

Decline in physical activity in the weeks preceding sustained ventricular arrhythmia in women



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BACKGROUND Heightened risk of cardiac arrest following physical exertion has been reported. Among patients with an implantable defibrillator, an appropriate shock for sustained ventricular arrhythmia was preceded by a retrospective self-report of engaging in mild-to-moderate physical activity. Previous studies evaluating the relationship between activity and sudden cardiac arrest lacked an objective measure of physical activity and women were often underrepresented.

OBJECTIVE To determine the relationship between physical activity, recorded by accelerometer in a wearable cardioverter-defibrillator (WCD), and sustained ventricular arrhythmia among female patients.

METHODS A dataset of female adult patients prescribed a WCD for a diagnosis of myocardial infarction or dilated cardiomyopathy was compiled from a commercial database. Curve estimation, to include linear and nonlinear interpolation, was applied to physical activity as a function of time (days before arrhythmia).

RESULTS Among women who received an appropriate WCD shock for sustained ventricular arrhythmia (N = 120), a quadratic relationship between time and activity was present prior to shock. Physical activity increased starting at the beginning of the 30-day period up until day -16 (16 days before the ventricular arrhythmia) when activity begins to decline.

CONCLUSION For patients who received treatment for sustained ventricular arrhythmia, a decline in physical activity was found during the 2 weeks preceding the arrhythmic event. Device monitoring for a sustained decline in physical activity may be useful to identify patients at near-term risk of a cardiac arrest.

KEYWORDS Defibrillation; Physical activity; Ventricular arrhythmia; Wearable cardioverter-defibrillator; Women

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Introduction

A heightened risk of cardiac arrest following physical exertion has been reported extensively.^{1–5} Among patients with an implantable cardioverter-defibrillator, an appropriate shock for sustained ventricular arrhythmia was preceded by engaging in mild-to-moderate physical activity in the minutes to hours before a shock.^{2,3} This short timeline between engaging in increased physical activity and subsequent cardiac arrest leaves little time for medical intervention beyond resuscitation. In many of the studies evaluating the relationship between activity and sudden cardiac arrest women are underrepresented, thereby precluding the assessment of sex differences. Among the

studies that reported sex-specific outcomes, the triggering effect of physical exertion preceding sudden cardiac arrest was less common among women when compared to men.^{5,6}

The reliance on self-reported^{2,3} and third-party accounts^{4,5} of physical activity at the time of cardiac arrest also limits the validity of these studies. In cases of cardiac arrest, the trauma associated with the event could lead patients to exhibit a recall bias regarding their level of activity at the time of the event. It is common for patients to look for causal links between a cardiovascular event and a behavior, such as physical exertion, that they believe can be controlled to minimize the likelihood of future cardiac events.⁷

An objective, continuous measure of physical activity in the weeks preceding a sustained ventricular arrhythmia has not been used to investigate the relationship between activity and sudden cardiac arrest. Thus, the aim of the present study was to determine the relationship between objectively measured

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KEY FINDINGS

- Women prescribed a wearable cardioverter-defibrillator for a recent diagnosis of dilated cardiomyopathy (DCM) or post-myocardial infarction (MI) experience a decline in physical activity in the weeks preceding a sustained ventricular arrhythmia.
- Women with newly diagnosed DCM or post-MI had an average of 3913 (interquartile range: 1783–6882) steps per day across the 30 days following the diagnosis.
- Among women, the most significant gain in physical activity following DCM or post-MI occurs during the first week; step count increases 18%, from 3287 to 3874 steps.

physical activity, as recorded by accelerometer, and sustained ventricular arrhythmia (ventricular tachycardia/ventricular fibrillation [VT/VF]) among a cohort of female participants prescribed a wearable cardioverter-defibrillator (WCD) after an acute cardiovascular event. In addition, we sought to report the objectively measured change in physical activity that occurs in the month following a diagnosis of dilated cardiomyopathy (DCM) or after a myocardial infarction (MI).

Methods

Patients

Information from all patients prescribed a WCD is kept and maintained by the manufacturer (ZOLL, Pittsburgh, PA). Consent is obtained from all patients to be included in this database and exempt institutional review board approval was granted for analysis of de-identified data. A dataset of female adult patients prescribed a WCD in 2017 for a diagnosis of MI or DCM was compiled from the commercial database. To be included in the dataset, patients had to have a minimum of 30 days of WCD wear with a minimum average wear time of 14 hours per day to allow for adequate WCD wear to capture activity data. This dataset included patients who did not receive a shock as well as appropriately and inappropriately shocked patients. Additionally, a dataset from 2016 with the same inclusion criteria composed of female patients who received an appropriate shock was also available. The remainder of the 2016 commercial database was not available to be analyzed.

Device description

The WCD automatically detects and treats sustained VT and VF. The device contains a monitor (about 0.77 kg) worn on a hip holster (or shoulder strap) and an electrode belt; the latter holds 4 dry electrodes creating 2 surface electrocardiogram channels, positioned in side-to-side and front-to-back configurations. A 3-axis accelerometer in the electrode belt determines the patient's step count and body position. Use of an accelerometer to assess step count among patients with heart failure, with⁸ and without⁹ a WCD, has been reported previ-

ously. The chest garment contains 2 defibrillation pads on the back and 1 at the left anterior part of the chest, close to the apical region of the heart. A pair of response buttons on the monitor allow a conscious patient to prevent a potential shock. The default programming for VT and VF are 150 and 200 beats per minute, respectively.¹⁰ A description of the WCD technical details have been reported elsewhere in the literature.¹⁰

Statistical analysis

Continuous variables are reported as mean \pm standard deviation, or median and interquartile range (IQR) for skewed data. The primary analysis was performed to determine the change in physical activity that occurs over the time leading up to sustained VT/VF (appropriate shock). Curve estimation, to include linear and nonlinear interpolation, was applied to activity (step count) as a function of time (days before sustained arrhythmia). A second curve estimation analysis was performed on 101 patients who received an inappropriate shock to determine if a relationship between activity and time was present.

An analysis was also conducted to determine the physical activity trajectory following newly diagnosed DCM or MI. For this analysis, we utilized the accelerometer data recorded by the WCD during the 30-day period following a new diagnosis among patients who did not receive defibrillation during WCD use. Multiple regression was used to calculate change in activity over time while controlling for age. Weekly percentage gains in activity were assessed to identify when the greatest increase in activity occurred.

Results

Female patients (mean age: 65 ± 13 years) prescribed a WCD for newly diagnosed MI ($n = 1391$) or DCM ($n = 3537$) were included. Median duration of WCD use was 87 (IQR: 55–113) days and on average patients wore the WCD for 23.3 (IQR: 22.4–23.7) hours per day.

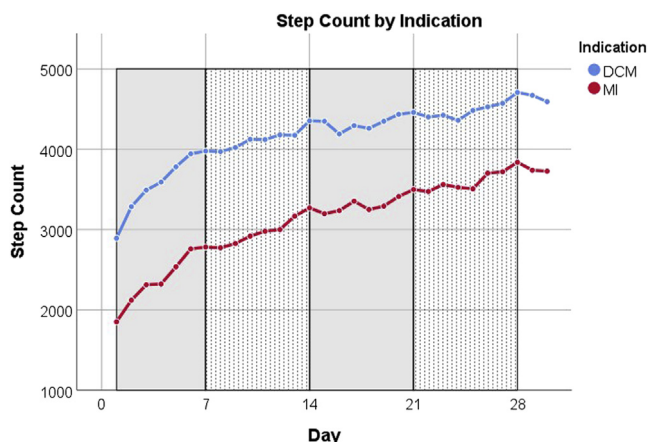


Figure 1 Median daily step count across the 30-day period following a new diagnosis of dilated cardiomyopathy (DCM) or myocardial infarction (MI).

Table 1 Demographic and wearable cardioverter-defibrillator data for No Shock and Appropriate Shock groups

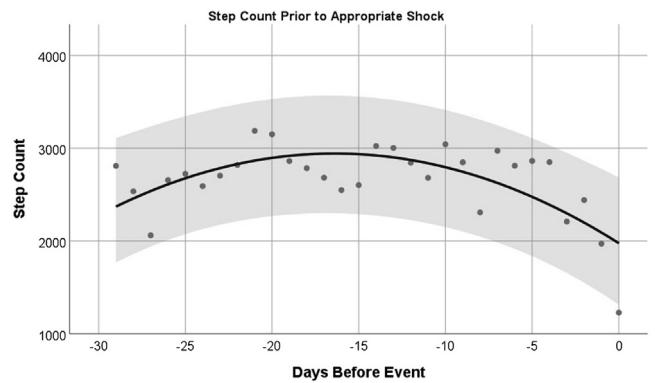
	No Shock (n = 4808)	Appropriate Shock (n = 120)
Age (SD)	65 (13.0)	65 (12.8)
Indication		
Myocardial infarction	1369 (28.5%)	22 (18.3%)
Dilated cardiomyopathy	3439 (71.5%)	98 (81.7%)
WCD duration, days (IQR)	87 (56–113)	57 (40–77)
WCD wear time, hours/day (IQR)	23.3 (22.3–23.7)	23.4 (22.9–23.7)

IQR = interquartile range; SD = standard deviation; WCD = wearable cardioverter-defibrillator.

Among women who did not receive a shock during WCD use (n = 4808), those with DCM were significantly younger (64 ± 13 years) than women post-MI (67 ± 12 years), $t = 7.9$, $P < .001$. Median daily step count across the entire 30-day period following a new diagnosis was 3913 (IQR: 1783–6882). Women with DCM demonstrated a higher step count than women post-MI, 4229 (IQR: 2018–7268) and 3162 (IQR: 1293–5882), respectively, after correcting for the difference in age between the groups, $P < .001$. The greatest increases in activity for all occurred from week 1 to week 2. Women with DCM or post-MI had a 17% and 26% increase, respectively, during the first week. Incremental increases in activity continued throughout the month following diagnosis (Figure 1).

A series of analyses performed on 120 consecutive women (Table 1) who experienced a sustained VT/VF during WCD wear showed a decrease in physical activity leading up temporally to the ventricular arrhythmia. On average, patients wore the WCD for 43 (IQR: 31–63) days prior to receiving a shock. Figure 2 shows the median step count for 30 days preceding the sustained VT/VF. Curve estimation confirmed that a quadratic relationship between time and activity is present prior to a shock. The line in Figure 2 represents the significant quadratic equation ($R^2 = 0.46$, $P < .001$). Using the equation $\text{step count} = 2000 - 111.2 * (\text{Day}) - 3.3 * (\text{Day})^2$, physical activity increased starting at the beginning of the 30-day period up until day -16 (16 days before the sustained VT/VF), when activity begins to decline. Activity continued to decline up to day 0 (day of sustained VT/VF).

In the original dataset of female patients prescribed a WCD in 2017, 101 patients received an inappropriate shock. The main causes for inappropriate shock delivery were electrocardiogram signal interference in 60% and supraventricular tachyarrhythmias in 27%, followed by multiple counting/oversensing in 12%. A change in physical activity was not present for patients who were inappropriately shocked. On average, patients wore the WCD for 29 (IQR: 16–56) days prior to receiving an inappropriate shock.

**Figure 2** Median daily step count across the 30-day period prior to receiving an appropriate shock for sustained ventricular arrhythmia.

Discussion

Among women, activity level over the 30-day period following an acute cardiovascular event and diagnosis of DCM or post-MI shows gradual improvement. The most significant gain in physical activity occurs during the first week: step count increases 18% from 3287 to 3874 steps. Activity continues to improve, though at a more modest pace, throughout the remaining 30-day study period. Among the women that experienced a sustained arrhythmia and were shocked by the WCD (n = 120), activity was recorded continuously for an average of 43 days prior to receiving an appropriate shock. A decline in physical activity began approximately 2 weeks (16 days) before the arrhythmic event. A relationship between shock and activity among a sub-group of 101 patients who received an inappropriate shock was not found.

These findings add to the current literature in 2 important ways. First, previous studies examining activity following an MI have relied on self-reported physical activity.^{11–13} In addition to the reliability and validity issues with self-reported data, these studies were unable to provide specific metrics, thus limiting the clinical utility of their findings. In the current study, a benchmark level of step count following an MI and the relative increase expected in the following weeks can be utilized by clinicians to compare the progress of a return to physical activity for patients in their clinic.

A second major contribution of our study is the identification of patients who are at risk of acute cardiac arrest. A number of studies have reported a triggering effect of physical activity on sudden cardiac arrest.^{2–5,14} Among patients with an implantable cardioverter-defibrillator, a relationship was found between appropriate shock and a self-report of engaging in mild-to-moderate physical activity in the 15 minutes³ up to 1 hour² before the shock. Rather than an objective measure of physical activity, these studies relied on patient self-report of activity during the time leading up to a shock. The retrospective self-report of physical activity at the time of cardiac arrest is susceptible to attribution error. Attributing the cause of sudden cardiac arrest to physical activity allows the patient to exert some level of control, such as restricting activity to prevent future cardiac arrest, over these

otherwise unpredictable events. In the current study, by using a continuous device-recorded accelerometer to assess change in physical activity over several weeks before sustained ventricular arrhythmia, we provide an objective assessment of activity. Although it is still possible that an intense burst of activity could result in cardiac arrest, the decline in typical level of physical activity found weeks prior to a cardiac event in the current study would allow time for medical intervention to occur beyond the lifesaving measures required in the event of sudden cardiac arrest. In addition, tracking patient activity over weeks or months allows for an individual level of baseline activity to be established. Comparison can then be made to this baseline to identify patients experiencing a decline in activity and provide clinicians with the critical time needed to intervene. It is interesting that the women receiving an appropriate shock for VT/VF showed an initial improvement in activity, similar to the nonshocked patients, but then changed course approximately 2 weeks prior to the shock event. This decline in physical activity may be the result of worsening heart failure and increased presentation of symptoms. Previous reports have noted that patients with heart failure limit their activity to minimize dyspnea and fatigue^{15,16} and their perceptions of these symptoms are elevated compared to healthy controls.¹⁷ Limiting physical activity diminishes a person's overall health and cardiorespiratory fitness, which may leave them more vulnerable to sudden cardiac arrest. In a meta-analysis of large epidemiological studies Jiménez-Pavón and colleagues¹⁸ found that low levels of cardiorespiratory fitness are predictive of an increased risk of sudden cardiac arrest. Consistently engaging in physical activity can minimize the risk of a sudden cardiac event, even during periods of physical exertion.^{5,19} The objective, continuous physical activity data available to clinicians treating patients who are wearing a WCD could be used to guide physical rehabilitation and modify heart failure therapies to help prevent a VT/VF event if a decline in physical activity is observed.

Our study has several strengths, including a large national cohort of women, continuous collection of activity data that were objectively measured by accelerometer, and detailed recording of arrhythmic activity. Limitations of the current study are consistent with studies that utilize a commercial database. Limited information is available for reporting covariates, and long-term patient outcomes are not available. Thus, we were unable to determine whether the decrease in activity prior to VT/VF was a cause or a result of worsening heart failure symptoms. The cause of shock in the cohort of inappropriately shocked patients was heterogenous. It is likely that opposing relationships are present between activity and various causes of inappropriate shock. For example, whereas an inappropriate shock resulting from signal interference may be indicative of increased activity, an inappropriate shock caused by a supraventricular tachyarrhythmia may be associated with decreased activity.²⁰ Future studies with a larger cohort of inappropriately shocked patients should evaluate the divergent relationships that may exist between activity and the various causes of inappropriate

shock. It should also be noted that our study specifically studied patients with a new WCD prescription after an acute event, and their risk profile and baseline activity levels may not be generalizable to the larger, chronic risk population, such as in patients with an implantable cardioverter-defibrillator. Because only female subjects were included, results of this study are only applicable to women. Given that many cardiac studies include a disproportionate number of men and sex-specific outcomes are often not reported, limiting the current study to female participants allows for the reporting of outcomes that can be applied to female patients. Finally, because this study utilized a dataset from patients having enough wear data to analyze, it is possible that this inclusion criterion may have influenced the results in some unexpected way such that the conclusions only apply to women who are compliant with device use.

Conclusion

Among patients with newly diagnosed DCM or recent MI, a return to physical activity is evident in the month following the event, with the most substantial gain in activity occurring over the first week. For patients who received treatment for sustained ventricular arrhythmia, a decline in physical activity was found during the 2 weeks preceding the arrhythmic event. Device monitoring for a sustained decline in physical activity may be useful to identify patients at near-term risk of a cardiac arrest. Further research is necessary to determine if this decline can be identified prospectively and if an intervention during this time could prevent cardiac arrest.

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References

1. Dahabreh IJ, Paulus JK. Association of episodic physical and sexual activity with triggering of acute cardiac events: systematic review and meta-analysis. *JAMA* 2011;305:1225–1233.
2. Fries R, König J, Schäfers H-J, Böhm M. Triggering effect of physical and mental stress on spontaneous ventricular tachyarrhythmias in patients with implantable cardioverter-defibrillators. *Clin Cardiol* 2002;25:474–478.

3. Lampert R, Joska T, Burg MM, Batsford WP, McPherson CA, Jain D. Emotional and physical precipitants of ventricular arrhythmia. *Circulation* 2002;106:1800–1805.
4. Reddy PR, Reinier K, Singh T, et al. Physical activity as a trigger of sudden cardiac arrest: The Oregon Sudden Unexpected Death Study. *Int J Cardiol* 2009;131:345–349.
5. Whang W, Manson JE, Hu FB, et al. Physical exertion, exercise, and sudden cardiac death in women. *JAMA* 2006;295:1399–1403.
6. Marijon E, Uy-Evanado A, Reinier K, et al. Sudden cardiac arrest during sports activity in middle age. *Circulation* 2015;131:1384–1391.
7. Burgess ES, Quigley JF, Moran G, Sutton FJ, Goodman M. Predictors of psychosocial adjustment in patients with implantable cardioverter defibrillators. *Pacing Clin Electrophysiol* 1997;20:1790–1795.
8. Burch AE, Scherr D, Rieth A, et al. Wearable cardioverter defibrillator-guided 6-min walk test performed at home is accurate and reliable: RESULTS OF THE TRENDS STUDY. *J Cardiopulm Rehabil Prev* 2020;40:E14.
9. Jehn M, Schmidt-Trucksäss A, Schuster T, et al. Accelerometer-based quantification of 6-minute walk test performance in patients with chronic heart failure: applicability in telemedicine. *J Card Fail* 2009;15:334–340.
10. Klein HU, Goldenberg I, Moss AJ. Risk stratification for implantable cardioverter defibrillator therapy: the role of the wearable cardioverter-defibrillator. *Eur Heart J* 2013;34:2230–2242.
11. Ekblom O, Ek A, Cider Å, Hambraeus K, Börjesson M. Increased physical activity post-myocardial infarction is related to reduced mortality: results from the SWEDEHEART Registry. *J Am Heart Assoc* 2018;7:e010108. 2018. Available at <https://www.ahajournals.org/doi/abs/10.1161/JAHA.118.010108>.
12. Gorczyca AM, Eaton CB, LaMonte MJ, et al. Change in physical activity and sitting time after myocardial infarction and mortality among postmenopausal women in the Women's Health Initiative-Observational Study. *J Am Heart Assoc* 2017;6:e005354.
13. Steffen-Batey L, Nichaman MZ, Goff DC, et al. Change in level of physical activity and risk of all-cause mortality or reinfarction. *Circulation* 2000;102:2204–2209.
14. Chahal HS, Mostofsky E, Mittleman MA, et al. Aerobic fitness and risk of ventricular arrhythmia following physical exertion. *Can J Cardiol* 2016;32:533–538.
15. Oka RK, Stotts NA, Dae MW, Haskell WL, Gortner SR. Daily physical activity levels in congestive heart failure. *Am J Cardiol* 1993;71:921–925.
16. Tierney S, Elwers H, Sange C, et al. What influences physical activity in people with heart failure? A qualitative study. *Int J Nurs Stud* 2011;48:1234–1243.
17. Güçlü MB, Barçi G, Katayifçi N, Şen F. Comparison of functional and maximal exercise capacity, respiratory and peripheral muscle strength, dyspnea, and fatigue in patients with heart failure with pacemakers and healthy controls: a cross-sectional study. *Physiother Theory Pract* 2019;1–12.
18. Jiménez-Pavón D, Lavie CJ, Blair SN. The role of cardiorespiratory fitness on the risk of sudden cardiac death at the population level: a systematic review and meta-analysis of the available evidence. *Prog Cardiovasc Dis* 2019;62:279–287.
19. Albert CM, Mittleman MA, Chae CU, Lee IM, Hennekens CH, Manson JE. Triggering of sudden death from cardiac causes by vigorous exertion. *N Engl J Med* 2000;343:1355–1361.
20. Puglisi A, Gasparini M, Lunati M, et al. Persistent atrial fibrillation worsens heart rate variability, activity and heart rate, as shown by a continuous monitoring by implantable biventricular pacemakers in heart failure patients. *J Cardiovasc Electrophysiol* 2008;19:693–701.