the childbearing.

Our results did not confirm the existence of "covert maternal depletion." After controlling for overall body fatness and age, the differences between low- and high-parity groups in hip and waist circumferences, WHR, hip/BMI, and waist/BMI were not statistically significant. There are two possible explanations for lack of "covert maternal depletion." First, it is possible that women in our study did not experience the "covert maternal depletion," because they were not only well nourished, but also had relatively high-dietary intake of PUFAs. Fat intake in the average diet of Polish women is higher than that recommended by WFO/FAO, but it consists mostly of saturated fatty acids (Dybkowska et al., 2007). The intake of PUFAs by general population of Polish women is, on average, lower than recommended, and it is similar to that in the US diet (Dybkowska et al., 2007). However, women from the studied rural population had relatively high consumption of PUFAs, which covered more than 98% of their daily requirements (Merklinger-Gruchala, Ph.D. thesis, in preparation). Therefore, it can be hypothesized that these women did not need to use PUFAs stored in their bodies, because they had sufficient amounts in their diets for the needs of developing brains of their babies.

It is also possible that statistical analyses based on ratios that were proposed to be indicators of "covert maternal depletion" (Lassek and Gaulin, 2006) have low power to detect relationships between parity and maternal nutritional status. The ratios are known to have unfavorable statistical properties (Jasienski and Bazzaz, 1999).

Our population is in many ways different from the US population, including socioeconomic status, reproductive characteristics, and physical activity. In addition, we were not able to compare parous versus nulliparous women, as in the study by Lassek and Gaulin (2006), due to fact that in the study group we only had four nulliparous women. Furthermore, we did not measure thigh circumferences, and changes in that part of the body may be additional important indicators of a covert maternal depletion.

In conclusion, our results show that the higher number of children is associated with slightly higher body mass and higher BMI later in life. We did not observe the existence of any form of "covert maternal depletion" in this well-nourished, rural, traditional population, perhaps due to the sufficient dietary intake of PUFAs.

LITERATURE CITED

Cashdan E. 2008. Waist-to-hip ratio across cultures: Trade-off between androgen- and estrogen dependent traits. Curr Anthropol 49:1099–1107.

Cederlöf R, Kaij L. 1970. The effect of childbearing on body-weight: A twin control study. Acta Psychiatr Scand 219:47–49.

Dribe M. 2004. Long-term effects of childbearing on mortality: Evidence from pre-industrial Sweden. Popul Stud 58:297–310.

Dybkowska E, Swiderski F, Waszkiewicz-Robak B. 2007. The intake of n-3 and n-6 polyunsaturated fatty acids in the Polish diet in relation to the intake in other countries. Polish J Nat Sci 22:722–732.

Gagnon A, Smith KR, Tremblay M, Vézina H, Paré P. In press. Is there a trade-off between fertility and longevity? A comparative study of women from three large historical databases accounting for mortality selection. Am J Hum Biol.

Harris HE, Ellison GTH. 1997. Do the changes in energy balance that occur during pregnancy predispose parous women to obesity? Nutr Res Rev 10:57–81.

Harris HE, Ellison GTH, Holliday M. 1997a. Is there an independent association between parity and maternal weight gain? Ann Hum Biol 24:507–519.

Harris HE, Ellison GTH, Holliday M, Lucassen E. 1997b. The impact of pregnancy on the long-term weight gain of primiparous women in England. Int J Obes 21:747–755.

Hornstra G. 2000. Essential fatty acids in mothers and their neonates. Am J Clin Nutr 71(suppl):1262S–1269S.

Humphries KH, Westendorp ICD, Bots ML, Spinelli JJ, Carere RG, Hofman A, Witteman JCM. 2001. Parity and carotid artery atherosclerosis in elderly women. Stroke 32:2259–2264.

Jasienska G, Ellison PT. 2004. Energetic factors and seasonal changes in ovarian function in women from rural Poland. Am J Hum Biol 2004; 16:563–580.

Jasienska G, Nenko I, Jasienski M. 2006. Daughters increase longevity of fathers, but daughters and sons equally reduce longevity of mothers. Am J Hum Biol 18:422–425.

Jasienski M, Bazzaz FA. 1999. The fallacy of ratios and the testability of models in biology. Oikos 84:321–326.

Jelliffe DB, Maddocks I. 1964. Ecologic malnutrition in the New Guinea Highlands. Clin Pediatr 3:432–438.

Khan KS, Chien PFW, Khan NB. 1998. Nutritional stress of reproduction: A cohort study of two consecutive pregnancies. Acta Obstet Gynecol Scand 77:395–401.

Kirchengast S, Gruber D, Sator M, Huber J. 1999. Postmenopausal weight status, body composition and body fat distribution in relation to parameters of menstrual and reproductive history. Maturitas 33:117–126.

Kramer FM, Stunkard AJ, Marshall KA, McKinney S, Liebschutz J. 1993. Breast-feeding reduces maternal lower-body fat. J Am Diet Assoc 93:429–433.

Kvåle G, Heuch I, Nilssen S. 1994. Parity in relation to mortality and cancer incidence: A prospective study of Norwegian women. Int J Epidemiol 23:691–699.

Lassek WD, Gaulin SJC. 2006. Changes in body fat distribution in relation to parity in American women: A covert form of maternal depletion. Am J Phys Anthropol 131:295–302.

Lawlor DA, Emberson JR, Ebrahim S, Whincup PH, Wannamethee SG, Walker M, Smith GD. 2003. Is the association between parity and coronary heart disease due to biological effects of pregnancy or adverse lifestyle risk factors associated with child-rearing? Findings from the British women's heart and health study and the British regional heart study. Circulation 107:1260–1264.

Ness RB. 1995. Parity, adiposity, and body fat distribution among Hispanic women. Am J Hum Biol 7:657–663.

Ness RB, Harris T, Cobb J, Flegal KM, Kelsey JL, Balanger A, Stunkard AJ, Dagostino RB. 1993. Number of pregnancies and the subsequent risk of cardiovascular disease. N Engl J Med 328:1528–1533.

Phinney SD, Stern JS, Burke KE, Tang AB, Miller G, Holman RT. 1994. Human subcutaneous adipose tissue shows site-specific differences in fatty acid composition. Am J Clin Nutr 60:725–729.

Rodrigues MLCF, Da Costa THM. 2001. Association of the maternal experience and changes in adiposity measured by BMI, waist:hip ratio and percentage body fat in urban Brazilian women. Br J Nutr 85:107–114.

Shell-Duncan B, Yung SA. 2004. The maternal depletion transition in nothern Kenya: The effects of settlement, development and disparity. Soc Sci Med 58:2485–2498.

Smith KR, Mineau GP, Bean LL. 2002. Fertility and post-reproductive longevity. Soc Biol 49:185–203.

Sohlström A, Forsum E. 1995. Changes in adipose tissue volume and distribution during reproduction in Swedish women assessed by magnetic resonance imaging. Am J Clin Nutr 61:287–295.

Tonkelaar I, Seidell JC, Noord PAH, Baanders EA, Ouwehand IJ. 1990. Fat distribution in relation to age, degree of obesity, smoking habits, parity and estrogen use: A cross-sectional study of 11,825 Dutch women participating in the DOM project. Int J Obes 1990; 14:753–761.

Tracer DP. 2002. Somatic versus reproductive energy allocation in Papua New Guinea: Life history theory and public health policy. Am J Hum Biol 14:621–626.

Winkvist A, Rasmussen KM, Habicht J-P. 1992. A new definition of maternal depletion syndrome. Am J Public Health 82:691–694.

Wolfe WS, Sobal J, Olson CM, Frongillo EA, Williamson DF. 1997. Parity-associated weight gain and its modification by sociodemographic and behavioral factors: A prospective analysis in US women. Int J Obes 1997; 21:802–810.