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Article *in* Journal of Women s Health & Gender-Based Medicine · October 2000

DOI: 10.1089/15246090050147745 · Source: PubMed

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JOURNAL OF WOMEN'S HEALTH & GENDER-BASED MEDICINE
Volume 9, Number 7, 2000
Mary Ann Liebert, Inc.

Physical Activity and Functional Capacity Measurement in Women: A Report from the NHLBI-Sponsored WISE Study

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ABSTRACT

Physical activity and functional capacity have not been assessed by questionnaire for criterion validity in women. We wished to evaluate the ability of a physical activity and a functional capacity assessment questionnaire to predict functional capacity measured by treadmill exercise stress testing, as well as correlate with cardiac risk factors and angiographic coronary artery disease (CAD) in women. In a National Heart, Lung and Blood Institute (NHLBI)-sponsored cross-sectional population study involving four academic medical centers, 476 women with cardiac risk factors undergoing coronary angiography for evaluation for suspected myocardial ischemia were enrolled in the Women's Ischemia Syndrome Evaluation (WISE). The main outcome measures were functional capacity measured during symptom-limited exercise treadmill testing, cardiac risk factors, and CAD, using core laboratory-determined measures. Physical activity measured by the Postmenopausal Estrogen and Progesterone Intervention physical activity questionnaire (PEPI-Q) and functional capacity measured by the Duke Activity Status Index (DASI) questionnaire, correlated with functional capacity measured in metabolic equivalents (METS), as estimated during symptom-limited exercise treadmill testing ($r = 0.27$, $p = 0.001$ and $r = 0.31$, $p = 0.0002$, respectively). The DASI was a significant independent predictor of functional capacity even after adjustment for cardiac risk factors, and the PEPI-Q was not. The DASI and PEPI-Q scores were inversely associated with

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This work was supported by contracts from the National Heart, Lung and Blood Institutes, Nos. N01-HV-68161, N01-HV-68162, N01-HV-68163, and N01-HV-68164, a GCRC grant MO1-RR00425 from the National Center for Research Resources, and grants from the Gustavus and Louis Pfeiffer Research Foundation, Denville, NJ, The Women's Guild of Cedars-Sinai Medical Center, Los Angeles, CA, and The Ladies Hospital Aid Society of Western Pennsylvania, Pittsburgh, PA.

higher numbers and levels of cardiac risk factors, as well as angiographic CAD. The DASI questionnaire is a reasonable correlate of functional capacity achieved during symptom-limited treadmill exercise testing in women with suspected myocardial ischemia. Lower functional capacity or physical activity measured by the DASI and PEPI-Q, respectively, is associated with more prevalent cardiac risk factors and angiographic CAD. These findings suggest that the DASI and, to a lesser extent, the PEPI-Q have criterion validity for use in health-related research in women.

INTRODUCTION

CARDIOVASCULAR DISEASE REMAINS the leading cause of morbidity and mortality in both men and women.[1] Prior epidemiological study has documented the role of physical activity in moderating the risk of cardiovascular disease in men,[2–4] but this relationship has not been as consistently observed in women.[5] Although women may have a different risk relationship between physical activity and cardiovascular disease compared with men, it has been alternatively proposed that the physical activity assessment tools typically used in men do not adequately reflect physical activity patterns in women. Specifically, most of the questions were designed for men and centered on sports-related leisure activities[2–4] that may not capture relevant physical activities in the lives of women. The more recent studies that have used broader physical activity measurement questionnaires have found relationships to cardiovascular disease in women.[6,7]

Physical fitness (a condition) is measured even more objectively than physical activity (a behavior). Prior literature has demonstrated improved cardiovascular risk stratification using physical fitness, measured by functional capacity during exercise stress testing, compared with physical activity, measured by behavioral assessment tools,[8] in a population that included women and men. Blair et al.[9] have suggested that this improved reliability of functional capacity measurement over the less reliably measured physical activity accounts for the greater strength of the association between functional capacity and cardiovascular disease.

The goal of our study was to test the criterion validity of two measures, the Postmenopausal Estrogen and Progesterone Intervention physical activity assessment (PEPI-Q), a questionnaire that evaluates physical activity, and the Duke Activity Status Index (DASI), a questionnaire that evaluates functional capacity, against exercise treadmill stress testing, cardiac risk factors, and angiographic coronary artery disease (CAD) in women enrolled in the Women's Ischemia Syndrome Evaluation (WISE).

MATERIALS AND METHODS

The WISE is an ongoing National Heart, Lung and Blood Institute (NHLBI)-sponsored four-center study that aims to improve the diagnostic reliability of cardiovascular testing in the evaluation of ischemic heart disease in women. The complete study design and methodology of the WISE study are described elsewhere.[10] Briefly, women with chest pain symptoms or suspected myocardial ischemia undergoing coronary angiography have an initial evaluation that includes the collection of demographic, medical history, cardiac risk factor, psychosocial, physical activity, and symptom data by questionnaire and blood sampling. Cardiac risk factors were defined using the National Cholesterol Education Program (NCEP) definitions.[11] Lipoprotein determinations were performed at a lipid core laboratory that participates in the Centers for Disease Control and Prevention (CDC) lipid standardization program previously used in multiple NHLBI-sponsored lipid-lowering intervention trials.[12,13] Subjects underwent a physical examination that included height, weight, and waist/hip ratio determination. A subset of WISE participants (n = 143) had symptom-limited exercise treadmill testing as part of a site-specific diagnostic protocol.

Measures of physical activity and functional capacity

The PEPI-Q[14] was used to assess physical activity. The range of the PEPI-Q scores is 1.0–12.0, with higher scores for higher levels of activity. For comparison with exercise treadmill stress testing, the total PEPI-Q score was used, defined as the sum total score in all three domains of physical activity: work, home, and leisure. The

DASI questionnaire[15] was used to estimate functional capacity. Scoring was completed by using positive responses, multiplying each positive response with a response of 1 by the weight, and then summing all responses. The range of DASI scores is 0–58.2, with higher scores for higher functioning status. Copies of both questionnaires are included in the Appendix.

Exercise treadmill stress testing

Following standard 12-lead ECG recordings and blood pressure measurements at rest, the Asymptomatic Cardiac Ischemia Pilot (ACIP) symptom-limited treadmill exercise protocol was performed using previously published methods,[16] as it provides continuous and more modest ramplike increases in work compared with the Bruce protocol. Metabolic equivalents (METS) achieved were estimated using exercise duration.

Measurement of coronary angiography

Coronary angiograms were interpreted by a core laboratory experienced in other multicenter trials with angiographic outcomes.[17] Measurements included quantitative assessment of the presence, severity, and complexity of epicardial coronary artery stenosis, using previously published methods and a coronary severity score.[17]

Statistical analysis

Data are presented as means and standard deviations (SD). Comparisons between those women undergoing vs. those not undergoing exercise treadmill stress testing were done by the Wilcoxon rank-sum test for continuous measures and by the chi-square test for discrete measures. Trends in PEPI-Q, DASI, and METS were assessed using the Mantel-Haenszel chi-square for categorical variables and the Jonckheere-Terpstra test for continuous data. Correlations among the PEPI-Q, DASI, and METS achieved during exercise treadmill stress testing used Pearson correlation coefficients. Stepwise regression analyses were used to explore the relationships among METS achieved, weighted PEPI-Q, DASI, and other covariates. Variables were entered into the model based on previous univariate and multivariate analyses as well as investigator experience of relevant covariates. The statistical criterion for entry into the model was $p = 0.1500$. Analyses were performed using the SAS system for windows release 6.12. Probability values of ≤ 0.05 were considered statistically significant.

RESULTS

In the cohort of 476 WISE participants with complete demographic, risk factor, and coronary angiography results, the subsets of 333 and 143 WISE participants without and with symptom-limited exercise treadmill testing are profiled in Table 1. Overall, 427 (88%) of the women had at least one cardiac risk factor, and 334 (69%) had multiple cardiac risk factors. Among the 431 women for which coronary angiography data were available, 187 (43%) had angiographically significant CAD, defined as ≥50% luminal diameter stenosis on one or more epicardial coronary arteries. Women who underwent symptom-limited exercise treadmill testing were younger and had generally fewer cardiac risk factors compared with those women who did not undergo exercise testing (Table 1) because of the ability of the women to undergo the WISE site-specific testing. The mean functional capacity achieved during symptom-limited exercise treadmill testing was 5.8 ± 2.4 (range 2.0–11.0) METS. The mean PEPI-Q was 5.8 ± 2.2; the mean DASI was 18.8 ± 13.1.

There were modest correlations between the DASI and METS achieved ($r = 0.31$, $p = 0.0002$), the PEPI-Q and METS achieved ($r = 0.27$, $p = 0.001$), and the DASI and PEPI-Q ($r = 0.49$, $p = 0.0001$). When stratified by terciles of METS achieved, the DASI and PEPI-Q scores both demonstrated good concordance with the symptom-limited exercise treadmill results (Table 2). In multivariate linear regression modeling using the variables listed in Table 1, DASI score ($p = 0.002$) and history of hypertension ($p = 0.0001$) significantly and independently predicted METS achieved. The PEPI-Q was not a predictor of METS achieved ($p = 0.59$) once other factors were considered.

Comparison of cardiac risk factors and angiographic CAD (≥50% stenosis) according to DASI and PEPI-Q scores is shown in Figures 1 and 2 and Tables 3 and 4. Women with greater DASI and PEPI-Q scores had significantly lower prevalences of cardiac risk factors and waist/hip ratios. There was less angiographic CAD in the higher DASI and PEPI-Q groups ($p = 0.03$ and 0.003, respectively) (Figs. 1 and 2). Repeat analysis in the

Table 1. Demographic and Clinical Variables Stratified by Availability of Exercise Testing ($n = 476$)

	No exercise test available (n = *333*)	*Exercise test available* (n = *143*)	p
Age (years) ±SD	60 ± 12	57 ± 10	0.01
Race (% white)	78	91	0.001
History of hypertension (%)	53	50	0.01
History of diabetes (%)	26	17	0.03
Current smoking (%)	18	21	0.51
History of dyslipidemia (%)	54	42	0.01
Postmenopausal (%)	77	73	0.28
Current HRT[a] use (%)	36	43	0.18
Coronary artery disease[b] (%)	47	36	0.05
Coronary artery severity score (±SD)	17 ± 17	14 ± 13	0.02

[a]HRT, hormone replacement therapy.
[b]Defined as (≥1 coronary ≥50%) and available on the 431 women for which coronary angiography data were available.

subgroup of women ($n = 244$) without angiographic CAD demonstrated similar results except for the PEPI-Q, which did not significantly discriminate cardiac risk factors other than waist/hip ratio ($p = 0.02$) and a trend toward diabetes ($p = 0.09$).

DISCUSSION

The current study findings demonstrate that the DASI questionnaire, a measure of functional capacity, is a reasonable correlate of METS achieved during symptom-limited treadmill exercise testing in women with suspected myocardial ischemia. The PEPI-Q, a questionnaire that measures physical activity, conversely, did not predict METS achieved. In addition, these results demonstrate that lower levels of functional capacity or physical activity measured by the DASI and PEPI-Q, respectively, are associated with more prevalent cardiac risk factors and angiographic CAD. These findings suggest that the DASI and, to a lesser extent, the PEPI-Q have criterion validity for use in health-related research in women.

Although there is controversy about how best to measure physical activity by questionnaire, these results offer some new observations to explain prior epidemiological studies that failed to find an association between physical activity and cardiovascular disease in women.[7] The DASI, a relatively new assessment questionnaire designed to determine functional capacity rather than physical activity, was developed in a population that included both women and men.[15] It assesses the capacity to perform activities of daily living (personal care, ambulation, household tasks, sexual function) in addition to leisure activities that are more sports oriented. Previous epidemiological investigations primarily used physical activity assessments that were validated in men and emphasized male-oriented activities,[2–4] possibly misclassifying women. More re-

Table 2. Stratification of DASI and PEPI-Q According to METS Achieved[a]

METS achieved	*<3 METS* (n = *17*)	*3–5.9 METS* (n = *46*)	*>6 METS* (n = *80*)	p[b]
DASI score	11.9 ± 8.1	20.2 ± 12.5	25.5 ± 13.6	0.001
PEPI-Q score	5.2 ± 2.0	6.3 ± 1.8	6.6 ± 2.3	0.05

[a]DASI, Duke Activity Status Index; METS, metabolic equivalents measured during symptom-limited exercise treadmill stress testing; PEPI-Q, Postmenopausal Estrogen/Progesterone Intervention Questionnaire.
[b]Jonckheere-Terpstra test is based on trends; however, for ease of presentation, means are shown.

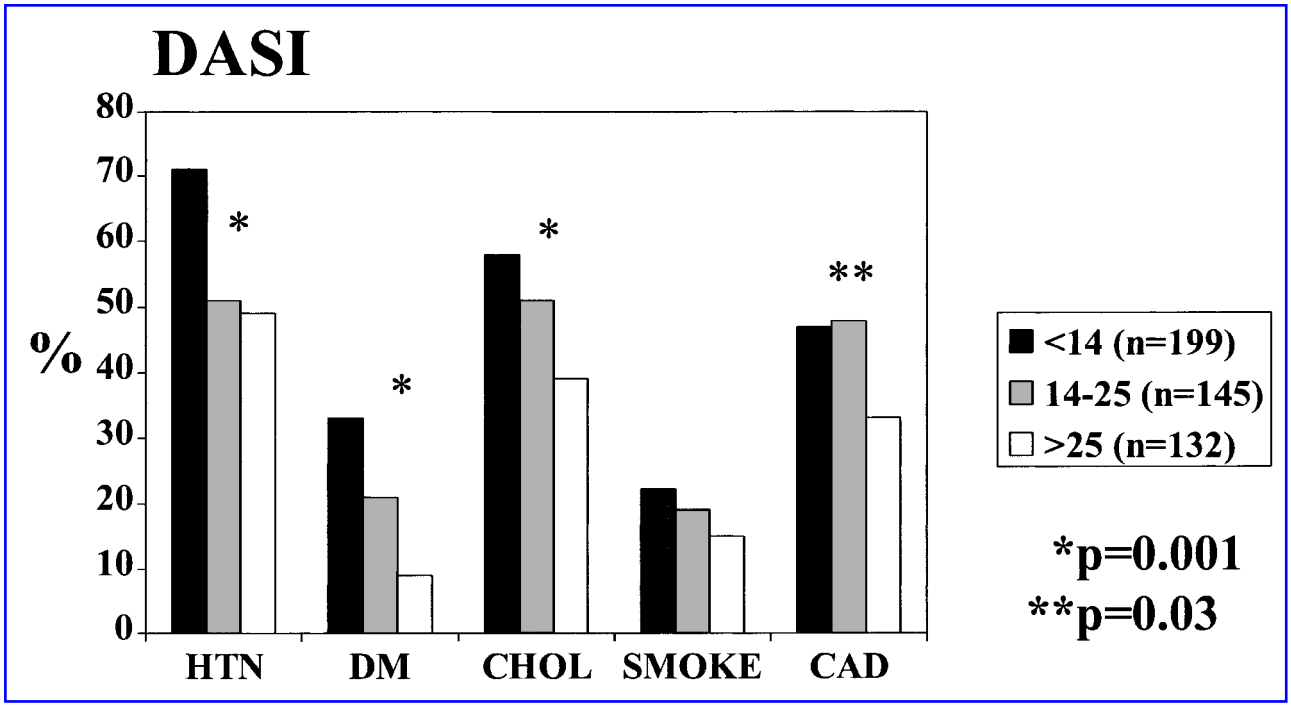

FIG. 1. Cardiac risk factors (history of hypertension [HTN], history of diabetes mellitus [DM], history of hyperlipidemia [CHOL], current cigarette smoking [SMOKE]) and angiographic CAD (≥50% luminal diameter stenosis is one or more epicardial coronary arteries) stratified by DASI score (n = 476 women).

cent studies,[6,7] using newer questionnaires are more consistent with our current study results, which suggest that the DASI is relevant to women with a wide variety of functional capacities (range 2–11 METS), across a relevant age range (35–80 years), in a population that included 22% minorities.

We found similar, although less robust, results

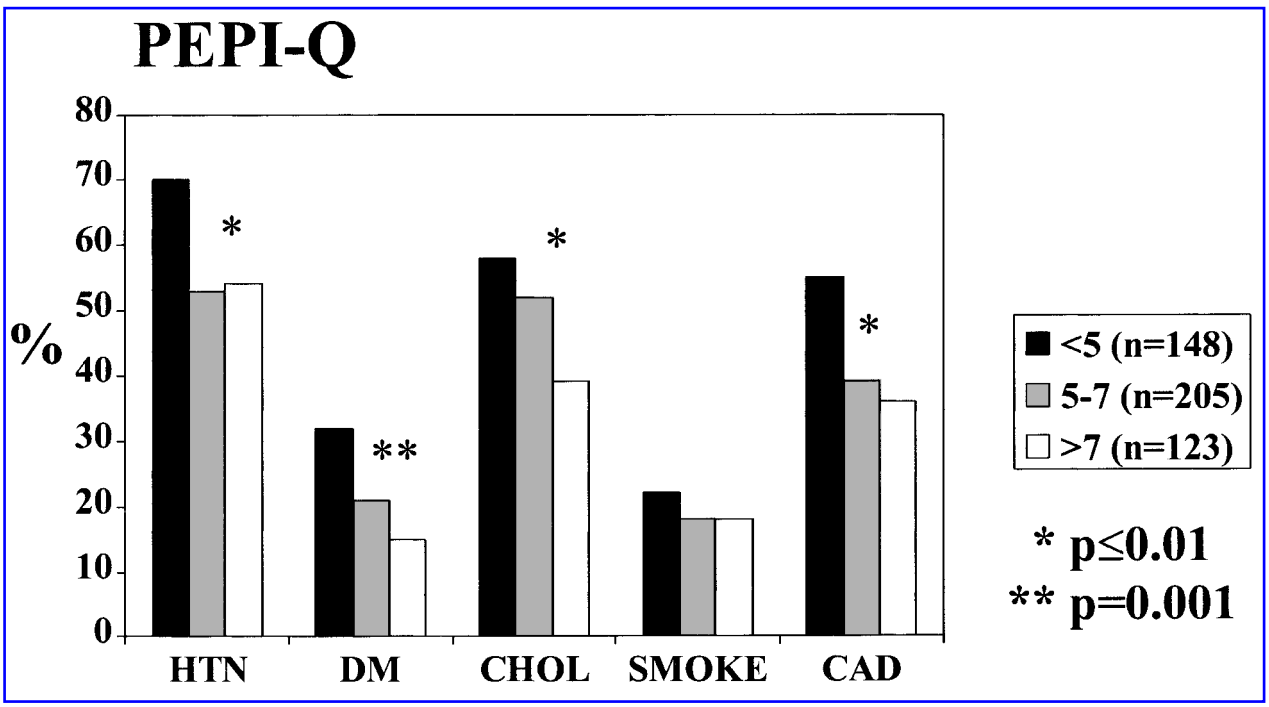

FIG. 2. Cardiac risk factors (history of hypertension [HTN], history of diabetes mellitus [DM], history of hyperlipidemia [CHOL], current cigarette smoking [SMOKE]) and angiographic CAD (≥50% luminal diameter stenosis is one or more epicardial coronary arteries) stratified by PEPI-Q score (n = 476 women).

Table 3. Cardiac Risk Factors and Resting Heart Rate Stratified by DASI

	DASI			
Cardiac risk factor (n)	*<14 (199)*	*14–25 (145)*	*>25 (132)*	p[a]
BMI[b]	30 ± 7	30 ± 6	28 ± 6	0.004
Waist/hip ratio	0.88 ± 0.11	73 ± 12	0.85 ± 0.10	0.002
Resting heart rate (bpm)	75 ± 13	73 ± 12	71 ± 11	0.02
Systolic blood pressure (mm Hg)	141 ± 23	134 ± 20	134 ± 18	0.009
Fasting blood sugar (mg/dl)	124 ± 64	122 ± 63	112 ± 45	0.20

[a]Jonckheere-Terpstra test is based on trends; however, for ease of presentation, means are shown.
[b]BMI, body mass index; bpm, beats per minute.

with the PEPI-Q, a newly developed questionnaire designed to capture usual physical activity in women. It includes measurement of activity at home, at work, and during leisure time.[14] Previous work has demonstrated that women have daily activities that frequently include home and family responsibilities that are not shared by men (e.g., caretaking and household chores)[16] that may contain important sources of physical activity. Although the PEPI-Q had a lower correlation and did not independently predict METS achieved during symptom-limited exercise treadmill testing, compared with the DASI, this may not be unexpected, as the PEPI-Q assesses usual physical activities over 12 months rather than capacity to perform activities. Factors other than habitual physical activities, such as musculoskeletal status, pulmonary status, and inherent maximal oxygen consumption capacity, influence functional capacity and likely lessen the correlation. Both the PEPI-Q and DASI similarly stratified both cardiac risk factors and angiographic CAD, suggesting similar criterion validity to correlate with these cardiovascular measures. Notably, our results demonstrate that the PEPI-Q appeared to be relevant to both women who work outside the home and those who do not, suggesting that measurement of domestic activity is relevant to women.

The current study data collection and quantitation procedures represent significant improvement compared with prior related study methods. Study subjects in the WISE underwent study coordinator-directed historical questionnaire data collection rather than mail-in self-report, and all outcome variables were analyzed/interpreted by masked core laboratories, validated for accuracy and reproducibility. Specifically, lipoprotein determinations were performed in batch analyses by a CDC-standardized core laboratory used in previous NHLBI-sponsored multicentered trials of lipid-lowering intervention on cardiovascular outcomes with known excellent coefficients of variation. Prior validations of physical activity questionnaires have focused on test-retest correlations rather than testing criterion validity against measured functional capacity, coronary angiography, and cardiac risk factors.[18,19] Thus,

Table 4. Cardiac Risk Factors and Resting Heart Rate Stratified by PEPI-Q

	PEPI-Q			
Cardiac risk factor (n)	*<5 (148)*	*5–7 (205)*	*>7 (123)*	p[a]
BMI[b]	30 ± 6	30 ± 7	29 ± 6	0.24
Waist/hip ratio	0.89 ± 0.10	0.87 ± 0.11	0.85 ± 0.11	0.001
Resting heart rate (bpm)	74 ± 13	73 ± 11	72 ± 12	0.09
Systolic blood pressure (mm Hg)	139 ± 23	139 ± 20	133 ± 20	0.06
Fasting blood sugar (mg/dl)	130 ± 70	118 ± 54	109 ± 48	0.03

[a]Jonckheere-Terpstra test is based on trends; however, for ease of presentation, means are shown.
[b]BMI, body mass index; bpm, beats per minute.

our current study results for these two questionnaires are likely due to our criterion validation design, as well as better methodological measurement of the cardiac risk factors and angiographic CAD.

Limitations

Our results are limited by the fact that we did not measure oxygen uptake but rather than estimated METS from exercise treadmill duration. The current study findings of a correlation of $r = 0.31$, $p = 0.0002$ between the DASI and METS estimated by symptom-limited exercise treadmill testing in our population is somewhat lower than the original DASI validation sample ($r = 0.58$, $p < 0.0001$), which used measured oxygen uptake.[15] Our results could be confounded by the presence of exercise-induced chest pain and angiographic CAD, such that women with disease were more likely to have cardiac risk factors and demonstrate a symptom-related limitation in terms of METS achieved. Our subgroup analysis, however, shows similar results when these women were excluded. Because our population was selected on the basis of cardiac symptoms and referred for coronary angiography, our results may not be relevant to the population of women at large who are asymptomatic and are not at high risk for CAD.

Relevance

Our findings show that a questionnaire that assesses functional capacity (DASI) and, to a lesser extent, a questionnaire that assesses physical activity (PEPI-Q) have criterion validity for prediction of functional capacity, cardiac risk factors, and angiographic CAD. Use of these questionnaires, therefore, should facilitate future efforts to understand the role of physical activity in women's health. Both questionnaires are short and easily administered, in contrast to other more complex labor-intensive measures.[2–4] Our relatively high minority racial representation and inclusion of women who work both in and outside the home broaden the relevance of these results to a heterogeneous mixture of women.

In summary, based on our results, the DASI and, to a lesser extent, the PEPI-Q questionnaires offer further research opportunities to investigate physical activity habits and cardiovascular outcomes, as well as testing of behavioral interventions designed to increase levels of physical activity and functional capacity in women.

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APPENDIX

POSTMENOPAUSAL ESTROGEN/PROGESTERONE INTERVENTION ACTIVITY QUESTIONNAIRE (PEPI-Q)

1. Thinking about the things you usually did at **work** during the **last 12 months,** how would you describe the kind of physical activity you performed?

   1. Inactive 2. Light 3. Moderate 4. Heavy 5. Not applicable

2. Thinking about the things you usually did at **home** during the **last 12 months,** how would you describe the kind of physical activity you performed?

   1. Inactive 2. Light 3. Moderate 4. Heavy 5. Not applicable

3. Thinking about the things you usually did in your **leisure time** during the **last 12 months,** how would you describe the kind of physical activity you performed?

   1. Inactive 2. Light 3. Moderate 4. Heavy 5. Not applicable

PEPI-Q scoring: The scores for each of the three domains (work, home, and leisure time) are summed, where the numbered item is equal to the number of points, to get a total score, which ranges from 1–12. Higher scores indicate higher physical activity. Not applicable responses provide no points.

DUKE ACTIVITY STATUS INDEX (DASI QUESTIONNAIRE)

Can you	*Weight*
1. Take care of yourself, that is, eating, dressing, bathing or using the toilet?	2.75
2. Walk indoors, such as around your house?	1.75
3. Walk a block or two on level ground?	2.75
4. Climb a flight of stairs or walk up a hill?	5.50
5. Run a short distance?	8.00
6. Do light work around the house like dusting or washing dishes?	2.70
7. Do moderate work around the house like vacuuming, sweeping floors, or carrying in groceries?	3.50

8.	Do heavy work around the house like scrubbing floors or lifting or moving heavy furniture?	8.00
9.	Do yardwork like raking leaves, weeding, or pushing a power mower?	4.50
10.	Have sexual relations?	5.25
11.	Participate in moderate recreational activities like golf, bowling, dancing, doubles tennis, or throwing a baseball or football?	6.00
12.	Participate in strenuous sports like swimming, singles tennis, football, basketball, or skiing?	7.50

DASI scoring: Positive responses are multiplied by the weight and summed to get a total score, which ranges from 0 to 58.2. Higher scores indicate higher functional capacity.

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