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ARTICLE

ActiGraph GT3X cut-points in coronary artery disease patients: A pilot study

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Abstract

Objectives: The purpose was to establish uniaxial and triaxial accelerometer cut-points denoting moderate and vigorous intensity physical activity (PA) among coronary artery disease patients based on relative exercise intensity. *Methods:* Eighteen coronary artery disease patients (Age: 58 ± 11 yr) wore an ActiGraph GT3X accelerometer during a cardiac stress test. Exercise intensity was measured at each stage. Receiver operator characteristic curve analyses were used to establish cut-points. *Results:* Uniaxial count ranges of 750-2299 and ≥2300 counts·min^{-1} were found to best identify moderate and vigorous intensity PA, respectively. Triaxial count ranges of 1800-3799 and ≥3800 counts·min^{-1} were found to best identify moderate and vigorous intensity PA, respectively. Cut-points were found to be lower than those for both middle-aged and older adults. *Conclusion:* Cut-points specific to coronary artery disease patients should be used rather than generic points established for healthy middle-aged and older adults. **Health & Fitness Journal of Canada 2015;8(2):13-21.**

Keywords: Coronary Artery Disease, Motor Activity, Acceleration, Physical Fitness, Cardiac Rehabilitation

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Introduction

Regular physical activity (PA) is an important determinant of cardiometabolic fitness in coronary artery disease patients. A graded, inverse relationship exists such that higher levels of PA (Nocon et al., 2008) and greater cardiorespiratory fitness (Sawada et al., 2012) are associated with a lower risk of all-cause mortality and rates of heart disease-related events (Warburton et al., 2006). Accurate measurement of PA is necessary to effectively monitor PA patterns in populations, assess relations between PA intensity and future disease, and for measuring the effectiveness of PA interventions (Prince et al., 2008).

Accelerometers provide a continuous measure of movement to generate a "count"; with larger counts indicative of higher PA intensities. To date, cut-points to differentiate PA intensities have largely been established using non-diseased populations (Freedson et al., 1998; Santos-Lozano et al., 2013; Sasaki et al., 2011). Cut-points have been shown to differ based on cardiorespiratory fitness levels (Ozemek et al., 2013) suggesting that cut-points developed in non-diseased, high-functional individuals are likely to result in misclassification of intensity levels for coronary artery disease patients who present with lower exercise capabilities (Ekelund et al., 2002).

The functional capacity of coronary artery disease patients may be reduced as a result of decreased maximal stroke volume and heart rate, detraining from self-induced and medically advised PA restrictions, and diminished exercise capacity from medications altering heart rate response (Ekelund et al., 2002). For example, a low functional capacity coronary artery disease patient may have a *maximal* exercise capacity of 5 metabolic equivalents (METs), which is considered moderate intensity PA for a healthy individual. Correspondingly, for individuals with reduced and varying functional capacity relative exercise intensity based cut-points provides an advantage over absolute exercise intensity cut-points by accounting for the differences in exercise capacity. Thresholds specific to the coronary artery disease population are needed to allow researchers to accurately analyze PA using accelerometers. Therefore, the objective of this study was to suggest uniaxial and triaxial count cut-points for the ActiGraph GT3X in order to differentiate between PA intensities (light, moderate, vigorous) in coronary artery disease patients.

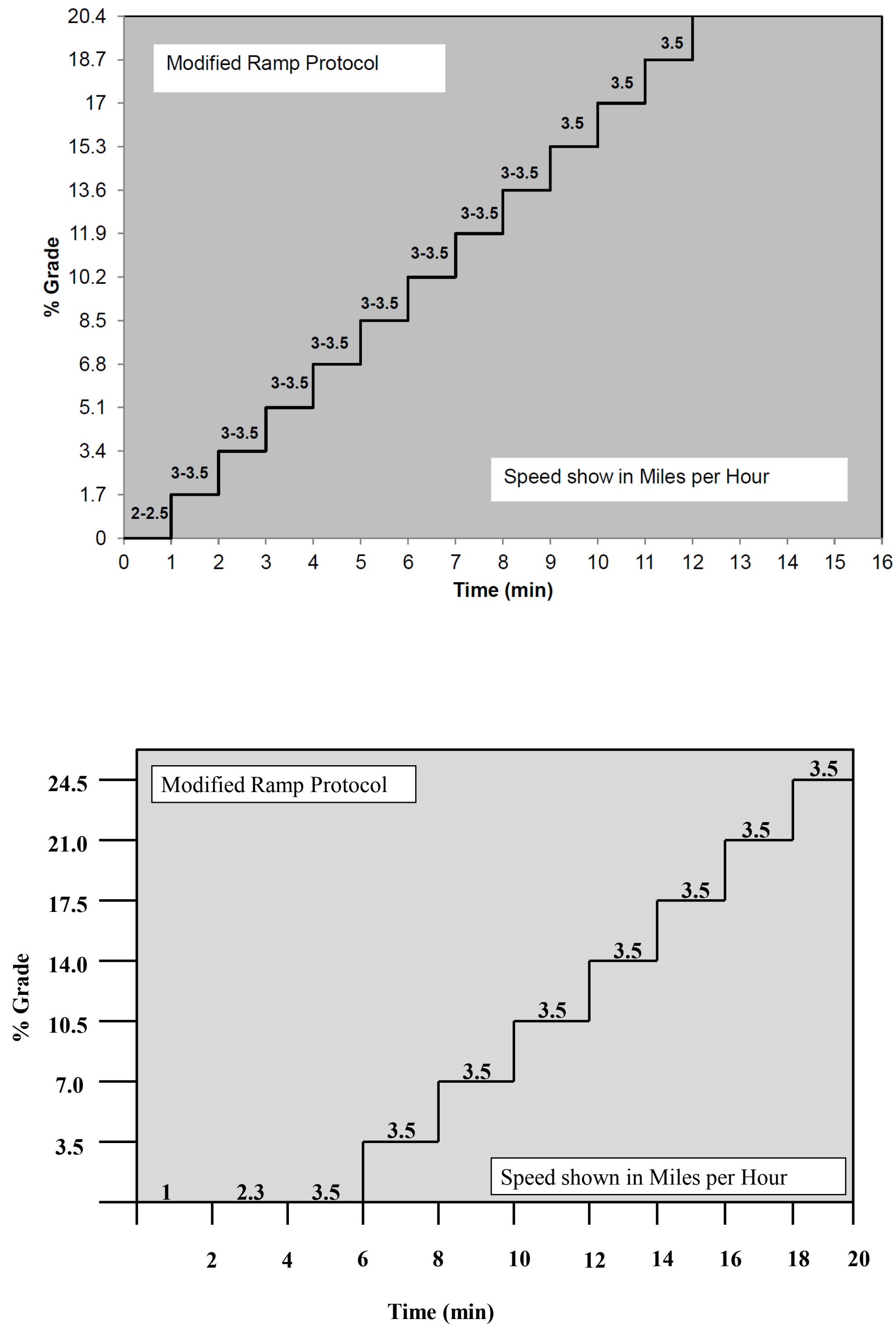
Methods

This study was conducted at [and approved by the Human Research Ethics Board; Protocol #'s: 2011139-01H, 20130276-01H] the University of Ottawa Heart Institute. Eligible patients had a documented diagnosis of coronary artery disease, were ≥18 years and had an exercise stress test ordered as part of their routine care. Exclusion criteria included patients with New York Heart Association class III or IV heart failure, or contraindications to exercise testing. A convenience sample of coronary artery disease patients was recruited from the cardiac rehabilitation population at the UOHI. All cardiac rehabilitation patients were screened for eligibility.

The ActiGraph GT3X accelerometer was used to establish light, moderate and vigorous intensity counts-per-minute for uniaxial and triaxial cut-points in coronary artery disease patients. ActiGraphs are the most widely used and extensively validated devices of their kind (www.actigraphcorp.com/). Vector magnitude (VM) was used to calculate triaxial counts as it provides a composite measure of all three axes ($VM = \sqrt{(x^2 + y^2 + z^2)}$). Counts-per-minute were calculated and compared to the corresponding relative exercise intensity (light: 0-44% $\dot{V}O_2$peak, moderate: 45-59% $\dot{V}O_2$peak, vigorous: ≥60% $\dot{V}O_2$peak) determined using a progressive treadmill exercise test; the same testing recommended for exercise prescription for cardiovascular rehabilitation (Mezzani et al., 2013).

Each participant completed a standard ramp treadmill graded exercise stress test. The modified ramp treadmill protocol had a predetermined speed and/or elevation increase every 1-2 minutes, as detailed in Figure 1, to allow for an increase in intensity of one metabolic equivalent (MET). For the one minute protocol participants started at either 2 or 2.5 mph on the treadmill, depending on functional capacity. The speed increased to either 3 or 3.5 mph for second stage and remained at that speed for the remainder of the test. The two protocols had identical overall increases in intensity. All participants continued until maximal effort was achieved (American College of Sports Medicine, 2013). To assemble the largest dataset possible, we combined data from two studies, which employed slightly different ramp protocols (one increased every minute, the other every 2 min). Exercise intensity was assessed at each stage of the test by oxygen uptake ($\dot{V}O_2$) using a metabolic cart (VMAX, Viasys Respiratory Health Inc., Yorba Linda, CA) with relative exercise intensity calculated by dividing ramp protocol stage $\dot{V}O_2$ by $\dot{V}O_{2peak}$).

Figure 1: Modified ramp protocols.



A mixed model (PROC MIXED) approach was used to model the relationship between counts-per-minute and relative exercise intensity to determine cut-points for light, moderate and vigorous intensity PA accounting for repeated measures within participants. Inclusion of covariates (e.g., age, BMI) did not improve the model fit. ROC curves using cut-points from the mixed models were used to optimize the sensitivity and specificity to determine the best threshold to predict moderate and vigorous intensity PA in this population. When two cut-points yielded the same error rate, the cut-point that maximized sensitivity (true positive rate) was selected. Analyses were completed using SAS version 9.2 (SAS, Cary, NC).

Results

A convenience sample of 18 coronary artery disease patients (17 males, 45-80 years, mean ± SD = BMI: 28.4 ± 5.6 kg·m^{-2}; resting blood pressure: 117 ± 15/69 ± 10 mm Hg) completed the study. One patient had low functional capacity (peak $\dot{V}O_2$ <16 ml·kg^{-1}·min^{-1}), one had moderate functional capacity (peak $\dot{V}O_2$ 16 to 21 mL·kg^{-1}·min^{-1}) while the remaining 16 patients had high functional capacity (peak $\dot{V}O_2$ ≥22 mL·kg^{-1}·min^{-1}) (Patterson et al., 1972). Peak $\dot{V}O_2$ ranged from 11.4 to 41.5 mL·kg^{-1}·min^{-1}. The progressive treadmill exercise tests continued until volitional fatigue. Medication information was not available for participants.

Table 1: Patient characteristics (n = 18).

Characteristic	
Age (year)	58.3 (10.7)
Sex (% male)	94.4
Weight (kg)	87.0 (16.1)
Height (cm)	173.8 (6.8)
BMI (kg·m^{-2})	28.4 (5.6)
Waist Circumference (cm)	100.2 (16.1)
Resting Heart Rate (bpm)	63.8 (12.3)
Systolic Blood Pressure (mmHg)	117.7 (14.7)
Diastolic Blood Pressure (mmHg)	69.4 (10.3)
Peak $\dot{V}O_2$ (mL·kg^{-1}·min^{-1})	29.3 (7.4)

Values are shown as mean (standard deviation) unless otherwise noted

The uniaxial formula from the mixed model analysis equation using the relative exercise intensity was:

$$\%\boldsymbol{Max} = \mathbf{0.2376} + \mathbf{0.00017} \cdot (\boldsymbol{counts} \cdot \mathbf{60}\boldsymbol{s}^{-1})$$

Uniaxial cut-points of 1249 and 2132 counts·min^{-1} were calculated to differentiate between moderate and vigorous intensity PA, respectively. Cut-points of 750 and 2300 counts·min^{-1} were found to better predict moderate and vigorous intensity PA, respectively, using ROC analysis (Table 2).

The triaxial formula from the mixed model analysis equation using the relative exercise intensity was:

$$\%\boldsymbol{Max} = -\mathbf{0.00123} + \mathbf{0.000171} \cdot (\boldsymbol{counts} \cdot \mathbf{60}\boldsymbol{s}^{-1})$$

Using the equation, triaxial cut-points of 2639 and 3516 counts·min^{-1} were calculated to represent the transition point to moderate and vigorous intensity PA, respectively. The ROC curve analysis identified that cut-points of 1800 and 3800 counts·min^{-1} better predicted moderate and vigorous intensity PA, respectively (Table 3).

Table 2: True positives, true negatives, false positives, false negatives and error rate for each possible uniaxial cut-point considered for moderate and vigorous intensity physical activity.

Accelerometer (counts·min^{-1})	True Positive (N)	True Negative (N)	False Positive (N)	False Negative (N)	Error Rate (%)
Moderate					
1800	10	6	7	11	52.9
1600	10	5	7	12	55.9
1500	12	4	5	13	52.9
1400	13	3	4	14	52.9
1249*	14	2	3	15	52.9
1100	14	2	3	15	52.9
1000	15	2	2	15	50.0
750	16	2	1	15	47.1
Vigorous					
2500	13	6	4	11	44.1
2300	14	6	3	11	41.2
2200	14	6	3	11	41.2
2132*	14	4	3	13	47.1
2000	14	4	3	13	47.1
1900	14	4	3	13	47.1
1800	14	4	3	13	47.1
1700	16	4	1	13	41.2

*cut-point predicted by mixed models analysis.

Table 3: True positives, true negatives, false positives, false negatives and error rate for each possible triaxial cut-point considered for moderate and vigorous intensity physical activity.

Accelerometer (counts·min^{-1})	True Positive (N)	True Negative (N)	False Positive (N)	False Negative (N)	Error Rate (%)
Moderate					
3000	11	10	6	7	38.2
2800	11	9	6	8	41.2
2639*	11	8	6	9	44.1
2400	11	8	6	9	44.1
2200	12	6	5	11	47.1
2000	14	6	11	3	41.2
1800	16	6	11	1	35.3
1600	16	5	12	1	38.2
Vigorous					
4100	10	10	7	7	41.1
4000	10	9	8	7	44.1
3900	12	8	9	5	41.1
3800	14	8	9	3	35.3
3700	14	8	9	3	35.3
3600	15	7	10	2	35.3
3516*	15	6	11	2	38.2
3200	15	5	12	2	41.1

*cut-point predicted by mixed models analysis.

Discussion

The current study sought to establish uniaxial and triaxial cut-points for moderate and vigorous intensity PA using the ActiGraph GT3X accelerometers in high functional capacity coronary artery disease patients. Uniaxial cut-points of 750 and 2300 counts•min^{-1} were found to minimize misclassification of moderate and vigorous intensity PA, respectively. Misclassification of moderate and vigorous intensity PA was minimized using triaxial cut-point of 1800 and 3800 counts·min^{-1}, respectively. Healthy adults have been shown to exhibit higher absolute exercise capacities than coronary artery disease patients ("American College of Sports Medicine position stand. Exercise for patients with coronary artery disease," 1994); therefore accelerometer counts for a given exercise intensity among healthy adults would likely be higher than those observed among coronary artery disease patients, even for high functional capacity coronary artery disease patients. Additionally, coronary artery disease patients may exhibit reduced functional capacity due to lower maximal stroke volume and heart rate, detraining from both self-induced and medically advised restrictions to PA, and reduced exercise capacity if taking medications that alter heart rate responses ("American College of Sports Medicine position stand. Exercise for patients with coronary artery disease," 1994).

Previous work examining energy expenditure in coronary artery disease patients using equations developed in healthy adults determined that the use of such equations is not appropriate for the coronary artery disease population (Ekelund et al., 2002) and supports results from the current study. Both uniaxial and triaxial cut-points for moderate and vigorous intensity PA in this group of coronary artery disease patients were found to be lower than those recommended in healthy adult populations using the ActiGraph (Freedson et al., 1998; Sasaki et al., 2011). The established and widely used uniaxial cut-points of 1952 and 5725 counts·min^{-1} for moderate and vigorous intensity PA, were developed in a healthy population (Freedson et al., 1998), much higher than the uniaxial cut-points suggested by the current investigation. To date, few studies have published triaxial, VM-derived cut-points for the ActiGraph GT3X, but all of these have done so in apparently healthy adult populations. One of the most widely cited was conducted by Sasaki et al. and suggests cut-points of 2690 and 6167 counts·min^{-1} for moderate and vigorous intensity PA, respectively (Sasaki et al., 2011). Santos-Lozano (2013) recently identified cut-points of 3208 and 8565 counts·min^{-1} to define moderate and vigorous intensity PA in adults (40-55 years) (Santos-Lozano et al., 2013). A key methodological difference exists between the current study and those conducted among healthy adults (Santos-Lozano et al., 2013; Sasaki et al., 2011). The studies in healthy adults relied on absolute exercise intensity based on METs and assumed a resting metabolic rate of 3.5 mL·kg·min^{-1} (Santos-Lozano et al., 2013; Sasaki et al., 2011). Using relative exercise intensity is critical, especially in coronary artery disease patients, due to the wide variation in their resting and maximum aerobic capacities (Gleeson and Protas, 1989; Roberts et al., 1984; Westerterp and Speakman, 2008). For healthy individuals moderate PA is considered to range between 3 and 5.99 METs; however, coronary artery disease patients with low or moderate functional capacity may only have a maximal exercise capacity of 4 or 5 METs falling within the moderate PA intensity range suggesting that absolute thresholds may not be appropriate. Interestingly, Santos-Lozano derived cut-points for older adults (65-80 years) and identified 2751 and 9359 counts·min^{-1} for moderate and vigorous intensity PA, respectively (Santos-Lozano et al., 2013). Evidence shows that cardiorespiratory fitness declines with age (Lee et al., 2010), yet these cut-points are still well above those derived from our coronary artery disease population, further highlighting the need for population-specific cut-points. Despite the above mentioned differences in the populations, the lower cut-points suggested by the current study are reasonable considering the functional capacity limitations of coronary artery disease patients ("American College of Sports Medicine position stand. Exercise for patients with coronary artery disease," 1994).

While the sample size was small, the strength of this investigation is its uniqueness; this is the first feasibility study to suggest ActiGraph accelerometer cut-points for moderate and vigorous intensity PA in a coronary artery disease population. Sub-group analyses of participants completing the two protocols (i.e. 1 and 2 minute stages) yielded the same results as the groups combined therefore the larger sample was maintained to increase the sample size. This study was limited to one modality of PA; however, walking is one of the more frequent modes of PA in coronary artery disease patients (Ekelund et al., 2002). With primarily male patients, the applicability of the results among females may be limited.

Conclusion

Reliance on self-report measures have made it difficult for researchers to determine whether coronary artery disease patients are meeting PA recommendations. Accelerometer measured PA eliminates these issues and allows researchers to quantify the frequency, intensity and duration of PA. Uniaxial and triaxial cut-points were found to be lower than those for both healthy middle-aged adults and older adults suggesting that they may not be appropriate when analyzing accelerometer data even among high functional capacity coronary artery disease patients. Further research is needed to confirm these cut-points in a larger sample of coronary artery disease patients including a larger number of females, and may consider individuals of varying functional capacities.

Authors' Qualifications

The authors' qualifications are as follows: Amy E. Mark, MSc, PhD; Jennifer L. Reed, MEd CS, PhD; Stephanie A. Prince, MSc, PhD; Robert D. Reid PhD MBA.

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Disclosures

The authors have no conflict of interest or financial disclosures. All authors have read and approved of the manuscript.

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