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Physical Activity in Individuals at Risk for Diabetes: Diabetes Prevention Program

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Abstract

Purpose and Methods—Leisure physical activity was assessed using questionnaires with different time frames in the Diabetes Prevention Program (DPP) cohort of 3234 overweight individuals aged > 25 yr with impaired glucose tolerance (IGT) from 27 centers across the United States. The three questionnaires were the Modifiable Activity Questionnaire (MAQ; past year), the Low-Level Physical Activity Recall (LOPAR; past 7 d), and the Third National Health and Nutrition Examination Survey (NHANES III; past month). This provided the opportunity to examine the relationship between the three activity measures and to compare activity levels of the DPP sample with that of a national sample with IGT.

Results—Leisure activity determined by the three questionnaires significantly correlated with each other, although the correlations between MAQ and NHANES III were stronger (men: $\rho = 0.52$; women: $\rho = 0.49$; $P < 0.01$) than between LOPAR and either measure (men: $\rho = 0.20$ for MAQ, 0.24 for NHANES; women: $\rho = 0.10$ for MAQ, 0.13 for NHANES). In the DPP, measures of obesity and glucose tolerance were significantly correlated with activity levels determined by MAQ and NHANES, but not LOPAR. Activity levels in DPP participants determined by the NHANES III questionnaire were generally higher than those reported by individuals meeting DPP eligibility criteria who were part of the NHANES cohort for similar age, body mass index, and race or ethnicity.

Conclusion—If the DPP participants were more active than a national sample of individuals with IGT, this would have implications for translation when using the DPP lifestyle intervention in less active or less motivated populations. Finally, the weak relationship between activity levels obtained with MAQ and LOPAR may result from the fact that they encompass different time frames and different components of leisure activity.

Keywords

DIABETES MELLITUS TYPE 2; EXERCISE; OBESITY IN DIABETES; QUESTIONNAIRES; RANDOMIZED CLINICAL TRIALS

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The Diabetes Prevention Program (DPP) was a randomized clinical trial of diabetes prevention in 3234 overweight individuals aged ≥ 25 yr with elevated fasting glucose levels and impaired glucose tolerance (27). The study was designed to determine whether a diet and exercise lifestyle intervention or treatment with metformin would delay the onset of diabetes in a heterogeneous group of individuals from 27 centers across the United States. Of the participants enrolled in the DPP, 45% were from ethnic or racial groups that suffer disproportionately from type 2 diabetes, including African Americans, Hispanic Americans, Asian Americans and Pacific Islanders, and American Indians. Participants were aged 25 yr and older, providing diversity of individuals by age as well.

Self-reported levels of leisure physical activity were assessed at baseline in the entire DPP cohort using physical activity questionnaires with three different time frames (8,10,11,16,20). One of these questionnaires, the Third National Health and Nutrition Examination Survey (NHANES III), was also administered to a national U.S. sample, a subgroup of which had impaired glucose tolerance (16). The time frame of these three activity assessment tools varied from the past week to the past year.

Given the success of the lifestyle arm of the DPP (5), it would be valuable to compare the DPP cohort with a national sample to better understand the generalizability of the DPP results. In addition, because (a) the physical activity questionnaires obtained at baseline in the DPP cohort assessed activity over different time frames and (b) the DPP population was highly diverse in regard to age, gender, race, and geographic location, it would be interesting to compare questionnaire results. Therefore, the purposes of this study were twofold: (a) to examine the magnitude of the correlations among reported physical activity levels in the DPP participants determined from three different baseline activity questionnaires and between physical activity levels determined by these questionnaires and measures of obesity and glucose tolerance; and (b) to compare the prevalence of inactivity in individuals from the DPP volunteer sample with the NHANES III cohort of individuals in the United States with impaired glucose tolerance who had completed the same leisure activity questionnaire a few years earlier.

METHODS

NHANES III

This survey was conducted by the National Center for Health Statistics at 89 U.S. locations between 1988 and 1994 (16). The survey used a stratified, multistage probability cluster design with an oversampling of African Americans, Hispanic Americans, and the elderly (16). A total of over 18,000 individuals who were at least 20 yr of age completed a household interview. The survey included a leisure physical activity questionnaire, which was also given to DPP participants at their baseline evaluation. The number of men and women who completed the physical activity portion of the NHANES III and met basic DPP eligibility criteria (see below) was 155 women and 144 men.

DPP

Details of the DPP study design have been described in detail (27). Participants were recruited for the DPP from 1996 to 1999. The institutional review board at each center approved the protocol, and all participants gave written, informed consent before baseline screening. Inclusion criteria included age of at least 25 yr, a body mass index value of $24 \text{ kg}\cdot\text{m}^{-2}$ or higher (22 or higher in Asian Americans), physical ability to walk a quarter mile in 10 min, and a plasma glucose concentration of $95\text{--}125 \text{ mg}\cdot\text{dL}^{-1}$ in the fasting state and $140\text{--}199 \text{ mg}\cdot\text{dL}^{-1}$ 2 h after a 75-g oral glucose load. Standardized interviewer-administered questionnaires were used to obtain data on personal and medical history. Height and weight measurements were used to calculate body mass index (BMI, $\text{kg}\cdot\text{m}^{-2}$) and waist and hip circumference measures

were used to determine the ratio of waist to hip circumference (WHR). Blood was drawn at baseline for fasting measurements of glucose, HbA1c, and insulin and for 75-g OGTT measurements of insulin (30 min postload) and glucose (120 min postload). Immunoreactive insulin and proinsulin were measured in the plasma. These measures have been described (6).

Self-reported physical activity levels were assessed at baseline using three activity questionnaires with different time frames: the Modifiable Activity Questionnaire (10), the Low-Level Physical Activity Recall (8,20), and the NHANES III (16). These are described in detail below.

The modifiable activity questionnaire

The Modifiable Activity Questionnaire (MAQ) was designed for easy modification to maximize the feasibility and appropriateness of physical activity assessment in a variety of minority populations and age groups (10) and is the primary questionnaire used in the DPP (5). A unique feature of the MAQ is that the list of leisure activities is comprehensive and appropriate for the DPP population because it was developed based on pilot work performed at all study sites. The MAQ has been shown to be both reliable and valid (through comparisons with activity monitors, fitness (field) testing, and the doubly labeled water technique) in adults and adolescents (2,9,25). The MAQ assesses past-year occupational and leisure activities, although leisure activity was the main focus of this effort. Estimates of leisure and occupational activity were calculated separately as hours per week ($\text{h}\cdot\text{wk}^{-1}$) averaged over the past year. Each activity was also weighted by its relative intensity, referred to as a MET, thereby deriving MET-hours per week ($\text{MET}\cdot\text{h}\cdot\text{wk}^{-1}$) as the final unit of expression. One MET represents the energy expenditure for an individual at rest ($1 \text{ MET} = 3.5 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ of oxygen consumption), whereas a 10-MET activity requires 10 times the resting energy expenditure.

The MAQ assesses both leisure and occupational physical activity over the past year. Only physical activities that demand energy expenditure greater than that required by activities of daily living (e.g., bathing, grooming, and feeding) are assessed. For the leisure section of the questionnaire, individuals were presented with a comprehensive list of activities developed for the entire DPP cohort (determined by pilot testing) and were asked to report the activities that they had participated in during the past 12 months. They were then asked to estimate the frequency and duration for each activity identified. For occupational activity, individuals were asked to list all jobs held during the past 12 months. For each job entry, data were collected for time spent walking or cycling to work per day, as well as the average job schedule (months per year, days per week, and hours per day worked). Activity on the job was determined by the number of hours spent sitting at work and the most common physical activities performed when not sitting.

Low-level physical activity recall

The original 7-d Physical Activity Recall (PAR) was developed primarily for use in large population studies to evaluate habitual physical activity levels in healthy persons (3,22,26). The Low-Level Physical Activity Recall (LOPAR) was modified from the 7-d PAR (23,26) and validated for use in its present form for persons having low levels of habitual physical activity because it was suggested that the original instrument might not be sufficiently sensitive to measure activity in persons who are primarily sedentary (8,20). The LOPAR was validated in patients with peripheral arterial disease as shown by correlations with maximal treadmill walking time ($r = 0.46$, $P < 0.01$), change in maximal treadmill walking time after exercise training ($r = 0.46$, $P < 0.05$), and energy expenditure during home-based exercise measured by Vitalog microcomputer ($r = 0.50$, $P < 0.05$). In type 2 diabetes, the LOPAR has also been correlated with markers of exercise performance including $\dot{V}\text{O}_{2\text{max}}$ ($r = 0.45$, $P < 0.05$; unpublished data, 1996).

As with the original PAR, the LOPAR provides a general measure of physical activity by assessing the total energy expenditure of the individual at work and during home and leisure-time activities for the preceding week (8,20). The LOPAR has been used in several treatment studies (exercise training and atorvastatin) in individuals with peripheral arterial disease (14, 19,20). It has also been used in physiologic studies of persons with uncomplicated and recently diagnosed diabetes at baseline and after treatment with exercise training (4).

The LOPAR assesses all types of physical activity (occupational, leisure, and home), although leisure activity was the main focus of the present study. The amount of energy expenditure for each activity is quantified in terms of metabolic equivalents for each activity. Participants are asked about the number of hours spent performing very light (1.0–1.5 METs), light (2–3 METs), moderate (3–5 METs), and heavy (≥ 6 METs) activities. Data are reported in MET-hours per week, derived by multiplying the amount of time spent performing an activity by the MET value of the activity.

Physical activity questionnaire from the NHANES III

The physical activity questionnaire from NHANES III asked whether individuals had engaged in any of the following activities over the past month: walking, jogging, bike riding, swimming, aerobics, dancing, calisthenics, gardening, weightlifting, or “other exercise, sports, or physically active hobbies not mentioned” (16). The summary leisure activity estimate was expressed as times per month because estimates of duration were not collected. Individuals were classified as inactive if they did not report engaging in any of these activities over the past month.

Statistical methods

For comparison of NHANES III cohort with DPP participants, the NHANES III sample was weighted according to the population weights provided for the morning, fasting sample. The weighted percent who reported being physically inactive based on the NHANES III instrument from the NHANES III cohort and the percent inactive among DPP participants were computed across age, BMI, and race groups.

Comparing physical activity estimates determined by three activity questionnaires among DPP participants

Spearman rank-order correlation coefficients were determined to assess both the bivariate associations between the various physical activity measures estimated from the three questionnaires and to examine the association between these physical activity estimates and measures of obesity and glucose tolerance adjusted for age and stratified by sex in this cohort. Leisure physical activity levels determined by the MAQ were compared between men and women, ethnic or racial groups, and age groups (< 45 yr, 45–59 yr, and ≥ 60 yr) using the non-parametric Mann–Whitney test. All analyses were performed using SAS software (Version 8.01; SAS Institute, Cary, NC).

RESULTS

Details of the baseline characteristics of the 3234 DPP participants have been reported (6). The overall mean age at baseline was 50.6 (± 10.7) yr. Nearly 68% of the participants were women, and more than 45% of the DPP participants belonged to a racial or ethnic U.S. minority group. The mean BMI for the entire cohort ranged across ethnic or racial groups from 28.3 to 32.5 $\text{kg}\cdot\text{m}^{-2}$ for men and from 30.7 to 36.3 $\text{kg}\cdot\text{m}^{-2}$ for women.

Baseline leisure physical activity levels of the DPP participants from the MAQ are presented in Figure 1, stratified by sex, age, and race or ethnicity. Women reported being less active than

men ($P < 0.0001$), and older individuals (≥ 60 yr of age) reported more leisure physical activity ($P < 0.0001$) compared with younger age groups. Finally, leisure-time physical activity levels varied by race or ethnicity, with the small number ($N = 20$) of American Indian men reporting more leisure activity than any other group ($P < 0.0002$). Similar patterns for leisure physical activity were observed based on the LOPAR questionnaire (i.e., highest in the oldest age group and somewhat higher in men than women; data not shown).

Correlations among the three physical activity measures (MAQ, LOPAR, NHANES III) collected at baseline of the DPP are presented in Table 1 stratified by sex. In general, leisure activity data collected from the three questionnaires were significantly correlated with each other, although the correlations between the MAQ and NHANES III were stronger in both men ($\rho = 0.52$; $P < 0.01$) and women ($\rho = 0.49$; $P < 0.01$) than between that of the LOPAR and either of the other two activity measures (men: $\rho = 0.20$ for the MAQ and 0.24 for NHANES, $P < 0.01$; women: $\rho = 0.10$ for the MAQ and 0.13 for NHANES).

Partial correlations (adjusted for age and stratified by sex) of activity levels as assessed by these three physical activity questionnaires collected at baseline and measures of obesity and glucose tolerance are presented in Table 2. For both men and women, physical activity estimates obtained from the MAQ (leisure and total activity) and the NHANES III (leisure activity) but not the LOPAR (leisure and total) were significantly and inversely associated with BMI, waist, and hip circumference measures. The NHANES leisure estimate was significantly related to waist-to-hip ratio in men but not in women. Likewise, physical activity estimates obtained from the MAQ (leisure and total activity) and the NHANES III (leisure activity) were generally significantly and inversely associated with fasting and 75-g OGTT measurements of insulin (fasting and 30 min postload), fasting plasma proinsulin, and HbA1c. The LOPAR leisure activity estimate was significantly and inversely correlated with fasting and 30-min postload insulin in men alone. Physical activity levels from these three questionnaires were not consistently associated with fasting or postload glucose values (Table 2).

Finally, presented in Table 3 are the leisure physical activity levels collected with the NHANES III instrument for the DPP participants compared with activity levels reported by individuals meeting DPP eligibility criteria who were part of the NHANES III cohort. In general, women were less active than men in both cohorts, with relatively more women reporting being physically inactive, consistent with the DPP's MAQ and the LOPAR results. The DPP women and men were less inactive than the NHANES III sample for most age, BMI, and race or ethnicity groups.

DISCUSSION

Many of the current findings regarding the physical activity levels of the DPP participants were anticipated and consistent with previous literature. Among the DPP participants, men reported participating in more leisure activity and, therefore, were less likely to report being inactive when compared with women. This was a consistent finding across three national U.S. surveys (National Health Interview Survey (NHIS) 1991, NHANES III 1988–1991, and the Behavioral Risk Factor Surveillance System 1992) (17), where the ratio for the prevalence of physical inactivity for women compared with men ranged from 1.2 to 1.7 across these three surveys (17). That men reported more leisure activity and less inactivity than women was also seen in the subgroup of the NHANES III cohort with known type 2 diabetes (15). Physical inactivity measurement in the NHANES III was based on reported participation in leisure-time physical activity alone and did not include participation in nonleisure activity such as housework or occupational activity.

Based on the average number of hours of reported leisure activity per week averaged over the past year, the most active age group in the DPP cohort was aged ≥ 60 yr. This trend held, for the most part, across all sex and ethnic groups. This finding is inconsistent with the general notion that physical activity decreases with age in adults (17,24). Closer examination of national data collected around the time of the DPP (17), however, showed that the percent of adults, particularly men, who reported regular, sustained leisure physical activity (five or more times per week for 30 or more minutes per occasion) was somewhat higher in the aged 65- to 74-yr group compared with the aged 30- to 44- or 45- to 64-yr groups. For example, the percent of men and women reporting participation in regular, sustained physical activity in the 1992 NHIS was 24.1, 24.2, and 29.2% in men and 20.4, 20.6, and 21.3% in women for the three age groups (30–44, 45–64, and 65–74 yr). Likewise, the percent of men and women reporting participation in regular, sustained leisure physical activity in the 1992 BRFSS was 17.4, 18.9, and 26.8% in men and 18.5, 19.4, and 19.0% in women for the same three age groups. An increase in leisure activity levels with retirement had also been seen in individuals from the Atherosclerosis Risk in Communities Study (7). These data suggest that a substantial number of older adults of retirement age spend a significant amount of their time engaging in measurable levels of leisure physical activity. An additional explanation may be that the older DPP participants may have been more physically active or lifestyle conscious throughout life, and thus may have attained a later age before becoming IGT and thus eligible for the DPP.

Three different activity questionnaires that varied by time frame were used to assess baseline physical activity levels in the DPP. The advantage of assessing activity using a survey with a short time frame, such as prior week, is that the estimate is less likely to suffer from recall bias. In contrast, assessment over a longer time period such as 1 yr is more likely to reflect “usual” behavior because activity levels can vary with season, poor health condition, or unexpected time pressures (10,12).

Comparing the leisure physical activity results from the three measures collected at baseline, it is not surprising that the MAQ (10) and the LOPAR (8,20,23,26) were not strongly related, at least in part because the latter assesses past-week activity, whereas the MAQ asks about physical activity over the past year. Previous studies in both adolescents (1) and adults (28) found stronger relationships between past-year physical activity assessment and the average of four past-weeks recalls collected over the same year than when just one past-week recall was used. It is possible that LOPAR repeated throughout the year would be more strongly related to the past-year MAQ than one time point alone.

Another consistent finding in the present study was that the leisure sections of the MAQ and the NHANES III questionnaires were more strongly related to each other than either one was to LOPAR. Part of the explanation for this finding is the specific components of physical activity that these three questionnaires assess. Both the MAQ and the NHANES III questionnaire assess the frequency of popular moderate- to high-intensity leisure activities, whereas LOPAR attempts to quantify the entire spectrum of intensities, including activities of daily living, by asking about the number of hours spent in sleep and in very light, light, moderate, and heavy leisure activities during the previous week. This difference in the components of physical activity assessed by these questionnaires resembles the comparison of food frequencies to that of food recalls in the dietary assessment literature and may explain, at least in part, the small correlations observed between the measures.

Biological variables of obesity (waist, hip, BMI, and WHR) and glucose tolerance (insulin, proinsulin, glucose, and HbA1c) were examined in relation to the physical activity estimates obtained by these three questionnaires as criterion measures to validate the questionnaires. In general, the NHANES III and the MAQ were significantly related to each other and to most of these biological variables, with the exception of glucose and WHR. In contrast, the LOPAR

was found to be less consistently related to any of these biological measures, suggesting that its use may be more appropriate in lower-functioning individuals for whom it was initially designed (8,20) or in a less diverse population.

The most interesting finding was that the level of reported physical inactivity in the DPP cohort was less than that reported in the NHANES III subgroup with impaired glucose tolerance. This finding was evident across most age, BMI, and racial or ethnicity groups. Although the small sample size of the NHANES III subgroup may suggest a chance reason for this finding, another explanation might be the different sample selection in the two studies. The NHANES III survey is a cross-sectional observational study of a random sample of the U.S. population. In contrast, the DPP cohort represents a volunteer sample of individuals committed to a long-term intervention study. In addition, one of the inclusion criteria for the DPP was that you had to be physically able to walk a quarter mile in 10 min, whereas such criteria for NHANES III did not exist. Considering the range of options described above for the finding that reported physical inactivity in the DPP was less than that reported in the NHANES III, the most likely explanation is that the DPP participants were a healthier and possibly more motivated group of individuals because they agreed to participate in this clinical trial and they met the DPP eligibility criteria. If this is true, these findings have implications for the translation of the DPP findings. On one hand, if the DPP cohort was healthier and somewhat more motivated than individuals in the general U.S. population with impaired glucose tolerance, then it could be more difficult to implement the DPP healthy lifestyle program in the latter. On the other hand, the impact of the DPP lifestyle intervention might be greater in those who are less active at baseline.

One of the main focuses in recent public health research is the effort to translate the lifestyle intervention portion of successful efficacy trials such as the DPP program into the community (18). Thus, the suggestion that those individuals in the general community in the United States with *prediabetes* would be less motivated than the DPP volunteer cohort is an important finding. Coupled with a smaller budget, less personnel, and less training and support, the likely addition of less motivated community participants adds to the challenge of these future translation efforts. In lieu of these difficulties, we need to adjust our expectations accordingly with regard to the potential impact of these community efforts.

In summary, baseline leisure activity in the DPP cohort suggests that men and women in the DPP trial may have been more active than the small subgroup of individuals from the NHANES III cohort who had impaired glucose tolerance. This may possibly be a “healthy volunteer effect”; if so, this would have implications for the future translation of the DPP lifestyle intervention in other populations. Finally, the weak relationship between leisure physical activity levels obtained with the MAQ and the LOPAR is consistent with the fact that they encompass both different time frames and different components of leisure physical activity.

References

1. Aaron D, Dearwater S, Anderson R, Olsen T, Kriska A, LaPorte R. Physical activity and the initiation of high-risk health behaviors in adolescents. *Med Sci Sports Exerc* 1995;27:1639–1645. [PubMed: 8614320]
2. Aaron DJ, Kriska AM, Dearwater SR, et al. The epidemiology of leisure physical activity in an adolescent population. *Med Sci Sports Exerc* 1993;25:847–853. [PubMed: 8350708]
3. Blair SN, Haskell WL, Paffenbarger RS Jr, Vranizan KM, Farquhar JW, Wood PD. Assessment of habitual physical activity by a seven-day recall in a community survey and controlled experiments. *Am J Epidemiol* 1985;122:794–804. [PubMed: 3876763]
4. Brandenburg SL, Bauer TA, Reusch JEB, Hiatt WR, Regensteiner JG. Effects of exercise training on oxygen uptake kinetic responses in women with type 2 diabetes mellitus. *Diabetes Care* 1999;22:640–646.

5. Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med* 2002;346:393–403. [PubMed: 11832527]
6. Diabetes Prevention Program Research Group. The diabetes prevention program. Baseline characteristics of the randomized cohort. *Diabetes Care* 2000;23:1619–1629. [PubMed: 11092283]
7. Evenson KR, Rosamond WD, Cai J, Diez-Roux AV, Brancati FL. Influence of retirement on leisure-time physical activity: The Atherosclerosis Risk in Communities Study. *Am J Epidemiol* 2002;155:692–699. [PubMed: 11943686]
8. Hiatt WR, Hirsch A, Regensteiner JG, Brass EP. Assessment of patients with peripheral arterial disease: Review of Approaches and Development of Recommendations for Therapeutic Trials. *Circulation* 1995;92:614–621. [PubMed: 7634476]
9. Kriska A, Knowler W, LaPorte A, Drash R, Wing S, Blair P, Bennett L. Development of questionnaire to examine relationship of physical activity and diabetes in Pima Indians. *Diabetes Care* 1990;13:401–411. [PubMed: 2318100]
10. Kriska AM, Caspersen CJ. Introduction to the collection of physical activity questionnaires in a collection of physical activity questionnaires for health-related research. Kriska and Caspersen (Eds.). Centers for Disease Control and Prevention. *Med Sci Sports Exerc* 1997;29(Suppl):S5–S9.
11. LaPorte RE, Montoye HJ, Caspersen CJ. Assessment of physical activity in epidemiologic research: Problems and prospects. *Public Health Rep* 1985;100:131–146. [PubMed: 3920712]
12. Matthews CE, Freedson PS, Hebert JR, et al. Seasonal variation in household, occupational, and leisure time physical activity: Longitudinal analysis from the Seasonal Variation of Blood Cholesterol Study. *Am J Epidemiol* 2001;153:172–183. [PubMed: 11159163]
13. Mayer EJ, Mayer EJ, Alderman BW, et al. Comparison of physical activity assessment measures in a biethnic rural population: the San Luis Valley Diabetes Study. *Am J Clin Nutr* 1991;53:812–820. [PubMed: 2008858]
14. Mohler ER 3rd, Hiatt WR, Creager MA. Cholesterol reduction with atorvastatin improves walking distance in patients with peripheral arterial disease. *Circulation* 2003;108:1481–1486. [PubMed: 12952839]
15. Nelson KM, Reiber G, Boyko EJ. Diet and exercise among adults with type 2 diabetes: Findings from the Third National Health and Nutrition Survey (NHANES III). *Diabetes Care* 2002;25:1722–1728. [PubMed: 12351468]
16. NHANES III: Plan and operation of the Third National Health and Nutrition Examination Survey, 1988–94. *Vital Health Statistics*, 1994.
17. Physical Activity and Health: A Report of the Surgeon General. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, President's Council on Physical Fitness and Sports; 1996.
18. Proceedings from Conference: From Clinical Trials to Community: The Science of Translating Diabetes and Obesity Research, 2004.
19. Regensteiner JG, Meyer T, Krupski W, Cranford L, Hiatt WR. Comparison of home vs hospital based rehabilitation for patients with peripheral arterial disease. *Angiology* 1997;48:291–299. [PubMed: 9112877]
20. Regensteiner JG, Steiner JF, Hiatt WR. Exercise training improves functional status in patients with peripheral arterial disease. *J Vasc Surg* 1996;23:104–115. [PubMed: 8558725]
21. Regensteiner JG, Meyer EJ, Shetterly SM, et al. Relationship between physical activity and insulin among persons with glucose intolerance: the San Luis Valley Diabetes Study. *Diabetes Care* 1995;18:490–497. [PubMed: 7497858]
22. Regensteiner JG, Meyer EJ, Shetterly SM, et al. Relationship between physical activity and hyperinsulinemia among nondiabetic men and women: the San Luis Valley Diabetes Study. *Diabetes Care* 1991;14:1066–1074. [PubMed: 1797488]
23. Sallis JF, Haskell WL, Wood PD, Fortmann TR, Blair SN, Paffenbarger RS. Physical activity assessment methodology in the five-city project. *Am J Epidemiol* 1985;121:91–106. [PubMed: 3964995]
24. Schoenborn CA, Barnes PM. Leisure-time physical activity among adults: United States, 1997–98. Advance Data from Vital and Health Statistics. Centers for Disease Control and Prevention 2002;325:1–24.

25. Schulz LO I, Harper T, Smith CJ, Kriska AM, Ravussin E. Energy intake and physical activity in Pima Indians: comparison with energy expenditure measured by doubly-labeled water. *Obes Res* 1994;2:541–548. [PubMed: 16355515]
26. Taylor CB, Coffey T, Berra K, Iaffaldano R, Casey K, Haskell WL. Seven day activity and self-report compared to a direct measure of physical activity. *Am J Epidemiol* 1984;120:818–824. [PubMed: 6507425]
27. The DPP Research Group. The Diabetes Prevention Program. Design and methods for a clinical trial in the prevention of type 2 diabetes. *Diabetes Care* 1999;22(4):623–634. [PubMed: 10189543]
28. Wolf AM, Hunter DJ, Colditz GA, et al. Reproducibility and validity of a self-administered physical activity questionnaire. *Int J Epidemiol* 1994;23:991–999. [PubMed: 7860180]

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FIGURE 1.

Median hours per week of baseline leisure physical activity levels based on the Modifiable Activity Questionnaire (MAQ) in Diabetes Prevention Program (DPP) participants by sex, ethnicity, and age. (There were too few American Indian men aged ≥ 60 yr to present.)

TABLE 1
Spearman rank-order correlations of the DPP physical activity measures (MAQ, LOPAR, NHANES III) among DPP participants at baseline.

		MAQ (Past Year)		NHANES III (Past Month)	
		Leisure	Occupational	Total	Leisure
Men					
LOPAR (past week)	Leisure	0.20 *	-0.04	0.06 *	0.24 *
	Occupational	-0.09 *	0.18 *	0.10 *	—
	Household	0.25 *	0.05	0.14 *	—
	Total	0.25 *	0.23 *	0.30 *	—
NHANES III (past month)	Leisure	0.52 *	—	—	—
Women					
LOPAR (past week)	Leisure	0.10 *	-0.07 *	0.01	0.13 *
	Occupational	-0.03	0.06 #	0.04 #	—
	Household	0.15 *	0.12 *	0.16 *	—
	Total	0.19 *	0.13 *	0.22 *	—
NHANES III (past month)	Leisure	0.49 *	—	—	—

* $P < 0.01$.
$P < 0.05$.

DPP, Diabetes Prevention Program; MAQ, Modifiable Activity Questionnaire; LOPAR, Low-Level Physical Activity Recall; NHANES III, Third National Health and Nutrition Examination Survey.

TABLE 2

Age-adjusted Spearman rank-order correlations of baseline physical activity as determined by three questionnaires and measures of obesity and diabetes stratified by sex.

	MAQ		LOPAR		NHANES III	
	Leisure	Total	Leisure	Total	Leisure	Total
Women						
BMI	-0.17554 *	-0.16691 *	0.02815	0.00860	-0.17546 *	
Waist	-0.13870 *	-0.13668 *	0.04713	0.04242	-0.15331 *	
Hip	-0.15313 *	-0.14677 *	0.02221	0.01086	-0.16770 *	
WHR	-0.02071	-0.03281	0.06350 *	0.06287 *	-0.02437	
Glucose						
Fasting	-0.04533 *	-0.03627	0.07449 *	0.06544 *	-0.03736	
120 min	0.00576	0.00719	0.01589	0.01146	0.01211	
A1C	-0.00386	0.01378	0.08348 *	0.04976	-0.06335 *	
Insulin						
Fasting	-0.09432 *	-0.07598 *	-0.01225 *	-0.00882	-0.11630 *	
30 min	-0.06505 *	-0.03376	-0.02419 *	-0.01190	-0.09706 *	
Fasting proinsulin	-0.09195 *	-0.10735 *	0.01569	-0.01182	-0.12795 *	
Men						
BMI	-0.06953 *	-0.13596 *	-0.01224	-0.03857	-0.19593 *	
Waist	-0.09701 *	-0.16934 *	-0.02487	-0.04755	-0.22193 *	
Hip	-0.09160 *	-0.18570 *	-0.02782	-0.05854	-0.20179 *	
WHR	-0.01587	-0.03362	-0.00177	0.00587	-0.11387	
Glucose						
Fasting	-0.00491	-0.04977	0.01306	0.01560	-0.03208	
120 min	0.05755	0.03106	0.00151	0.00341	-0.07174 *	
A1C	-0.06987	-0.05173	-0.02682	-0.02031	-0.06872 *	
Insulin						
Fasting	-0.10994 *	-0.09094 *	0.02474	-0.01234	-0.15204 *	
30 min	-0.05959 *	0.04534	0.00753	-0.02415	-0.11428 *	
Fasting proinsulin	-0.06773	-0.09566	-0.00847	-0.04059	-0.09961 *	

* $P < 0.05$.

MAQ, Modifiable Activity Questionnaire; LOPAR, Low-Level Physical Activity Recall; NHANES III, Third National Health and Nutrition Examination Survey; WHR, waist to hip circumference; BMI, body mass index.

TABLE 3

Percent of men and women reporting being physically inactive (no reported leisure activities over the past month) based on the Third National Health and Nutrition Examination Survey (NHANES III) physical activity questionnaire, in both the NHANES III cohort restricted to those meeting Diabetes Prevention Program (DPP) eligibility criteria (weighted) and the DPP cohort.

	NHANES III		DPP	
	Women	Men	Women	Men
	(N= 155)	(N= 144)	(N= 2189)	(N= 1043)
	(%)	(%)	(%)	(%)
Age (yr)				
< 45	11 ^a	19 ^a	14	10
45–59	23	1 ^a	16	7
59+	26	14	14	5
BMI				
< 25	33 ^a	14 ^a	12 ^a	8 ^a
25–29	23	13	13	4
30+	19	5	16	9
Race or ethnicity				
African American	39	5 ^a	20	7
Hispanic	25	14	16	8
White	21	10	13	6
American Indian	—	—	15	5 ^a
Asian American	—	—	22	11

^a Original cell contained a sample size less than 10.