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BRIEF REPORT

Dyadic associations between physical activity and body mass index in couples in which one partner has diabetes: results from the Lifelines cohort study

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Abstract Physical activity and body mass index (BMI) are linked to the prevention and management of type 2 diabetes (T2D). Romantic partners influence each other's health and the behavioral management of T2D often involves both partners. Therefore, this study examined dyadic associations between physical activity and BMI in couples in which one partner has T2D. Data came from the Lifelines cohort study. The actor–partner interdependence model was applied to cross-sectional data from 1133 couples in which only one partner had T2D. The physical activity of the person with diabetes was inversely associated with his/her partner's BMI. However, partner physical activity was not associated with the BMI of the person with diabetes. These results suggest that people with diabetes may influence the BMI of their partners. Future research should consider how people with diabetes influence the health outcomes of their partners, which is an area that is often overlooked in the literature.

Keywords Type 2 diabetes · Physical activity · Body mass index · Dyadic · Actor–partner interdependence model

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Introduction

The prevalence of type 2 diabetes (T2D) is expected to increase worldwide (Wild et al., 2004), so many countries have implemented policies that aim to prevent new cases of T2D and to minimize the progression of the condition among those with T2D (World Health Organization, 2016). Many of these efforts target physical activity and its downstream correlate—body mass index (BMI)—because physical activity and a lower BMI can prevent or delay the onset of the disease in individuals at risk for T2D and can mitigate the progression of T2D in individuals with the condition (Hu et al., 2004; Sluik et al., 2012; Wing et al., 2011). Although *intraindividual* associations between physical activity and body mass index (BMI) have been established (Avery et al., 2012; Donnelly et al., 2009), *interindividual* associations have not been considered. Therefore, this study examined dyadic associations between physical activity and BMI in romantic couples in which one partner has T2D.

Evidence and theory suggest that the social context provided by romantic partners shape health behaviours and outcomes. For example, evidence from the general population suggests that romantic partners tend to be concordant in physical activity and BMI (Meyler et al., 2007) and that partners' beliefs are associated with each others' physical activity intentions (Howland et al., 2016). Furthermore, theoretical models, such as the interdependence model of communal coping and behavior change, posit that the health behaviors of both members of a couple can be influenced by a health threat, such as T2D (Lewis et al., 2006).

In the context of T2D, romantic partners seem to be particularly influential in shaping health behaviors and outcomes. In couples in which one partner has T2D, both partners are often involved in facilitating the behavior

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changes required to manage T2D (e.g., encouraging physical activity) and the partner without diabetes is often faced with lifestyle changes him/herself (e.g., joining in on physical activity) (Lister et al., 2013). More broadly, both PWDs and their partners report the need to work together to manage the condition (Beverly et al., 2008) and can experience distress tied to the disease (Franks et al., 2010).

However, despite the interpersonal aspects of T2D, relatively few studies in this area have treated the couple as the unit of analysis (Lister et al., 2013). Moreover, the limited research in this area has largely adopted a caregiver approach (Reed et al., 2013) by examining how *partners* influence *PWDs'* health behaviors. For example, research suggests that spousal encouragement is associated with PWDs' dietary adherence (Stephens et al., 2010) and that spousal diabetes efficacy is associated with PWDs' dietary and exercise adherence (Johnson et al., 2013). However, the extent to which *PWDs* influence the health outcomes of their *partners* has largely been overlooked. This gap in the literature is inconsistent with dyadic models of health behaviour change, which point to behavioral changes by both partners when facing a health threat (Lewis et al., 2006). Furthermore, partners of PWDs are at increased risk of developing T2D themselves (Leong et al., 2014). Thus, determining if the physical activity of PWDs is linked to their partners' BMI could point to possible mechanisms underlying this increased risk.

Therefore, the purpose of this study was to examine dyadic associations between physical activity and BMI in couples in which only one person has T2D. Using a complete dyadic design, rather than a caregiver approach, permits consideration of *all* interindividual associations between physical activity and BMI within a couple, above and beyond intraindividual associations. Interindividual associations between physical activity and BMI were hypothesized. PWD physical activity was expected to be negatively associated with partner BMI and partner physical activity was expected to be negatively associated with PWD BMI. Given that relational influences on health often differ by gender (Kiecolt-Glaser & Newton, 2001), differences between men and women were explored.

Methods

Data came from the Lifelines cohort study. Lifelines is a multi-disciplinary prospective population-based cohort study examining, in a unique three-generation design, the health and health-related behaviours of 167,729 persons living in the North of The Netherlands. It employs a broad range of investigative procedures in assessing the biomedical, socio-demographic, behavioural, physical and psychological factors that contribute to the health and disease of the general population, with a special focus on multi-morbidity and complex genetics. Participants registered for the study between 2006 and 2013. Participants were recruited into Lifelines by their general practitioners. The majority (73%) of general practitioners in the recruitment area invited all of their patients aged 25 through 50 to participate, unless the patient had a severe psychiatric or physical illness, limited life expectancy, or poor knowledge of the Dutch language. Participants were encouraged to invite their family members (i.e., spouses, children, parents) to participate. At baseline and every 5 years, participants are scheduled to complete physical examinations and a comprehensive questionnaire. Short questionnaires are administered approximately every 1.5 years. The study design is further detailed elsewhere (Scholtens et al., 2015). Participants provided informed consent and the protocol was approved by the University Medical Centre Groningen ethics committee.

The present study used cross-sectional data from the baseline (2014) wave because it included objective measurements of height and weight and a comprehensive measure of physical activity. Inclusion criteria for the present study were romantic couples (i.e., married, in a registered partnership, or cohabitating) participating in Lifelines in which only one member self-reported being diagnosed with T2D and both members provided physical activity, height and weight data. Couples in which both partners reported having diabetes were excluded.

Participants

A total of 1133 couples met the inclusion criteria and were therefore included in the analyses. The majority (99.29%) of couples were heterosexual. Of the PWDs, 59.66% were men. On average, PWDs were 59.23 years old (SD = 9.38) and their partners were 58.43 years old (SD = 9.72). PWDs reported having T2D for an average of 7.35 years (SD = 9.41). Couples reported being in a relationship for an average of 35.22 years (SD = 10.96).

Measures

Physical activity was measured with the vigorous intensity subscale of the Short Questionnaire to Assess Health-enhancing Physical Activity (SQUASH) (Wendel-Vos et al., 2003). The SQUASH is a self-report measure that has been validated in the Dutch context (Wendel-Vos et al., 2003). Participants were asked to indicate on how many days they performed various physical activities during an average week in the past months. If applicable, participants indicated how much time they spent on the activity and how strenuous the activity was. Activities that require at least 6.5 metabolic equivalents (METs; e.g., fast bicycling, some

sports) contributed to the vigorous intensity score, which is calculated by multiplying the number of minutes engaged in vigorous activities by an intensity score. The scoring algorithm is detailed elsewhere (Wendel-Vos et al., 2003). Higher scores indicate greater activity. Given the large range of scores observed in this study (0–23,220), raw scores were divided by 1000 to simplify the reporting of coefficients. The vigorous intensity subscale was selected to be consistent with Dutch physical activity guidelines, which recommend that adults engage in at least 150 min of moderate to vigorous physical activity per week, such as brisk walking (Health Council of the Netherlands, 2017). Brisk walking is included in the vigorous intensity score.

BMI (weight in kg/height in m^2) was calculated with height and weight measurements taken by Lifelines staff. Participants wore light clothing and did not wear shoes. Covariates were assessed via self-report and included relationship and diabetes durations in years, as well PWDs' and partners' age, sex, and education (less than intermediate vocational education/apprenticeship; intermediate vocational education/apprenticeship or higher).

Statistical analysis

Analyses utilized the actor–partner interdependence model (APIM) (Kenny et al., 2006) to examine associations between couple members' physical activity and both their own and their partners' BMI at baseline. The APIM treats the couple as the unit of analysis thereby accounting for interdependent observations within a couple. The model simultaneously estimates actor and partner effects for both members of the couple. Actor effects are associations between one's physical activity score and one's own BMI. Partner effects are associations between one's physical activity score and his/her partner's BMI. Members of dyads were distinguished by diabetes status. Models were estimated via path models (see Fig. 1). Covariances between PWD and partner physical activity, as well as between PWD and partner BMI, were modeled. An unadjusted model and a model adjusted for covariates were conducted. Paths from each covariate to PWD BMI and partner BMI were modeled. Covariances among all covariates were modeled. Covariances between covariates and PWD and partner physical activity were also modeled. To explore if path coefficients significantly differed across PWD's sex, procedures for testing differences between groups in SEMs recommended by Acock (2013) were utilized. First, separate path models adjusted for all covariates, except sex, were constructed for men and women. Next, path coefficients from each model were tested for invariance with Wald tests (Acock, 2013).

Results

Bivariate correlations between BMI, physical activity, and covariates are presented in Table 1. The physical activity ($r = .29$, $p < .001$) and BMI ($r = .28$, $p < .001$) of PWDs and their partners were positively correlated. Descriptive statistics for physical activity and BMI for PWDs and their partners are presented in Fig. 1. The unadjusted model (Fig. 1a; CFI = 1.00, RMSEA = 0.00) revealed significant actor effects. Among PWDs, physical activity was inversely associated with own BMI, such that every 1 unit increase in physical activity was associated with a reduction of .23 on BMI. Similarly, partner physical activity was inversely associated with own BMI, such that every 1 unit increase in physical activity was associated with a reduction of .16 on BMI. A significant partner effect indicated that PWD physical activity was inversely associated with partner BMI, such that every 1 unit increase in PWD's physical activity was associated with a reduction of .17 on BMI for the partner. However, partner physical activity was not associated with PWD BMI in the APIM model. This pattern of results held when adjusting for covariates (Fig. 1b; CFI = 1.00, RMSEA = 0.00). Exploratory analyses revealed that actor and partner effects for PWDs and their partners did not significantly differ if the PWD was a man or a woman (all $p > .48$).

Discussion

This study was the first to examine dyadic associations between physical activity and BMI in couples in which one partner was diagnosed with T2D. Consistent with past literature (Avery et al., 2012; Donnelly et al., 2009), individual physical activity was inversely associated with one's own BMI. Moreover, as hypothesized, PWD physical activity was inversely associated with partner BMI, above and beyond the partner's own physical activity. The strength of this association was comparable to the strength of the association between the partner's physical activity and his/her own BMI. However, contrary to the hypotheses, partner physical activity was not associated with PWD BMI, above and beyond the PWD's own physical activity. Observed effect sizes were small, which is consistent with previous work that has examined cross-sectional associations between physical activity and BMI (Bize & Plotnikoff, 2009; Dowda et al., 2003).

By adopting a fully dyadic design, this study provided some of the first evidence to suggest that the BMI of partners may be influenced by PWDs. This design contrasts much of the dyadic research in the context of T2D, which has adopted a caregiver perspective by focusing on how

Table 1 Bivariate correlations between physical activity, BMI, and covariates (n = 1133 couples)

	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. PWD physical activity	.29*	− .12*	− .10*	− .04	.04	.19*	.17*	− .03	− .02	.15*	.06*
2. Partner physical activity		− .05	− .10*	.00	.00	.16*	.17*	− .01	− .04	.14*	.08*
3. PWD BMI			.28*	.17*	− .16*	− .24*	− .19*	− .03	.02	− .18*	− .01
4. Partner BMI				.04	− .03	− .13*	− .13*	− .07*	− .02	− .14*	.04
5. PWD sex					− .99*	− .13*	.10*	− .08*	.08*	− .04	− .07*
6. Partner sex						.14*	− .10*	.08*	− .08*	.04	.07*
7. PWD age							.91*	− .16*	− .20*	.81*	.19*
8. Partner age								− .16*	− .19*	.84*	.16*
9. PWD education									.21*	− .15*	− .08*
10. Partner education										− .22*	− .08*
11. Relationship duration											.14*
12. Diabetes duration											

Sex coded 0 = *Male*, 1 = *Female*. Education coded 0 = *less than intermediate vocational education/apprenticeship*, 1 = *intermediate vocational education/apprenticeship or higher*

PWD person with diabetes, *BMI* body mass index

*$p < .05$

partners influence the health behaviour or outcomes of PWDs. However, a caregiver approach is not consistent with evidence suggesting that T2D is a condition that affects the health and wellbeing of both members of a couple (Lister et al., 2013) and theory suggesting that the behavior both partners may be affected by a health threat, such as T2D (Lewis et al., 2006). Given that partners of PWDs are at increased risk of developing T2D themselves (Leong et al., 2014), the present results suggest that PWD physical activity might contribute to this increased risk by influencing partner BMI. More broadly, these results suggest that moving beyond the caregiver approach to consider the possible pathways through which PWDs influence the health of their partners is a promising avenue of research that is largely unexplored.

Why might the physical activity of PWDs be associated with their partners' BMI? The present research cannot speak to the specific mechanisms underlying this partner effect, but prior research suggests possible explanations. Stress is positively associated with adiposity and can influence the extent to which fat is lost during physical activity (Boutcher & Dunn, 2009). Moreover, partners of PWDs can experience stress when T2D self-management regimens are not adhered to (Franks et al., 2012). Therefore, it is possible that partners experience stress when the PWD does not exercise, which, in turn, influences their own BMI. Additionally, healthy lifestyle behaviors can cluster together. For example, individuals with diabetes who regularly engage in physical activity also tend to regularly eat a healthy diet (Lippke et al., 2012). Given that spouses likely engage in other health behaviors together, such as eating meals, these shared health behaviours may also influence partners' BMI.

However, why might partner physical activity not be associated with PWD BMI, above and beyond the PWD's own physical activity? It may be that the BMI of PWDs is less malleable than that of their partners. The physiological changes that can accompany diabetes and its treatment can hamper the extent to which physical activity translates into weight loss (Boutcher & Dunn, 2009). Thus, partner influences may not manifest as changes in BMI. Similarly, sleep problems are relatively common amongst PWDs and may be associated with decreased responsiveness to weight loss efforts as well as weight gain (Luyster & Dunbar-Jacob, 2011; Spiegel et al., 2009; Valrie et al., 2015). Alternatively, this asymmetric influence may be attributable to relationship power, which is the ability of an individual to exert influence on his/her partner to obtain desired outcomes (Simpson et al., 2015). In the context of health behaviours and outcomes related to T2D, the complex self-management regimen, required knowledge, and progressive nature of the disease may shape the extent to which partners influence each other.

Strengths of this study include the large sample size, the collection of dyadic data from individuals with T2D and their partners, objective measures of height and weight, and a comprehensive measure of physical activity. However, this study also has limitations that can be addressed in future research. Due to the cross-sectional design, the directionality of the associations cannot be determined. Although research has consistently demonstrated that physical activity is prospectively associated with BMI (Avery et al., 2012; Donnelly et al., 2009), evidence has

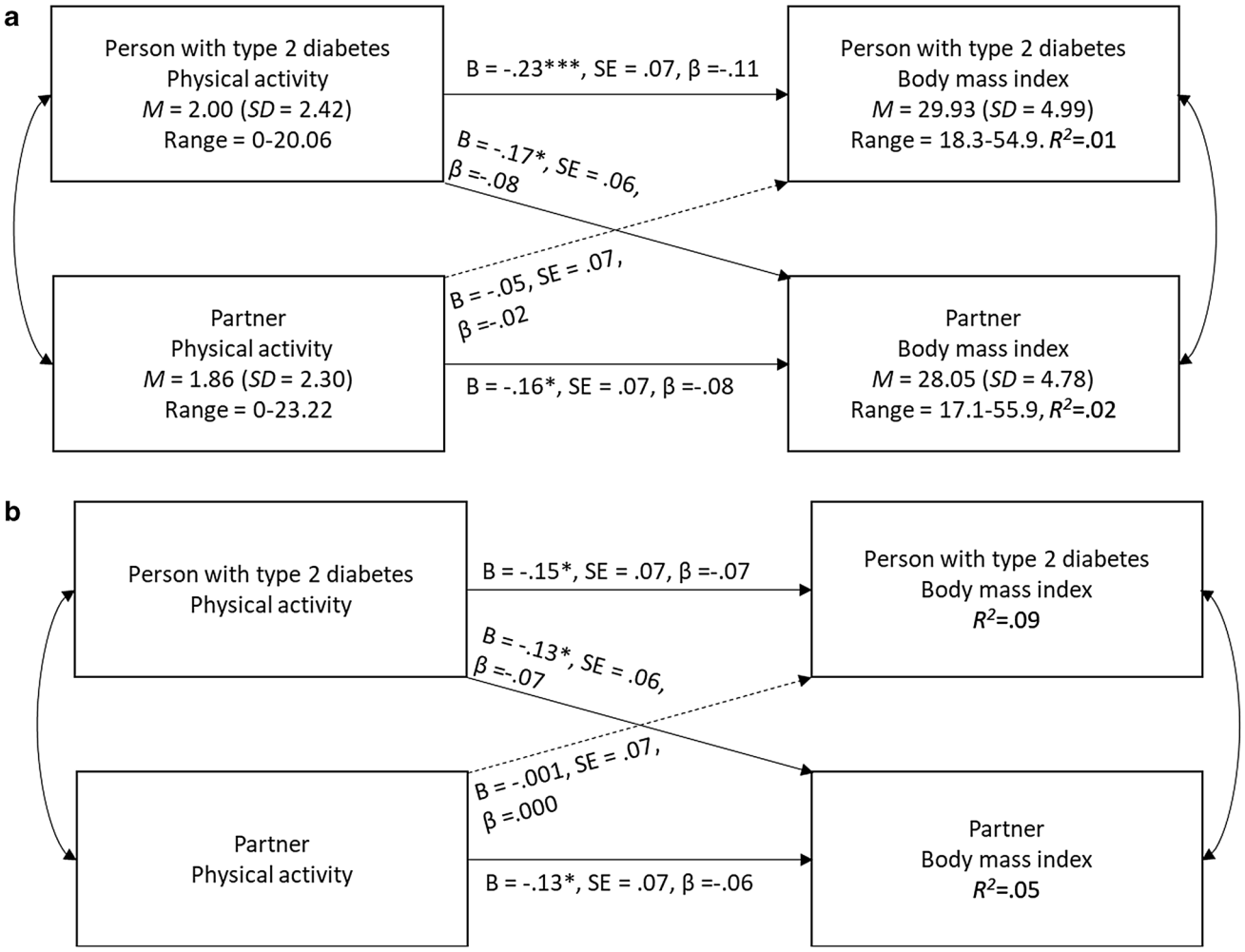

Fig. 1 Actor partner interdependence models ($n = 1133$ couples) testing dyadic associations between physical activity and body mass index. Panel **a** presents results from the unadjusted model. Panel **b** presents results from the model that adjusted for age, sex, education, diabetes duration, and relationship duration. Solid lines represent significant paths. Dashed lines represent paths that were modeled, but were not significant. $^{*}p < .05$; $^{***}p \leq .001$

also demonstrated that BMI is prospectively associated with physical activity (Petersen et al., 2004; Preiss et al., 2015). Given the design of the study, it is possible that BMI influenced physical activity or that physical activity and BMI are reciprocally related. Future research must determine the directionality and causes of the asymmetrical dyadic associations between physical activity and BMI observed in this study. Additionally, although the physical activity measure was comprehensive, it relied on self-report, and is thus subject to recall bias and socially desirable responding. The majority of couples were heterosexual, so it is not clear if findings would generalize to same-sex couples. Similarly, given the inclusion criteria, it is not clear if the observed pattern of results generalizes to couples in which both partners have diabetes. Finally, given the design of the Lifelines study, it is possible that there were some sibling or parent–child relationships across dyads.

In conclusion, this study extends previous research by considering interpersonal associations between physical activity and BMI in couples in which one person has T2D. This study adopted a fully dyadic approach, which considered the BMI of *both* the partner and the PWD, thereby extending previous work that has largely focused on delineating how partners influence the health outcomes of PWDs. As a result, this study provided some of the first evidence to suggest that the physical activity of PWDs may influence the BMI of their partners. Given that the partners of people with T2D are at risk of developing T2D themselves (Leong et al., 2014), future research should examine other avenues through which PWDs influence their partners' health and explore if couple-level inter-

ventions are helpful in reducing the incidence of T2D in the population.

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Compliance with ethical standards

Conflict of interest Drs. Burns, Fillo, Deschenes and Schmitz each declare that he/she has no conflict of interest.

Human and animal rights and Informed consent All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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