



Short Communication

Leisure-time, occupational, household physical activity and insulin resistance (HOMAIR) in the Midlife in the United States (MIDUS) national study of adults

Vera K Tsenkova

University of Wisconsin-Madison, Institute on Aging, 1300 University Avenue, 2245 MSC, Madison, WI 53706, United States

ARTICLE INFO

Article history:

Received 19 December 2016

Accepted 30 December 2016

Available online 03 January 2017

Keywords:

Exercise

Diabetes mellitus

Insulin resistance

Prediabetic state

ABSTRACT

Physical activity is a critical cornerstone of successful diabetes prevention and management. Current U.S. physical activity guidelines do not differentiate among physical activity for leisure, work, or other purposes, effectively implying that physical activity in any domain confers the same health benefits. It is currently unknown whether physical activity performed in different domains (leisure-time physical activity = LTPA, occupational physical activity = OPA, and household physical activity = HPA) is associated with insulin resistance. The associations between LTPA, OPA, HPA, and insulin resistance (indexed by homeostatic model assessment of insulin resistance = HOMAIR) were determined in the MIDUS (Midlife in the U.S.; 1995–2006) national study ($N = 1229$, ages 34–84). Not meeting physical activity guidelines with LTPA was associated with a 34% higher HOMAIR among participants with diabetes, 42% higher HOMAIR among participants with prediabetes, and 17% higher HOMAIR among participants with normal gluco-regulation. These associations were slightly attenuated but remained significant after further adjusting for obesity status, education, smoking, and alcohol intake. There was no evidence that engaging in OPA or HPA was significantly associated with HOMAIR. These results confirm the health-promoting role of LTPA and suggest that LTPA may provide unique gluco-regulatory benefits, as opposed to HPA and OPA. Physical activity domain is an important dimension that potentially belongs in the guidelines, similarly to intensity, frequency, duration, and type.

© 2016 Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

Following the success of the Diabetes Prevention Program, physical activity has been the main target of successful diabetes prevention efforts (Knowler et al., 2002). Current U.S. physical activity guidelines are based on the most recent scientific review of the health benefits associated with physical activity and provide specific recommendations about optimum intensity, frequency, duration, and type of physical activity (U.S Department of Health and Human Services, 2009). The guidelines are based on convincing evidence that people who engage in at least moderate intensity activity for 150 min a week have a significantly lower risk of developing type 2 diabetes, as well as better glycemic control if diabetes is already present. However, the guidelines do not differentiate among physical activity for leisure, work, or other purposes, effectively implying that physical activity in any domain confers the same health benefits. Emerging studies have contrasted the health benefits attributed to leisure-time physical activity (LTPA), occupational physical activity (OPA), and household physical activity (HPA) and have shown that the domain in which physical activity was

performed has important implications for gluco-regulation. For example, there is consistent evidence that engaging in LTPA is associated with lower insulin resistance and lower risk for type 2 diabetes (Honda et al., 2015; Huai et al., 2016; Larsson et al., 2012; Meisinger et al., 2005; Pai et al., 2016; Waller et al., 2010). However, considerably less is known about the gluco-regulatory sequelae of OPA and HPA.¹ One study found that OPA was associated with lower diabetes risk in a Finnish sample (Hu et al., 2003), while a study in a Swedish population found a positive relationship between OPA and insulin resistance (Larsson et al., 2012). Contributing to the mixed findings, studies in Asian samples have found no associations between OPA and incident diabetes (Honda et al., 2015; Villegas et al., 2006). It is unknown whether OPA and HPA are associated with insulin resistance in a U.S. sample. The main goal of this study was to determine the associations between LTPA, OPA, and HPA and insulin resistance in a national U.S. sample of middle and older aged adults.

¹ MIDUS = Midlife in the United States; LTPA = leisure-time physical activity; OPA = occupational physical activity; HPA = household physical activity; HOMAIR = homeostatic model assessment of insulin resistance; GCRC = General Clinical Research Centers; MET = metabolic equivalent; MMW = MET minutes per week

E-mail address: tsenkova@wisc.edu.

2. Methods

2.1. Sample

Data were drawn from MIDUS, a longitudinal study of health and well-being. MIDUS 1 began in 1995–96 as a national random digit dial sample of non-institutionalized, English-speaking adults living in the United States. The MIDUS study was originally designed to cover a wide chronological range that would allow for studying transitions into and out of midlife. A final sample of 7108 participants ages 25–74 completed telephone and mail surveys in MIDUS 1. Approximately 9–10 years later, 4963 (75% response rate adjusted for mortality) were successfully contacted to participate in another phone interview and self-administered questionnaire (MIDUS 2 Survey). Participants who completed both MIDUS 1 and MIDUS 2 Survey were invited to be part of the MIDUS biomarker project. Participants who were healthy enough to travel and consented to participate in the biomarker project were invited to stay overnight at one of three regional General Clinical Research Centers (GCRCs) at UCLA, Georgetown, or the University of Wisconsin. Further details of the study design, recruitment, and retention are available at midus.wisc.edu. The biological subsample of the Midlife in the US (MIDUS 2) national study included 1255 participants ages 34 to 84 (57% female); the analyses are based on 1229 participants with complete data.

2.2. Measures

2.2.1. Glucoregulation

Fasting blood glucose, insulin, and hemoglobin A1c were collected during the GCRC visits. Hemoglobin A1c was assayed via colorimetric total-hemoglobin determination combined with an immunoturbidimetric hemoglobin A1c assay (Wolf et al., 1984; Zander et al., 1984). Insulin was measured with an ADVIA Centaur Insulin assay. Glucose was measured via an enzymatic assay photometrically. The homeostatic model assessment of insulin resistance (HOMAIR), a commonly used measure of insulin resistance, was calculated as a product of glucose (G_0 , mg/dl) and insulin (I_0 , μ U/L) divided by the constant 405: $HOMAIR = (G_0 \times I_0) / 405$ (Matthews et al., 1985). Current criteria from the American Diabetes Association (American Diabetes Association, 2016) were used to define prediabetes (hemoglobin A1c 5.7–6.4% or fasting glucose 100–125 mg/dl, and NOT taking diabetes medications) and diabetes (hemoglobin A1c \geq 6.5% or fasting glucose \geq 126 mg/dl, or taking diabetes medications).

2.2.2. Physical activity domains

Physical activity data were collected as part of medical history data collection during the GCRC stay. Respondents were first asked if they engaged in any type of regular physical activity for 20 min or more at least three times a week. Those who indicated 'no' were classified as non-exercisers. If a respondent answered 'yes,' they then provided specific type(s) of physical activity, and duration, frequency, and intensity (light, moderate, or vigorous) of each type of physical activity. Uniform definitions of what constituted light, moderate, and vigorous activity were provided to respondents. As per the physical activity guidelines, only moderate and vigorous physical activity was included in calculating the physical activity measures (U.S. Department of Health and Human Services, 2009). Data were converted to metabolic equivalents (METs) minutes per week (MMW) following established criteria: minutes per week of activity was multiplied by an activity factor (Moderate = 3; Vigorous activities = 6) (Ainsworth et al., 2011). The domain of activity (LTPA, OPA, and HPA) was determined by referencing the major activity categories within the Compendium of Physical Activity (Ainsworth et al., 2011). OPA was determined by cross-referencing respondents' occupation indicated earlier in the MIDUS 2 survey. Specific activities that fit in the major categories of home activities and home repair were classified as HPA. All other activities were considered LTPA.

Federal guidelines recommend that adults engage in at least 150 min of moderate or vigorous physical activity each week, which is equivalent to 500 METs MMW. Therefore three binary variables were created to reflect whether federal recommendations were met with LTPA, OPA, or HPA.

2.2.3. Control variables

Demographic covariates included age (in years), gender (male or female), race/ethnicity (White or Other), and education levels (continuous). Additional covariates included obesity (body mass index >30), alcohol intake (ranging from 0 = every day to 5 = never), and currently smoking (yes or no).

2.3. Statistical analyses

First, descriptive statistics were generated. Means, standard deviations, and ranges for all continuous variables and proportions for categorical variables were examined. Hierarchical linear regression analyses stratified by glucoregulation status (no diabetes/prediabetes/diabetes) documented the associations among LTPA, OPA, HPA, and insulin resistance. Model 1 controlled for race, gender, and age. Model 2 further added obesity status, education, smoking, and alcohol intake. All models included LTPA, OPA, and HPA simultaneously in the same step of the modeling.

3. Results

Descriptive statistics for all measures are presented in Table 1. The participants were predominantly White (78%). The majority of participants showed evidence for hyperglycemia: overt diabetes was present in 216 participants (18%) and 583 met the criteria for pre-diabetes (47%). Approximately 35% of participants met the physical activity guidelines with LTPA, while 9% met the physical activity guidelines with OPA, and 9% met the physical activity guidelines with HPA.

Table 2 shows the associations observed between physical activity and HOMAIR. Not meeting physical activity guidelines with LTPA was associated with a 34% higher HOMAIR among participants with diabetes, 42% higher HOMAIR among participants with prediabetes, and 17% higher HOMAIR among participants with no hyperglycemia (Model 1), adjusted for age, race, and gender. These associations were slightly attenuated but remained significant after further adjusting for obesity status, education, smoking, and alcohol intake (Model 2). There was no evidence that engaging in OPA and HPA was associated with HOMAIR in any subgroup. Given the small number of participants who reported engaging in HPA or OPA, supplemental analyses combined OPA and HPA in one category in which physical activity guidelines could be met with HPA or OPA. Consistent with the findings presented above, there was no evidence of an association between the combined OPA/HPA category and HOMAIR.

4. Discussion

Physical activity is a modifiable health behavior whose benefits for prevention of chronic disease cannot be overstated. This is the first study to determine the associations among physical activity domains and HOMAIR in middle and older aged adults across the glycemic spectrum. While engaging in LTPA was associated with lower HOMAIR, there was no evidence that engaging in OPA or HPA conferred similar beneficial effects.

The key finding regarding LTPA is consistent with the large literature on the health-promoting role of physical activity. While the current physical activity guidelines suggest that OPA and HPA are options for meeting physical activity recommendations (U.S. Department of Health and Human Services, 2009), the present study adds to the emerging literature that questions the health benefits of OPA and HPA. Some studies have found no significant associations between OPA and

Table 1
Descriptive Statistics in the MIDUS (Midlife in the U.S.; 1995–2006) national study of U.S. Adults.
Meeting Physical Activity Guidelines, per Domain.

	Full MIDUS Sample N = 1229	Less than 500 MMW LTPA N = 793	Greater or Equal to 500 MMW LTPA N = 436	Less than 500 MMW OPA N = 1118	Greater or Equal to 500 MMW OPA N = 111	Less than 500 MMW HPA N = 1117	Greater or Equal to 500 MMW HPA N = 112
HOMA1R original value	3.58 (3.98)	4.11 (4.6)	2.61 (2.18)	3.59 (4.06)	3.50 (3.13)	3.57 (3.79)	3.71 (5.58)
HOMA1R log transformed	0.93 (0.79)	1.06 (0.81)	0.70 (0.70)	0.93 (0.79)	0.93 (0.80)	0.93 (0.79)	0.92 (0.79)
Glucoregulation							
Normoglycemia	35%	30.8%	42.7%	34.9%	36%	35.4%	31.3%
Prediabetes	47.4%	48%	46.3%	47%	51.4%	46.9%	52.7%
Diabetes	17.6%	21.2%	11%	18.1%	12.6%	17.7%	16.1%
Using insulin	2.7%	3.3%	1.6%	2.8%	1.8%	2.8%	1.8%
Education	7.46 (2.53)	7.1 (2.5)	8.12 (2.49)	7.54 (2.54)	6.66 (2.31)	7.48 (2.54)	7.23 (2.47)
Race							
White	78.4%	73.9%	86.5%	78.7%	74.8%	77.4%	88.4%
Other	21.6%	26.1%	13.5%	21.3%	25.2%	22.6%	11.6%
Age	54.5 (11.73)	54.72 (11.82)	54.08 (11.58)	54.90 (11.87)	50.39 (9.31)	54.16 (11.74)	57.84 (11.16)
Gender							
Female	56.5%	58%	53.7%	59.3%	27.9%	56.8%	52.7%
Male	43.5%	42%	46.3%	40.7%	72.1%	43.2%	47.3%
Alcohol intake	3.53 (1.56)	3.67 (1.5)	3.28 (1.63)	3.55 (1.55)	3.32 (1.62)	3.54 (1.56)	3.40 (1.60)
Obese	41.2%	46.5%	31.4%	41.6%	36.9%	41.1%	42%
Currently smoking	13.7%	17.4%	6.9%	12.4%	26.1%	13.8%	12.5%

cardiovascular risk factors (Sisson et al., 2009; Sofi et al., 2007) and others have found evidence for positive associations with obesity, insulin resistance, and blood pressure (Clays et al., 2012; Larsson et al., 2012). From a physiological perspective, most benefits of physical activity on glucoregulation are realized through acute and chronic improvements in glucose uptake into active muscles and better insulin sensitivity, accomplished with aerobic and resistance training (Colberg et al., 2010). In contrast to these health promoting movements associated with LTPA, OPA (and HPA to a lesser degree) typically includes heavy lifting, prolonged standing, highly repetitive work, working with the hands lifted to shoulder height or higher and working with the back twisted or bent forward (Lund et al., 2006), with limited opportunities to rest when needed. Examining the physiological, biobehavioral, and mental health correlates of physical activity is an essential next step, as understanding these pathways is critical for developing effective preventive efforts centered around physical activity. Notably, individuals in blue-collar occupations were approximately 50% more likely to be classified as insufficiently active (Burton and Turrell, 2000), and examining the interactions among LTPA, HPA, and OPA on insulin resistance and related cardiometabolic risk factors will sharpen the focus on possible subgroup differences.

4.1. Study limitations and strengths

The findings of the present study should be interpreted in light of study limitations. The key limitation is its cross-sectional design. Future

research that utilizes longitudinal samples will provide further insights into the timeline and causal directionality of the associations between physical activity and insulin resistance. Self-reported physical activity is subject to recall bias and future studies will benefit from objectively measuring OPA, HPA, and LTPA; doing so will provide a more precise measure of physical activity and sharpen the focus on the underlying mechanisms that account for the observed associations. These findings need to be replicated in samples that contain a larger number of participants who engage in OPA and HPA, which would allow more power to detect associations and also investigate possible interactions among LTPA, HPA, and OPA. Further, the analyses were modeled to capture risk for developing type 2 diabetes, but information was not available on whether participants had type 1 or type 2 diabetes. Given that only 5% of Americans with diabetes have type 1 diabetes (Centers for Disease Control and Prevention, 2014), the results are unlikely to have been significantly affected by this misclassification. Finally, the small numbers of non-black minority participants precluded investigating potential race/ethnic differences in insulin sensitivity. A notable strength was the use of different glucoregulatory biomarkers to assess insulin resistance and ascertain glycemic status.

5. Conclusions

These findings show that the domain in which physical activity was performed may have important implications for glucoregulation. Patients and providers will benefit from recognizing that engaging in

Table 2
Associations among Leisure-time physical activity (LTPA), occupational physical activity (OPA), household physical activity (HPA), and Log-transformed Insulin Resistance (HOMA1R) stratified by glucoregulation status in the MIDUS (Midlife in the U.S.; 1995–2006) national study of U.S. adults.

	Model 1			Model 2		
	Normoglycemia N = 430	Prediabetes N = 583	Diabetes N = 216	Normoglycemia N = 430	Prediabetes N = 583	Diabetes N = 216
LTPA						
β (95% CI)	0.16 (0.04; 0.28)*	0.35 (0.23; 0.47)**	0.29 (0.06; 0.52)*	0.12 (0.01; 0.24)*	0.22 (0.11; 0.33)**	0.25 (0.02; 0.48)*
OPA						
β (95% CI)	0.08 (−0.14; 0.29)	0.16 (−0.04; 0.36)	−0.04 (−0.43; 0.35)	0.08 (−0.12; 0.27)	0.08 (−0.10; 0.26)	−0.01 (−0.39; 0.37)
HPA						
β (95% CI)	−0.16 (−0.37; 0.06)	0.10 (−0.09; 0.29)	−0.23 (−0.58; 0.12)	−0.07 (−0.27; 0.13)	0.09 (−0.08; 0.26)	−0.18 (−0.51; 0.16)

Note. LTPA, OPA, and HPA measures are binary (1 = <500 MMW in the specific domain). Model 1 includes LTPA, OPA, HPA, age, gender, and race. Model 2 further adjusts for education, obesity status, current smoking status, alcohol intake, and insulin use (in diabetes group only).

* $p < 0.05$.

** $p < 0.01$.

OPA and HPA may not be as beneficial as engaging in LTPA. If replicated in samples with greater number of respondents who engage in OPA and HPA, these findings suggest that physical activity domain is a dimension that belongs in the guidelines. While the importance of targeting physical inactivity is undisputed, promoting the most beneficial form of physical activity will be informed by considering not only intensity, frequency, duration, and type, but also domain.

Funding source

This work was supported by a grant from the National Institute on Aging (P01-AG020166; Carol D. Ryff, Principal Investigator) to conduct a longitudinal follow-up of the MIDUS (Midlife in the US) investigation. The original study was supported by the John D. and Catherine T. MacArthur Foundation Research Network on Successful Midlife Development. Data collection was supported by the following grants: M01-RR023942 (Georgetown), M01-RR00865 (UCLA) from the General Clinical Research Centers Program, and 1UL1RR025011 (UW) from the Clinical and Translational Science Award (CTSA) program of the National Center for Research Resources, National Institutes of Health. The author (VKT) of this study was supported by the National Institute on Aging (K01AG041179). The content is solely the responsibility of the author and does not necessarily represent the official views of the National Institutes of Health. No conflict of interest.

Transparency document

The [Transparency document](#) associated with this article can be found, in the online version.

References

- Ainsworth, B.E., Haskell, W.L., Herrmann, S.D., et al., 2011. 2011 compendium of physical activities: a second update of codes and MET values. *Med. Sci. Sports Exerc.* 43: 1575–1581. <http://dx.doi.org/10.1249/MSS.0b013e31821ece12>.
- U.S. Department of Health and Human Services, 2009. Physical activity guidelines advisory committee report, 2008. To the Secretary of Health and Human Services. Part A: executive summary. *Nutr. Rev.* 67:114–120. <http://dx.doi.org/10.1111/j.1753-4887.2008.00136.x>.
- American Diabetes Association, 2016. 2. Classification and diagnosis of diabetes. *Diabetes Care* 39 (Suppl. 1):S13–S22. <http://dx.doi.org/10.2337/dc16-S005>.
- Burton, N.W., Turrell, G., 2000. Occupation, hours worked, and leisure-time physical activity. *Prev. Med.* 31:673–681. <http://dx.doi.org/10.1006/pmed.2000.0763>.
- Centers for Disease Control and Prevention, 2014. National Diabetes Statistics Report: Estimates of Diabetes and its Burden in the United States, 2014, Atlanta, GA.
- Clays, E., De Bacquer, D., Van Herck, K., De Backer, G., Kittel, F., Holtermann, A., 2012. Occupational and leisure time physical activity in contrasting relation to ambulatory blood pressure. *BMC Public Health* 12:1002. <http://dx.doi.org/10.1186/1471-2458-12-1002>.
- Colberg, S.R., Sigal, R.J., Fernhall, B., et al., 2010. Exercise and type 2 diabetes: the American College of Sports Medicine and the American Diabetes Association: joint position statement. *Diabetes Care* 33:e147–e167. <http://dx.doi.org/10.2337/dc10-9990>.
- Honda, T., Kuwahara, K., Nakagawa, T., Yamamoto, S., Hayashi, T., Mizoue, T., 2015. Leisure-time, occupational, and commuting physical activity and risk of type 2 diabetes in Japanese workers: a cohort study. *BMC Public Health* 15:1004. <http://dx.doi.org/10.1186/s12889-015-2362-5>.
- Hu, G., Qiao, Q., Silventoinen, K., et al., 2003. Occupational, commuting, and leisure-time physical activity in relation to risk for type 2 diabetes in middle-aged Finnish men and women. *Diabetologia* 46:322–329. <http://dx.doi.org/10.1007/s00125-003-1031-x>.
- Huai, P., Han, H., Reilly, K.H., Guo, X., Zhang, J., Xu, A., 2016. Leisure-time physical activity and risk of type 2 diabetes: a meta-analysis of prospective cohort studies. *Endocrine* 52:226–230. <http://dx.doi.org/10.1007/s12020-015-0769-5>.
- Knowler, W.C., Barrett-Connor, E., Fowler, S.E., et al., 2002. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N. Engl. J. Med.* 346: 393–403. <http://dx.doi.org/10.1056/NEJMoa012512>.
- Larsson, C.A., Kroll, L., Bennet, L., Gullberg, B., Rastam, L., Lindblad, U., 2012. Leisure time and occupational physical activity in relation to obesity and insulin resistance: a population-based study from the Skaraborg Project in Sweden. *Metabolism* 61:590–598. <http://dx.doi.org/10.1016/j.metabol.2011.09.010>.
- Lund, T., Labriola, M., Christensen, K.B., Bultmann, U., Villadsen, E., 2006. Physical work environment risk factors for long term sickness absence: prospective findings among a cohort of 5357 employees in Denmark. *BMJ* 332:449–452. <http://dx.doi.org/10.1136/bmj.38731.622975.3A>.
- Matthews, D.R., Hosker, J.P., Rudenski, A.S., Naylor, B.A., Treacher, D.F., Turner, R.C., 1985. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia* 28, 412–419.
- Meisinger, C., Lowel, H., Thorand, B., Doring, A., 2005. Leisure time physical activity and the risk of type 2 diabetes in men and women from the general population. The MONICA/KORA Augsburg cohort study. *Diabetologia* 48:27–34. <http://dx.doi.org/10.1007/s00125-004-1604-3>.
- Pai, L.W., Li, T.C., Hwu, Y.J., Chang, S.C., Chen, L.L., Chang, P.Y., 2016. The effectiveness of regular leisure-time physical activities on long-term glycemic control in people with type 2 diabetes: a systematic review and meta-analysis. *Diabetes Res. Clin. Pract.* 113:77–85. <http://dx.doi.org/10.1016/j.diabres.2016.01.011>.
- Sisson, S.B., Camhi, S.M., Church, T.S., et al., 2009. Leisure time sedentary behavior, occupational/domestic physical activity, and metabolic syndrome in U.S. men and women. *Metab. Syndr. Relat. Disord.* 7:529–536. <http://dx.doi.org/10.1089/met.2009.0023>.
- Sofi, F., Capalbo, A., Marcucci, R., et al., 2007. Leisure time but not occupational physical activity significantly affects cardiovascular risk factors in an adult population. *Eur. J. Clin. Invest.* 37:947–953. <http://dx.doi.org/10.1111/j.1365-2362.2007.01884.x>.
- Villegas, R., Shu, X.O., Li, H., et al., 2006. Physical activity and the incidence of type 2 diabetes in the Shanghai women's health study. *Int. J. Epidemiol.* 35:1553–1562. <http://dx.doi.org/10.1093/ije/dyl209>.
- Waller, K., Kaprio, J., Lehtovirta, M., Silventoinen, K., Koskenvuo, M., Kujala, U.M., 2010. Leisure-time physical activity and type 2 diabetes during a 28 year follow-up in twins. *Diabetologia* 53:2531–2537. <http://dx.doi.org/10.1007/s00125-010-1875-9>.
- Wolf, H.U., Lang, W., Zander, R., 1984. Alkaline haematin D-575, a new tool for the determination of haemoglobin as an alternative to the cyanhaemoglobin method. II. Standardisation of the method using pure chlorohaemin. *Clin. Chim. Acta* 136, 95–104 (0009-8981(84)90251-1 pii).
- Zander, R., Lang, W., Wolf, H.U., 1984. Alkaline haematin D-575, a new tool for the determination of haemoglobin as an alternative to the cyanhaemoglobin method. I. Description of the method. *Clin. Chim. Acta* 136, 83–93 (0009-8981(84)90250-X pii).