AD NUMBER

ADB239007

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies only; Proprietary Info.; Oct 97. Other requests shall be referred to U.S. Army Medical Research and Materiel Command, Fort Detrick, MD 21702-5012.

AUTHORITY

USAMRMC ltr, 23 Aug 2001

AD ________________

GRANT NUMBER DAMD17-95-1-5070

TITLE: Pregnancy-Induced Changes in Body Fat, Physical Fitness and Energy Requirements in Military and Civilian Women

PRINCIPAL INVESTIGATOR: Nancy F. Butte, Ph.D.

CONTRACTING ORGANIZATION: Baylor College of Medicine
Houston, Texas 77030-3498

REPORT DATE: October 1997

TYPE OF REPORT: Annual

PREPARED FOR: Commander
U.S. Army Medical Research and Materiel Command
Fort Detrick, Frederick, Maryland 21702-5012

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
October 1997

3. REPORT TYPE AND DATES COVERED
Annual (25 Sep 96 - 24 Sep 97)

4. TITLE AND SUBTITLE
Pregnancy-Induced Changes in Body Fat, Physical Fitness and Energy Requirements in Military and Civilian Women

5. FUNDING NUMBERS
DAMD17-95-1-5070

6. AUTHOR(S)
Nancy F. Butte, Ph.D.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Baylor College of Medicine
Houston, Texas 77030-3498

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Commander
U.S. Army Medical Research and Materiel Command
Fort Detrick, Frederick, Maryland 21702-5012

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Distribution authorized to U.S. Government agencies only (proprietary information, Oct 97). Other requests for this document shall be referred to U.S. Army Medical Research and Materiel Command, 504 Scott Street, Fort Detrick, Maryland 21702-5012.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200*

This study addresses the impact of pregnancy-induced changes in body composition and physical fitness on postpartum return to duty readiness. We hypothesize that moderate levels of physical activity will maintain physical fitness and limit excess fat deposition during pregnancy without jeopardizing fetal growth if dietary intake is not restricted. Furthermore, moderate levels of physical activity will facilitate fat mobilization and conserve fat-free-mass (FFM) during postpartum weight loss.

Physical activity, weight, FFM and fat mass, fitness, strength, and iron status will be measured in 34 military reservists and 34 civilian women with low to normal pre-pregnancy BMI through a complete reproductive cycle (0, 8, 22, 36 wk gestation; 2, 6 and 24 wk postpartum). Physical activity will be quantified as the difference between total energy expenditure and basal metabolic rate measured by the doubly-labeled water method and room respiration calorimetry. Body volume (hydrodensitometry), total body water ($^{2}H/^{18}O$ dilution), potassium (^{40}K counting), nitrogen (prompt-gamma activation), and bone mineral (dual X-ray absorptiometry) will be used to calculate FFM and fat mass. Physical fitness will be determined by submaximal and maximal aerobic capacity tests. This report presents preliminary results on women prior to, during and after pregnancy. Data obtained prior to pregnancy strongly indicate a need to revise military equations used to predict body fat of women.

14. SUBJECT TERMS
Defense Women's Health Research Program

15. NUMBER OF PAGES
35

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Limited

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18

FOREWORD

Opinions, interpretations, conclusions and recommendations are those of the author and are not necessarily endorsed by the U.S. Army.

____ Where copyrighted material is quoted, permission has been obtained to use such material.

____ Where material from documents designated for limited distribution is quoted, permission has been obtained to use the material.

NFB Citations of commercial organizations and trade names in this report do not constitute an official Department of Army endorsement or approval of the products or services of these organizations.

____ In conducting research using animals, the investigator(s) adhered to the "Guide for the Care and Use of Laboratory Animals," prepared by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Resources, National Research Council (NIH Publication No. 86-23, Revised 1985).

NFB For the protection of human subjects, the investigator(s) adhered to policies of applicable Federal Law 45 CFR 46.

____ In conducting research utilizing recombinant DNA technology, the investigator(s) adhered to current guidelines promulgated by the National Institutes of Health.

____ In the conduct of research utilizing recombinant DNA, the investigator(s) adhered to the NIH Guidelines for Research Involving Recombinant DNA Molecules.

____ In the conduct of research involving hazardous organisms, the investigator(s) adhered to the CDC-NIH Guide for Biosafety in Microbiological and Biomedical Laboratories.

Nancy Felicia Bratte 10/10/97

PI - Signature Date

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

5. INTRODUCTION

A. Subject, Hypothesis and Technical Objectives of the Research

The level of fatness associated with optimal physical fitness in women is less than the level of fatness associated with optimal fetal growth and survival. Women with low pre-pregnancy energy stores are at greater risk for fetal loss, premature delivery and intrauterine growth retardation. However, a low pre-pregnancy body mass index (BMI) can be compensated for by a greater pregnancy weight gain. In this study the effect of physical activity level on changes in physical fitness, weight, FFM, fat mass, energy expenditure will be evaluated through a complete reproductive cycle in sixty-eight women enrolled equally into 2 cells according to military or civilian status and stratified by pre-pregnancy BMI. Measurements will be done prior to pregnancy to establish pre-pregnancy nutritional status and physical fitness. During pregnancy measurements will be made at 8 wk (first trimester), 22 wk (second trimester), and 36 wk (third trimester). Postpartum measurements will be made at 2 wk to establish postpartum baseline body composition; at 6 wk when military and many civilian women return to work; and at 24 wk when military women must meet weight and physical fitness standards. We will investigate if military policies requiring women to return to weight and physical fitness standards by 6 mo postpartum are physiologically reasonable. The appropriateness of military body weight retention standards and the accuracy of the military equations used to predict body fat will be assessed in postpartum women.

Hypothesis

Moderate levels of *physical activity* will maintain *physical fitness* and limit *excess fat deposition* during pregnancy without jeopardizing fetal growth if dietary intake is not restricted, and facilitate *fat mobilization* and conserve *fat-free mass* during postpartum weight loss.

Technical Objectives

1. *The effect of physical activity level on pregnancy-induced and postpartum changes in weight, FFM and fat mass will be compared in military and civilian women with low to normal pre-pregnancy BMI.* Changes in FFM and fat mass will be computed from measurements of body volume, total body water, potassium, nitrogen and bone mineral through a complete reproductive cycle (pre-pregnancy-6 mo postpartum).

2. *The effect of physical activity level on pregnancy-induced and postpartum changes in physical fitness will be compared in military and civilian women.* Submaximal and maximal aerobic capacity will be measured through a complete reproductive cycle. The impact of body composition (specifically FFM, muscle mass and body fat), and iron status on physical performance will be assessed.

3. *The effect of physical activity level on the energy requirements of physically-active military and civilian adult women will be determined prior to pregnancy, during pregnancy*

and postpartum. Energy requirements will be estimated from rates of energy expenditure and energy deposition/mobilization.

B. Background of Previous Work

Military weight and body fat standards

The rationale for weight and body fat standards for accession and retention in the military as stated in Army regulation 600-9 (1) is "to insure that all personnel are able to meet the physical demands of their duties under combat conditions and present a trim military appearance at all times". Although similar, weight and body fat standards differ somewhat among the military services. If an individual exceeds the acceptable weight for height standard, body fat is assessed using anthropometric measures. The Army uses height, weight, and circumferences of neck, forearm, wrist, and hips in women to calculate body fat (2). The Navy uses height, weight and circumferences of neck, waist and hips in women (3). The Marines use height, weight, flexed biceps, forearm, neck, waist and thigh circumferences for women (4). The Air Force uses height, weight and forearm circumference (5).

The weight and body fat standards for accession and retention differ for men and women. Between 1960 and 1983 the maximum weight limits for women were lowered by 15-20 pds (AR 40-501)(6). The tables for women are considerably more restrictive relative to the national population. The military standard levels for body fatness are lower in men than women, acknowledging the fact that women biologically have higher body fat.

Table 1. Body fat standards for women as a percent of body weight (7)

Age	17-20y	21-27y	28-39y	>40y
Army	30%	32%	34%	36%
Navy	------------------------36%	---------------------------------		
Air Force	-----------------28%	------------------------34%	----------	

However, accession and retention weight criteria are stricter for women than men. For enrollment into the Army men may be 37% above the desirable weight based on the 1959 Metropolitan Life Insurance Tables, while women can be only 6% above. For retention in the Army men can be 14% above desirable weight, and women only 5% above. Consequently, 29% of women Army recruits are rejected in contrast to 3% of male recruits (8). Military weight standards for women are set at an upper BMI limit of 24. Therefore, military women enter pregnancy with a low to normal BMI.

Performance standards

For retention in the military, personnel are evaluated regularly not only for weight compliance, but also for aerobic fitness (7). Physical fitness tests for women consist of a 1.5-2-mile run, push-ups and sit-ups or curl-ups. Although the tasks of military women are increasingly diverse, the military contends that all individuals need to maintain a certain level of physical fitness to preserve the combat readiness of the services. If an individual fails to meet the body fat or physical fitness standards, he/she is assigned a program of diet and exercise. Individuals who do not lose sufficient weight or body fat are discharged from the military.

Pregnancy-induced changes in body weight

In the Institute of Medicine (9) appointed a Subcommittee to review the effect of gestational weight gain on maternal and child health and to make recommendations for optimal weight gain during pregnancy. Gestational weight gains associated with optimal infant outcome were found to be a function of maternal pre-pregnancy BMI. Several epidemiologic studies demonstrated that the effect of a given weight gain is greatest in thin women and least in overweight women. Pre-pregnancy BMI is also a determinant of fetal growth above and beyond its effect on gestational weight gain. Women with low pre-pregnancy BMIs tend to have smaller infants than those of their heavier counterparts. Low gestational weight gain is associated with a higher risk of intrauterine growth retardation and subsequent poor somatic and neurobehavioral development. Increased perinatal mortality among infants born to women with low weight gain especially those with low pre-pregnancy weight for height was seen in the Collaborative Perinatal Project (10) and the 1980 National Fetal Mortality Survey (11).

The Subcommittee concluded that desirable gestational weight gains should be based on pre-pregnancy BMI and should include the mean weight gain for women delivering full-term infants with birth weights in the optimal range of 3 to 4 kg (9).

Table 2. Recommended ranges of gestational weight gain by pre-pregnancy BMI (9)

Weight for height category	Recommended total gain (kg)
Low (BMI<19.8)	12.5-18.0
Normal (BMI=19.8-26.0)	11.5-16.0
High (BMI>26.0-29.0)	7.0-11.5

Although gestational weight gain is correlated with birth weight, which component(s) of gestational weight gain is(are) critical for optimal fetal growth is unknown. Fetal growth may be influenced more by specific changes in fat-free mass (FFM), fat or water than by total gestational weight gain. In a study of 56 Swedish women total weight gain (14.8 kg), but not fat mass accretion (4-5 kg), was positively correlated with birth weight (12). However, their estimates of fat mass based on skinfolds were relatively imprecise. In another study of 115 Scottish women the lack of correlation between maternal fat accretion, estimated from weight retention 2-3 wk postpartum, and birth weight was confirmed (13). These results should be interpreted cautiously, since fat accretion was not measured directly and only women with normal pre-pregnancy BMI (22.5) were studied. In women with low pre-pregnancy BMI fat accretion may be more critical to fetal growth. There may be a threshold for maternal fat gain below which fetal growth is compromised. Further studies on the composition of weight gain in women with low and normal BMI and its impact on pregnancy outcome are needed.

Pregnancy-induced changes in body composition

The amount of FFM and fat accreted at any given gestational weight gain is poorly defined. Theoretical estimations of protein and fat deposition in the maternal (uterus, breasts, blood, adipose tissue, extracellular fluid) and fetal (fetus, placenta, amniotic fluid) compartments have been calculated for a 12.5 kg weight gain (14). Total body water increases continuously through pregnancy, primarily in extracellular fluids; therefore, the hydration of FFM increases substantially through pregnancy (15). Protein accretion rates estimated by recent nitrogen balance studies agree with Hytten's theoretical values (16). Therefore, it seems unlikely that protein is stored in excess of the amounts accounted for by the fetus and maternal reproductive tissues. The suggestion that protein is stored in muscle early in pregnancy, based on urinary 3-methylhistidine excretion data (17), has been refuted by others who attributed the higher urinary excretion of 3-methylhistidine to decreased renal tubular reabsorption and higher skeletal muscle turnover (16). Our measurements of total body nitrogen and potassium retention in pregnancy will resolve the amount and partitioning of protein deposited.

During pregnancy fat is deposited primarily in the subcutaneous adipose of the lower and upper trunk, and thighs (18-20), however, the amount of fat deposited is uncertain. Because of the increased hydration of FFM during pregnancy, standard techniques used to estimate fat deposition are invalid during pregnancy. Corrections were not applied in earlier dilution studies (15,21), but were in a later study (22), in which the mean fat gain was 2.77 ± 3.23 kg. Based on underwater weighing corrected for changes in the density of FFM, fat mass accretion was 2.7 ± 2.2 kg (23). Based on combined measurements of TBW and TBK, mean fat gains were 1.87 ± 2.23 kg (24) and 5.8 ± 4.0 kg (25). Recent values of fat gain differ from Hytten's original estimate of 3.3 kg fat. Technical errors undoubtedly contribute to the high variability in fat gain, but gestational weight gain, which is positively correlated with fat gain, is also variable in healthy women (26). Because of wide variation, changes in body composition can only be estimated from serial measurements, preferably with pre-pregnancy baseline values.

Postpartum weight and body fat loss

Postpartum weight loss is influenced by total gestational weight gain, age, parity, pre-pregnancy BMI, and feeding mode (27). The 1988 National Maternal and Infant Survey indicated a strong positive association between gestational weight gain and postpartum weight retention 10 to 18 months postpartum (28). Excessive weight retention was more common in black women in every weight gain category. Greater weight losses were observed in women with lower pre-pregnancy weights (20). Lactation facilitates weight loss in most women. Lactating women averaged 0.7 kg/mo weight loss during the first 4-6 mo postpartum (29,30). This weight loss was compatible with successful lactation and was associated with a decrease in body fat from 28.0 to 26.3%. Acceleration of weight loss may compromise lactation performance. Short-term energy restriction (1591 kcal/d for 1 wk resulting in a weight loss of 1.18 kg/wk) was associated with a fall in subsequent milk output and infant weight gain (31).

Accelerated weight loss may result in an undesirable loss of muscle mass in postpartum women (32). Whenever body weight is reduced, both FFM and fat mass contribute to the weight loss. For any given change in weight, the ratio ΔFFM/ ΔWT is inversely related to initial body fat. However, exercise-training has been shown to enhance FFM preservation during diet restriction. Moderate exercise training reduced the amount of body weight lost as FFM compared to dietary restriction alone (33). Exercise training also can induce a greater energy deficit and mobilization of fat. We therefore hypothesize that dietary restriction combined with moderate levels of physical activity may preserve FFM in postpartum women.

When pregnant women perform nonweight-bearing exercise such as stationary cycling, oxygen consumption (VO_2 ($l\cdot min^{-1}$)) is either unchanged or only slightly increased at any given submaximal work rate compared to nonpregnant women (34). During submaximal weight-bearing exercise (eg. walking, running, treadmill exercise) maternal VO_2 ($l\cdot min^{-1}$) is significantly increased approximately in proportion to maternal weight gain. VO_2 expressed in $ml\cdot kg^{-1}\cdot min^{-1}$ is similar to or slightly reduced during pregnancy compared to nonpregnant state at the same speed and grade of walking. Limited data indicate that maximal VO_2 ($l\cdot min^{-1}$) during cycle ergometry and treadmill exercise is not altered by pregnancy compared to the postpartum period (35,36). However, in the only study in which aerobic capacity was assessed prior to pregnancy, VO_{2max}($ml\cdot kg^{-1}\cdot min^{-1}$) during cycle ergometry was higher pre-pregnancy compared to 4 to 8 wk postpartum (37). The decrement in VO_{2max} was attributed to increased body weight and decreased physical activity through pregnancy and the postpartum period. Whether this deconditioning effect is an inevitable consequence of pregnancy or whether moderate exercise throughout pregnancy can ameliorate the decline in aerobic capacity is uncertain. The effect of pregnancy-induced changes in body composition on physical fitness has not been evaluated through a reproductive cycle.

Moderate exercise under the ACOG Guidelines (38) poses minimal risk to the mother and her fetus. Such exercise programs may maintain aerobic fitness and control gestational weight gain (34). Strenuous exercise, on the other hand, may result in inadequate weight gain and give rise to smaller (300-500 g less) infants.

Effect of iron status on work capacity and performance

Maximal aerobic capacity in linearly related to hemoglobin concentration in humans (39). In iron deficiency without anemia skeletal muscle function is impaired by a decrease in mitochondrial iron-dependent enzymes of the electron transport chain and cytochromes. Iron deficiency induces a greater dependence on anaerobic glucose utilization, with lactic acidemia as a consequence. These defects reduce endurance and submaximal work performance. This is of practical importance since most human work is performed at submaximal levels (40% of VO_{2max}). In iron-deficient women without overt anemia total O_2 uptake and total energy expenditure were decreased, and post-exercise lactate concentration was increased in response to a progressive, graded aerobic capacity test on a cycle ergometer (40). Peak oxygen consumption was not impaired.

Postpartum women are "at risk" for iron deficiency or anemia. Iron losses during pregnancy include loss to the fetus and placenta, blood loss at delivery, and basal losses totalling approx. 840 mg (9). Blood loss during a cesarean delivery is almost twice that of a vaginal delivery. While we do not expect to find overt anemia in pregnant military women under medical surveillance, marginal iron deficiency may be present.

Pregnancy-induced changes in energy requirements

The energy requirement of pregnancy is a topic of considerable uncertainty as reflected in the lack of consensus in international recommendations: +1.20 MJ/d for all trimesters (41); +1.25 MJ/d for the last 2 trimesters (42); +0.80 MJ/d for the third trimester (43).

The energy requirement of pregnancy entails the energy deposited in maternal and fetal tissues and their associated increase in energy expenditure. Basal metabolic rate (BMR) steadily rises through pregnancy, due primarily to the products of conception and to a lesser extent to increased maternal cardiac and respiratory work. By late pregnancy VO_2 is 16-32% above nonpregnant values. Serial measurements of BMR through pregnancy indicate considerable interindividual variation in metabolic response (22,25,44,45), which was correlated to pre-pregnancy fatness, weight gain and fat gain (22). BMR actually declined in the first trimester in some women, suggesting increased metabolic efficiency. The lean women tended to be energy-sparing and the fatter women energy-profligate.

Total energy expenditure (TEE) using room calorimetry (46,47) and the doubly-labeled water method (22,48) has been measured longitudinally in only a few pregnant women. Near term TEE increased 1.5-2 MJ/d. Although changes in BMR accounted for most the increment in TEE, the level of physical activity contributed significantly to the variability in TEE.

The energy requirement of pregnancy will depend on the woman's gestational weight gain and the level of physical activity maintained throughout pregnancy. If a moderate level of physical activity and therefore physical fitness are maintained, it is of paramount importance that dietary intake is sufficient to meet maternal and fetal needs. In women with low pre-pregnancy BMI, if dietary intake is not sufficient to replenish maternal stores, fetal growth will be suboptimal. However, recommendations for dietary intake cannot be made, since the energy requirements of physically active pregnant women with low to normal pre-pregnancy BMI have not been quantified.

Nutritional implications for military women during reproduction

The nutritional problems of military women are similar to physically active civilian women participating in recreational sports. Inadequate intakes of iron and calcium place these weight-conscientious women at risk for anemia and osteoporosis (49). Friedl (50) reported that 36.6% of West Point cadets were at risk of developing iron deficiency. Inadequate iron nutriture may impact physical performance through its effect on O_2 transport and oxidative metabolism (39). The nutritional status of military women may be further jeopardized by the need to meet military body weight and fat standards.

Because pregnant military women are required to meet weight and physical fitness standards by 6 mo postpartum, they may restrain food intake and possibly jeopardize fetal growth. Postpartum military women may seriously restrict food intake to accelerate weight loss resulting in loss of fat and FFM, and possibly compromising milk production, if breast-feeding. Military women enter pregnancy with low to normal BMIs, since the military retention weight standards are equivalent to a BMI of 24. We calculated desirable gestational weight gains for optimal infant outcome and postpartum weight loss for women with low and normal pre-pregnancy BMIs (Table 3) based on the IOM recommendations for weight gain; an immediate weight loss associated with the baby, placenta and amniotic fluid of 4.85 kg (14); diuresis resulting in an additional 3.0 kg loss by da 15 postpartum; further weight loss at an average rate of 0.7 kg/mo.

Table 3. Expected gestational weight gain and postpartum weight retention in military women

	Low BMI	Normal BMI
Weight gain (kg)	12.5-18.0	11.5-16.0
Weight retention day 1 postpartum (kg)	7.6-13.1	6.6-11.2
Weight retention day 15 postpartum (kg)	4.6-10.1	3.6-8.2
Weight retention day 42 postpartum (kg)	3.6-9.1	2.7-7.2
Weight retention day 180 postpartum (kg)	0.4-5.9	0.6-4.0

If military women gain at the recommended levels and lose at a reasonable rate postpartum, they will return to active duty at da 42 postpartum with significant excess weight. At 6 mo when military women are expected to meet weight standards, many women will be 0.5-6.0 kg above their pre-pregnancy weight. In order the achieve the weight standards by 6 mo, military women must restrict dietary intake to accelerate weight loss.

The level of physical activity maintained by pregnant military women is uncertain. Although military "pregnancy profiles" exempt women from jobs requiring heavy physical work and eliminates physical fitness testing, these physically-fit women may voluntarily continue to exercise. Or they may become relatively inactive and physical fitness may decline due to deconditioning. Upon returning to work at 6 wk postpartum, military women are expected to perform at their pre-pregnancy work capacity. Whether pre-pregnancy physical fitness has been regained by 6 wk postpartum is uncertain. In only one study was aerobic capacity assess prior to pregnancy and 4-8 wk postpartum; a decline in aerobic capacity was observed postpartum and attributed to weight gain and decreased physical activity during pregnancy (37). Whether this detraining effect is inevitable during pregnancy or whether exercising throughout pregnancy ameliorates the decline is unknown.

Application of the body fat equations to postpartum women is questionable. Although the prediction equations for body fat have been cross-validated for men and women, they have not been evaluated for postpartum women (3). The Army and Navy equations may overestimate total body fat since these equations use hip circumference, a site of predominate fat deposition in pregnant women. The Air Force equation may underestimate total body fat since it uses forearm circumference which changes little during pregnancy.

Information relevant to the Military Recommended Dietary Allowances (51) for energy intakes of active duty and reserve military women will be provided by this study. Energy requirements of physically active women will be defined prior to, during and after pregnancy which may assist in the design of feeding strategies and food rations for military women.

6. Methods

Study Design

The effect of physical activity level on changes in physical fitness, weight, FFM, fat mass, and energy expenditure will be evaluated through a complete reproductive cycle in sixty-eight women. Women will be studied prior to conception, at each trimester, and at 2, 6 and 24 wk postpartum.

Table 4. Study design

	Pregnancy				Postpartum		
Study variables	0	8wk	22wk	36wk	2wk	6wk	24wk
Anthropometry	x	x	x	x	x	x	x
Hydrodensitometry	x	x	x	x	x		x
TBK	x	x	x	x	x		x
DEXA	x				x	x	x
TBN	x				x		x
TBW		x			x		
TEE/TBW	x		x	x			x
24-h calorimetry	x	x	x	x			x
Physical fitness	x	x	x	x		x	x
Iron status	x	x	x	x		x	x

Subjects

Sixty-eight women will be enrolled equally into 2 cells according to military or civilian status and stratified by pre-pregnancy BMI. An upper BMI limit of 24.0 was designated in accordance with military weight standards. However, we are enrolling women with BMI≤26, to better match the military reserve population. Subjects will be healthy, physically-active, nonsmoking, ages 18-39 years, parity not greater than 4, no chronic medications or alcohol/drug abuse. Health history should be unremarkable (i.e., normotensive, glucose tolerant, nonanemic and euthyroid).

Methodology

Anthropometry. Maternal body weight to the nearest 0.1 kg will be measured with a digital balance (Scale-Tronix, Dallas TX). Height to the nearest 1 mm will be measured with a stadiometer (Holtain, Ltd, Crymmych, Pembs, UK). The circumferences of the head, chest, upper arm, forearm, wrist, neck, abdomen, thigh, and calf will be measured to the nearest 1 mm in duplicate with a metal tape. These sites include those currently used in military equations to predict body fat. Skinfold thicknesses will be measured to the nearest 0.5 mm in duplicate with a Lange skinfold caliper (Cambridge Scientific Industries, Cambridge, MD) at the following sites: triceps, biceps, subscapular, thigh, and suprailiac.

The U.S. Army, Navy and Air Force equations used to predict the body fat of women will be compared against other body composition models.

Table 5. Fat mass prediction equations for the U.S. Army, Navy, and Air Force servicewomen(7)

U.S. Army

$$FM(\%) = 105.3 \times \log_{10}(weight) - 0.20 \times waist - 0.533 \times neck - 1.574 \times forearm + 0.173 \times hip - 0.515 \times height - 35.6$$

U.S. Navy

$$Density = -0.35 \times \log_{10}(abdomen\ I + hip - neck) + 0.221 \times \log_{10}(height) + 1.296$$

$$FM(\%) = 100 \times [(4.95/density) - 4.5]$$

U.S. Air Force

$$FFM(kg) = 1.619 \times forearm + 0.311 \times height - 47.76$$

$$FM(\%) = 100 \times (weight - FFM)/weight$$

Weight is in kg; height and body circumferences are in cm.
Note: As of 1996 the Air Force adopted the Navy equations for prediction of fat mass.

Hydrodensitometry. An underwater weighing system utilizing "force cube" transducers (Precision Biomedical Systems, Inc., State College, PA) will be used for body density measurements (52). Each subject will be requested to urinate, defecate, shampoo, shower, change to a swimming suit, and then submerge herself and exhale maximally while her body weight in the water is being measured. Residual lung volume will be measured using the simplified nitrogen washout method (53). Body density will be calculated from body weights in and out of the water and residual lung volume.

Total Body Potassium (TBK). Total body ^{40}K content of each subject will be measured using the CNRC low-background whole-body counter. The CNRC counting system consists of a total of 30 NaI(T1) detectors (each 10 cm x 10 cm x 45 cm) for a total detection volume of 135,000 cc. The detectors are arranged into two arrays positioned above and below the bed with the subject in a supine position. The subject will lie supine for 15 minutes while the body's natural gamma ray signal is recorded. The gamma signal is directly proportional to the amount of potassium in the body. The precision of the ^{40}K counting is <1% in adults.

Dual Energy X-ray Absorptiometry (DEXA). Composition of the total body and major subregions will be measured using a Hologic QDR 2000W system (Hologic, Inc., Madison, WI). Subregions include the head, thoracic spine, ribs, lumbar spine, pelvis, arms, and legs. The whole body scan takes approximately 15 minutes with the subject lying supine. The low dose (<0.01 mSv) has allowed for IRB approval of research measurements in healthy individuals. Over a 2 y period the average precision for bone mineral density using the spine phantom was ±0.6%.

Total Body Nitrogen (TBN). Prompt-Gamma Activation Analysis will be used to measure TBN. The subject is placed in a very weak neutron beam: neutrons interact with body tissues and generate a gamma signal that can be detected external to the body. This technique induces activities of interest that are very short-lived (less than 1 μsec) which requires the detection system to be included in the irradiator assembly. Two shielded, collimated AmBe sources provide a bilateral beam through which the subject is scanned. Four large volume NaI(T1) detectors with custom designed neutron/gamma shielding are positioned at 90° to both the bed and sources. The scan time is about 15 min; the dose is less than 0.3 mSv (comparable to a chest x-ray). In pigs, the *in vivo* precision was determined to be 3.5% for body nitrogen.

Muscle and Nonmuscle Mass. In the nonpregnant women TBK and TBN will be used to estimate the relative amounts of protein in muscle and nonmuscle components of the body and the mass of each component (54). The principle underlying this approach is that the K/N ratio for muscle is higher than that of nonmuscle tissues (3.03 vs 1.33 meq/g). Assuming the values of 30 g N/kg and 91 meq K/kg muscle, and 36 g N/kg and 48 meq K/kg nonmuscle, total muscle mass is equal to (K-1.33N)/51.0 and total nonmuscle mass is equal to (3.03 N-K)/61.2.

Body Composition Models. The Fuller (55) four-compartment model that combines total body water (TBW), body density and DEXA measurements will be used to compute fat-free mass (FFM) and fat mass (FM). A constant ratio of bone mineral to non-osseous mineral (0.8191:0.1809) is assumed. The equation used is: FM(kg) = 2.747 body volume - 0.710 TBW + 1.460 total body bone ash - 2.050 weight. Gestational values for total body bone ash will be linearly interpolated from pre-pregnancy and day 15 postpartum measurements. Regional fat deposition during pregnancy and mobilization postpartum will be studied through all reproductive phases using anthropometry and DEXA. Subregions described by DEXA include the head, thoracic spine, ribs, lumbar spine, pelvis, arms, and legs.

Total Body Water (TBW). After collection of baseline saliva samples, 40 mg ^2H_2O/kg in the form of water will be administered orally at 8 and 36 wk of gestation, and 2 and 24 wk postpartum. The ^2H abundance in saliva samples will be measured by gas-isotope-ratio mass spectrometry. TBW will be calculated from the elevation of ^2H abundance in the 4-h and 6-h postdose samples. TBW will be determined from $^2H_2{}^{18}O$ dilution prior to pregnancy and at 22 wk gestation, and at 24 wk postpartum (see TEE).

Total Energy Expenditure. Total energy expenditure (TEE) over a 14-day period will be calculated from the fractional turnover rates of ^2H and ^{18}O following oral ingestion of 100 mg/kg ^2H_2O and 125 mg ^{18}O as water (56). Isotope dilution spaces will be used to compute TBW. Baseline saliva samples will be collected from each subject. Subsequently, one daily saliva sample will be collected by each subject at home for the next 14 days. The ^2H and ^{18}O abundances of the saliva samples will be measured by gas-isotope-ratio mass spectrometry. Carbon dioxide production (VCO_2) will be calculated from the dilution spaces and fractional turnover rates of ^2H and ^{18}O using the multipoint slope-intercept method of calculation. Fractionated insensible water losses will be calculated from ventilatory volume and body surface area, both expressed as functions of CO_2 production. Respiratory quotient will be computed from the food quotient based on dietary records (57). TEE will be calculated using the Weir equation (58).

Room Respiration Calorimetry. Oxygen consumption (VO_2) and VCO_2 of mothers will be measured and monitored continuously in a room-sized indirect calorimeter for 24-h (59). Energy expenditure will be calculated from VO_2 and VCO_2. Performance tests with N_2 and CO_2 infusions demonstrated that the accuracy of individual measurements of VO_2 and VCO_2 were 3%. System response to a step change exceeded 90% in 4 min. Sleeping metabolic rate (SMR), and basal metabolic rate (BMR) will be extracted from specific time periods. BMR will be measured for 40 minutes while the subject lies quietly 30 min after awaking and voiding. Fat and carbohydrate net utilization will be computed using 24-h excretion rates of urinary nitrogen according to Livesey (60).

The heart rate of the subject will be monitored and recorded continuously by telemetry (Dynascope 3300 Telemetry System, Fukuda Denshi America). During the 24-h period in the calorimeter, subjects will be asked to adhere to a schedule of feeding, sleeping and exercise times. Energy intake will be controlled according to body weight. Subjects will walk twice for 10 minute each at 2.5 and 3.5 mph, no grade, on a treadmill.

Physical Activity. Physical activity level, our major independent variable, will be determined by combining the doubly-labeled water method with respiration calorimetry. Physical activity level will be quantified in terms of MJ/d as the difference between TEE and BMR. Physical activity level will be described qualitatively using the Minnesota Leisure Time Activity Scale (61) combined with the Health Insurance Plan (HIP) Questionnaire for assessment of occupational activity (62).

Physical Fitness. Maximal VO_2 will be measured in nonpregnant women who will undergo a stepwise increase in exercise intensity until volitional fatigue is achieved (3-Corval 400, LODE B.V., Groningen, Holland and 2-Combi Cycle EX80, Combi, Co., LTD. Tokyo). Subjects will cycle for 4 min at 50 watts for steady state determination of VO_2, and then the workload will be increased by 25 watts every minute. VO_2 consumption will be measured continuously via the open circuit technique with a metabolic cart (SensorMedics 2900; Yorba Linda, CA). Heart rate and blood pressure will be monitored. Steady-state heart rate and VO_2 values will be used to estimate VO_{2max}.

Submaximal VO_2 also will be measured in the room respiration calorimeter, unimpeded by a mouthpiece apparatus. In the morning and afternoon women will walk for 20 minute at 2.5 mph, no grade, on a treadmill (905E, Precor, Bothell, WA); heart rate will not be allowed to exceed 140 bpm in pregnant women.

Strength. Prior to the 1 RM strength assessments, the subject will practice using the equipment to become familiar with the proper exercise techniques and to prevent injuries. The upper and lower body 1 RM strength tests will be done utilizing the Cybex Smith Press and the Cybex Latissimus Pulldown (upper body), and the Cybex Modular Leg Press and the Cybex Leg Extension (lower body). The 1 RM is defined as the maximum amount of weight that can be lifted successfully one time only. Starting with a weight used in the practice session, the subjects will attempt lifts with gradually increasing weight (10% at first, decreasing to 5 and 2.5% as difficulty becomes evident). Successive attempts will be made with a 90-s rest between attempts until failure occurs. These measurements will be done at the Texas Children's Hospital Wellness Center within the Department of Pediatrics.

Infant Outcome. Birthweight, length and gestational age will be recorded from medical records.

Biochemical Analysis. A 12-h fasting blood sample will be obtained for the following analyses. A Complete Blood Count and Differential including hemoglobin and hematocrit will be performed by Smith Kline Beecham Clinical Laboratories. Standard techniques of flow cytometry, automated cytochemistry and microscopy are used. Serum iron and total iron binding capacity will be measured using atomic absorption spectrophotometry (Perkin-Elmer Corp., Norwalk, Conn). Serum ferritin will be determined by ^{125}I-radioimmunoassay (Diagnostic Products Corp., CA). To correct calorimetry data, 24-h urinary nitrogen will be determined by the Kjeldahl method (Tecator, Höganäs, Sweden).

Statistical Analysis. Analysis of variance and covariance with repeated measures will be used to test our hypothesis. The grouping factors will be status (military or civilian) and pre-pregnancy BMI stratification criteria (<19.8 or 19.9-26.0). The within factors will be pregnancy status (antepartum or postpartum), and time (levels= 0, 8, 22, 36 wk gestation; 2, 6 and 24 wk postpartum). The major independent variable to be tested is physical activity level. The dependent variables to be analyzed under this model will be weight, FFM, fat mass, energy expenditure, and physical fitness. Covariates to be included in the model are age, parity, iron status and infant feeding mode. Pre-pregnancy BMI will be treated also as a continuous variable in a separate analysis. We will also use multiple regression analysis to investigate relationships between the various dependent variables, and test if these relationships differ between military and civilian women. Statistical analyses will be performed using BMDP (63) and Minitab (64) statistical packages. Microsoft ACCESS will be used for data management.

7. RESULTS and DISCUSSION

Preliminary Data Presentation:

Preliminary data will be presented on the first 62 women enrolled into the study. **While it is tempting to examine longitudinal changes, the number of women who have completed the study are too few to make any firm conclusions regarding the effects of physical activity level on pregnancy-induced changes in weight, body composition, physical fitness and energy requirements, or to assess postpartum return to weight and physical fitness standards.** The sample size of women studied prior to pregnancy is sufficient to evaluate the accuracy of the military equations used to predict body fat.

Subject Description:

A total of 530 women responded to recruiting initiatives, of whom 165 passed the screening criteria and accepted our invitation to tour the CNRC facility with their spouse (or partner) and received an overview of the study. To date, 62 women have been enrolled into the "Fit for Life" study. Of the 62 participants, 54 women are civilians and 8 are military reservists. The sample consists of 45 Caucasian, 9 Afro-American, and 8 Hispanic women. The age of the women ranges from 20 to 39 y. Baseline measurements have been performed on 62 women, of whom 19 have become pregnant. Nine women have completed the entire protocol.

Reproductive History:

Reproductive history indicates normal menses, except in a few cases with prolonged use of oral contraceptives. Five women have been asked to return for an abbreviated list of baseline measurements, because of failure to conceive within one year.

Table 6. Reproductive history	
	n=62
Maternal age (y)	30.3 ± 4.3*
Menarche age (y)	12.9 ± 1.6
Menses interval (d)	29.2 ± 4.6
Menses duration (d)	4.4 ± 1.1
Gravidity	0.8 ± 1.1
Parity	0.4 ± 0.6

*Mean ± SD

Pregnancy Outcome:

Of the 14 deliveries, all were term, healthy infants except for one preterm infant born at 33 weeks of gestation. Four pregnant women did not complete the study, because of: 1) twins, 2) triples, 3) stillbirth, and 4) lost to follow-up.

Table 7. Pregnancy outcome	
Gender	8M/6F
Gestational age (wk)	38.8 ± 2.2*
Birthweight (kg)	3.16 ± 0.71
Birth length (cm)	50.4 ± 2.6
Apgar score- 1 min	7.8 ± 0.4
- 5 min	8.8 ± 0.6

*Mean ± SD

Iron Status:

Iron status will be assessed throughout the reproductive cycle, because of its potential effect on pregnancy outcome, work capacity, and physical fitness. Prior to pregnancy, there is no evidence of iron deficiency or anemia in these women, based on normal values for hemoglobin, hematocrit, serum iron, and transferrin. Serum ferritin, an indicator of iron stores, and transferrin receptor, an index of tissue iron need, also fell within the normal limits for all women.

Iron metabolism and erythrocyte indices are altered by the physiological changes of normal pregnancy. Serum iron decreases with increasing duration of pregnancy due to plasma volume expansion. Serum transferrin increases by ~2.4 fold due to estrogen-stimulated hepatic protein synthesis; iron saturation accordingly decreases. Serum ferritin decreases as iron stores are used for expansion of erythrocyte mass. Because of these changes in iron metabolism, it is difficult to distinguish anemia due to iron deficiency from dilutional anemia. To provide a more sensitive indicator of iron deficiency in pregnancy, we are using an EIA assay for serum transferrin receptor (Ramco Laboratories Inc.). In contrast to ferritin, serum transferrin receptor is not elevated with inflammation or infection. Any elevation of serum transferrin receptor during pregnancy is due to maternal iron deficiency. Serum ferritin, transferrin and transferrin receptor will be monitored throughout the reproductive cycle to evaluate the impact of iron status on pregnancy outcome and postpartum recovery. The data also will be analyzed for evidence of an effect of iron deficiency on basal energy expenditure and submaximal work performance.

Table 8. Iron status

	Pre-pregnancy n=62	8 wk pregnancy n=20	22 wk pregnancy n=17	36 wk pregnancy n=12	6 wk postpartum n=11	24 wk postpartum n=5
Hemoglobin (g/dl)	13.7 ± 0.9*	13.2 ± 0.9	12.0 ± 0.8	12.3 ± 1.0	12.8 ± 0.9	13.6 ± 0.4
Hematocrit (%)	40.5 ± 2.8	38.8 ± 2.6	35.2 ± 2.4	36.6 ± 3.1	38.3 ± 2.4	41.3 ± 0.9
Serum iron (μg/dl)	104.5 ± 33.8	107.4 ± 24.9	100.0 ± 34.1	99.2 ± 50.8	62.7 ± 20.6	79.2 ± 37.5
Iron binding capacity (μg/dl)	322.6 ± 50.8	304.0 ± 32.7	353.8 ± 43.1	413.5 ± 41.0	308.6 ± 41.8	275.2 ± 48.1
Iron saturation (%)	32.8 ± 10.9	36.0 ± 8.7	28.4 ± 10.3	23.9 ± 12.0	21.4 ± 10.3	27.8 ± 10.4
Ferritin (ng/ml)	48.3 ± 32.3	59.8 ± 38.3	31.6 ± 24.0	20.4 ± 11.8	37.9 ± 34.1	39.0 ± 19.3
White blood cell count (WBC) ($x10^9$/L)	6.1 ± 1.8	8.1 ± 2.8	11.6 ± 3.6	11.3 ± 2.7	5.7 ± 1.0	5.9 ± 1.3
Red blood cell count (RBC) ($x10^{12}$/L)	4.4 ± 0.4	4.4 ± 0.3	3.8 ± 0.3	4.0 ± 0.4	4.3 ± 0.3	4.4 ± 0.2
Mean corpuscular volume (MCV) (fL)	91.2 ± 3.7	89.4 ± 5.4	92.9 ± 4.8	92.5 ± 6.6	89.7 ± 5.5	93.5 ± 3.1
Mean corpuscular hemoglobin (MCH) (pg)	30.8 ± 1.4	30.5 ± 2.1	31.7 ± 1.9	31.1 ± 2.5	30.0 ± 2.1	30.9 ± 1.3
Transferrin receptor (ng/ml)	4.5 ± 1.2	3.5 ± 0.7	3.9 ± 0.7	5.8 ± 2.9	6.4 ± 2.8	6.3 ± 3.3

*Mean±SD

Anthropometry

The anthropometric measurements reflect a wide array of body sizes. Prior to pregnancy, the mean BMI was 21.8 ± 2.5 kg/m^2. Height ranges between 151 and 177 cm. Prior to conception, weight varied between 40 and 86 kg. Anthropometric measurements will be used to monitor gestational weight gain/postpartum weight loss, and site-specific deposition/postpartum mobilization of subcutaneous body fat. In the 12 women who have delivered, the mean weight gain at 36 wk was 13.9 ± 3.9 kg; the total gestational weight gain at delivery was 15.2 ± 4.0 kg.

Table 9. Anthropometry

	Pre-pregnancy n=62	8 wk pregnancy n=20	22 wk pregnancy n=18	36 wk pregnancy n=12	2 wk postpartum n=12	6 wk postpartum n=12	24 wk postpartum n=9
Weight (kg)	59.9 ± 8.9*	59.0 ± 9.6	64.9 ± 10.0	70.9 ± 9.7	65.3 ± 11.5	63.6 ± 11.5	62.1 ± 11.1
Height (cm)	165.1 ± 6.4	163.9 ± 7.3	162.19 ± 8.85	162.8 ± 7.1	162.6 ± 7.8	162.0 ± 7.9	160.8 ± 5.9
Body mass index (BMI) (kg/m^2)	21.8 ± 2.5	21.9 ± 3.0	24.7 ± 3.2	26.8 ±3.8	24.6 ± 3.4	24.1 ± 3.2	24.0 ± 4.0
Circumferences (cm):							
Head	54.9 ± 1.9	54.4 ± 1.2	54.5 ± 1.0	54.6 ± 1.2	54.8 ± 0.9	54.7 ± 1.2	54.4 ± 1.5
Neck	31.3 ± 1.6	31.4 ± 2.0	31.5 ± 1.6	37.7 ± 19.0	32.6 ± 1.9	32.3 ± 2.1	31.9 ± 1.9
Chest	88.0 ± 5.8	89.8 ± 6.0	95.8 ± 7.1	96.8 ± 7.6	95.5 ± 7.1	94.6 ± 6.5	92.0 ± 7.5
Waist	69.9 ± 5.8	71.9 ± 6.6	82.1 ± 6.7	92.0 ± 9.3	79.2 ± 5.6	77.9 ± 5.2	76.2 ± 7.1
Hip	95.2 ± 6.2	95.7 ± 7.2	99.1 ± 6.6	100.6 ± 7.0	97.2 ± 9.1	98.9 ± 7.5	95.6 ± 7.4
Thigh	48.8 ± 4.1	48.2 ± 4.8	50.1 ± 4.8	51.1 ± 4.6	50.5 ± 5.8	49.5 ± 5.9	49.6 ± 5.9
Calf	35.5 ± 2.8	34.8 ± 2.7	35.9 ± 2.7	37.0 ± 2.9	35.7 ± 3.6	35.4 ± 3.5	36.1 ± 3.1
Wrist	14.4 ± 0.6	14.1 ± 0.8	14.4 ± 0.7	14.7 ± 0.5	14.4 ± 0.9	14.5 ± 0.7	14.6 ± 0.6
AF Forearm	23.2 ± 1.5	23.0 ± 1.8	23.4 ± 2.1	23.4 ± 1.7	23.5 ± 2.3	23.6 ± 2.3	23.8 ± 2.1
Army forearm	23.4 ± 1.5	23.2 ± 1.9	23.8 ± 2.3	24.5 ± 1.7	24.3 ± 2.2	24.0 ± 2.5	24.3 ± 2.3
Upper arm	26.5 ± 2.8	26.4 ± 3.5	27.4 ± 3.7	27.5 ± 2.7	27.4 ± 4.5	28.0 ± 3.7	28.0 ± 3.2
Skinfolds (mm):							
Triceps	15.4 ± 6.5	17.3 ± 6.9	19.1 ± 8.9	16.9 ± 7.2	19.2 ± 7.8	18.8 ± 7.5	20.7 ± 10.9
Biceps	6.0 ± 4.0	6.5 ± 5.7	8.3 ± 7.0	6.8 ± 3.2	7.6 ± 6.1	7.5 ± 5.6	6.6 ± 4.3
Subscapular	14.2 ± 7.8	15.5 ± 8.4	18.1 ± 9.2	17.0 ± 8.3	20.5 ± 8.1	19.1 ± 8.4	17.5 ± 11.0
Suprailiac	16.4 ± 9.2	18.7 ± 10.3	24.7 ± 10.2	22.9 ± 10.5	25.5 ± 9.3	24.6 ± 10.1	21.0 ± 14.1
Thigh	25.1 ± 8.6	27.4 ± 9.2	31.3 ± 11.4	29.1 ± 10.9	32.8 ± 11.4	29.6 ± 10.9	*25.7 ± 12.3
Sagittal diameter (cm)	14.4 ± 1.5	**	**	**	17.4 ± 2.0	16.9 ± 2.1	15.8 ± 2.7

*Mean ± SD; **Measurement not performed during pregnancy

Body Composition

Standard 2-component body composition models based on deuterium dilution, hydrodensitometry, or total body potassium, while applicable prior to conception, are invalidated during pregnancy due to the expansion of body fluid compartments. Further, postpartum normalization of FFM hydration has not been well characterized, and therefore, the validity of standard 2-component models is uncertain for an undetermined time period following delivery. To obtain more accurate estimates of FFM and FM in reproductive women, we have chosen the Fuller 4-component model, which minimizes assumptions regarding the hydration of FFM and the bone mineral content of dry FFM, by incorporating measurements of total body water, body density, and BMC (55). This model also provides more accurate body composition estimates in non-pregnant individuals. A comparison of FM estimated by the standard and multicomponent body composition models is presented in Table 10. Systematic differences between methods in the estimation of fat mass are evident.

Table 10. Fat mass (FM) estimated by deuterium dilution, hydrodensitometry, total body potassium, DEXA, and skinfold thicknesses, and multi-component models

		Pre-pregnancy N=62	8 wk pregnancy n=20	22 wk pregnancy n=18	36 wk pregnancy n=12	2 wk postpartum n=12	6 wk postpartum n=12	24 wk postpartum n=9
Deuterium dilution								
Total body water (TBW)	kg	32.29 ± 4.20*	31.49 ± 4.16	34.16 ± 3.93	39.10 ± 2.60	33.41 ± 2.26	31.31 ± 2.26	31.79 ± 2.03
FM	kg	15.7 ± 5.4	17.5 ± 7.6	18.8 ± 7.8	22. 0 ± 10.1	18.3 ± 6.6	16.2 ± 4.4	15.2 ± 7.2
Hydrodensitometry (HD)								
Body volume	l	57.59 ± 9.14	56.40 ± 9.61	63.10 ± 10.28	72.39 ± 12.54	64.58 ± 12.03	63.79 ± 13.65	57.01 ± 8.19
Body density	kg/l	1.036 ± 0.014	1.035 ± 0.012	1.030 ± 0.012	1.028 ± 0.012	1.026 ± 0.012	1.027 ± 0.012	1.034 ± 0.009
FM	kg	16.81 ± 5.86	16.69 ± 5.76	19.29 ± 6.38	21.25 ± 7.85	20.61 ± 7.18	21.46 ± 7.72	17.30 ± 4.84
Total body potassium (TBK)								
FM	kg	15.60 ± 6.01	17.53 ± 7.29	21.34 ± 6.79	23.39 ± 10.23	21.86 ± 8.22	20.12 ± 7.29	19.61 ± 7.36
Dual energy x-ray absorptiometry (DEXA)								
FM	kg	15.93 ± 5.43	**	**	**	23.08 ± 7.90	20.56 ± 7.52	20.66 ± 6.56
Skinfold thicknesses (SF:Durnin & Womersley)								
Body density	kg/l	1.037 ± 0.013	1.035 ± 0.012	1.029 ± 0.013	1.032 ± 0.013	1.027 ± 0.012	1.029 ± 0.013	1.027 ± 0.015
FM	kg	16.63 ± 5.56	17.19 ± 5.62	20.40 ± 6.51	21.13 ± 6.35	21.21 ± 7.01	20.31 ± 6.93	21.47 ± 8.40
Multi-component models								
FM-Siri (TBW, HD)	kg	16.09 ± 5.14	17.54 ± 7.23	19.12 ± 7.03	21.51 ± 9.18	18.13 ± 6.03	17.05 ± 4.52	16.18 ± 6.36
FM-Fuller (TBW, HD, DEXA)	kg	16.70 ± 5.57	15.29 ± 7.68	18.82 ± 7.11	21.61 ± 8.89	20.57 ± 8.03	20.43 ± 7.25	18.80 ± 7.19

*Mean ±SD; ** Measurement not performed during pregnancy; Abbreviations: TBW, total body water; HD, hydrodensitometry; TBK, total body potassium; DEXA, dual energy x-ray absorptiometry; SF, skinfold thicknesses.

Mean pre-pregnancy body fat was 16.7 ± 5.6 kg, or 27.0 ± 6.3% by the Fuller 4-component model (Table 10). FM and % body fat at the pre-pregnancy time point estimated by military equations and by standard and multi-component models are listed in Table 11. Fat mass predicted from military equations depends on different anthropometric sites. The Army equation uses the waist and hip circumferences and builds in BMI, ie. weight and height measurements; the Navy equation predicts density from abdomen, hip and height; the Air Force has adopted the Navy equations. Most subjects would have been eligible for enrollment into each branch of the Armed Services, according to the currently used Army and Navy equations. One women would not have qualified for the Army or Navy, and five exceeded cut-offs for the Air Force.

FM derived from the Fuller 4-component model and military equations were highly correlated ($r^2 = 0.75$-0.83). Percent FM derived from the Fuller 4-component model and military equations also were significantly correlated, but to a lesser extent ($r^2 = 0.56$-0.70) (Figures 1-3). The Air Force equation significantly overestimated both the mean FM and % FM in this group of women, and the Army and Navy equations tended to underestimate mean FM and % FM. The Army and Navy prediction equations are conservative, in that direct measurement of FM would have rendered more women ineligible for service.

Bland-Altman plots illustrate the differences in %FM derived from the Fuller 4-component model and military equations (Figures 4-6). The negative slope indicates that the difference between methods is a function of %FM. The underestimation of %FM was greater in fatter women. The mean differences (or relative biases), 2 ± 6% for the Army and Navy equations, were statistically significant (p=0.001). The standard deviation is the estimation of error. These data imply wide confidence intervals for the prediction of %FM for individuals.

We will also evaluate these predictive equations for use in postpartum women. Further, the effect of gestational weight gain and fat accretion on the ability to return to body fat standards in the 6 months following delivery will be assessed.

Table 11. Body fat mass (FM) predicted from military equations and body composition models at the pre-pregnancy and 24 wk postpartum study intervals

	Fat mass (kg)		Fat mass (%WT)	
	Pre-pregnancy	24 wk postpartum	Pre-pregnancy	24 wk postpartum
	n=62	n=9	n=62	n=9
FM-Army equation	15.7 ± 4.6*	19.1 ± 5.7	25.8 ± 4.4	29.0 ± 4.6
FM-Navy equation	15.5 ± 5.5	20.0 ± 7.1	25.3 ± 5.6	30.1 ± 5.9
FM-Air Force equation	18.5 ± 6.0	23.1 ± 7.6	30.3 ± 5.8	34.8 ± 6.0
FM (TBW)	15.7 ± 5.4	15.2 ± 7.2	25.8 ± 6.6	25.0 ± 8.4
FM (HD)	16.8 ± 5.8	17.3 ± 4.8	27.7 ± 6.5	28.9 ± 4.2
FM (TBK)	15.6 ± 6.0	19.6 ± 7.3	25.8 ± 7.5	30.0 ± 7.0
FM (DEXA)	15.9 ± 5.4	20.6 ± 6.5	26.7 ± 6.5	31.8 ± 4.9
FM (SF)	16.6 ± 5.5	21.4 ± 8.4	27.3 ± 5.8	32.0 ± 7.0
FM-Siri (TBW, HD)	16.0 ± 5.1	16.1 ± 6.3	26.5 ± 5.8	26.8 ±6.6
FM-Fuller (TBW, HD, DEXA)	16.1 ± 4.8	16.4 ± 6.3	27.0 ± 6.3	27.3 ± 6.6

*Mean ± SD

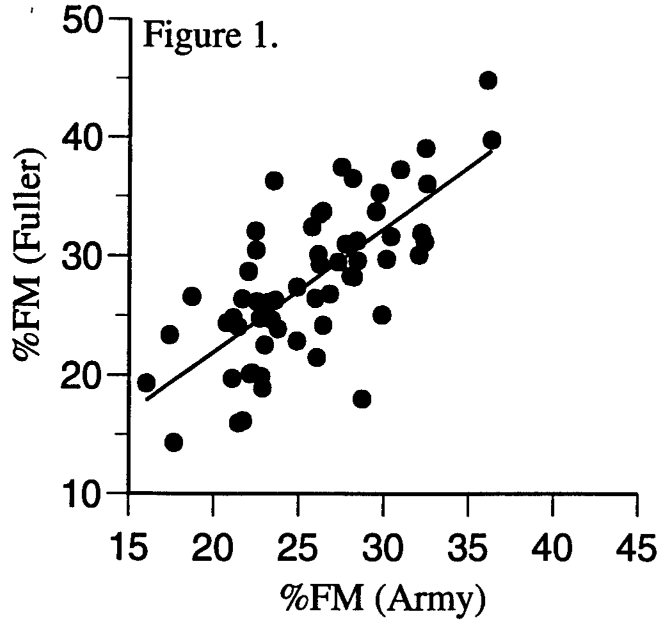
Figure 1.
%FM (Fuller)
%FM (Army)
50
40
30
20
10
15 20 25 30 35 40 45

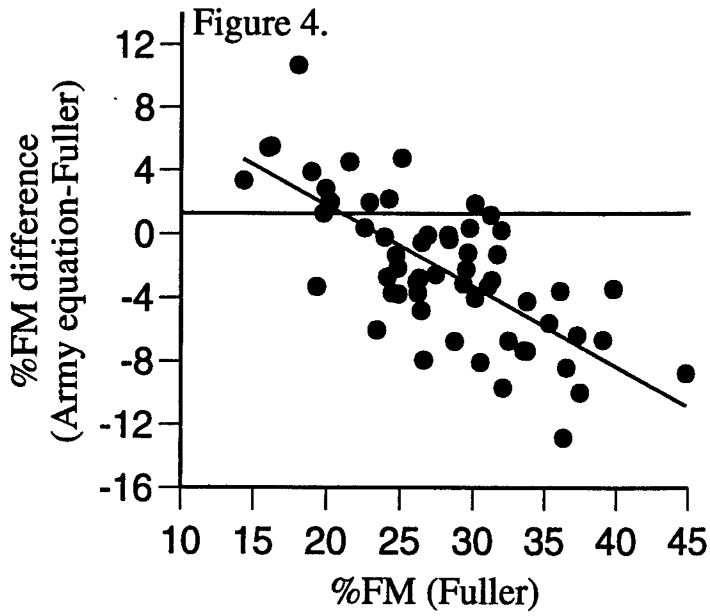
Figure 4.
%FM difference
(Army equation-Fuller)
%FM (Fuller)
12
8
4
0
-4
-8
-12
-16
10 15 20 25 30 35 40 45

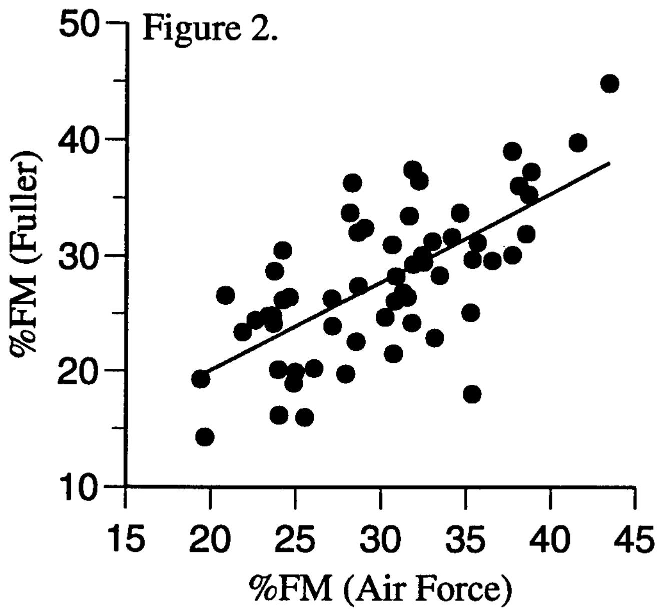
Figure 2.
%FM (Fuller)
%FM (Air Force)
50
40
30
20
10
15 20 25 30 35 40 45

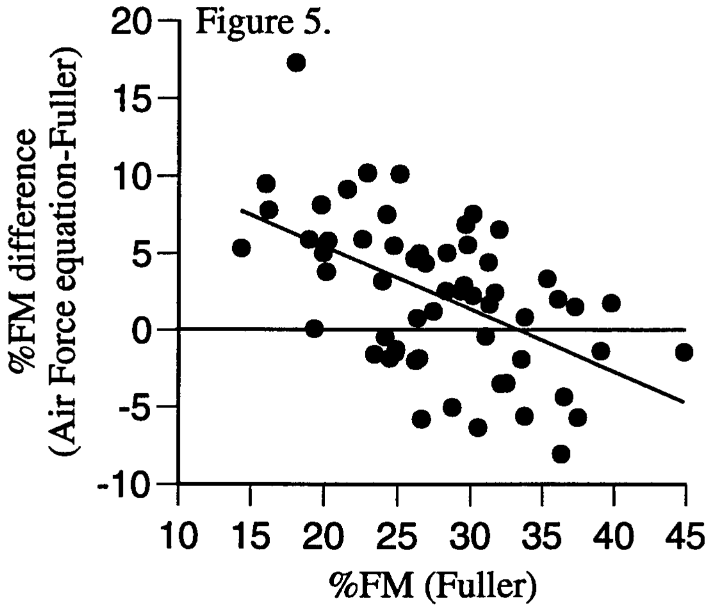
Figure 5.
%FM difference
(Air Force equation-Fuller)
%FM (Fuller)
20
15
10
5
0
-5
-10
10 15 20 25 30 35 40 45

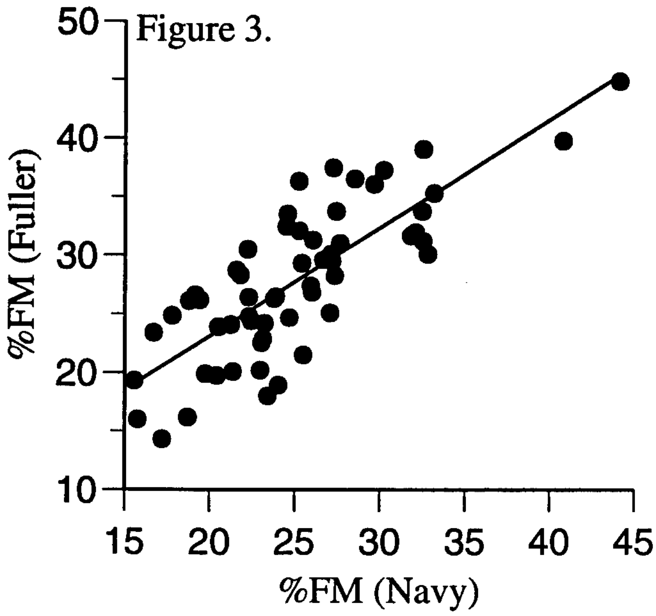
Figure 3.
%FM (Fuller)
%FM (Navy)
50
40
30
20
10
15 20 25 30 35 40 45

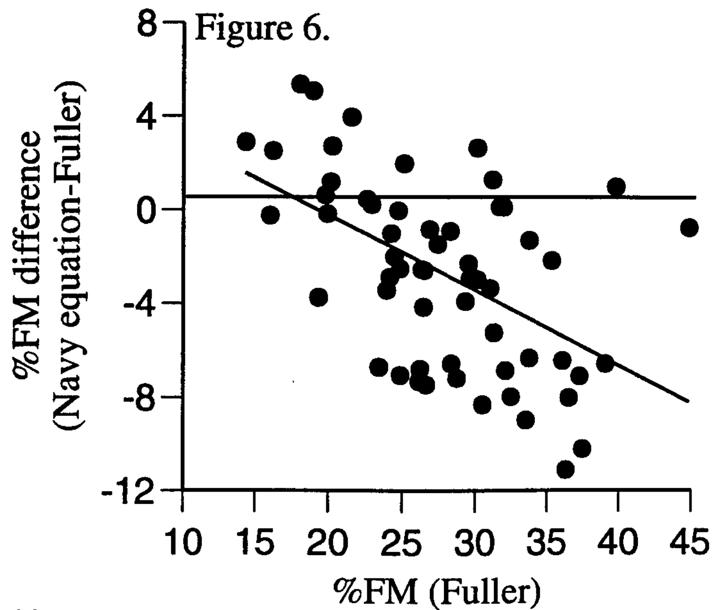
Figure 6.
%FM difference
(Navy equation-Fuller)
%FM (Fuller)
8
4
0
-4
-8
-12
10 15 20 25 30 35 40 45

Fat-Free Mass Compartment

In terms of work capacity and physical fitness, the fat-free mass compartment is the metabolically active part of the body. We will monitor changes in FFM during pregnancy and the postpartum period. We will test whether physical activity can maintain a higher level of physical fitness throughout pregnancy and prevent an undesirable loss of muscle mass associated with postpartum weight loss. We will also be able to relate changes in FFM to any changes in strength.

Based on the principle that the K/N ratio for muscle is higher than that of nonmuscle tissues (3.03 vs 1.33 meq/g), TBK and TBN will be used to estimate the relative amounts of protein in muscle and nonmuscle components of the body and the mass of each component prior to conception and postpartum.

Prior to conception, bone mineral density of all subjects was within the normal range (0.98 to 1.36). Changes in bone mineral density will be determined in the postpartum period in these reproductive women.

Table 12. Fat-free mass (FFM) compartment determined by total body potassium, DEXA, and prompt-gamma activation

		Pre-pregnancy N=62	8 weeks pregnancy n=20	22 weeks pregnancy n=18	36 weeks pregnancy n=12	2 wk postpartum n=12	6 wk postpartum n=12	24 wk postpartum n=9
Total body potassium (TBK)								
TBK	g	102.5 ± 14.4*	97.6 ± 13.9	103.7 ± 15.0	114.0 ± 14.6	101.3 ± 10.3	103.8 ± 15.1	103.3 ± 11.3
^{40}K lean body mass	kg	43.6 ± 6.1	41.4 ± 6.1	44.0 ± 6.3	48.4 ± 6.2	43.0 ± 4.3	44.1 ± 6.4	43.9 ± 4.8
^{40}K body cell mass	kg	21.8 ± 3.0	20.7 ± 3.0	22.1 ± 3.2	24.3 ± 3.1	21.5 ± 2.2	22.1 ± 3.2	22.0 ± 2.4
Dual energy x-ray absorptiometry (DEXA)			**	**	**			
Bone mineral content (BMC)	kg	2.24 ± 0.32				2.26 ± 0.22	2.19 ± 0.27	2.25 ± 0.20
Bone mineral density (BMD)	g/cm^2	1.14 ± 0.09				1.16 ± 0.07	1.15 ± 0.07	1.17 ± 0.05
Lean body mass	kg	40.2 ± 5.2				41.4 ± 4.4	39.6 ± 5.2	40.4 ± 4.8
Prompt-gamma activation analysis (PGA)			**	**	**		**	
Total body nitrogen	g	1495± 202				1592± 222		1645 ± 274
Muscle mass	kg	12.6 ± 3.5				10.0 ± 2.2		9.0 ± 3.6
Nonmuscle mass	kg	31.0 ± 5.7				35.2 ± 5.5		38.2 ± 9.8

*Mean ±SD

**Measurement not performed during pregnancy or at 6 wk postpartum

Energy Expenditure and Substrate Utilization by Room Respiration Calorimetry

Preconceptional baseline levels of energy expenditure and substrate utilization are summarized in Tables 13 and 14. By study design, the mean 24-h TEE and heart rates are representative of sedentary conditions. These data will be used to evaluate changes in energy metabolism and their impact on energy requirements throughout the reproductive cycle in women with low and normal BMIs.

Table 13. Respiration room calorimetry						
		Pre-pregnancy n=62	8 wk pregnancy n=20	22 wk pregnancy n=18	36 wk pregnancy n=12	24 wk postpartum n=9
Total energy expenditure (TEE)						
Heart rate	bpm	66 ± 8*	69 ± 10	76 ± 9	80 ± 14	67 ± 11
Activity	counts	98 ± 21	88 ± 16	93 ± 12	113 ± 25	101 ± 13
VO_2	lpm	0.25 ± 0.03	0.25 ± 0.03	0.26 ± 0.02	0.32 ± 0.04	0.25 ± 0.03
VCO_2	lpm	0.22 ± 0.02	0.22 ± 0.02	0.23 ± 0.02	0.28 ± 0.03	0.23 ± 0.03
RQ		0.87 ± 0.02	0.89 ± 0.02	0.89 ± 0.02	0.87 ± 0.02	0.90 ± 0.02
TEE	kcal/m	1.23 ± 0.13	1.23 ± 0.13	1.30 ± 0.12	1.55 ± 0.17	1.23 ± 0.13
TEE	kcal/d	1767 ± 185	1776 ± 181	1872 ± 166	2230 ± 250	1778 ± 193
TEE	kcal/kg/d	29.59 ± 2.61	30.33 ± 2.73	29.97 ± 2.73	30.42 ± 3.96	27.93 ± 3.73
Basal metabolic rate (BMR)						
Heart rate	bpm	63 ± 9	66 ± 10	73 ± 10	74 ± 15	59 ± 10
Activity	counts	4 ± 5	4 ± 5	5 ± 6	5 ± 5	11 ± 13
VO_2	lpm	0.19 ± 0.02	0.20 ± 0.02	0.21 ± 0.02	0.25 ± 0.04	0.19 ± 0.02
VCO_2	lpm	0.15 ± 0.02	0.16 ± 0.02	0.17 ± 0.02	0.20 ± 0.03	0.16 ± 0.02
RQ		0.81 ± 0.05	0.82 ± 0.03	0.83 ± 0.04	0.81 ± 0.04	0.83 ± 0.04
BMR	kcal/m	0.91 ± 0.09	0.95 ± 0.11	1.01 ± 0.12	1.21 ± 0.20	0.94 ± 0.10
BMR	kcal/d	1306 ± 136	1368 ± 164	1455 ± 175	1748 ± 288	1355 ± 148
BMR	kcal/kg/d	21.88 ± 2.04	23.35 ± 2.45	22.79 ± 2.29	23.80 ± 3.86	21.29 ± 2.83
TEE/BMR		1.36 ± 0.07	1.30 ± 0.08	1.31 ± 0.05	1.29 ± 0.10	1.31 ± 0.09
Sleeping metabolic rate (SMR)						
Heart rate	bpm	58 ± 12	63 ± 9	71 ± 10	74 ± 13	60 ± 12
Activity	counts	7 ± 4	11 ± 5	13 ± 6	18 ± 7	9 ± 4
VO_2	lpm	0.19 ± 0.02	0.19 ± 0.02	0.21 ± 0.02	0.25 ± 0.03	0.19 ± 0.02
VCO_2	lpm	0.15 ± 0.02	0.16 ± 0.02	0.18 ± 0.02	0.21 ± 0.03	0.17 ± 0.03
RQ		0.83 ± 0.02	0.85 ± 0.03	0.86 ± 0.04	0.85 ± 0.03	0.86 ± 0.03
SMR	kcal/m	0.90 ± 0.09	0.94 ± 0.10	1.01 ± 0.09	1.22 ± 0.15	0.94 ± 0.12
SMR	kcal/kg/d	21.72 ± 1.86	23.16 ± 2.13	23.19 ± 2.46	23.88 ± 2.98	21.34 ± 3.02
Minimal metabolic rate (MMR)						
Heart rate	bpm	57 ± 15	62 ± 10	71 ± 11	73 ± 15	61 ± 14
Activity	counts	3 ± 12	3 ± 5	3 ± 6	3 ± 4	4 ± 5
VO_2	lpm	0.17 ± 0.02	0.18 ± 0.02	0.20 ± 0.02	0.23 ± 0.03	0.18 ± 0.02
VCO_2	lpm	0.14 ± 0.02	0.15 ± 0.02	0.17 ± 0.02	0.20 ± 0.03	0.15 ± 0.02
RQ		0.84 ± 0.04	0.85 ± 0.03	0.86 ± 0.04	0.86 ± 0.04	0.86 ± 0.03
MMR	kcal/m	0.83 ± 0.10	0.87 ± 0.10	0.96 ± 0.11	1.11 ± 0.14	0.86 ± 0.11
MMR	kcal/kg/d	20.12 ± 2.25	21.41 ± 2.22	22.00 ± 3.33	21.87 ± 3.01	19.47 ± 2.67

*Mean ± SD

Table 14. Substrate utilization estimated from 24-h respiration calorimetry						
		Pre-pregnancy n=62	8 wk pregnancy n=20	22 wk pregnancy n=18	36 wk pregnancy n=12	24 wk postpartum n=9
Energy intake	kcal/d	1675 ± 172*	1779 ± 254	2104 ± 315	2368 ± 391	1649 ± 228
Diet fat	% EI	30 ± 2	31 ± 2	31 ± 1	32 ± 2	31 ± 2
Diet carbohydrate	% EI	51 ± 3	51 ± 3	50 ± 2	50 ± 2	49 ± 2
Diet protein	% EI	20 ± 1	19 ± 1	19 ± 1	19 ± 2	21 ± 1
Energy balance	kcal/d	-86 ± 135	-6 ± 211	231 ± 283	137 ± 335	-99 ± 177
Urinary nitrogen	g/d	9.3 ± 2.8	10.3 ± 3.0	10.0 ± 4.1	10.3 ± 2.0	9.3 ± 5.3
Respiratory quotient		0.87 ± 0.02	0.89 ± 0.02	0.89 ± 0.02	0.87 ± 0.02	0.90 ± 0.02
Protein utilization	g/d	58 ± 17	64 ± 19	62 ± 25	64 ± 12	58 ± 33
Carbohydrate utilization	g/d	210 ± 36	231 ± 37	262 ± 37	274 ± 51	256 ± 75
Fat utilization	g/d	62 ± 18	51 ± 15	52 ± 19	79 ± 18	40 ± 11
Protein utilization	% TEE	15 ± 4	17 ± 5	15 ± 6	13 ± 2	15 ± 9
Carbohydrate utilization	% TEE	50 ± 7	54 ± 6	58 ± 7	51 ± 7	61 ± 10
Fat utilization	% TEE	33 ± 8	27 ± 7	25 ± 8	34 ± 6	22 ± 8
Nonprotein VO_2	l/d	300 ± 38	295 ± 43	322 ± 42	389 ± 50	295 ± 53
Nonprotein VCO_2	l/d	264 ± 32	265 ± 37	292 ± 35	342 ± 45	271 ± 55
Nonprotein RQ		0.88 ± 0.03	0.90 ± 0.03	0.91 ± 0.03	0.88 ± 0.02	0.92 ± 0.03
Nonprotein EE	kcal/d	1468 ± 186	1452 ± 211	1589 ± 202	1903 ± 246	1459 ± 272
Carbohydrate utilization	%NPEE	60 ± 9	66 ± 8	69 ± 9	60 ± 7	72 ± 9
Fat utilization	%NPEE	39 ± 9	33 ± 8	30 ± 9	39 ± 7	27 ± 9

*Mean ± SD

Abbreviations: EI=energy intake; RQ=respriatory quotient; TEE=total energy expenditure; NPEE=nonprotein energy expenditure.

Total Energy Expenditure by Doubly-Labeled Water Method

Free-living energy expenditure averaged 2481±401 kcal/d or 42±7 $kcal \cdot kg^{-1} \cdot d^{-1}$ in these nonpregnant women. Mean activity energy expenditure [AEE=TEE-(BMR-0.1TEE)] of 932±334 kcal/d and the physical activity level (PAL=TEE/BMR) of 1.92±0.29 both indicate a high level of physical activity. Inspection of individual AEE or PAL values revealed moderate to high levels of physical activity. This is not surprising since our study design called for physically-active women participating in some form of exercise. Except for 4 cases, these rates of daily energy expenditure would be classified as moderate (1.64) or heavy (1.82), according to FAO/WHO/UNU (4).

Measurements of TEE, AEE, and PAL will allow us to assess changes in activity during pregnancy and the postpartum period. In conjunction with the fitness and strength tests, we can assess whether pregnancy-induced changes in activity influence the ability to return to military duty.

Table 15. Total energy expenditure (TEE) by doubly-labeled water method				
	Pre-pregnancy n=51	22 wk pregnancy n=17	36 wk pregnancy n=11	24 wk postpartum n=4
^{2}H dilution space (kg)	33.49 ± 4.31*	35.57 ± 4.10	40.67 ± 2.71	33.06 ± 2.11
^{18}O dilution space (kg)	32.34 ± 4.13	34.64 ± 3.99	39.77 ± 2.48	32.60 ± 2.26
$^2H/^{18}O$	1.04 ± 0.02	1.03 ± 0.02	1.02 ± 0.04	1.01 ± 0.04
^{2}H slope (k_H)	-0.11 ± 0.04	-0.10 ± 0.03	-0.11 ± 0.03	-0.12 ± 0.01
^{18}O slope (k_O)	-0.14 ± 0.04	-0.13 ± 0.04	-0.13 ± 0.03	-0.14 ± 0.02
rCO_2 (mol/d)	19.46 ± 3.15	20.22 ± 2.88	21.51 ± 3.37	22.13 ± 2.18
rO_2 (mol/d)	22.63 ± 3.66	23.51 ± 3.35	25.01 ± 3.92	25.73 ± 2.54
TEE (kcal/d)	2481 ± 401	2577 ± 367	2741 ± 429	2820 ± 278
TEE ($kcal \cdot kg^{-1} \cdot d^{-1}$)	41.75 ± 6.73	39.98 ± 4.82	37.80 ± 5.48	48.43 ± 5.09

*Mean ± SD

Fitness and Strength

The measurement of VO_2max allowed us to categorize these women in terms of pre-pregnancy fitness. The mean VO_2max was 34 $ml/kg^{-1}min^{-1}$ which would be categorized as in the "good" range of fitness, defined as 34-44 $ml/kg^{-1}min^{-1}$ for women. There was variability in the group with women in all categories of fitness, "low" (N=1), "fair" (N=15), "average" (N=26), "good" (N=15) and "high" (N=5). With the additional women since the last report, the maximal heart rates and the high RQ (1.21) also demonstrate that a true maximum was achieved. The average maximal workload was 167 watts, indicating a fairly high level of work reached at exhaustion. The steady-state cycle exercise at 50 watts was approximately 45% of VO_2max.

For the one-repetition maximum strength testing, it appears that these women are fairly strong prior to pregnancy. The women can bench press about 59% of their body weight. For the lower body, the leg extension is high (86 lbs). As with the fitness levels, there seems to be a great deal of variability in the group for strength. About half the women report that they strength train regularly.

Changes prior to pregnancy and 6 weeks postpartum were examined in a subset of women (N=9). VO_2max/kg was lower post-partum (34.1 to 26.8 $ml/kg^{-1}min^{-1}$). Strength measures also decreased slightly for the leg press (69 to 64 lbs) and more markedly for the bench press (87 to 78 lbs), with little change in the leg extension or latissimus pulldown. Although the sample size is small at this point, it is interesting to note these decreases in fitness and strength at 6 wk postpartum. As more of the women complete all the fitness and strength tests, we will be able to assess whether women in the military can accomplish their work tasks when they are asked to return to duty after pregnancy.

Table 16. Physical fitness and strength

		Pre-pregnancy n=62	8 wk pregnancy n=20	22 wk pregnancy n=18	36 wk pregnancy n=12	6 wk postpartum n=12	24 wk postpartum n=9
Steady state exercise on stationary ergometer							
Workload	watts	50				50	50
Heart rate	bpm	118 ± 18*				123 ± 18	126 ± 24
VO_2	lpm	0.92 ± 0.86				0.89 ± 0.68	0.96 ± 0.18
VO_2	$ml \cdot kg^{-1} \cdot m^{-1}$	15.39 ± 1.98				14.44 ± 2.37	14.78 ± 1.82
Respiratory quotient (RQ)		0.93 ± 0.06				1.00 ± 0.08	1.01 ± 0.09
Ventilation rate	lpm	24 ± 3				26 ± 5	29 ± 6
Respiration rate	breaths/m	21 ± 4				24 ± 6	23 ± 5
Percent VO_2max	%	44.4 ± 11.5				47.3 ± 11.6	49.3 ± 15.3
Maximal exercise on stationary cycle ergometer							
Workload	watts	167 ± 35				136 ± 33	146 ± 46
Heart rate	bpm	176 ± 9				170 ± 9	173 ± 13
VO_2	lpm	2.04 ± 0.40				1.67 ± 0.34	1.88 ± 0.47
VO_2	$ml \cdot kg^{-1} \cdot m^{-1}$	34.22 ± 7.37				26.38 ± 5.30	30.93 ± 11.69
RQ		1.21 ± 0.07				1.25 ± 0.13	1.25 ± 0.08
Ventilation rate	lpm	76 ± 15				65 ± 12	75 ± 15
Respiration rate	breaths/m	40 ± 7				39 ± 5	40 ± 8
Strength testing: 1-Repetition Maximum							
Cybex modular leg press	lb	76 ± 37				72 ± 31	72 ± 30
Cybex leg extension	lb	86 ± 20				85 ± 23	98 ± 25
Smith bench press	lb	77 ± 18				82 ± 19	86 ± 21
Cybex latissimus pull-down	lb	64 ± 11				62 ± 10	65 ± 7
Submaximal exercise on treadmill @ 2.5 mph							
Heart rate	bpm	95 ± 13	98 ± 16	106 ± 15	112 ± 19		97 ± 22
VO_2	lpm	0.71 ± 0.12	0.70 ± 0.13	0.69 ± 0.11	0.80 ± 0.17		0.71 ± 0.18
VCO_2	lpm	0.64 ± 0.12	0.65 ± 0.12	0.64 ± 0.11	0.72 ± 0.14		0.66 ± 0.17
RQ		0.91 ± 0.03	0.93 ± 0.02	0.92 ± 0.03	0.90 ± 0.02		0.93 ± 0.02
Energy expenditure	kcal/m	3.49 ± 0.61	3.47 ± 0.65	3.43 ± 0.55	3.95 ± 0.81		3.51 ± 0.91

*Mean ± SD

8. CONCLUSIONS

This study addresses the impact of pregnancy-induced changes in body composition and physical fitness on postpartum return to duty readiness. In this second annual report, preliminary data are presented on the subjects enrolled thus far. Prior to conception, the subjects represent healthy, moderately-active women. Based on military standards, nearly all subjects would be eligible for the Armed Services. The weight, body fat, bone density and iron status of these women are within normal limits. Energy expenditure measurements indicate that these women are physically active. VO_2max and strength tests confirm that the women are fit and fairly strong. Our evaluation of military equations for the prediction of fat mass based on 62 women prior to pregnancy strongly indicates a need to revise the equations. The Army and Navy equations underestimate body fat. Although conservative, the equations do not perform equally across the range of body fat mass. The underestimation is exaggerated at higher levels of fat mass. Our preliminary data indicate a mean gestational weight gain of 15 kg and deconditioning at 6 wk postpartum. Further, the effect of gestational weight gain, fat accretion and deconditioning on the ability to return to weight, body fat and fitness standards in the 6 mo following delivery will be assessed. With more complete data we will be able to test our hypothesis that moderate levels of physical activity will maintain physical fitness and limit excess fat deposition during pregnancy and facilitate fat mobilization and conserve fat-free mass during postpartum weight loss.

9. REFERENCES

1. U.S. Department of Army. 1986. Army Regulation 600-9, "The Army Weight Control Program." September 1, Washington D.C.

2. Vogel JA, Kirkpatrick JW, Fitzgerald PI, Hodgdon JA, Harman EA. Derivation of anthropometry based body fat equations for the Army's weight control program. 1988. Technical Report No. T17-88, U.S. Army Research Institute of Environmental Medicine, Natick, MA.

3. Hodgdon JA, Beckett MB. Prediction of percent body fat for U.S. Navy women from body circumference and height. 1984. Report No. 84-29. Naval Health Research Center, San Diego, CA.

4. Wright HF, Wilmore JH. Estimation of relative body fat and lean body weight in a United States Marine Corps population. 1974. Aerospace Med 45: 301-6.

5. Brennan EH. Development of a binomial involving anthropometric measurements for predicting lean mass in young women. 1974. M.S. thesis. Incarnate Word College, San Antonio, TX.

6. U.S. Department of Army. 1983. Army Regulation 40-501, Change 34, "Standards of Medical Fitness." December 1, Washington, D.C.

7. Institute of Medicine, Food and Nutrition Board, Committee on Military Nutrition Research. 1992. In: Mariott BM, Grumstrup-Scott J. (ed), Body composition and physical performance. National Academy Press.

8. Laurence MT. Enlistment height/weight standards and attrition from the military. Defense Manpower Data Center, Arlington, VA.

9. Institute of Medicine, Food and Nutrition Board, Committee on Nutritional Status During Pregnancy and Lactation. Nutrition during pregnancy. Part I. Weight gain. Part II. Nutrient supplements. 1990. Washington, DC: National Academy Press.

10. Naeye RL. Weight gain and the outcome of pregnancy. 1979. Am J Obstet Gynecol 135:3-9.

11. Taffel SM. Maternal weight gain and the outcome of pregnancy: US, 1980. 1986. Vital and Health Statistics, Series 21, No. 44. DHHS Publ. No. (PHS) 86-1922.

12. Langhoff-Roos J, Lindmark G, Gebre-Medhin M. Maternal fat stores and fat accretion during pregnancy in relation to infant birthweight. 1987. Brit J Obs Gyn 94:1170-7.

13. Lawrence M, McKillop FM, Durnin JVGA. Women who gain more fat during pregnancy may not have bigger babies: implications for recommended weight gain during pregnancy. 1991. Brit J Obs Gyn 98:254-9.

14. Hytten FE. Weight gain in pregnancy. 1991. In: Clinical physiology in obstetrics. Hytten FE, Chamberlain G, eds. Blackwell Scientific Publications. Oxford.

15. Hytten FE, Thomson AM, Taggert N. Total body water in normal pregnancy. 1966. J Obstet Gynaecol Br Commonw 73:553-61.

16. Fitch WL, King JC. Protein turnover and 3-methylhistidine excretion in non-pregnant, pregnant and gestational diabetic women. 1987. Hum Nutr Clin Nutr 41C:327-39.

17. Naismith DJ. Maternal nutrition and the outcome of pregnancy - a critical appraisal. 1980. Proc Nutr Soc 39:1-11.

18. Sohlström A, Wahlund L-O, Forsum E. Total body fat and its distribution during human reproduction as assessed by magnetic resonance imaging. 1993. In: Ellis K (ed), Human Body Composition pp 181-184.

19. Dewey KG, Heinig MJ, Nommsen LA. Maternal weight-loss patterns during prolonged lactation. 1993. Am J Clin Nutr 58:162-166.

20. Brewer MM, Bates MR, Vannoy LP. Postpartum changes in maternal weight and body fat depots in lactating vs non-lactating women. 1989. Am J Clin Nutr 49:259-265.

21. Taggart NR, Holliday RM, Billewics WZ, Hytten FE, Thomson AM. Changes in skinfolds during pregnancy. 1967. Br J Nutr 21:439-51.

22. Goldberg GR, Prentice AM, Coward WA, Davies HL, Murgatroyd PR, Wensing C, Black AE, Harding M, Sawyer M. Longitudinal assessment of energy expenditure in pregnancy by the doubly labelled water method. 1993. Am J Clin Nutr 57:494-505.

23. van Raaij JMA, Peek MEM, Vermaat-Miedema SH, Schonk CM, Hautvast JGAJ. New equations for estimating body fat mass in pregnancy from body density or total body water. 1988. Am J Clin Nutr 48:24-9.

24. Pipe NGJ, Smith T, Halliday D, Edmonds CJ, Williams C, Coltart TM. Changes in fat, fat-free mass and body water in human normal pregnancy. 1979. Br J Obstet Gynaecol 86:929-40.

25. Forsum E, Sadurskis A, Wager J. Resting metabolic rate and body composition of healthy Swedish women during pregnancy. 1988. Am J Clin Nutr 47:942-47.

26. King JC, Butte NF, Bronstein MN, Kopp LE, Lindquist SA. Energy metabolism during pregnancy: influence of maternal energy status. 1994. Am J Clin Nutr 59:439S-45S.

27. Johnson EM. Weight changes during pregnancy and the postpartum period. 1991. Progress in Food and Nutr Sci 15:117-57.

28. Keppel K, Taffel S. Pregnancy-related weight gain and retention: implications of the 1990 Institute of Medicine Guidelines. 1993. Am J Publ Health 83:1100-3.

29. Butte NF, Garza C, Stuff JE, Smith EO, Nichols BL. Effect of maternal diet and body composition on lactational performance. 1984. Am J Clin Nutr 39:296-306.

30. Manning-Dalton C, Allen LH. The effects of lactation on energy and protein consumption, postpartum weight change and body composition of well nourished North American women. 1983. Nutr Res 3:293-308.

31. Strode MA, Dewey KG, Lonnerdal B. Effect of short-term maternal caloric restriction on lactation performance of well-nourished mothers. 1986. Acta Paediatr Scand 75:222-9.

32. Forbes GB. Human Body Composition. 1987. Springer-Verlag, New York.

33. Ballor DL, Poehlman. Exercise-training enhances fat-free mass preservation during diet-induced weight loss: a meta-analytical finding. 1994. International J Obesity 18:35-40.

34. McMurray RG, Mottola MF, Wolfe LA, Artal R, Millar L, Pivarnik JM. Recent advances in understanding maternal and fetal responses to exercise. 1993. Med Sci Sports Exerc 25:1305-21.

35. Sady SP, Carpenter MW, Sady MA, Haydon B, Hoegsberg B, Cullinane EM, Thompson PD, Coustan DR. Prediction of $Vo_{2\,max}$ during cycle exercise in pregnant women. 1988. J Appl Physiol 65:657-61.

36. Lotgering FK, van Doorn MB, Struijk PC, Pool J, Wallenburg HCS. Maximal aerobic exercise in pregnant women: heart rate, O_2 consumption, CO_2 production, and ventilation. 1991. J Appl Physiol 70:1016-23.

37. South-Paul JE, Rajagopal KR, Tenholder MF. Exercise responses prior to pregnancy and in the postpartum state. 1992. Med Sci Sports Exerc 24:410-4.

38. American College of Obstetricians and Gynecologists. Exercise during pregnancy and the postnatal period. 1985. ACOG Home Exercise Programs. Washington, DC: ACOG.

39. Viteri FE. Influence of iron nutrition on work capacity and performance. 1989. In: Dietary Iron: Birth to Two Years, ed LF Filer, Jr. Raven Press, Ltd., New York, 141-60.

40. Lukaski HC, Ball CB, Siders WA. Altered metabolic response of iron-deficient women during graded, maximal exercise. 1991. Eur J Appl Physiol 63:140-5.

41. FAO/WHO/UNU Expert Consultation. Energy and protein requirements. 1985. Technical Report Series 724, WHO, Geneva.

42. National Research Council. Recommended dietary allowances. 10th ed. Washington, DC: National Academy Press, 1989.

43. Committee on Medical Aspects of Food Policy. Dietary reference values for food energy and nutrients for the United Kingdom. 1991. Dept Hlth Rep Hlth Soc Subj 41. London: HMSO.

44. Durnin JVGA, McKillop FM, Grant S, Fitzgerald G. 1987. Energy requirements of pregnancy in Scotland. Lancet ii:897-900.

45. van Raaij JMA, Schonk CM, Vermaat-Miedema SH, Peek MEM, Hautvast JGAJ. Body fat mass and basal metabolic rate in Dutch women before, during, and after pregnancy: a reappraisal of energy cost of pregnancy. 1989. Am J Clin Nutr 49:765-72.

46. Prentice AM, Goldberg GR, Davies HL, Murgatroyd PR, Scott W. Energy-sparing adaptations in human pregnancy assessed by whole-body calorimetry. 1989. Br J Nutr 62:5-22.

47. de Groot LCPGM, Boekholt HA, Spaaij CJK, van Raaij JMA, Drijvers JJMM, van der Heijden LJM, van der Heide D, Hautvast JGAJ. Energy balances of healthy Dutch women before and during pregnancy: limited scope for metabolic adaptations in pregnancy. 1994. Am J Clin Nutr 59:827-32.

48. Forsum E, Kabir N, Sadurskis A, Westerterp K. Total energy expenditure of healthy Swedish women during pregnancy and lactation. 1992. Am J Clin Nutr 56:334-42.

49. King N, Fridlund KE, Askew EW. Nutrition issues of military women. 1993. J Amer Coll Nutr 12:344-8.

50. Friedl KE, Marchitelli LJ, Sherman DE, Tulley R. Nutritional Assessment of Cadets at the US Military Academy: Part 1. Anthropometric and Biomedical Measures." Natick MA: US Army Research Institute of Environmental Medicine. 1990. USARIEM Technical Report T4-91.

51. U.S. Department of the Army, Navy and the Air Force. Army Regulation 40-25/Naval Command Medical Instruction 10110.1/Air Force Regulation 160-95. Nutrient Allowances, Standards, and Education. May 15, 1985, Washington, DC.

52. Akers R, Buskirk ER. An underwater weighing system utilizing "force cube" transducers. 1969. J Appl Physiol 26:649-52.

53. Wilmore JH, Vodak PA, Parr RB, Girandola RN, Billing JE. Further simplification of a method for determination of residual lung volume. 1980. Med Sci Sports Exercise 12:216-8.

54. Burkinshaw L, Hill GL, Morgan DB. Mass and composition of the fat-free tissues of patients with weight loss. 1979. Clin Sci 68:455-62.

55. Fuller NJ, Jebb SA, Laskey MA, Coward WA, Elia M. Four-compartment model for the assessment of body composition in humans: comparison with alternative methods, and evaluation of the density and hydration of fat-free mass. 1992. Clinical Science 82:687-93.

56. International Dietary Energy Consulting Group. The doubly-labeled water method for measuring energy expenditure: Technical Recommendations for use in humans. 1990. (Prentice AM, ed) International Atomic Energy Agency, Vienna, Austria.

57. Black AE, Prentice AM, Coward WA. Use of food quotients to predict respiratory quotients for the doubly labeled water method for measuring energy expenditure. 1986. Hum Nutr Clin Nutr 40C:381-91.

58. de V Weir JB. New methods for calculating metabolic rate with special reference to protein metabolism. 1949. J Physiol 109:1-9.

59. Moon JK, Vohra FA, Valerio-Jimenez OS, Butte NF. Closed-loop control of carbon dioxide concentration and pressure improves response of room respiration calorimetry. 1994. J Nutr [in press].

60. Livesey G, Elia M. Estimation of energy expenditure, net carbohydrate utilization, and net fat oxidation and synthesis by indirect calorimetry: evaluation of errors with special reference to the detailed composition of fuels. 1988. Amer J Clin Nutr 47:608-25.

61. Taylor HL, Jacobs DR, Schucker B, Knudsen J, Leon AS, Bebacker G. A questionnaire for the assessment of leisure time physical activities. 1978. J Chron Dis 31:741-55.

62. Shapiro S, Weinblatt E, Frank CW, Sagen V. The H.I.P. study of incidence and prognosis of coronary heart disease. 1965. J Chron Dis 18:527-58.

63. Dixon WJ (ed) 1983 BMDP, Biomedical computer programs. University of California Press, Berkeley, CA.

64. Minitab version 6.1 1988 Minitab, Inc., State College, PA.

65. Katch FI, McArdle WD (ed) 1983 Nutrition, weight control and exercise. Philadelphia, Lea & Febiger, p291.

DEPARTMENT OF THE ARMY
US ARMY MEDICAL RESEARCH AND MATERIEL COMMAND
504 SCOTT STREET
FORT DETRICK, MARYLAND 21702-5012

REPLY TO
ATTENTION OF:

MCMR-RMI-S (70-1y) 23 Aug 01

MEMORANDUM FOR Administrator, Defense Technical Information Center (DTIC-OCA), 8725 John J. Kingman Road, Fort Belvoir, VA 22060-6218

SUBJECT: Request Change in Distribution Statement

1. The U.S. Army Medical Research and Materiel Command has reexamined the need for the limitation assigned to the technical reports listed at enclosure. Request the limited distribution statement for these reports be changed to "Approved for public release; distribution unlimited." These reports should be released to the National Technical Information Service.

2. Point of contact for this request is Ms. Judy Pawlus at DSN 343-7322 or by e-mail at judy.pawlus@det.amedd.army.mil.

FOR THE COMMANDER:

Encl

PHYLIS M. RINEHART
Deputy Chief of Staff for
Information Management

Reports to be Downgraded to Unlimited Distribution

ADB241560	ADB253628	ADB249654	ADB263448
ADB251657	ADB257757	ADB264967	ADB245021
ADB263525	ADB264736	ADB247697	ADB264544
ADB222448	ADB255427	ADB263453	ADB254454
ADB234468	ADB264757	ADB243646	
ADB249596	ADB232924	ADB263428	
ADB263270	ADB232927	ADB240500	
ADB231841	ADB245382	ADB253090	
ADB239007	ADB258158	ADB265236	
ADB263737	ADB264506	ADB264610	
ADB239263	ADB243027	ADB251613	
ADB251995	ADB233334	ADB237451	
ADB233106	ADB242926	ADB249671	
ADB262619	ADB262637	ADB262475	
ADB233111	ADB251649	ADB264579	
ADB240497	ADB264549	ADB244768	
ADB257618	ADB248354	ADB258553	
ADB240496	ADB258768	ADB244278	
ADB233747	ADB247842	ADB257305	
ADB240160	ADB264611	ADB245442	
ADB258646	ADB244931	ADB256780	
ADB264626	ADB263444	ADB264797	