Incidental Physical Activity Is Positively Associated with Cardiorespiratory Fitness

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ABSTRACT

ROSS, R., and K. A. MCGUIRE. Incidental Physical Activity Is Positively Associated with Cardiorespiratory Fitness. *Med. Sci. Sports Exerc.*, Vol. 43, No. 11, pp. 2189–2194, 2011. **Purpose**: The primary aim was to determine whether incidental physical activity (IPA), expressed either as duration or intensity, was associated with cardiorespiratory fitness (CRF). **Methods**: Participants were inactive abdominally obese men (n = 43, waist circumference ≥ 102 cm) and women (n = 92, waist circumference ≥ 88 cm) recruited from Kingston, Canada. IPA (>100 counts per minute) was determined by accelerometry during 7 d and categorized into duration (min·d^{-1}) and intensity (counts per minute). In secondary analyses, IPA was further categorized as light physical activity (LPA, 100–1951 counts per minute) and sporadic moderate physical activity (MPA, ≥1952 counts per minute accumulated in bouts <10 consecutive minutes). CRF was assessed using a maximal treadmill exercise test. **Results**: Participants accumulated 308.2 ± 98.8 (mean ± SD) min of IPA per day of which 19.2 ± 13.5 min was spent in sporadic MPA. Mean CRF was 26.8 ± 4.7 mL·kg^{-1} body weight·min^{-1}. IPA duration was positively associated with CRF in the univariate model (r^2 = 0.03, P < 0.05) and after control for gender and body mass index (r^2 = 0.53, P < 0.01). Likewise, IPA intensity was positively associated with CRF in univariate (r^2 = 0.18, P < 0.001) and multivariate analyses (r^2 = 0.56, P < 0.01). After further control for each other, IPA duration was not associated with CRF (P = 0.05), whereas IPA intensity remained a significant predictor (r^2 = 0.57, P < 0.001). In secondary analyses, LPA was not associated with CRF (P > 0.05). Sporadic MPA was associated with CRF (r^2 = 0.20, P < 0.001) and remained a positive correlate after control for gender, body mass index, and the other physical activity variables (r^2 = 0.60, P < 0.001). **Conclusions**: In this study, both duration and intensity of IPA were positively associated with CRF among inactive abdominally obese adults. Sporadic MPA, but not LPA, was an independent predictor of CRF.

Key Words: HABITUAL ACTIVITY, RISK FACTORS, MORTALITY, MORBIDITY

Unequivocal evidence demonstrates that moderate or high levels of cardiorespiratory fitness (CRF) are associated with a reduced risk of cardiovascular disease and all-cause mortality independent of other risk factors (14). One of the primary determinants of CRF is habitual physical activity (15,17). Current guidelines suggest that physical activity must be performed at a minimum level of 40%–50% of HR reserve or 64%–70% of maximal HR (i.e., moderate-to-vigorous physical activity) and accumulated in bouts of at least 10 min in duration to elicit improvement in CRF (25). This infers that, with respect to CRF, the benefits of physical activity do not occur along a continuum and that physical activity performed below the designated threshold would not influence CRF. This notion is supported by self-report questionnaires demonstrating that light physical activity (LPA, physical activity performed at 20%–39% of HR reserve or 50%–63% of maximal HR [25]) is not independently associated with CRF (18). However, by design, self-report measurement tools are prone to various forms of bias, such as recall or social desirability bias, and typically do not capture nonbouted and incidental or nonpurposeful daily activity (23,26). Thus, the association between objectively measured incidental physical activity (IPA, i.e., nonpurposeful physical activity accrued through activities of daily living) and CRF remains to be determined. Demonstration that IPA alone is sufficient to improve CRF would reinforce the notion that all physical activity is beneficial regardless of the intensity and pattern in which it is accumulated and, thus, would have important clinical and public health implications.

Accelerometry provides an objective measure of daily physical activity patterning and overcomes many of the limitations inherent to self-report questionnaires. Thus, we sought to determine whether the duration and intensity of objectively measured IPA were associated with CRF. Secondary analyses examined the associations between LPA, moderate physical activity (MPA), and CRF. We explored these associations in a sample of abdominally obese men and women who by consensus guidelines (3,27) were defined as inactive and failed to accumulate physical activity in a pattern thought to improve CRF. This sample of inactive abdominally obese adults represents over 60% of the North American population (4,8,10,12) who are at substantially increased health risk.

METHODS

Participants. Participants for this study were men and women age 35–65 yr who were inactive, did not smoke, had an elevated waist circumference (defined as

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at least 102 cm in men and at least 88 cm in women), and a body mass index (BMI) between 25.0 and 39.9 kg·m^{-2}. Participants were recruited for participation in an exercise intervention (MCT190617). The exclusion criteria included any physical impairment that would make physical activity difficult or unsafe according to the participant's physician (history of myocardial infarction, stroke, coronary bypass surgery or angioplasty in the last 6 months, peripheral artery disease, unstable angina or ischemia), if they had diabetes or were taking glucose-lowering medication, and if they consumed >21 alcoholic drinks per week. The study was approved by the Queen's University Health Sciences Research Ethics Board. All participants received medical clearance from their personal physician and gave written informed consent before participation in the study.

Anthropometry. Body mass and height were measured to the nearest 0.1 cm and 0.1 kg, respectively, with participants dressed in standard T-shirts and shorts. These measures were used to calculate BMI (kg·m^{-2}). Waist circumference was obtained in a standing position using the mean of two measures acquired at the superior edge of the iliac crest measured to the nearest 0.1 cm.

CRF. CRF measured as oxygen consumption per unit of time (peak $\dot{V}O_2$) was determined using a maximal treadmill test combined with standard open-circuit spirometry techniques (SensorMedics Corp., Yorba Linda, CA). The relative value of maximal oxygen consumption (mL·kg^{-1} body weight·min^{-1}) was used in all analyses. CRF values were classified on the basis of gender- and age-specific standards (19).

Physical activity. Physical activity was measured with the ActiGraph GT3X accelerometer (ActiGraph, Pensacola, FL). Accelerometers were programmed to collect data in 1-min epochs during a 7-d period and were worn on an elastic belt positioned over the right hip at all times except during water-based activities. In addition, participants completed a log sheet indicating when they went to bed at night, woke up in the morning, and removed the accelerometer.

To be included in the analysis, participants were required to wear the accelerometer for at least four complete days (including one weekend day) within the monitoring period. A complete day was defined as at least 10 h of wear time during the day. Wear time was calculated after extended periods of consecutive zero counts ≥60 min and sleep time (determined using both the participant logs and visual examination of the data) were excluded. Twenty participants either did not meet the compliance criteria for accelerometer wear time or were missing data. Therefore, a total of 135 participants (43 men and 92 women) were used in the analyses.

The accelerometer cut points in this study used to translate the "count" value into an estimate of physical activity intensity were those developed by Freedson et al. (9). IPA was defined as ≥100 counts per minute (cpm), LPA was defined as 100–1951 cpm, moderate physical activity (MPA) was defined as 1952–5724 cpm, and vigorous physical activity was defined as ≥5725. Ninety-two percent of the participants in this study did not accumulate any vigorous physical activity. Of those who did, <5 min was accrued per person during the entire wear period. Therefore, all physical activity ≥1952 cpm was defined as MPA. Activity accumulated during each complete day of monitoring was quantified as 1) average duration, in minutes per day (min·d^{-1}), of each IPA, LPA, and MPA; 2) average intensity, in cpm, of IPA, LPA, and MPA; 3) average minutes of sporadic MPA per day (accumulated in <10 consecutive minutes); and 4) average minutes of MPA per day accumulated in bouts (≥10 consecutive minutes in duration). This duration is consistent with recommendations suggesting that MPA should be accumulated in bouts of 10 minutes or more for health/fitness benefit (13,22,25). Because periods of rest are common during activity (e.g., waiting for a light to change color at a crosswalk during a run), participants were required to spend at least 80% of the bouts above the threshold value for the bout to be counted. For example, in a 10-min bout of MPA, only eight of those minutes would need to fall at or above 1952 cpm. Thirty-seven participants did not accrue any bouted MPA. In the remaining participants, less than one bout of MPA per day was accumulated; therefore, all MPA was classified as sporadic.

Statistical analyses. Descriptive characteristics are summarized as mean values ± SD. All physical activity variables except IPA intensity were logarithmically transformed because of skewed distributions. Gender differences in descriptive characteristics and physical activity variables were determined using independent Student's *t*-tests. Gender differences in the relationship between physical activity and CRF were tested by adding the interaction terms to the regression models. No differences were detected; therefore, analyses were collapsed across gender. To assess the primary objective, the association between the duration and intensity of IPA and CRF, the following linear regression models were used: 1) unadjusted; 2) control for time accelerometer was worn and gender; 3) control for time accelerometer was worn, gender, and BMI; and 4) control for time accelerometer was worn, gender, BMI, and each other. To assess the secondary objective, the association between LPA, MPA, and CRF, the same models outlined above were used with the following exception: in model 4, covariates entered were time was accelerometer worn, gender, BMI, and each other. Only the covariates that significantly influenced the regression models were retained. Results from the regression analyses are summarized as unstandardized β values (95% confidence intervals).

Participants were then divided into tertiles according to sporadic MPA accumulation, and CRF scores were converted to MET (1 MET is the energy cost of resting quietly and is defined as an oxygen uptake of 3.5 mL·kg^{-1}·min^{-1} [1]). A univariate ANCOVA was used to identify differences between groups after controlling for gender, BMI, and MPA intensity. Tertile 1, the group with the lowest

TABLE 1. Participant characteristics.

Variable	Men (n = 43)	Women (n = 92)	Total (n = 135)
Age (yr)	54.3 ± 8.3	52.5 ± 7.3	53.1 ± 7.6
BMI (kg·m^{-2})	32.9 ± 3.4	32.9 ± 5.0	32.9 ± 4.6
Waist circumference (cm)	115.9 ± 8.5	107.3 ± 11.3**	11.0 ± 11.2
CRF (mL·kg^{-1} body weight·min^{-1})	31.0 ± 3.9	24.9 ± 3.8**	26.8 ± 4.7
Physical activity (accelerometry)			
Daytime wear hours (min·d^{-1})	970.9 ± 127.9	940.2 ± 88.1	950.0 ± 103.0
IPA duration (min·d^{-1})	306.5 ± 129.6	309.0 ± 81.4	308.2 ± 98.8
IPA intensity (cpm)	736.5 ± 143.7	660.8 ± 128.9	684.9 ± 137.9
LPA duration (min·d^{-1})	282.6 ± 117.5	292.0 ± 77.4	289.0 ± 91.7
LPA intensity (cpm)	556.4 ± 78.9	531.7 ± 73.9	539.6 ± 76.1
MPA duration (min·d^{-1})	23.9 ± 17.4	17.0 ± 10.6*	19.2 ± 13.5
MPA intensity (cpm)	2886.7 ± 353.5	2765.5 ± 374.1	2804.1 ± 370.6

Data are means ± SD.
Significant difference between sexes: * $P < 0.01$, ** $P < 0.001$.

accumulation of daily MPA, was used as the referent group.

Significance was set at $P < 0.05$ for main effects and at $P < 0.1$ for interaction. All statistical analyses were performed using SPSS 18.0 software (SPSS, Chicago, IL).

RESULTS

Participant characteristics are shown in Table 1. Women had lower levels of CRF and participated in fewer minutes of MPA than men ($P < 0.01$). Approximately 5 h of IPA, which consisted primarily of LPA (i.e., 94%), were accumulated daily in men and women combined. None of the participants accumulated sufficient physical activity to meet the consensus physical activity guidelines of at least 150 min·wk^{-1} of moderate-to-vigorous physical activity accumulated in bouts of at least 10 consecutive minutes (3,27). Participants achieved CRF values in the low to good range (i.e., 26–35 mL·kg^{-1}·min^{-1} for men and 20–31 mL·kg^{-1}·min^{-1} for women) (19).

As illustrated in Figure 1, IPA duration was significantly associated with CRF (r^2 = 0.03, $P < 0.05$; Table 2) and remained a positive correlate after statistical control for gender and BMI (r^2 = 0.53, $P < 0.01$). Similarly, IPA intensity was positively associated with CRF (r^2 = 0.18, $P < 0.05$) and remained a significant predictor after statistical control for gender and BMI (r^2 = 0.56, $P < 0.01$). After control for each other, there was a trend for significance between IPA duration and CRF (P = 0.05), whereas IPA intensity remained significantly associated (r^2 = 0.57, $P < 0.001$).

As illustrated in Figure 2, LPA was not a significant predictor of CRF ($P > 0.05$). Results remained the same after statistical control for gender, BMI, and MPA ($P > 0.1$; Table 2). MPA was associated with CRF in the univariate analysis (r^2 = 0.23, $P < 0.001$) and remained a significant predictor after control for gender, BMI, and other physical activity variables (r^2 = 0.60, $P < 0.001$).

Participants were then divided into tertiles on the basis of accumulated sporadic MPA, and CRF was converted to MET values (Fig. 3). In addition to accumulating very low levels of MPA, men and women in the referent group (tertile 1) had low CRF values. After control for gender, BMI, and MPA intensity, participants in both tertiles 2 (mean = 16.9 min·d^{-1} of MPA) and 3 (mean = 33.6 min·d^{-1}

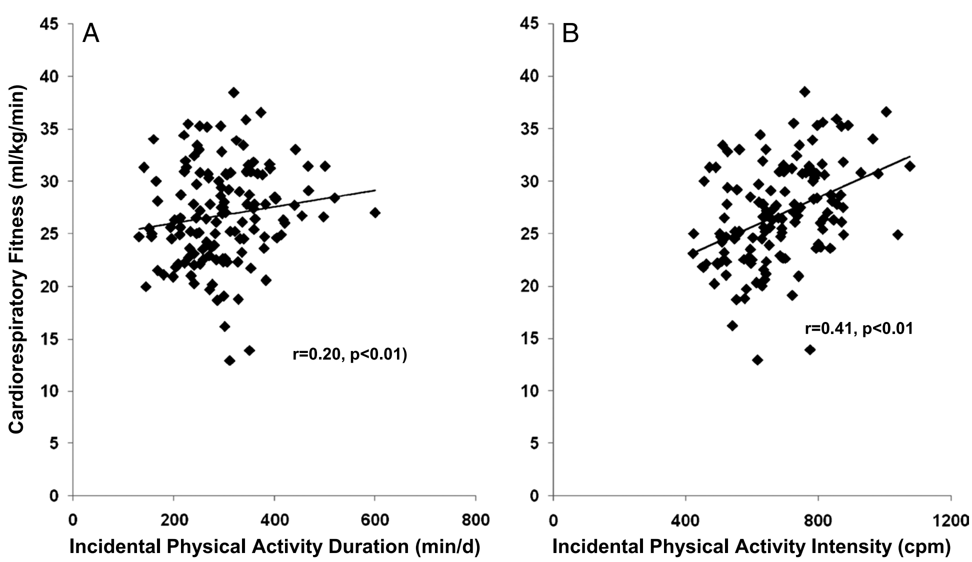

FIGURE 1—Associations between IPA duration (A) and intensity (B) with CRF.

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TABLE 2. Regression analysis of physical activity variables with CRF.

	B	95% CI	*P*	Adjusted R^2
Model 1				
IPA duration (min·d^{-1})	0.31	0.02 to 0.60	0.04	0.03
IPA intensity (cpm)	0.01	0.01 to 0.02	0.001	0.18
LPA duration (min·d^{-1})	0.28	−0.01 to 0.58	0.06	0.02
MPA duration (min·d^{-1})	1.45	0.99 to 1.90	0.001	0.23
Model 2				
IPA duration (min·d^{-1})	0.35	0.12 to 0.57	0.003	0.41
IPA intensity (cpm)	0.01	0.01 to 0.01	0.001	0.45
LPA duration (min·d^{-1})	0.36	0.14 to 0.59	0.002	0.41
MPA duration (min·d^{-1})	1.09	0.71 to 1.47	0.001	0.49
Model 3				
IPA duration (min·d^{-1})	0.30	0.10 to 0.50	0.004	0.53
IPA intensity (cpm)	0.01	0.01 to 0.01	0.001	0.56
LPA duration (min·d^{-1})	0.28	0.08 to 0.49	0.008	0.52
MPA duration (min·d^{-1})	0.99	0.65 to 1.33	0.001	0.60
Model 4				
IPA duration (min·d^{-1})	0.20	−0.00 to 0.40	0.05	0.57
IPA intensity (cpm)	0.01	0.00 to 0.01	0.001	0.57
LPA duration (min·d^{-1})	0.06	−0.15 to 0.27	0.55	0.60
MPA duration (min·d^{-1})	1.36	0.61 to 2.10	0.001	0.60

Model 1: unadjusted.
Model 2: adjusted for gender.
Model 3: adjusted for gender and BMI.
Model 4: adjusted for gender, BMI, and other physical activity variables.
CI, confidence interval.

of MPA) had a higher MET value than those in tertile 1 (mean = 6.2 min·d^{-1} of MPA) ($P < 0.01$). Participants in tertile 3 also had a significantly higher MET value than participants in tertile 2 ($P < 0.05$).

DISCUSSION

The primary finding of this study was that both the duration and intensity of IPA were significantly associated with CRF in this sample of inactive abdominally obese men and women independent of gender and BMI. Given the established association of CRF with morbidity and mortality, these observations have important clinical and public health implications and provide empirical evidence that the positive effects of physical activity on CRF occur along a continuum.

To our knowledge, this is the first study to assess the association between objectively measured IPA and CRF. Our findings counter the notion that to improve CRF, physical activity must be accumulated at a minimum threshold of 40%–50% of HR reserve or 64%–70% of maximal HR and accumulated in bouts of at least 10 consecutive minutes (25). To the contrary, our results indicate that nonpurposeful activity accrued sporadically throughout the day is associated with higher CRF. Although we also found that IPA intensity was a stronger predictor of CRF than IPA duration, the average IPA intensity was low. The average accelerometer count values we observed (i.e., 100–1951) are associated with walking at a slow, leisurely pace (i.e., <5.0 km·h^{-1}). Moreover, even the physical activity accumulated sporadically because MPA was equivalent to walking at a comfortable pace (i.e., 5.8 km·h^{-1}). These results are encouraging and provide options that may be more feasible and enjoyable for inactive individuals attempting to engage in physical activity for health benefit.

It is important to note that although IPA was significantly associated with CRF, this observation was driven in large part by the sporadically obtained MPA and not LPA. Stated differently, despite the accumulation of approximately 5 h of LPA, the differences in CRF were due to the participation in 20 min of MPA. This is consistent with previous literature demonstrating that physical activity intensity is positively associated with CRF (21).

Previous studies have reported a relationship between bouted MPA and CRF (5,6,20); however, this is the first study to specifically examine the association between sporadic MPA and CRF. This was made possible with the use of accelerometers, objective measurement tools that provide minute-by-minute recording of physical activity thereby

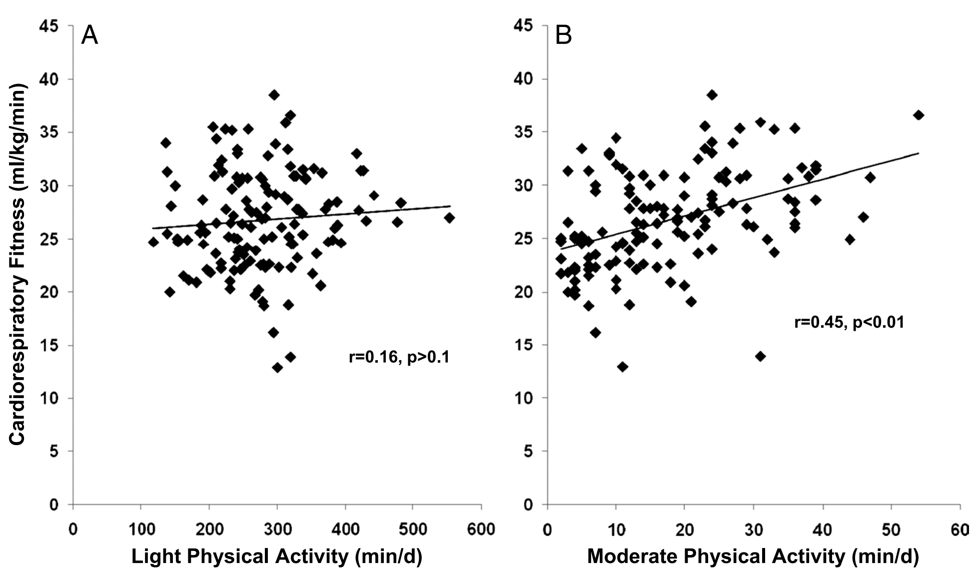

FIGURE 2—Associations between LPA (A) and MPA (B) with CRF.

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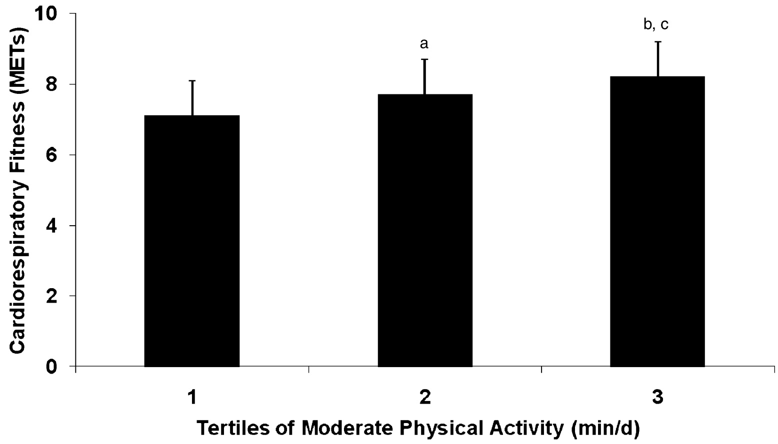

Variable	1	2	3
N	45	45	45
M/F	14/31	15/30	14/31
MPA Duration (min/d)	6.7 (2.9)	17.3 (4.0)	33.6 (12.3)
MPA Intensity (cpm)	2612.0 (313.2)	2816.4 (337.7)	2983.9 (367.9)
CRF (METs)	7.1 (1.4)	7.7 (1.2)	8.2 (1.3)
CRF (ml/kg/min)	25.2 (4.5)	27.0 (4.2)	29.0 (3.9)

FIGURE 3—Tertiles of MPA and CRF with corresponding participant characteristics for each tertile. [a]represents a Significantly different than tertile 1 (p = 0.004). [b]Represents a significantly different than tertile 1 (P < 0.001). [c]Significantly different than tertile 2 (P = 0.04).

overcoming the limitations inherent to self-report questionnaires and allowing for a detailed examination of physical activity patterns (7). It is noteworthy that although sporadic MPA was a significant predictor of CRF, most participants in this study achieved peak CRF values in the lower end of the CRF spectrum (19). Thus, although sporadic MPA is associated with higher CRF in inactive individuals, it is doubtlessly true that a much greater difference would be observed in individuals accumulating bouted MPA and/or vigorous physical activity. For example, men and women age 50–59 yr who regularly perform bouted or structured moderate-to-vigorous physical activity may have CRF values >11 and >9 METs, respectively (19), which are approximately 2 METs higher than the average MET values observed in this study.

A 1-MET increase in CRF is associated with a 13% and 15% reduction in all-cause mortality and cardiovascular disease, respectively (14). This suggests that the 0.5-MET difference in CRF between individuals in the middle tertile compared with the lowest tertile may be associated with a decreased risk of 6.5% for all-cause mortality and 7.5% for cardiovascular disease. This is a substantial reduction in risk for only a 10-min increase in sporadic MPA. Further, the 1.0-MET (~3.5 $mL \cdot kg^{-1}$ body $weight \cdot min^{-1}$) difference in CRF between individuals in the highest tertile of MPA compared with the lowest tertile may be associated with a risk reduction of 13% in all-cause mortality and 15% in cardiovascular disease. Stated differently, in our study, a 30-min increase in the accumulation of sporadic MPA was associated with a 1.0-MET increase in CRF and, potentially, a significant risk reduction in morbidity and mortality.

It is important to note that despite the daily accumulation of approximately 5 h of IPA, all of the participants in the current study were abdominally obese and therefore thought to be at increased health risk as compared with individuals without abdominal obesity (11). Nevertheless, previous research has demonstrated that in individuals presenting with obesity, those who have higher CRF are at a substantially decreased risk of morbidity and mortality compared with those with low CRF (2,24). In men with elevated abdominal obesity and moderate to high levels of CRF (~9–10 METs), the risk of all-cause mortality was no different than lean men with high CRF (16). By comparison, the men in our study who were in the highest tertile of MPA had a similar average CRF (~9 METs) (17).

The current study was cross-sectional and conducted in a sample relatively homogenous in terms of abdominal obesity and physical activity levels (10,13). However, given that a large percentage of the North American population both is abdominally obese (12) and does not meet consensus physical activity recommendations (10), our results are relevant to a large proportion of the general population.

In summary, the duration and intensity of IPA is positively associated with CRF suggesting that all forms of physical activity carry a health benefit and that the need to target thresholds of physical activity to improve CRF may not be required. Health care providers are encouraged to promote all forms of physical activity to improve CRF, an established risk factor of morbidity and mortality (14). Further studies are required to determine whether the associations found in the present investigation hold true in a more heterogeneous sample (i.e., in individuals of different ethnicity or phenotype) and whether IPA is associated with corresponding improvement in cardiometabolic risk factors.

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The authors have no relevant conflict of interest to disclose. K.A.M. performed data acquisition and data analysis and interpretation, and was a significant article writer. R.R. contributed the concept and design, and was a significant article reviewer/reviser.

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