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Research Article

Population-Based Estimates of Physical Activity for Adults with Type 2 Diabetes: A Cautionary Tale of Potential Confounding by Weight Status

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At a population level, the method used to determine those meeting physical activity guidelines has important implications, as estimating "sufficient" physical activity might be confounded by weight status. The objective of this study was to test the difference between three methods in estimating the prevalence of "sufficient activity" among Canadian adults with type 2 diabetes in a large population sample ($N = 1614$) while considering the role of weight status as a potential confounder. Our results revealed that estimates of physical activity levels vary by BMI categories, depending on the methods examined. Although physical activity levels were lower in the obese, their energy expenditure estimates were not different from those who were overweight or of a healthy weight. The implications of these findings are that biased estimates of physical activity at a population level may result in inappropriate classification of adults with type 2 diabetes as "sufficiently active" and that the inclusion of body weight in estimating physical activity prevalence should be approached with caution.

1. Introduction

At a population level, the method used to determine those meeting physical activity guidelines has important implications [1]. For example, estimating "sufficient" physical activity (PA) might be confounded by weight status. This is possible since an increase in mean weight status of a population may result in spurious estimates of increasing physical activity-related energy expenditure over time [2]. This hypothesis is particularly important for those who work with type 2 diabetes populations because weight loss is a salient clinical target and can be achieved through energy restriction alone or in combination with an increase in energy expenditure. Consequently, as argued above, valid changes (i.e., increases or decreases) in PA patterns might not be entirely and therefore correctly captured. If this were to occur, assessing population-based strategies geared towards increasing physical activity and reducing body weight among adults with type 2 diabetes might be limited by measurement error.

Low physical activity levels in adults with type 2 diabetes have been widely reported [3–9] yet there appear to be some irregularities among these data. For example, being older [3, 6] and being female [7, 9] were reported to

Table 1: Methods of assessment.

Method	Calculation	"Sufficiently active" thresholds
Kcal	Hours per week of moderate intense activities × (4 METS) + hours of vigorous intense activities × (7.5 METS) × body weight (kg)	≥800/week
Met·mins	Minutes per week of moderate intense activities × (4 METS) + minutes of vigorous intense activities × (7.5 METS)	≥600/week
MVPA mins	Minutes per week of moderate intense activity + minutes per week of vigorous intense activity (unweighted for intensity)	≥150

be negatively associated with physical activity yet in other studies, age [7, 9] and sex [6] had no significant relationship with physical activity. We contend that this discordance reflects methodological differences in data synthesis and the thresholds used to quantify physical activity levels sufficient for health benefit, notably the use of weight dependent thresholds [9].

In response, we postulated that the methods for assessing self-reported physical activity might serve to explain some of the discordance. The objective of this study was to compare three different methods to classify individuals with type 2 diabetes as "sufficiently active" using a validated measure of physical activity instrument [10]. We hypothesized that the prevalence of those classified as "sufficiently" active (i.e., proportional estimates) would be different according to the method used to calculate weekly physical activity and that these differences would be confounded with the inclusion of body weight in indirectly estimating physical activity-related energy expenditure.

2. Method

2.1. Subjects. The current study is a component of the Alberta Longitudinal Exercise and Diabetes Research Advancement (ALEXANDRA) Study, a prospective assessment of physical activity determinants [8]. The participants in this study were residents in the province of Alberta, Canada ($N = 1614$) with type 2 diabetes and were assessed at three time points: baseline, 6 months, and 18 months. Demographic characteristics, recruitment, and response rates have been previously described [8]. Briefly, participants were 62.9 ± 12.1 years of age, moderately overweight to obese (BMI $= 29.6 \pm 5.9\,\text{kg/m}^2$), and represented equally by sex (51.4% male), and 72.0% of the sample indicated were Canadian while 28.0% were either Arab, Asian, African, European, Aboriginal, or Latin/South American. The demographic characteristics of this study population generally reflect Canada's and Alberta's adult type 2 diabetes population in terms of age and sex distributions [8, 11]. Participants were recruited by (1) mailing questionnaires and consent forms to individuals from the Canadian Diabetes Association registry, requesting completion from those with diabetes or (2) through a random digit dialing method to recruit individuals living with diabetes in Alberta; households that were contacted could also nominate a family member or friend with diabetes. This study received ethical approval from the Health Research Ethics Board.

2.2. Physical Activity Assessment. Physical activity was assessed with the Godin Leisure-Time Exercise Questionnaire (GLTEQ) [10]. Participants were dichotomized as "sufficiently active" or "inactive" based on three different classifications as presented in Table 1: (1) the estimated *kilocalories method* (Kcal)(hours per week of moderately intense activities [×4 METS] + hours per week of vigorously intense activities [×7.5 METS] × body weight (kg)); (2) the *Met.mins method* (minutes per week of moderately intense activities [×4 METS] + minutes per week of vigorously intense activities [×7.5 METS]); (3) the *unweighted moderate and vigorous method* (MVPA mins) (minutes per week of moderately intense activities + minutes per week of vigorously intense activities). Thresholds for categorization of "sufficiently active" for each method, respectively, were ≥800/week for the kilocalories which is based on previous population surveys [2] and reflects achieving ≥150 mins of moderate activity/week for an 80 kg person [2]; ≥600/week for Met·mins (reflecting ≥150 mins of moderate activity/week); 150 minutes/week for MVPA mins. These thresholds were selected based on public health guidelines [12] and diabetes-specific [13, 14] guidelines for achieving moderate activity of at least 150 mins per week.

Related to the first two methods, in calculating the indirect estimate of weekly energy expenditure, the number of minutes was computed by multiplying the frequency and duration of (i) weekly minutes of moderate physical activity ×4.0 METS and (ii) weekly minutes of vigorous physical activity ×7.5 METS. The weekly minutes for moderate and vigorous were then summed for a total Met score. One minute of vigorous physical activity is equivalent to 1.875 minutes of moderate activity (7.5/4.0) based on the average Met levels for vigorous activity (Met level = 7.5) and moderate activity (Met level = 4.0) set by Brown and Bauman [2] and employed in the original paper of the ALEXANDRA study [8]. This weighting provides more credit for participating in vigorous activity. Individuals who accumulated ≥600 Met-minutes per week (Method Two) were classified as "adequately active for health benefit" while those who did not were classified as "inadequately active" [2]. This criterion reflects achieving 150 minutes of moderate activity [4.0 Mets] or 80 minutes of vigorous [7.5 Mets] activity per week, or any combination thereof [2].

2.3. Statistical Analysis. Using only baseline data, for each physical activity assessment method, one-way analysis of variance (ANOVA; with BMI as the independent variable)

Table 2: Means and one-way ANOVA results for each of the three methods of assessment.

BMI	N	Kcal			Met·mins			MVPA mins		
		Mean	SD	(n)	Mean	SD	(n)	Mean	SD	(n)
<25	341	746.5	2051.4	(99)	853.6	1516.5	(135)	172.0	243.9	(115)
25–<30	570	798.2	1675.6	(170)	767.7	1221.4	(208)	158.3	231.7	(181)
≥30	704	650.4	1450.1	(175)	557.4	928.1	(182)	112.7	165.7	(156)
		$F = 1.3$; $P = .28$			$F = 9.0$; $P < .001$			$F = 12.2$; $P < .001$		

Table 3: Proportion of adults classified as "sufficiently" active based on the three methods stratified by BMI.

BMI	N	Sufficiently active based on Kcal n (%)	Sufficiently active based on Met·mins n (%)	Sufficiently active based on MVPA mins n (%)
<25	341	99 (29.0)	135 (39.6)	115 (33.7)
25–<30	570	170 (29.8)	208 (36.5)	181 (31.8)
≥30	704	175 (24.9)	182 (25.9)	156 (22.2)
		$\chi^2(2) = 4.4$	$\chi^2(2) = 26.1^*$	$\chi^2(2) = 21.4^*$

*Significantly different ($P < .001$)

was used to examine whether physical activity (as a continuous variable) varied significantly across normal weight (BMI < 25.0), overweight (BMI 25.0–<30.0), or obese (BMI ≥ 30.0) categories. Chi-square tests were conducted to examine differences in the proportion of participants classified as "sufficiently" active across body weight status categories. The Kappa statistic was employed to examine agreement between the three methods, and effect sizes using Cohen's h [15] were reported to assess the magnitude of differences between the methods.

Considering that the mean age of the study sample was ~63 years, a sensitivity analysis was also conducted with Met·mins set at the lower cutoff (i.e., weekly minutes of moderate physical activity ×3.0 METS and weekly minutes of vigorous physical activity ×6.0 METS to calculate total Met·mins). ANOVAS and chi-square analyses described above were repeated using this new Met·min variable.

3. Results

When examining physical activity levels for each method, ANOVA analyses revealed significant (P's < .001) differences for Met·mins and MVPA mins but total physical activity did not vary across BMI categories using the estimated kilocalories method (see Table 2). Chi-square analyses also revealed significant (P's < .001) differences in the proportion of those classified as sufficiently active for Met·mins and MVPA mins methods but not for the kilocalories method (see Table 3). Further, it is noteworthy that the obese group generally had similar proportions that were sufficiently active, regardless of the physical activity measure (see Table 3).

Estimates for those meeting "sufficient activity" guidelines for each method across BMI categories are shown in Tables 4(a), 4(b), and 4(c). In terms of relative comparisons, the Met·mins method was consistently higher for all weight categories. The largest proportion was found for the normal weight category in the Met·mins methods (39.6%) and the smallest for the obese category in the MVPA mins method (22.2%). The magnitudes of the differences were the greatest when comparing the Met·mins and MVPA mins methods, with effect sizes ranging from .03 to .22. The discordance between the Kcal and the MVPA mins methods was moderately lower than that between the Met·mins and Kcal methods (effects sizes from .09 to .12) and the lowest for the Kcal and the MVPA mins methods (.05 to .10).

The sensitivity tests (ANOVA's and chi-square analyses) revealed significant differences for Met·mins ($F = 8.6$; $P < .001$; $\chi^2 = 29.2$) but not for estimated Kcals ($F = 1.2$; $P = .31$; $\chi^2 = 4.4$; $P = .11$). Kappa values across the three respective BMI categories (<25, 25–30, and ≥30) for the three methods were .90, .92, and .76 for the Kcal and Met·mins methods; 0.90, 0.89, and 0.85 for the MVPA mins and Met·mins methods; 0.81, 0.92, and 0.86 for the MVPA mins and Kcal methods.

4. Discussion

The objective of this study was to test the difference between three methods in estimating the prevalence of "sufficient activity" among Canadian adults with type 2 diabetes in a large sample, while considering the role of weight status as a potential confounder. In addition to the unique population, our study expands on the Brown and Bauman [2] methodology by including a third measure of physical activity (MVPA mins) in addition to kilocalories and Met·minutes scores in comparing physical activity prevalence.

Overall, our results for all methods are generally in agreement with previous prevalence estimates of physical activity which show that approximately 60–70% of adults with type 2 diabetes are not "sufficiently active" [3–7, 9]. However, our results suggest that estimates of physical activity levels vary by BMI categories, depending on the methods examined. Upon further comparison of methods considered appropriate for estimating physical activity, we suggest that

Table 4

(a) Comparison of agreement between Kcal method and Met·mins method across BMI categories.

Body mass index	Met·mins <25		Met·mins 25–30		Met·mins ≥30	
	Inactive n (%)	Active n (%)	Inactive n (%)	Active n (%)	Inactive n (%)	Active n (%)
Kcal						
Inactive	206 (60.4)	36 (10.6)	361 (63.3)	39 (6.8)	506 (71.9)	23 (3.3)
Active	0 (0)	99 (29.0)	1 (0.1)	169 (29.7)	16 (2.2)	159 (22.6)
	Kappa = 0.77 (n = 341)		Kappa = 0.84 (n = 570)		Kappa = 0.85 (n = 704)	
	ES = 0.12		ES = 0.10		ES = 0.09	

(b) Comparison of agreement between Kcal method and MVPA mins method across BMI categories.

Body mass index	MVPA mins <25		MVPA mins 25–30		MVPA mins ≥30	
	Inactive n (%)	Active n (%)	Inactive n (%)	Active n (%)	Inactive n (%)	Active n (%)
Kcal						
Inactive	220 (64.5)	22(6.5)	385 (67.5)	15 (2.6)	521(74.0)	8 (1.1)
Active	6 (1.8)	93 (27.3)	4 (0.7)	166 (29.1)	27 (3.8)	148 (21.0)
	Kappa = 0.81 (n = 341)		Kappa = 0.92 (n = 570)		Kappa = 0.86 (n = 704)	
	ES = 0.10		ES = 0.05		ES = 0.06	

(c) Comparison of agreement between MVPA mins method and Met·mins method across BMI categories.

Body mass index	Met·mins <25		Met·mins 25–30		Met·mins ≥30	
	Inactive n (%)	Active n (%)	Inactive n (%)	Active n (%)	Inactive n (%)	Active n (%)
MVPA mins						
Inactive	206 (60.4)	20 (5.9)	362 (63.5)	27 (4.7)	522 (74.1)	26 (3.7)
Active	0 (0)	115 (33.7)	0 (0)	181 (31.8)	0 (0)	156 (22.2)
	Kappa = 0.87 (n = 341)		Kappa = 0.90 (n = 570)		Kappa = 0.90 (n = 704)	
	ES = 0.22		ES = 0.15		ES = 0.03	

the Met·mins method may be more appropriate even though it may categorize a larger proportion as sufficiently active relative to the other methods when stratifying by weight status.

When comparing the difference between the methods, we found the magnitude to be small (i.e., .03 to .22) according to Cohen's definition [15]: there were nonetheless differences worthy of comment. Most notably, the largest effect sizes were found between the MVPA mins and the Met·mins methods suggesting higher discordance between these methods. Overall, when classifying individuals as "sufficiently active" the magnitude of the differences between the methods appears to be consistent regardless of the stratification by weight status but the magnitude of difference appears to be lower for the Met·mins method. Although this difference may seem statistically trivial, the impact of such differences at a population level may be profound.

It is noteworthy (see Table 3) that although physical activity levels were lower in the obese, their energy expenditure estimates were similar with those who were overweight or of a healthy weight. This finding supports existing evidence indicating that the energy cost of physical activity is greater in the obese [16]. Further, it is acknowledged that physical activity energy expenditure is important for weight maintenance and that weight maintenance is problematic because physical activity levels are low among this population. Consequently, because energy expenditure estimates at a population level are not always considered with physical activity surveillance, taking into account physical activity energy expenditure may be important in the obese population.

This study is not without caveats. First, our data were based on self-reported physical activity and may reflect a population who are more highly active and with lower body weights status. Second, the somewhat broad use of metabolic equivalents (MET) for estimating energy expenditure is imprecise as it should incorporate resting metabolic rate to more accurately gauge energy expenditure on an individual level. Third, since there is no established "gold standard" for self-reported physical activity, the addition of an objective measure (i.e., accelerometer) would have provided stronger support for our argument for the use of the Met·mins method when assessing physical activity in this population. Finally, future studies on this topic should examine physical activity change scores in longitudinal designs.

5. Conclusions

The implications of our study are that biased estimates of physical activity at a population level may result in inappropriate classification of adults with type 2 diabetes as "sufficiently active" and that the inclusion of a weight-dependent estimate (i.e., Kcal method) of physical activity prevalence should be approached with caution as 80% of individuals with type 2 diabetes are overweight or obese [17]. If a weight-dependent estimate of physical activity is used however, an estimate of weight stability should be included within the temporal reference with which physical activity behaviors are collected.

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