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Physical Activity and Changes in Abdominal Fat Over 18 Months: A Prospective Study of Middle-Aged Women

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PHYSICAL ACTIVITY AND CHANGES IN ABDOMINAL FAT OVER 18 MONTHS: A PROSPECTIVE STUDY OF MIDDLE-AGED WOMEN

by

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GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

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This thesis has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

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As chair of the candidate's graduate committee, I have read the thesis of Lance E. Davidson in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

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ABSTRACT

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Objective: To investigate the extent to which changes in physical activity predict changes in abdominal fat in women over an 18-month period, while statistically controlling the effects of possible confounders, such as age, total body fat percent, and energy intake.

Design: A prospective cohort design over 18 months. There was no intervention or treatment. Changes in objectively-measured physical activity were used to predict changes in abdominal fat over the study period.

Subjects: 110 healthy, middle-aged women (mean: 41.3±3.3 yrs), primarily Caucasian, educated, and married.

Measurements: An objective measure of physical activity (ACT) using CSA accelerometers, worn continuously for 7 consecutive days at baseline and again at follow-up. Total body fat and abdominal fat percent were assessed by dual energy x-ray absorptiometry (DEXA). Energy intake was estimated using 7-day, weighed food records for the days in which subjects wore accelerometers.

Results: No significant change between baseline and follow-up means for abdominal fat, physical activity, or energy intake over the study period. Moreover, change in physical activity was not a significant predictor of change in abdominal fat, with or without statistical control of confounders. Change in energy intake was a predictor of abdominal fat (*P*=0.0688), and this association was strengthened after adjusting for age, baseline total body fat, and changes in physical activity.

Conclusions: Apparently, when measured using accelerometers, changes in physical activity are not predictive of changes in abdominal fat over an 18-month period. However, changes in energy intake seem to predict changes in abdominal fat. Evidently, increases and decreases in abdominal fat are more a function of energy intake than physical activity in middle-aged women.

Keywords: Abdominal fat, physical activity, energy intake

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PHYSICAL ACTIVITY AND CHANGES IN ABDOMINAL FAT

OVER 18 MONTHS: A PROSPECTIVE STUDY OF

MIDDLE-AGED WOMEN

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Abstract

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Introduction

Over the past three decades, the prevalence of overweight and obesity has increased several-fold, with more than a third of the U.S. population considered overweight or obese.[1] When a body mass index (BMI) of 25.0 is used as a cut-point, 63 and 55 percent of men and women, respectively, are overweight.[2] The seriousness of this problem is evident as results from six major epidemiologic studies in the U.S. indicate that the annual number of deaths attributable to obesity now exceeds 300,000 – second only to tobacco-related deaths.[3]

Obesity has recently been distinguished as one of the top five independent causes of cardiovascular disease.[4] Additionally, epidemiologic and metabolic studies confirm that obesity contributes to a host of other medical conditions such as hypertension, dyslipidemia, insulin resistance, glucose intolerance, diabetes mellitus, sleep apnea, arthritis, hyperuricemia, gallbladder disease, and certain types of cancer.[5] Certainly, obesity is no longer considered merely a cosmetic problem, but has become a major medical malady.

Perhaps of more clinical importance than general obesity is the regional distribution of adiposity in overweight individuals. Excess fat deposited in the abdominal region is a stronger predictor of cardiovascular disease and Type II diabetes mellitus than general obesity.[6,7] The predictive power of abdominal fat may be partially explained by the excess accumulation of visceral fat, which is an independent correlate of insulin resistance and dyslipidemia.[8] The risk-laden characteristics of centrally-located obesity have led to the incorporation of abdominal fat into a collection of associated diseases called syndrome X, or the plurimetabolic syndrome.[9] Abdominal obesity is highly correlated to other diseases in this syndrome, namely Type II diabetes, dyslipidemia, and hypertension. Given that abdominal fat is so closely related to these major health problems suggests that substantially reducing abdominal girth may be beneficial, not only for attenuating the direct health risk of obesity, but also for reducing the effects of its associated diseases.[10,11]

Reviews by both DiPietro[12] and Ross et al.[13] indicate that increases in physical activity result in corresponding decreases in total body fat, assuming a controlled diet. Whether this apparent dose-response relationship applies to abdominal fat has yet to be determined. To date, relatively few studies have addressed directly the extent to which physical activity influences abdominal fat.[13] Though hardly a consensus, most of the studies investigating abdominal fat and physical activity report an inverse relationship.[14-17] One such study found that exercise, even without weight loss, reduces abdominal fat and prevents further weight gain.[16] In light of the heart disease risk already found to be linked to central adiposity, it seems that greater emphasis should be placed on clarifying the relationship between abdominal fat and physical activity, especially as a strategy for risk reduction.

In developing a more solid understanding of the role physical activity plays regarding changes in abdominal fat, studies must employ the most effective research methods. Inherent to weight change research is the element of time. A few weeks or months are usually too brief a period to observe meaningful body composition fluctuation without extreme intervention measures. Since subject compliance is difficult to maintain over the long term in experimental research, prospective studies are important in revealing trends in body composition change.

In a review of current literature, DiPietro[18] established a list of priorities for further research regarding physical activity and obesity. She stressed the need for prospective studies in middle-aged women and called for improved physical activity measurement methods as well as more thorough statistical control of confounders.

In a recent report provided by the American College of Sports Medicine on dose-response relationships, Ross and Janssen[13] concluded that, to their knowledge, no longitudinal studies report attenuation of normal age-related increases in total and abdominal fat with physical activity. Undoubtedly, the need for further research, especially with the advantages that prospective data provide, is necessary to elucidate the relationship between physical activity and abdominal fat.

This prospective cohort study examined the extent to which changes in physical activity were predictive of changes in abdominal fat in middle-aged females over an 18-month period. An ancillary purpose was to determine whether changes in energy intake were predictive of changes in abdominal fat, and if the relationship between physical activity and abdominal obesity was affected by age, baseline body fat, and total energy intake in this cohort.

Methods

Subjects

This research was conducted in cooperation with the Brigham Young University Lifestyle Project, a prospective cohort study. The original cohort of 275 women was recruited using flyers, company e-mails, and newspaper advertisements. Baseline and follow-up measures of abdominal fat were taken on 110 of these participants. Data collection on the other members of the cohort is ongoing, but complete data were available for analysis of 80 of the 110 subjects. These 80 subjects began the current study as healthy, non-obese (BMI<30), women with an average age of 41.3±3.3 years. A majority of these women were Caucasian, educated, and married. Smokers and those who planned to become pregnant during the study were excluded.

Measurements

Age, physical activity, abdominal fat percentage, total body fat percentage, energy intake, and changes in these variables across 18 months were all measured in this study.

Methodology and testing standards remained the same from baseline to the 18-month follow-up to ensure comparable results. Change in each variable was measured by subtracting baseline from the respective follow-up values.

Physical Activity. To reduce measurement error inherent in self-reported physical activity, this study used Computer Science and Applications (CSA) accelerometers (Shalimar, FL) to measure the actual daily physical activity performed by participants. Each subject wore a nylon belt, which was fastened securely around her waist at the level of the umbilicus. A CSA accelerometer was attached to the belt, positioned over her left hip. Each subject wore the accelerometer continuously for seven consecutive days at baseline, and another consecutive seven days at follow-up, with allowance to loosen the belt for comfort during sleeping hours. The CSA accelerometer was removed only when the subject was bathing or during activities in which the monitor may have been submerged in water. If the accelerometer was not worn according to protocol, the subject was asked to redo the testing week. If she refused to participate in a retest, she was dropped from the cohort. A total of three subjects were lost due to non-compliance to activity monitor requirements.

Activity counts, accumulated in one-minute increments over the testing week, were divided into 10 minute epochs, totaling 144 per day and 1008 per week. Physical activity was defined in this study as the sum of all activity counts recorded by the accelerometer over seven consecutive days. Physical activity change was the difference of total activity counts accumulated during the baseline week subtracted from activity counts gathered during the follow-up week.

A pilot study conducted with 15 subjects from this cohort performed various grades and speeds of walking, jogging, and climbing up and down stairs while wearing CSA acclerometers. The activity monitors were capable of measuring differences of 0.1 mph and 1% grades. Test-retest reliability was performed with at least one day between tests. Intraclass correlations greater than 0.90 were seen across each of the activities, demonstrating the reliability of the CSA accelerometer in monitoring a variety of activities.

Bassett et al.[19] conducted a comparative analysis of four commonly-used accelerometers, using a portable metabolic system as a standard. The study required 81 adults to perform six different tasks of varying intensities while wearing the accelerometers and having energy expenditure simultaneously assessed by indirect calorimetry. The CSA accelerometer had a higher correlation ($r>0.90$) with energy expenditure than any of the other monitors. These findings support the use of the CSA accelerometer as a valid and objective measurement of physical activity in humans.

Total and Abdominal Fat Percentages. Total body fat percent was measured using Hologic's dual-energy x-ray absorptiometry (DEXA) machine, model 4500 W (Hologic QDR, Waltham, MA). Abdominal fat was measured by adjusting the full-body scan analysis to obtain an abdominal region measurement. Baseline fat percentages were subtracted from follow-up values to determine abdominal fat change. To reduce variation in analysis, all scans were analyzed by the same investigator. The abdominal region extended from the top of the second lumbar vertebra to the bottom of the fourth lumbar vertebra, and laterally to the inner aspect of the ribs.

The region defined above has been shown to capture maximally the risk-laden intra-abdominal fat in women,[20] and has been used in multiple abdominal fat studies by Samaras et al.[21,22] using a Hologic DEXA machine. Studies have confirmed that DEXA's capability of measuring regional adiposity is accurate, precise, and that the radiation dose is minimal.[23,24] Specifically, Jensen et al.[25] found that computed tomography (CT) and DEXA had total abdominal fat measures that were highly correlated ($r=0.985$, $P<0.001$) in 21 subjects with a wide range of abdominal and visceral fat masses. Svendsen et al.[26] showed a similar correlation between DEXA and

CT abdominal fat measures (r=0.90, SEE: 7%) in 25 post-menopausal women. These studies support the use of DEXA as a valid and objective measure of abdominal fat.

Reliability of the DEXA was tested using 60 subjects from the study. A test-retest was performed with subjects completely repositioned between tests. Scans from both test and retest were analyzed without reference from one to the other, and the outcomes were compared by intraclass correlation. Abdominal fat analyses showed an intraclass correlation of 0.98 ($P<0.001$), and total body fat results were 0.97 ($P<0.001$).

Energy Intake. Energy intake was measured using seven-day weighed diet records at baseline and again at the 18-month follow-up. Changes in energy intake were calculated by subtracting the follow-up daily calorie average from the baseline daily average. At each assessment period, subjects were given seven blank diet logs, with space for recording weight and descriptions of food. An Ohaus 2000 electronic scale (Florham Park, NJ), which gives digital readings in grams, was issued to the subjects. All food consumed during seven consecutive days was weighed and recorded by the subject. The food intake record was conducted on the same seven days in which the subject was wearing the CSA accelerometer, measuring dietary intake and physical activity simultaneously.

Certain precautions were taken to encourage accurate diet results. First, research personnel made contact with each subject by telephone every other day to answer questions and remind her to be diligent in her reporting. Second, subjects' body weight was assessed before and after the testing week on an electronic scale (Tanita Corporation, Japan) to ensure that significant weight change did not occur. Third, the diet logs were analyzed by a registered dietitian using the ESHA Research software program, version 7.6 (Salem, OR). If total caloric intake did not exceed 130% of her estimated 24-hour resting metabolic rate, the subject was asked to redo the log. Literature supports this cut-off point for under-reporting.[33] If she refused to repeat the 7-

day assessment, she was dropped from the study. A total of seven subjects were lost for refusing to submit to the dietary assessment requirements.

Diet records, especially weighed food records, are often used as a standard for energy intake assessment in validation studies.[27,28] Some debate has occurred in the literature as to how many days of food recording are required to accurately determine a subject's mean energy and macronutrient intake. Study recommendations range from 3-14 days when using a weighed intake diary, with most agreeing that seven days is more than sufficient.[29-32] The present study used two seven-day periods for a total of 14 days intake data on each subject.

Data Analysis

DEXA scans from both assessments were analyzed for abdominal fat, total body fat, and changes in these percentages over 18 months. Physical activity change was calculated by subtracting total CSA activity counts of the baseline assessment from the follow-up total. Regression analysis using the general linear model (GLM) procedure was used to determine the extent to which changes in physical activity and changes in energy intake were predictive of changes in abdominal fat over the study period. Potential confounding variables, like total body fat, age, and energy intake, were controlled using partial correlation. Alpha was set at the 0.05 level. All statistical analyses were computed using the SAS® system (Cary, NC).

Results

Univariate results of key variables in the present study are reported in Table 1. Overall, the cohort maintained total body and abdominal fat percent and did not change in activity level. Energy intake tended to increase from baseline to 18-month follow-up but was only borderline significant (P=0.0688).

Physical Activity and Abdominal Fat

As shown in Table 2, changes in physical activity were not predictive of changes in abdominal fat over the 18 month study period, and the lack of significance remained with statistical control of potentially confounding variables. When controlling the effects of body fat percent at baseline and changes in energy intake, the relationship was strengthened, but remained non-significant.

Energy Intake and Abdominal Fat

Although only an ancillary purpose of the study, the relationship between energy intake and abdominal fat was also examined. Without controlling other variables, the relationship between changes in energy intake and changes in abdominal fat was borderline significant (0.0637). Table 2 shows the progressive increase in significance as the effects of age, changes in physical activity, and baseline body fat percent were controlled. After adjusting statistically for the combined effects of the above variables, the relationship between changes in energy intake and changes in abdominal fat was significant (P=0.020). Specifically, subjects who increased their daily energy intake by 500 kilocalories gained one percentage point of abdominal fat, and those who decreased daily intake by the same amount had corresponding decreases in abdominal fat over an 18-month period.

Discussion

The primary aim of this study was to determine the extent to which changes in physical activity were predictive of abdominal fat changes in women over an 18-month period. The study was prospective in design, using no intervention but time to induce changes in the outcome variables. As time- or age-related fat gain is currently a topic of interest in a nation of burgeoning obesity, a prospective cohort design is important in elucidating the lifestyle factors which tend to affect risk of gradual abdominal fat gains over time.

To date, no longitudinal studies have reported attenuation of normal age-related increases in total and abdominal fat with physical activity.[13] Given the outcomes of the present study, in which there were no significant changes in the means of abdominal fat and physical activity across 18 months, the findings seem to be consistent with the apparent paucity of longitudinal data examining physical activity and age-related gains in abdominal fat.

Physical Activity and Abdominal Fat

The results of this study revealed no apparent relationship between changes in physical activity and changes in abdominal fat across 18 months in middle-aged women. This lack of statistical relationship remained consistent with and without control for the effects of age, baseline body fat percent, baseline activity, and changes in energy intake.

In a prospective study, where change across time is essential in determining the extent of associations, lack of change from baseline to follow-up undermines the ability to statistically link correlates. In this cohort, none of the variables measured for change at the 18-month follow-up were statistically different from their baseline means. That is not to say that change did not occur within individual subjects. The standard deviation associated with each change value in Table 1 reveals that the average subject varied considerably over the study period. When subjects vary about the mean equally in both directions, absolute change is lost in the mean. The lack of overall change observed may have contributed to the inability of physical activity to predict changes in abdominal fat.

Another possible explanation for the lack of association between physical activity and abdominal fat could be that although each subject wore an accelerometer for a total of 14 days, those days may have not been representative of that subject's preceding weeks and months of physical activity. Steps were taken to remind each subject to maintain a normal lifestyle, but total compliance to these requests is often difficult, even in a willing subject. Activity monitor data, in particular, showed wide variation about the mean (see Table 1).

Notwithstanding that no previous prospective studies have yet reported changes in physical activity being predictive of age-related abdominal fat changes, the findings of this study were inconsistent with current experimental research. One of the more powerful experimental studies in the field of abdominal adiposity was conducted by Ross et al.,[16] who found that a large increase in daily physical activity was more highly related to abdominal fat reduction than was a calorie-reducing diet. Perhaps the magnitude of physical activity change observed in the current study was insufficient to produce abdominal fat changes.

Energy Intake and Abdominal Fat

Although a secondary purpose in the present study, changes in energy intake were predictive of changes in abdominal fat. After adjusting for differences in age, baseline body fat, and changes in physical activity, the association between energy intake and abdominal fat was strengthened. Specifically, increasing daily caloric intake by 500 calories translated to a one percentage point increase in abdominal fat. Since the relationship was bi-directional, decreasing daily caloric intake would yield proportional reductions in abdominal fat.

Finding significance in the relationship between energy and abdominal fat in the absence of a physical activity relationship lends credence to the idea that energy intake may be a more powerful predictor of body fat change than physical activity when comparing the two ends of the energy balance model: energy intake and energy expenditure. Although these findings remain unsupported by studies directly examining changes in abdominal fat, recent prospective research substantiates that changes in energy intake have greater predictive strength than physical activity in regards to changes in body weight and composition.[34]

In summary, results from the current study were unable to establish a significant relationship between changes in physical activity and changes in abdominal fat over 18 months in a cohort of healthy, middle-aged women. Controlling the effects of age, baseline body fat percentage, and energy intake did not produce significance in the physical activity and abdominal fat relationship. Changes in energy intake, however, proved to be a predictor of changes in abdominal fat, especially after adjustment for confounders, including age, baseline body fat percent, and changes in physical activity. Without question, further research is needed with a focus on elucidating the causes of abdominal fat change, especially as it applies to age-related gains in abdominal adiposity.

References

1. Kuczmarski RJ, Flegal KM, Campbell SM, Johnson CL. The increasing prevalence of overweight among US adults. The National Health and Nutrition Examination Surveys, 1960 to 1991. *JAMA* 1994;**272**:205-211.
2. Must A, Spadano J, Coakley EH, Field AE, Colditz G, Dietz WH. The disease burden associated with overweight and obesity. *JAMA* 1999;**282**:1523-1529.
3. Mokdad AH, Serdula MK, Dietz WH, Bowman BA, Marks JS, Koplan JP. The spread of the obesity epidemic in the United States, 1991-1998. *JAMA* 1999;**282**:1519-1522.
4. Eckel RH, Krauss RM. American heart association call to action: obesity as a major risk factor for coronary heart disease. *Circ* 1998;**97**(21):2099-2100.
5. National Institutes of Health and National Heart, Lung and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the Evidence Report. *Obes Res* 1998;**6**(Suppl 2):51S-209S.
6. Despres JP, Moorjani S, Lupien PJ, Tremblay A, Nadeau A, Bouchard C. Regional distribution of body fat, plasma lipoproteins, and cardiovascular disease. *Arteriosclerosis* 1990;**10**:497-511.
7. Ross R, Fortier L, Hudson R. Separate associations between visceral and subcutaneous adipose tissue distribution, insulin and glucose levels in obese women. *Diabetes Care* 1996;**19**:1404-1411.
8. Despres JP, Lemieux S, Lamarche B, Prud'homme D, Moorjani S, Brun LD, Gagne C, Lupien PJ. The insulin resistance-dyslipidemic syndrome: contribution of visceral obesity and therapeutic implications. *Int J Obes Relat Metab Disord* 1995;**19**(Suppl 1):S76-S86.
9. Timar O, Sestier F, Levy E. Metabolic syndrome X: a review. *Can J Cardiol* 2000;**16**:779-789.

10. Astrup A. Healthy lifestyles in Europe: prevention of obesity and type II diabetes by diet and physical activity. *Public Health Nutr* 2001;**4**:499-515.

11. Markovic TP, Campbell LV, Balasubramanian S, Jenkins AB, Fleury AC, Simons LA, Chisholm DJ. Beneficial effect on average lipid levels from energy restriction and fat loss in obese individuals with or without type 2 diabetes. *Diabetes Care* 1998;**21**(5):695-700.

12. DiPietro L. Physical activity, body weight, and adiposity: an epidemiologic perspective. *Exerc Sports Sci Rev* 1995;**23**:275-303.

13. Ross R, Janssen I. Physical activity, total and regional obesity: dose-response considerations. *Med Sci Sports Exerc* 2001;**33**:S521-S527.

14. Mourier A, Gautier JF, De Kerviler E, Bigard AX, Villette JM, Garnier JP, Duvallet A, Guezennec CY, Cathelineau G. Mobilization of adipose tissue related to the improvement in insulin sensitivity in response to physical training in NIDDM. *Diabetes Care* 1997;**20**:385-391.

15. Binder EF, Birge SJ, Kohrt WM. Effects of endurance exercise and hormone replacement therapy on serum lipids in older women. *J Am Geriatr Soc* 1996;**44**:231-236.

16. Ross R, Dagnone D, Jones PJ, Smith H, Paddags A, Hudson R, Janssen I. Reduction in obesity and related comorbid conditions after diet-induced weight loss or exercise-induced weight loss in men: a randomized controlled trial. *Ann Intern Med* 2000;**133**:92-103.

17. Kohrt WM, Obert KA, Holloszy JO. Exercise training improves fat distribution patterns in 60- to 70-year-old men and women. *J Gerontol Med Sci* 1992;**47**:M99-M105.

18. DiPietro L. Physical activity in the prevention of obesity: current evidence and research issues. *Med Sci Sports Exerc* 1999;**31**:S542-S546.

19. Bassett D, Ainsworth B, Swartz A, Strath S, O'Brien W, King G. Validity of 4 motion sensors in measuring physical activity. *Med Sci Sports Exer* 2000;**32**(Suppl 5):S81.

20. Ross R, Shaw K, Martel Y, deGuise J, Hudson R, Avruch L. Adipose tissue distribution measured by magnetic resonance imaging in obese women. *Am J Clin Nutr* 1993;**47**:216-228.

21. Samaras K, Kelly PJ, Chiano MN, Spector TD, Campbell LV. Genetic and environmental influences on total-body and central abdominal fat: the effect of physical activity in female twins. *Ann Intern Med* 1999;**130**:873-882.

22. Samaras K, Spector TD, Nguyen TV, Baan K, Campbell LV, Kelly PJ. Independent genetic factors determine the amount and distribution of fat in women after the menopause. *J Clin Endocrinol Metab* 1997;**82**:781-785.

23. Mazess RB, Barden HS, Bidek JP, Hanson J. Dual energy x-ray absorptiometry for total-body and regional bone-mineral and soft-tissue composition. *Am J Clin Nutr* 1190;**51**:1106-1112.

24. Haarbo J, Gotsfredsen A, Hassager C, Christiansen C. Validation of body composition measurement by dual energy x-ray absorptiometry (DEXA). *Clin Physiol* 1991;**11**:331-341.

25. Jensen MD, Kanaley JA, Reed JE, Sheedy PF. Measurement of abdominal and visceral fat with computed tomography and dual energy x-ray absorptiometry. *Am J Clin Nutr* 1995;**61**:274-278.

26. Svendsen OL, Hassager C, Bergmann I, Christiansen C. Measurement of abdominal and intra-abdominal fat in postmenopausal women by dual energy x-ray absorptiometry and anthropometry: comparison with computerized tomography. *Int J Obes* 1993;**17**:45-51.

27. Jain M, Howe GR, Rohan T. Dietary assessment in epidemiology: comparsion on food frequency and a diet history questionnaire with a 7-day food record. *Am J Epidemiol* 1996;**143**(9):953-960.

28. Bingham SA, Cassidy A, Cole TJ, Welch A, Runswick SA, Black AE, Thurnham D, Bates C, Khaw KT, Key TJ. Validation of weighed records and other methods of dietary assessment using the 24 h urine nitrogen technique and other biological markers. *Br J Nutr* 1995;**73**(4):531-550.

29. Hartman AM, Brown CC, Palmgren J, Pietinen P, Verkasalo M, Myer D, Virtamo J. Variability in nutrient and food intakes among older middle-aged men. Implications for design of epidemiologic and validation studies using food recording. *Am J Epidemiol* 1990;**132**(5):999-1012.

30. Guthrie HA, Crocetti AF. Variability of nutrient intake over a 3-day period. *J Am Diet Assoc* 1985;**85**(3):325-327.

31. Basiotis PP, Welsh SO, Cronin FJ, Kelsay JL, Mertz W. Number of days of food intake records required to estimate individual and group nutrient intakes with defined confidence. *J Nutr* 1987;**117**(9):1638-1641.

32. Gay C. Estimation of population distributions of habitual nutrient intake based on a short-run weighed food diary. *Br J Nutr* 2000;**83**(3):287-293.

33. Goldberg GR, Black AE, Jebb SA, Cole TJ, Murgatroyd PR, Coward WA, Prentice AM. Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. *Eur J Clin Nutr* 1991; **45**(12):569-581.

34. Peterson TR, Tucker LA. The relative contribution of changes in energy intake and physical activity to change in body composition [abstract]. *Med Sci Sports Exer*c 2002;**34**(5):S120.

Table 1. Changes in Key Variables From Baseline to Follow-up

Variable	Assessment Period		Change (n=80)	***F***	***P***
	Baseline (n=80)	**Follow-up (n=80)**			
Age (years)	41.3±3.3	—	—	—	—
Abdominal Fat (%)	25.21±6.84	25.22±6.45	0.01±2.62	0.0009	0.9748
Total Body Fat (%)	30.42±6.77	30.34±6.53	-0.08±2.68	0.0677	0.7993
Activity Counts†	2612.4±810.7	2574.4±921.7	-38.0±718.5	0.2209	0.6372
Energy Intake (kcal)	1906.8±323.8	1974.3±430.4	67.5±329.3	3.4225	0.0688

†Activity monitor counts were divided by 1000 to make reported values more manageable.

Table 2. Predictors of Abdominal Fat Change With and Without Controls

Predictor of abdominal fat change Confounder controlled	***b***	***F***	***P***
Physical activity change			
No controls	0.0000	0.10	0.7504
Age	0.0000	0.09	0.7654
Age, baseline ACT	0.0000	0.08	0.7769
Age, baseline BF%	0.0000	0.83	0.3659
Age, Δenergy intake	0.0000	0.32	0.5708
Age, baseline BF%, Δenergy intake	0.0000	1.62	0.2085
Energy intake change			
No controls	0.0017	3.54	0.0637
Age	0.0017	3.86	0.0530
Age, ΔACT	0.0018	4.06	0.0475
Age, baseline BF%	0.0018	4.88	0.0302
Age, baseline BF%, ΔACT	0.0020	5.65	0.0200

Δ = change across the 18-month study

ACT = daily physical activity, indexed by daily activity count totals

BF% = the percentage of total body mass that is fat, as measured by DEXA

Appendix A

Prospectus

Chapter 1

Introduction

Over the past three decades, the prevalence of overweight and obesity has increased several-fold, with more than a third of the U.S. population considered overweight or obese.[1] When a body mass index (BMI) of 25.0 is used as a cut-point, 63 and 55 percent of men and women, respectively, are overweight.[2] The seriousness of this problem is evident as results from six major epidemiologic studies in the U.S. indicate that the annual number of deaths attributable to obesity now exceeds 300,000 – second only to tobacco-related deaths.[3]

Obesity has recently been distinguished as one of the top five independent causes of cardiovascular disease.[4] Additionally, epidemiologic and metabolic studies confirm that obesity contributes to a host of other medical conditions such as hypertension, dyslipidemia, insulin resistance, glucose intolerance, diabetes mellitus, sleep apnea, arthritis, hyperuricemia, gallbladder disease, and certain types of cancer.[5] Certainly, obesity is no longer considered merely a cosmetic problem, but has become a major medical malady.

Perhaps of more clinical importance than general obesity is the regional distribution of adiposity in overweight individuals. Excess fat deposited in the abdominal region is a stronger predictor of cardiovascular disease and Type II diabetes mellitus than general obesity.[6,7] The predictive power of abdominal fat may be partially explained by the excess accumulation of visceral fat, which is an independent correlate of insulin resistance and dyslipidemia.[8] The risk-laden characteristics of centrally-located obesity have led to the incorporation of abdominal fat into a collection of associated diseases called syndrome X, or the plurimetabolic syndrome.[9] Abdominal obesity is highly correlated to other diseases in this syndrome, namely Type II diabetes, dyslipidemia, and hypertension. That abdominal fat is so closely related to these major health problems suggests that substantially reducing abdominal girth may be beneficial, not only for attenuating the direct health risk of obesity, but also reducing the effects of its associated diseases.[10,11]

Reviews by both DiPietro[12] and Ross et al.[13] indicate that increases in physical activity result in corresponding decreases in total body fat, assuming a controlled diet. Whether this apparent dose-response relationship applies to abdominal fat has yet to be determined. To date, relatively few studies have addressed directly the extent to which physical activity influences abdominal fat.[13] Though hardly a consensus, most of the studies investigating abdominal fat and physical activity report an inverse relationship.[14-17] One such study found that exercise, even without weight loss, reduces abdominal fat and prevents further weight gain.[16] In light of the heart disease risk already found to be linked to central adiposity, it seems that greater emphasis should be placed on clarifying the relationship between abdominal fat and physical activity, especially as a strategy for risk-reduction.

In developing a more solid understanding of the role physical activity plays regarding changes in abdominal fat, studies must employ the most effective research methods. Inherent to weight change research is the element of time. A few weeks and months are usually too brief a period to observe meaningful body composition fluctuation without extreme intervention measures. Since subject compliance is difficult to maintain over the long term in experimental research, prospective studies are important in revealing trends in body composition change.

In a review of current literature, DiPietro[18] established a list of priorities for further research in the area of physical activity and obesity. She stressed the need for prospective studies in middle-aged women and called for improved physical activity measurement methods as well as more thorough statistical control of confounders.

In a recent report provided by the American College of Sports Medicine on dose-response relationships, Ross and Janssen[13] concluded that, to their knowledge, no longitudinal studies report attenuation of normal age-related increases in total and abdominal fat with physical activity. Undoubtedly, the need for further research, especially with the advantages that prospective data provide, is necessary to elucidate the relationship between physical activity and abdominal fat.

Statement of the Problem

The proposed prospective cohort study will determine the extent to which physical activity and changes in physical activity are predictive of changes in abdominal fat in approximately 120 females over an 18-month period. Ancillary objectives will be to define the extent to which the relationship between physical activity and abdominal obesity are affected by total body fat, age, and total energy intake in this cohort, and to examine the influence of energy intake on changes in abdominal fat.

Research Questions

1. To what extent does physical activity at baseline predict changes in abdominal fat percent over an 18-month period in middle-age women?
2. To what extent do changes in physical activity predict changes in abdominal fat percent over an 18-month period in middle-age women?
3. To what extent is the relationship between physical activity and abdominal fat percent influenced by possible confounders such as total body fat, age, and total energy intake in this cohort?
4. To what extent do changes in daily energy intake predict changes in abdominal fat?

Assumptions

Subjects will adhere to the self-testing protocol, including wearing the activity monitor correctly throughout a week of typical physical activity and properly weighing and recording all dietary intake while maintaining normal or representative eating habits.

Limitations

In spite of the objectivity of the measures chosen for this study, elements of human error or bias can still be introduced. The activity monitors may produce variable results if not worn as instructed. The diet record may not be recorded accurately, or the subject may subconsciously change her eating habits. Both the diet and activity monitor data are gathered without researcher supervision and subject non-compliance may introduce error.

Delimitations

This study will be conducted in cooperation with the Brigham Young University (BYU) Lifestyle Project, an ongoing prospective cohort study. The subjects used for the proposed analysis were originally accepted into the cohort on condition that they were healthy, had a BMI less than 30, had not yet reached menopause, and were between the ages of 35 and 45. None smoked tobacco, and most were Caucasian women. DEXA scans obtained from the cohort 18 months previously will be analyzed for abdominal fat content after proposal approval and will be used for comparison purposes with results from this study to compute changes over time.

Operational Definitions

Physical activity - Movement of the body produced by skeletal muscles, measured in this study by Computer Science and Application (CSA) accelerometers, which sense motion at the left hip.

Abdominal fat - Fat percentage of the midsection, indexed by dual energy x-ray absorptiometry (DEXA), focusing specifically on the area which includes the second through fourth vertebrae and extending laterally to the inner aspect of the ribs.

Obesity Having a total body fat percentage of 32 or greater, or a body mass index (BMI) of 30 or greater.

Visceral fat - A component of abdominal fat that is within the visceral cavity or near the abdominal organs.

Total energy intake - Daily energy consumption expressed in kilocalories, determined by an average of the analyzed 7-day food log.

Chapter 2

Review of the Literature

Population studies worldwide suggest that patterns of decreased daily physical activity contribute substantially to the rising prevalence of overweight and obesity.[19,20] Numerous studies, summarized in reviews by DiPietro[12] and Ross[13], agree that increased physical activity levels are associated with reductions in total body fat. Relatively few studies, however, have attempted to examine the independent influence of physical activity on regional fat distribution, specifically abdominal adiposity.

This review of current literature will refer to studies which specifically address the independent relationship between physical activity levels and abdominal fat. Only studies with methodology which allowed for independent analysis of the variables of physical activity and abdominal fat will be considered. Acceptable measures of abdominal fat are magnetic resonance imaging (MRI), computed tomography (CT), dual energy x-ray absorptiometry (DEXA), waist circumference, and waist-to-hip ratio (WHR).

This review of literature will be categorized by research design into three categories: cross-sectional, experimental, and prospective research.

Cross-sectional Research

Cross-sectional design, by nature, examines relationships between variables without consideration of their interaction over time. Although causal links between physical activity and abdominal fat are impossible to determine by a simple cross-sectional approach, large-group studies examining populations can obtain data suggesting the strength of relationships, which directs the attention of further investigation by experimental or prospective designs. The following studies suggest an inverse relationship between physical activity and abdominal adiposity. To understand the lack of unanimity of the reports, attention must be paid to the method of measurement of both physical activity and abdominal fat in most large-group studies.

Kaye et al.[21] examined the association of fat distribution and a number of lifestyle factors in the Iowa Women's Health Study, a random sample of 40,980 postmenopausal women, aged 50 to 69 years. Although only an ancillary objective of the study, body fat distribution was indexed by the waist-to-hip ratio, which was significantly and negatively associated with self-reported physical activity. After controlling for body mass index (BMI) and a few other factors, however, statistical significance of the physical activity to WHR relationship disappeared.

Slattery et al.[22] conducted a study with 5,115 black and white young adults, also measuring various dietary and lifestyle habits. A physical activity history questionnaire was used to assess habitual activity. An inverse association between reported physical activity and WHR was found, with an exception in white women, who nevertheless showed skinfold-thickness differences similar to the other groups at the various activity levels ($p<0.01$).

Troisi et al.[23] used cross-sectional data from 765 men, aged 43-85 years, in the Normative Aging Study. Intent of the study was to determine which underlying factors could explain previously-reported results that smokers weigh less than non-smokers, yet have greater waist-to-hip circumference ratios. As well as distinguishing alcohol consumption as a confounder, multiple linear regression analysis revealed that physical activity was negatively associated with increasing WHR.

Wing et al.[24] also took cross-sectional data from a cohort of 487 middle-aged women from the Healthy Women's Study. Subjects completed the Harvard Alumni Activity Survey to quantify weekly physical activity. Subjects were then divided into quartiles based on exercise energy expenditure. The lowest quartile of expenditure (0-500 kcal/wk) had a significantly higher mean WHR than the other quartiles combined ($p<0.05$), even after adjustment for BMI.

Seidell et al.[25] used a survey to assess physical activity in a population of 512 38-year-old European men. Sports activity scores were negatively related to WHR ($\beta \pm$ standard error of the mean: -0.009 ± 0.003). The inverse relationship between physical activity and abdominal fat was independent of BMI and smoking.

Tremblay et al.[26] administered a survey to a sample of 1,257 and 1,366 Canadian men and women, respectively, aimed at determining whether intensity of physical activity was independently related to fat distribution. The strength of this study was the thoroughness of the leisure-time activity questions. In order to differentiate the higher- from lower-intensity activities, subjects were asked more details about their physical activity than in other surveys, lending more information to analyze than the often-used single-question physical activity indexes. Although total energy expenditure was merely an ancillary variable in this study, the results echo those of other cross-sectional studies: the more regularly subjects participated in physical activity, the less likely they were to be found in the upper regions of the WHR index.

All of the above studies used waist-to-hip ratio as a measure of abdominal adiposity. With the emergence of more accurate central fat determiners, such as magnetic resonance imaging, computed tomography, and dual energy x-ray absorptiometry (DEXA), waist-to-hip ratio is increasingly considered a crude measurement of fat distribution and studies have shown that it poorly predicts changes in visceral fat.[27] Moreover, multiple studies show that waist circumference is a much better predictor of abdominal fat than the more commonly used WHR.[28,29]

Poehlman et al.[30] indexed central adiposity by waist circumference in a sample of healthy men (427) and women (293), ages ranging from 17 to 90 years. Physical activity data were obtained by a leisure time physical activity questionnaire. Waist circumference was most strongly associated with declines in leisure-time physical activity in men and peak VO2 in women. Thus, physiological characteristics which reflect a decline in energy expenditure due to physical activity were important predictors of the increases in total and central fatness.

When working with non-obese women, measuring abdominal fat by DEXA is superior to waist circumference.[28] Of the current cross-sectional research available on abdominal fat and physical activity, a study by Samaras et al.[31] provides the most objective and reliable methodology. A DEXA measurement was taken of the fat percentage in the abdominal region of 970 healthy female twins (mean age 55.5 years, range 39-70 years), followed by two questionnaires thoroughly assessing daily physical activity. Data on dietary intake, socioeconomic status, smoking status, and use of hormone replacement therapy were also gathered. Not only was abdominal fat 0.44 kg lower in women who reported vigorous weight-bearing activity, but after controlling for genetic and environmental factors, physical activity was the strongest predictor of central abdominal fat in this study.

The cross-sectional inverse association of physical activity to abdominal adiposity has been demonstrated consistently across populations and by varying research methods. Variations in results as to the strength of the association may be partially explained by inadequacies of some methods in measuring either activity or fatness. Even though the best-designed cross-sectional analyses yielded highly-significant results, further research is needed. Whether physical activity prevents gains in abdominal adiposity, or vice versa, cannot be established independent of time. Intervention research and longitudinal studies, which observe changes across time, are essential in determining the relationship between abdominal fat and physical activity.

Experimental Research

Experimental trials involve some intervention, which usually alters an outcome over time in comparison to a control group. Frequently, experimental studies are separated by design into nonrandomized trials and randomized, controlled trials. The experimental studies dealing with physical activity as it relates to abdominal fat will be categorized according to design and then discussed by order of improving abdominal fat measurement methods. As in cross-sectional research, methods of fat distribution measurement in experimental trials range from simple anthropometry to the more reliable DEXA, CT, and MRI scans. Stringency of diet control and magnitude of physical activity manipulation should also be considered in interpreting results.

Nonrandomized trials

Pratley et al.[32] studied reductions in abdominal fat due to aerobic training as an ancillary objective to an investigation on insulin responses to exercise. This 9-month study of 17 middle-aged men progressively increased the intensity (50-60% to 80-85% relative HRmax) and the duration (30-45 to 45-60 minutes) of a 3-4 day/wk exercise routine. Diets were controlled, but increased in caloric content to prevent weight loss. Waist circumference decreased by 2% ($p = 0.038$) and WHR by 1% ($p = 0.035$) over the study, indicating a marginally-significant decrease in abdominal fat by these measures.

Kohrt et al.[17] conducted a similar study, but with older men and women (60-70 yrs) walking or jogging for roughly 45 minutes at approximately 80% of maximal heart rate. The study extended from nine months to a year in length. Mean exercise energy expenditure per week was 1890 and 1120 kcal/week for men and women, respectively.[13] The largest absolute and relative fat changes occurred in the abdominal circumference and skinfold measurements of these subjects, suggesting a training-induced preferential loss of fat from the central regions of the body in both men and post-menopausal women.

Despres et al.[33] used an exercise duration of 90 minutes at lower intensity (55% of VO_2max), 4-5 days/wk over 14 months with a sample of 13 obese, premenopausal women. Mean energy expenditure per week from exercise was 2450 kcal.[13] Despite significant within-group variation, adipose tissue area change as measured by computed tomography (CT) indicated a greater loss of abdominal fat compared with mid-thigh adiposity ($p < 0.05$).

Schwartz et al.[34] compared exercise-induced changes in abdominal fat in healthy younger (n = 13, mean age 28 yrs) and older men (n = 15, mean age 68). The 6-month endurance training program consisted of aerobic activity demanding approximately 2520 and 1120 kcal/wk from the young and old groups, respectively.[13] Computed tomography showed that, although the older men had two-fold greater intra-abdominal fat depots than the young men, both groups displayed decrements in total abdominal adipose tissue, averaging 0.4 and 0.8 percent fat per week for the young and older men, respectively.

The largest non-randomized study was performed by Wilmore et al.[35] who used 557 black and white men and women from the HERITAGE family study. The group began exercising at 55% of aerobic capacity for 30 minutes, 3 times per week. The subjects progressed to 75% of aerobic capacity maintained for 50 minutes by the 14th week, and maintained that workout duration and intensity through the last six weeks. All measures of body composition, including computed tomography of the abdominal region, decreased significantly from baseline to follow-up, although the authors suggest that exercise of a greater magnitude and sustained for longer periods of time would result in more meaningful biological changes.

Findings from non-randomized trials agree that significant decreases in abdominal fat can occur with increases in exercise, independent of other environmental factors. Obviously, the stronger the intervention or magnitude of exercise change, the more meaningful the abdominal fat reduction.

Randomized trials

Five studies, using randomized trials, measured changes in abdominal fat and related it to an imposed physical activity treatment. These studies further emphasize the importance of exercise magnitude in producing abdominal fat losses.

Grediagin et al.[36] identified differences in intensity of physical activity in inducing fat loss. In a sample of 12 untrained, moderately-obese women, subjects were randomly assigned to be in either a high-intensity or low-intensity exercise group. Both groups were required to expend only 300 kcal per week in four monitored sessions.[13] Dietary control was imposed only by instructing subjects to maintain normal diet patterns. Resulting analysis of skinfold measures found no significant differences between groups in abdominal fat loss, suggesting that fat loss is a function of energy expended rather than exercise intensity.

Binder et al.[15] studied abdominal fat changes as an ancillary objective to a hormone replacement therapy (HRT) trial. Exercise consisted of two months of low-intensity exercise followed by nine months of vigorous exercise for 45 min/day, three or more days/week, at 65-85% maximal heart rate. A total of 17 subjects comprised the control group, and 25 comprised the exercise group. The magnitude of exercise intervention was estimated at approximately 980 kcal/wk. Abdominal fat change in exercisers, indexed by waist circumference, was 0.68 mm/wk – a significant ($p < 0.05$) loss when compared to slight gains in the control group.

DiPietro et al.[37] also tested abdominal fat as a subsidiary aim in a randomized, controlled trial with 16 healthy, older men and women. Over a 16-week period, nine of these subjects exercised four times per week for 60-minute sessions, equaling an estimated 910 kcal/wk exercise expenditure.[13] The control group participated in supervised stretching and yoga. Baseline and follow-up abdominal fat estimates were obtained by computed tomography and anthropometry. With the small subject numbers and low weekly expenditure compared to controls, it was not surprising that the aerobic training intervention had no significant effect on abdominal fat.

Ross et al.[16] conducted a randomized, controlled trial to assess the independent effect of diet-induced or exercise-induced weight loss on abdominal adiposity in moderately-obese men. Where other studies have intervened with fewer than 1000 kcal/wk expended through exercise, these 52 subjects expended 4900 kcal/wk in exercise (assessed by a two-point doubly-labeled water method) for three months. The exercise without weight loss group had abdominal subcutaneous (1.5%/wk), visceral (2.3%/wk), and total intra-abdominal fat (1.9%/wk) reductions that were significantly ($p = 0.001$ in all sections) greater than controls. The authors concluded that exercise even without weight loss reduces abdominal fat and prevents further weight gain.

Certainly, magnitude of the exercise intervention is key to obtaining significant independent reductions of abdominal fat from exercise training. However, these intervention trials confirm the general inverse relationship between abdominal adiposity and physical activity suggested by cross-sectional research. More intervention trials which isolate abdominal fat change are needed to establish a dose-response relationship as has been confirmed with exercise and total body fat.[13]

Prospective research

Prospective research is observational in nature, much like cross-sectional studies; unlike cross-sectional research, however, it can observe changes and relationships as they interact over time in subjects. Meaningful change data are only available through experimental and prospective designs. Unfortunately, no longitudinal studies have ever reported whether physical activity can attenuate the upward trend in abdominal fat that occurs with advancing age. Cohort studies have investigated weight change with physical activity, but to date, none have included a reliable abdominal fat measure as well as physical activity change data to specifically identify the influence of increasing physical activity in the prevention of abdominal fat gain.

In a study investigating metabolic changes in 35 women, some of whom were experiencing a change into menopause, Poehlman et al.[38] observed that some of the changes included abdominal fat increases (indexed by WHR) corresponding with decreases in physical activity during leisure time. The analysis lacked, however, the statistical power to investigate those women who may have increased physical activity in spite of menopause to observe whether abdominal fat would have been attenuated.

In a follow-up data collection of the Healthy Women's Study cohort by Wing et al.[24] referred to earlier in cross-sectional research, changes in WHR were observed with decreasing physical activity, independent of changes in body mass index ($r = 0.18$, $p < 0.05$). Menopausal status was not controlled for in the statistical analysis. Because of the lack of control of this known confounder, additional information regarding the physical activity and abdominal fat relationship over time cannot be gained from these data.

Further investigation using prospective cohort studies with a focus on age-related abdominal fat accumulation and physical activity is needed. In a review of current literature, DiPietro[18] emphasized the need for powerful longitudinal studies of women, especially surrounding the advent of menopause, due to the fact that women during middle-age have the highest risk of substantial weight gain.

Conclusions

Current literature generally supports an inverse relationship between abdominal adiposity and physical activity. The strength and independent nature of this relationship, however, needs to be further examined by studies possessing sufficient power and reliable measurement methods. Precise measurements of abdominal fat have begun to emerge in later studies, and albeit some work has been done with less predictive measures, like waist-to-hip ratio, more reliable or precise methods will likely shed further light on abdominal fat and its relationship with physical activity.

Another general inadequacy in nearly all of the studies reviewed is measurement of activity. In cross-sectional and longitudinal studies, rarely has physical activity been assessed by any method other than a self-report questionnaire or recall interview. Despite efforts to obtain accurate recall data, questionnaires often overestimate energy expended in physical activity. Although measurement of aerobic capacity (measured in some recent studies) is a step in the right direction, it still does not give a reliable indication of the energy expended in daily activity among subjects. Until more studies adopt reliable measurement methods of both daily physical activity and abdominal fat, the relationship between these two variables cannot be elucidated.

The proposed study responds to a few of the inadequacies of previous research which were addressed in this review. First, abdominal adiposity and changes in that fat depot will be measured by DEXA, a method proven to be more reliable than WHR or waist circumference. Second, total physical activity will be measured using accelerometers worn for a full week at the hip – a precise, objective indicator of daily physical activity. Third, confounders such as energy intake, age, and total body fat percentage will be assessed by reliable methodology and statistically controlled. Finally, the prospective nature of this study responds to the apparent paucity of longitudinal research in the area of abdominal fat and physical activity.

Chapter 3

Methods

This study will examine the relationship between physical activity and abdominal fat in middle-age women over an 18-month period. Objective measures of both physical activity and abdominal fat will be used to determine the extent to which physical activity and changes in physical activity predict changes in abdominal fat. A secondary purpose of the study will be to determine the extent to which possible confounding factors, such as total body fat, age, and energy intake, influence the relationship between physical activity and abdominal fat.

Subjects

The proposed study will be conducted in cooperation with the BYU Lifestyle Project, an ongoing, prospective cohort study. To date, the cohort has participated in two data collection periods, 18 months apart. The proposed study will focus on a third period, which will commence in January of 2002.

The existing cohort of women was recruited initially by advertising to the general population of the Utah Valley area. Potential subjects were interviewed by phone to determine whether they fit the prescribed parameters. Only healthy, non-obese (BMI<30), premenopausal women between the ages of 35-45 years were included in the original cohort. Smokers and those who planned to become pregnant during the study were also excluded. The proposed study will use the same women who participated in the original cohort. A total of approximately 120 subjects are expected to participate in the present study.

Measurement Methods and Instrumentation

Physical activity, abdominal fat percentage, total body fat percentage, age, and energy intake will be the variables measured in this study. Changes in these variables will also be assessed. Comparisons will be made between the measurements taken in the proposed study and data collected 18 months previously on the same subjects as part of the BYU Lifestyle Project.

Physical Activity

To provide an objective measure of physical activity, this study will use Computer Science and Application (CSA) accelerometers (Shalimar, FL). Each subject will wear a nylon belt, which will be fastened securely around her waist at the level of the umbilicus. The CSA accelerometer will be attached to the belt, positioned over her left hip. The subject will wear the accelerometer continuously for seven consecutive days, with allowance to loosen the belt for comfort during sleeping hours. The CSA accelerometer will be removed only when the subject is bathing or during activities in which the monitor may become submerged in water. If the accelerometer is not worn according to protocol, the subject will be asked to redo the testing week. If she refuses to participate in a retest, she will be dropped from the cohort.

Research by Ekelund et al.,[39] comparing CSA accelerometer data to doubly-labeled water, concluded that CSA activity counts significantly relate to energy expenditure data ($r=0.58$, $P<0.01$). Furthermore, in a comparison with three other accelerometers, Bassett et al.[40] found that the CSA accelerometer had the highest correlation ($r>0.90$) with energy expenditure, measured by a portable metabolic system, while 81 adults performed six different tasks of varying intensities. These findings support the use of the CSA accelerometer as a valid and objective measurement of physical activity in humans.

Total and Abdominal Fat Percentages

Total body fat percent will be measured using Hologic's dual-energy x-ray absorptiometry (DEXA) machine, model 4500 W (Hologic QDR, Waltham, MA). Abdominal fat will be measured by manipulating the full-body scan analysis to obtain an abdominal region measurement. The same investigator will assess abdominal fat percent on scans from both the proposed study and the scans performed 18 months previously. The abdominal region will extend from the top of the second lumbar vertebrae to the bottom of the fourth lumbar vertebrae, and laterally to the inner aspect of the ribs.

The above region has been shown to capture maximally the risk-laden intra-abdominal fat in women,[41] and has been used in multiple abdominal fat studies by Samaras et al.[42,31] using a Hologic DEXA machine. Studies have confirmed that DEXA's capability of measuring regional adiposity is accurate, precise, and that the radiation dose is minimal.[43,44] Specifically, Jensen et al.[45] found that computed tomography (CT) and DEXA had total abdominal fat measures that were highly correlated ($r = 0.985$, $p < 0.001$) in 21 subjects with a wide range of abdominal and visceral fat masses. Svendsen et al.[46] showed a similar correlation between DEXA and CT abdominal fat measures ($r = 0.900$, s.e.e.%: 7%) in 25 post-menopausal women. These studies support the use of DEXA as a valid, objective measure of abdominal fat.

Energy Intake

Energy intake will be measured using 7-day weighed diet records. Each subject will be given seven blank diet logs (see Appendix A-1), with space for recording weight and descriptions of food. An Ohaus 2000 electronic scale (Florham Park, NJ), which gives digital readings in grams, will be issued to the subject. All food consumed during seven consecutive days will be weighed and recorded by the subject. This food intake record will be conducted on the same seven days in which the subject will be wearing the CSA accelerometer, measuring dietary intake and physical activity simultaneously.

Certain precautions will be taken to encourage accurate diet results. First, research personnel will make contact with each subject by telephone every other day to answer questions and remind her to be diligent in her reporting. Second, subjects will be weighed before and after the testing week on an electronic scale (Tanita Corporation, Japan) to ensure that significant weight change does not occur. Third, the diet logs will be analyzed by a registered dietitian using the ESHA Research software program, version 7.6 (Salem, OR). If total caloric intake does not exceed 130% of her estimated 24-hour resting metabolic rate, the subject will be asked to redo the log. If she refuses to repeat the 7-day assessment, she will be dropped from the study.

Diet records, especially weighed food records, are often used as a standard for energy intake assessment in validation studies.[47,48] Some debate has occurred in the literature as to how many days of food recording are required to accurately determine a subject's mean energy and macronutrient intake. Study recommendations range from 3-14 days when using a weighed intake diary, with most agreeing that seven days is more than sufficient.[49-52] Support for an under-reporting cut-off point is also found in the literature.[53]

Procedure

Beginning in January 2002, a letter will be sent to all subjects in the BYU Lifestyle Project cohort, informing them that the third data collection phase will soon begin. Subjects, in order of their previous testing date, will be called to make appointments. Two appointments for testing sessions at the Brigham Young University Human Performance Research Center will be made for each subject, scheduled eight days apart. Subjects will be given directions to the Human Performance Research Center, where they will be met by a research assistant and given a parking pass. Written consent and premedical screening (see Appendix A-2 and A-3) will be required before any assessments are taken.

Full-body scans using DEXA will occur during the first appointment. The subject will be weighed in a standard one-piece BYU swimsuit and scanned immediately following. She will then change back into her street clothes and receive instructions for the energy intake and physical activity assessments. These two assessments will be performed outside of the BYU laboratory for seven consecutive days, while the subject conducts a week of her daily activities, representative of her “normal” lifestyle. She will be issued a digital scale, a 7-day diet log, and a CSA accelerometer. Research assistants will explain how to use the scale and what to write in the diet log. A written explanation of how to wear the activity monitor will be provided as a reminder (Appendix A-4). The subject will also be shown that the accelerometer should be worn snugly over her left hip, and told that it must be worn day and night, except when showering, bathing, or when participating in water activities. Emphasis will be placed on maintaining a normal or representative lifestyle – not to begin a new exercise regimen or diet, for example.

During the week between appointments, research personnel will call the subject periodically to answer any questions she may have about her assessments, encourage her to continue to adhere to measurement and recording protocol, and thank her for her efforts to ensure that her measurements are a valid representation of her lifestyle. At the second appointment, the subject will return the scale, log, and accelerometer. She will be weighed again in a standard BYU swimsuit and asked questions about the normalcy of her diet and physical activity that week. All data will be reviewed in detail, and the subject may be asked to redo her testing week if protocol was not followed. When the data are determined complete, the subject will be mailed test results with a letter of appreciation and a $25 gift certificate.

Data Analysis

Since the proposed study intends to determine the extent to which initial physical activity and changes in physical activity predict changes in abdominal fat, differences between follow-up and baseline must be calculated. DEXA scans from both assessments must be analyzed for abdominal fat percentage, and the change over 18 months recorded. Physical activity change will be calculated by subtracting total CSA activity counts of the baseline assessment from the follow-up total. Subjects will then be divided into categories based on their physical activity, both by initial level and level of activity change. Regression analysis using the general linear model (GLM) procedure will be used to determine the extent to which abdominal fat and changes in abdominal fat differ according to the physical activity categories. Potential confounding variables, like total body fat, age, and energy intake, will be controlled using partial correlation. All statistical analyses will be computed using the SAS® system (Cary, NC). Findings will be drawn from the data analysis; conclusions and recommendations will be made from the findings.

References

1. Kuczmarski RJ, Flegal KM, Campbell SM, Johnson CL. The increasing prevalence of overweight among US adults. The National Health and Nutrition Examination Surveys, 1960 to 1991. *JAMA*. 1994;272:205-11.
2. Must A, Spadano J, Coakley EH, Field AE, Colditz G, Dietz WH. The disease burden associated with overweight and obesity. *JAMA*. 1999;282:1523-29.
3. Mokdad AH, Serdula MK, Dietz WH, Bowman BA, Marks JS, Koplan JP. The spread of the obesity epidemic in the United States, 1991-1998. *JAMA*. 1999;282:1519-22.
4. Eckel RH, Krauss RM. American Heart Association Call to Action: Obesity as a Major Risk Factor for Coronary Heart Disease. *Circulation*. 1998;97:2099-2100.
5. National Institutes of Health and National Heart, Lung and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the Evidence Report. *Obes Res*. 6(Suppl. 2), 1998.
6. Despres JP, Moorjani S, Lupien PJ, Tremblay A, Nadeau A, Bouchard C. Regional distribution of body fat, plasma lipoproteins, and cardiovascular disease. *Arteriosclerosis*. 1990;10:497-511.
7. Ross R, Fortier L, Hudson R. Separate associations between visceral and subcutaneous adipose tissue distribution, insulin and glucose levels in obese women. *Diabetes Care*. 1996;19:1404-11.
8. Despres JP, Lemieux S, Lamarche B, Prud'homme D, Moorjani S, Brun LD, et al. The insulin resistance-dyslipidemic syndrome: contribution of visceral obesity

and therapeutic implications. *Int J Obes Relat Metab Disord*. 1995;19(Suppl 1):S76-86.

9. Timar O, Sestier F, Levy E. Metabolic syndrome X: a review. *Can J Cardiol*. 2000;16:779-89.

10. Astrup A. Healthy lifestyles in Europe: prevention of obesity and type II diabetes by diet and physical activity. *Public Health Nutr*. 2001;4:499-515.

11. Markovic TP, Campbell LV, Balasubramanian S, Jenkins AB, Fleury AC, Simons LA, Chisholm DJ. Beneficial effect on average lipid levels from energy restriction and fat loss in obese individuals with or without type 2 diabetes. *Diabetes Care*. 1998 May;21(5):695-700.

12. DiPietro L. Physical activity, body weight, and adiposity: an epidemiologic perspective. *Exerc Sports Sci Rev*. 1995;23:275-303.

13. Ross R, Janssen I. Physical activity, total and regional obesity: dose-response considerations. *Med Sci Sports Exerc*. 2001;33:S521-7.

14. Mourier A, Gautier JF, De Kerviler E, et al. Mobilization of adipose tissue related to the improvement in insulin sensitivity in response to physical training in NIDDM. *Diabetes Care*. 1997;20:385-91.

15. Binder EF, Birge SJ, Kohrt WM. Effects of endurance exercise and hormone replacement therapy on serum lipids in older women. *J Am Geriatr Soc*. 1996;44:231-6.

16. Ross R, Dagnone D, Jones PHJ, et al. Reduction in obesity and related comorbid conditions after diet-induced weight loss or exercise-induced weight loss in men: a randomized controlled trial. *Ann Intern Med*. 2000;133:92-103.

17. Kohrt WM, Obert KA, Holloszy JO. Exercise training improves fat distribution patterns in 60- to 70-year-old men and women. *J Gerontol Med Sci*. 1992;47:M99-105.

18. DiPietro L. Physical activity in the prevention of obesity: current evidence and research issues. *Med Sci Sports Exerc*. 1999;31:S542-46.

19. Grundy SM, Blackburn G, Higgins M, Lauer R, Perri MG, Ryan D. Roundtable consensus statement: physical activity in the prevention of obesity and its comorbidities. *Med Sci Sports Exer*. 1999;31:S502-8.

20. National Institutes of Health; National Heart, Lung, and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. *Obes Res*. 1998;6:S51-210.

21. Kaye SA, Folsom AR, Prineas RJ, Potter JD, Gapstur SM. The association of body fat distribution with lifestyle and reproductive factors in a population study of postmenopausal women. *Int J Obes*. 1990;14(7):583-91.

22. Slattery ML, McDonald A, Bild DE, Caan BJ, Hilner JE, Jacobs DR Jr, Liu K. Associations of body fat and its distribution with dietary intake, physical activity, alcohol, and smoking in blacks and whites. *Am J Clin Nutr*. 1992;55(5):943-9.

23. Troisi RJ, Heinold JW, Vokonas PS, Weiss ST. Cigarette smoking, dietary intake, and physical activity: effects on body fat distribution--the Normative Aging Study. *Am J Clin Nutr*. 1991;53(5):1104-11.

24. Wing RR, Matthews KA, Kuller LH, Meilahn EN, Plantinga P. Waist to hip ratio in middle-aged women. Associations with behavioral and psychosocial factors and with changes in cardiovascular risk factors. *Arterioscler Thromb*. 1991;11(5):1250-7.

25. Seidell JC, Cigolini M, Deslypere JP, Charzewska J, Ellsinger BM, Cruz A. Body fat distribution in relation to physical activity and smoking habits in 38-year-old European men. The European Fat Distribution Study. *Am J Epidemiol*. 1991;133(3):257-65.

26. Tremblay A, Despres JP, Leblanc C, Craig CL, Ferris B, Stephens T, Bouchard C. Effect of intensity of physical activity on body fatness and fat distribution. *Am J Clin Nutr*. 1990;51(2):153-7.

27. Van der Kooy K, Leenen R, Seidell JC, Deurenberg P, Droop A, Bakker CJ. Waist-hip ratio is a poor predictor of changes in visceral fat. *Am J Clin Nutr*. 1993;57(3):327-33.

28. Rankinen T, Kim SY, Perusse L, Despres JP, Bouchard C. The prediction of abdominal visceral fat level from body composition and anthropometry: ROC analysis. *Int J Obes Relat Metab Disord*. 1999;23(8):801-9.

29. Kamel EG, McNeill G, Han TS, Smith FW, Avenell A, Davidson L, Tothill P. Measurement of abdominal fat by magnetic resonance imaging, dual-energy X-

ray absorptiometry and anthropometry in non-obese men and women. *Int J Obes Relat Metab Disord*. 1999;23(7):686-92.

30. Poehlman ET, Toth MJ, Bunyard LB, Gardner AW, Donaldson KE, Colman E, Fonong T, Ades PA. Physiological predictors of increasing total and central adiposity in aging men and women. *Arch Intern Med*. 1995;155(22):2443-8.

31. Samaras K, Kelly PJ, Chiano MN, Spector TD, Campbell LV. Genetic and environmental influences on total-body and central abdominal fat: the effect of physical activity in female twins. *Ann Intern Med*. 1999;130:873-82.

32. Pratley RE, Hagberg JM, Dengel DR, Rogus EM, Muller DC, Goldberg AP. Aerobic exercise training-induced reductions in abdominal fat and glucose-stimulated insulin responses in middle-aged and older men. *J Am Geriatr Soc*. 2000;48(9):1055-61.

33. Despres JP, Pouliot MC, Moorjani S, Nadeau A, Tremblay A, Lupien PJ, Theriault G, Bouchard C. Loss of abdominal fat and metabolic response to exercise training in obese women. *Am J Physiol*. 1991;261(2 Pt 1):E159-67.

34. Schwartz RS, Shuman WP, Larson V, Cain KC, Fellingham GW, Beard JC, Kahn SE, Stratton JR, Cerqueira MD, Abrass IB. The effect of intensive endurance exercise training on body fat distribution in young and older men. *Metabolism*. 1991;40(5):545-51.

35. Wilmore JH, Despres JP, Stanforth PR, Mandel S, Rice T, Gagnon J, Leon AS, Rao D, Skinner JS, Bouchard C. Alterations in body weight and composition

consequent to 20 wk of endurance training: the HERITAGE Family Study. *Am J Clin Nutr*. 1999;70(3):346-52.

36. Grediagin A, Cody M, Rupp J, Benardot D, Shern R. Exercise intensity does not effect body composition change in untrained, moderately overfat women. *J Am Diet Assoc*. 1995;95(6):661-5.

37. DiPietro L, Seeman TE, Stachenfeld NS, Katz LD, Nadel ER. Moderate-intensity aerobic training improves glucose tolerance in aging independent of abdominal adiposity. *J Am Geriatr Soc*. 1998;46(7):875-9.

38. Poehlman ET, Toth MJ, Gardner AW. Changes in energy balance and body composition at menopause: a controlled longitudinal study. *Ann Intern Med*. 1995;123(9):673-5.

39. Ekelund U, Sjostrom M, Yngve A, Poortvliet E, Nilsson A, Froberg K, Wedderkopp N, Westerterp K. Physical activity assessed by activity monitor and doubly labeled water in children. *Med Sci Sports Exerc*. 2001;33:275-81.

40. Bassett D, Ainsworth B, Swartz A, Strath S, O'Brien W, King G. Validity of 4 motion sensors in measuring physical activity. *Med Sci Sports Exer*. 2000;32(suppl 5):S81.

41. Ross R, Shaw K, Martel Y, deGuise J, Hudson R, Avruch L. Adipose tissue distribution measured by magnetic resonance imaging in obese women. *Am J Clin Nutr*. 1993;47:216-28.

42. Samaras K, Spector TD, Nguyen TV, Baan K, Campbell LV, Kelly PJ. Independent genetic factors determine the amount and distribution of fat in women after the menopause. *J Clin Endocrinol Metab*. 1997;82:781-5.

43. Mazess RB, Barden HS, Bidek JP, Hanson J. Dual energy x-ray absorptiometry for total-body and regional bone-mineral and soft-tissue composition. *Am J Clin Nutr*. 1990;51:1106-12.

44. Haarbo J, Gotsfredsen A, Hassager C, Christiansen C. Validation of body composition measurement by dual energy x-ray absorptiometry (DEXA). *Clin Physiol*. 1991;11:331-41.

45. Jensen MD, Kanaley JA, Reed JE, Sheedy PF. Measurement of abdominal and visceral fat with computed tomography and dual energy x-ray absorptiometry. *Am J Clin Nutr*. 1995;61:274-8.

46. Svendsen OL, Hassager C, Bergmann I, Christiansen C. Measurement of abdominal and intra-abdominal fat in postmenopausal women by dual energy x-ray absorptiometry and anthropometry: comparison with computerized tomography. *Int J Obes*. 1993;17:45-51.

47. Jain M, Howe GR, Rohan T. Dietary assessment in epidemiology: comparsion on food frequency and a diet history questionnaire with a 7-day food record. *Am J Epidemiol*. 1996;143(9):953-60.

48. Bingham SA, Cassidy A, Cole TJ, Welch A, Runswick SA, Black AE, Thurnham D, Bates C, Khaw KT, Key TJ, et al. Validation of weighed records and other

methods of dietary assessment using the 24 h urine nitrogen technique and other biological markers. *Br J Nutr*. 1995;73(4):531-50.

49. Hartman AM, Brown CC, Palmgren J, Pietinen P, Verkasalo M, Myer D, Virtamo J. Variability in nutrient and food intakes among older middle-aged men. Implications for design of epidemiologic and validation studies using food recording. *Am J Epidemiol*. 1990;132(5):999-1012.

50. Guthrie HA, Crocetti AF. Variability of nutrient intake over a 3-day period. *J Am Diet Assoc*. 1985;85(3):325-7.

51. Basiotis PP, Welsh SO, Cronin FJ, Kelsay JL, Mertz W. Number of days of food intake records required to estimate individual and group nutrient intakes with defined confidence. *J Nutr*. 1987;117(9):1638-41.

52. Gay C. Estimation of population distributions of habitual nutrient intake based on a short-run weighed food diary. *Br J Nutr*. 2000;83(3):287-93.

53. Goldberg GR, Black AE, Jebb SA, Cole TJ, Murgatroyd PR, Coward WA, Prentice AM. Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. *Eur J Clin Nutr*. 1991; 45(12):569-81.

Appendix A-1

Informed Consent

Consent To Be a Research Subject (please read carefully)

This study is being conducted by Eric Strong, Lance Davidson, Darcie Ellis, Laura Gardner, Celia Bowles, and Kenric Russell, graduate students in Exercise Science at Brigham Young University, and Dr. Larry Tucker, a professor at BYU. The purpose of this project is to examine lifestyle and risk factors and how they contribute to health over time. Because you participated in previous phases of this project and indicated you were willing to continue as a subject, we have invited you back for the next phase of this project.

As a participant in this project, you will have the opportunity to participate in several health and fitness activities. As a participant, you will need to come to our facility located in the Richards Building at BYU on two different days for assessments. However, like before, you will do some of the assessments by yourself in your own home. During your visits to our lab, you will receive body composition, fitness, and atherosclerosis (vascular disease) assessments. Your body composition will be assessed using the Bod Pod™ and DEXA. Like before, the Bod Pod™ will require that you sit in a chamber wearing a BYU swim suit for about 5 minutes while a computer analyzes your body volume. The DEXA assessment will require you to lay on a table while a lens above you moves back and forth scanning your body. The DEXA assessment will also be used to provide bone density data. Circumference measures of your wrist, hips, waist, and arms, along with your body weight, will also be measured. Fitness testing will involve jogging on a treadmill at an increasing incline and speed until maximal exertion is achieved. To measure your muscular strength, you will be asked to perform sit-ups, the bench press, and to jump as high as you can. To examine the amount of plaque you have in your arteries, ultrasound images will be taken of your carotid (neck) arteries. While at our facility, you will also receive instructions for other assessments you will complete in your own home. In total, the assessments will take about 2 hours during each visit to our lab. Parking passes will be provided so you can park near our facility.

The assessments you do in your own home will mostly involve keeping track of your daily lifestyle. Like before, you will be asked to complete questions about your general lifestyle, the day-to-day health choices you make, and your dietary intake. These questionnaires will require about 30 minutes each to complete. You will also need to weigh and record everything you eat for 7 days. You will be provided with a small scale so you can easily weigh your food. You will also need to wear a tiny activity monitor for 7 days, like before. This monitor will be worn near your hip at all times other than when you're in water. So we can analyze the cholesterol, insulin, and C-reactive protein levels in your blood, you will be asked to visit the laboratory at Timpanogos Hospital on 800 North in Orem after fasting for 12 hours. Drinking water will be OK. While at the lab, a small blood sample (about 2 tablespoons) will be taken from your arm, like last time. It will only take about 10 minutes to participate in the blood draw.

The risks and discomforts associated with the assessments you will receive will be minimal. The fitness assessments may cause some soreness and the blood test may cause some discomfort. A little bruising on your arm could result from the blood test. The risks that accompany the blood test are the same as they would be if you had your blood drawn at a doctor's office. There are no known risks associated with the ultrasound pictures taken of your carotid arteries. The DEXA assessment that will measure your bone density will expose you to a very small amount of x-ray radiation. To put the amount in perspective, every day we are exposed to radiation from the sun, TV, cell phones, etc. Your DEXA bone and body composition assessment will expose you to less radiation than you would typically get from a day snow skiing or during a round trip flight coast-to-coast in an airplane. The DEXA assessment will have an effective radiation dose that is many times less than a dental x-ray or a chest x-ray. Additionally, there will be a very small risk of heart attack (less than 1 in 10,000) associated with the treadmill fitness test. Steps will be taken to minimize these risks. If during the fitness tests you experience chest pain or severe discomfort, you should ask that the test be stopped.

You will receive many benefits from participating in this study. You will receive an enormous amount of valuable information regarding your current lifestyle, fitness level, body composition, artery health, diet, and health status. Having the assessments performed for free will allow you to track your health and take action to overcome any health risks or problems that are uncovered. Additionally, after completing all of the assessments during the next few weeks, you will receive a $25 gift certificate.

Participation in this research is voluntary. You have the right to refuse to participate and the right to withdraw from this study at any time without penalty. However, you will only receive your test results and the $25 gift certificate if you complete all of the assessments. All data from this study will be kept strictly confidential. When the data are stored and analyzed they will be coded by number to ensure confidentiality.

If you have any questions regarding this research project, you may contact a member of the research team at 378-1845 or 378-4494, or Dr. Larry Tucker, 237 Smith Field House, Brigham Young University at 378-4927.

If you have any questions regarding your rights as a participant in this study, you may contact Dr. Shane Schulthies, Chair of the Institutional Review Board, 122 A RB, Brigham Young University, Provo, Utah 84602; phone 378-5490.

I have read, understood and received a copy of the above consent form and desire of my own free will and volition to participate in this study and accept the benefits and risks associated with this study.

______________________________ ____________

Research Participant Date

______________________________ ____________

Witness Date

Appendix A-2

Preliminary Medical Screening Questionnaire

Name: ____________________________ Date: ___________________________

PRELIMINARY MEDICAL SCREENING QUESTIONNAIRE

Major Coronary Risk Factors

Yes	No	Unsure	
☐	☐	☐	Age: Are you a male older than 45, or a female older than 55?
☐	☐	☐	Family History: Do you have a family history of coronary (heart) disease or other atherosclerotic disease in parents or siblings prior to age 55?
☐	☐	☐	Current cigarette smoking: Do you smoke?
☐	☐	☐	Hypertension: Do you have elevated blood pressure ($\geq$140/90 mmHg)?
☐	☐	☐	Hypercholesterolemia: Do you have high blood cholesterol ($\geq$240 mg/dL)?
☐	☐	☐	Sedentary lifestyle/physical inactivity: Are you a physically inactive individual?

Major Symptoms or Signs

Yes	No	Unsure	
☐	☐	☐	Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
☐	☐	☐	Do you feel pain in your chest when you do physical activity?
☐	☐	☐	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	☐	Do you lose you balance because of dizziness or do you ever lose consciousness?
☐	☐	☐	Do you have a bone or joint problem that could be made worse by a change in your physical activity?
☐	☐	☐	Is you doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	☐	Do you know of any other reason why you should not do physical activity?

Appendix A-3

Sample Food Log

Detailed Food Log [Include everything you put into your mouth. Don't forget snacks!] **Day: Monday**

??? Are you wearing your activity monitor ???

Food Item Eaten Be Very Specific	**Weight** g or fl oz.	**Food Item Eaten** Be Very Specific	**Weight** g or fl oz.
1. ______	______	21. ______	______
2. ______	______	22. ______	______
3. ______	______	23. ______	______
4. ______	______	24. ______	______
5. ______	______	25. ______	______
6. ______	______	26. ______	______
7. ______	______	27. ______	______
8. ______	______	28. ______	______
9. ______	______	29. ______	______
10. ______	______	30. ______	______
11. ______	______	31. ______	______
12. ______	______	32. ______	______
13. ______	______	33. ______	______
14. ______	______	34. ______	______
15. ______	______	35. ______	______
16. ______	______	36. ______	______
17. ______	______	37. ______	______
18. ______	______	38. ______	______
19. ______	______	39. ______	______
20. ______	______	40. ______	______

Comments/Notes (refer to the line number of the food item when appropriate). Use the space below to add details and explain foods.

If more space is needed for comments or notes, please use the back of this page and refer to the food item by line number.