Assessing Population-Based Adherence To The Updated Physical Activity Guidelines is All But Obvious

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Research Article

Keywords: physical, adherence, CRF, absolute

Posted Date: November 16th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-1043779/v1

Version of Record: A version of this preprint was published at European Journal of Public Health on September 1st, 2022. See the published version at https://doi.org/10.1093/eurpub/ckac078.

Abstract

Objective: The aerobic part of the recently updated physical activity (PA) guidelines for adults no longer requires the minimum 10-minute bouts for the accumulated time. In this study, the adherence of Finnish adult population to the new PA guidelines was evaluated using both absolute and relative cut-points describing the individual cardiorespiratory fitness (CRF) in relation to the intensity of PA.

Methods: Totally, 1645 adults aged 20-64 years, participated in this study. The participants were instructed to wear a triaxial hip-worn accelerometer for one week. The participants with estimated maximal oxygen uptake less than 7.9 MET were categorized as low CRF group and the others as adequate CRF group.

Results: The adequate CRF group had higher adherence to PA guidelines with the absolute thresholds, but the use of relative thresholds inverted the results. The adherence varied from 16 % to 100 % depending on the fitness group and the analysis parameters of accelerometer data.

Conclusion: The absolute thresholds provide a more appropriate basis to assess the adherence to PA recommendations in population-based samples and interventions. The use of individually determined relative thresholds may be more useful for individual exercise prescriptions in PA counseling.

1 Introduction

Regular physical activity (PA) and high cardiorespiratory fitness (CRF) have numerous scientifically documented health benefits.[1,2] The aerobic part of the recently updated PA guidelines for adults recommends at least 150 to 300 min of moderate (MPA) or 75 to 150 min of vigorous PA (VPA) weekly, or some combination of them.[3,4] A striking change from the previous PA guidelines is that the at least 10-minute bouts are no more required for the accumulation of relevant physical activity. Recent studies employing device-measured PA have indicated that the total volume of moderate-to-vigorous physical activity (MVPA) is related to many health benefits whereas time-specific bouts are not essential.[2,5]

PA-related health benefits and self-reported MVPA have shown an inverse, curvilinear dose-response relationship.[2] Even small amounts of PA confer health benefits while they are most evident for the least active individuals.[6] The health benefits continue across the full range of commonly achievable volumes, although they have diminishing returns for MVPA levels over 150 to 300 min per week.[2] However, it seems that daily 30-40 min of accelerometer-measured MVPA may attenuate the association between sedentary time and risk of death,[7] being substantially lower than previously estimated 60-75 min based on self-reported data.[8]

High cardiorespiratory fitness (CRF) is associated with a significant reduction in all-cause mortality at any level of habitual PA, without evidence of a plateau effect or U-shaped association.[1] CRF is more strongly associated with all-cause mortality than self-reported PA in men and women.[9] The minimum CRF

conferring substantial risk reduction is estimated to be 7.9 MET (metabolic equivalents, 1 MET = 3.5 mL/kg/min of oxygen consumption).[10]

To assess trends regarding the adherence to PA guidelines, it is important to regularly measure population-level PA with valid methods. Such methods should be able to measure the frequency, duration, and intensity of PA, and desirably also the type of activity and its context. These methods can be divided into self-reports and device-based.[11] The self-reports are known to overestimate the exercise time while underestimate the activity time accumulated during daily routines. The device-based methods can assess PA in a more standardized manner regardless of the current fitness level and body weight which both may influence the subjectively perceived and reported intensity of PA.[12–43] Self-reported data can supplement device-based data, for example, by providing information on the specific type or context of PA.[15,16]

The intensity of aerobic PA can be expressed in either absolute or relative terms. Absolute intensity is the amount of energy expended during the given activity without considering a person's CRF or aerobic capacity. Relative intensity denotes the level of effort relative to a person's individual maximum aerobic capacity.[4,7] The use of relative intensity has been recommended when it is feasible in device-based PA studies, but in large-scale population studies, it can be too laborious and costly to conduct individual exercise testing in laboratory conditions.[17] However, the 6-min walk test (6MWT), a cost-effective and well-documented field test of CRF,[18,19] has recently been validated for predicting VO_2max also among healthy adults.[20]

It is known that the choice of parameters employed in the analysis of device-measured PA data can substantially affect the results. The use of relative intensity thresholds may lead to paradoxical results regarding the total amount of MVPA time.[21] Likewise, the use of different epoch lengths and cut-points to define the intensity (MPA or VPA) can essentially change the estimates of the accumulated PA time.[21] Shorter epoch lengths will capture instantaneous and sporadic instances of movement, which are most likely missed with longer epochs due to the inherent smoothing effect. On the other hand, the smoothing effect of the long epoch allows the intensity temporarily to drop below the cut-point.[22,23] The cut-points together with the epoch length determine the time spent in MPA and VPA levels. The selected intensity cut-points should be validated in a sample population closely matching the study group of interest and the selected epoch length should be the same that was used to validate the cut-points.[24]

The purpose of the present study is to systematically examine the device-based adherence to the aerobic part of the updated 24-h movement guideline in Finland. The new guideline for adults aged 18 to 64 years combines recommendations for the PA, sedentary behavior, and sleep across the whole day (Fig. 1). Also, a scheme for assessing population-based adherence to the aerobic part of the PA guidelines is outlined.

2 Results

The number of participants in the low and adequate CRF groups is shown in Table 1. The mean body mass index (BMI) of the low CRF group was higher than in the adequate CRF group. The proportion of the low CRF participants increased with age.

Table 1
Number of participants in CRF and age groups and mean (standard deviation) of the BMI.

		Low CRF		Adequate CRF	
	Age group	N	BMI (kg/m^2)	N	BMI (kg/m^2)
Men	20-34 yrs	3	40.5 (7.2)	114	25.7 (3.7)
	35-49 yrs	7	36.6 (7.5)	224	26.1 (3.7)
	50-64 yrs	35	31.0 (5.0)	275	26.5 (2.9)
Women	20-34 yrs	16	32.1 (4.3)	188	23.2 (3.1)
	35-49 yrs	49	34.4 (4.7)	288	23.8 (3.0)
	50-64 yrs	130	31.3 (4.3)	316	24.5 (2.9)

The proportions of participants adhering to the PA guidelines using the absolute MET-based thresholds are shown in Figure 2. Except for the 6 s epoch and men, both the men and women in the adequate CRF group had higher adherence to PA guidelines than those in the low CRF group, whereas with the 6 s epoch almost all participants were sufficiently active. The device-based adherences were highest with the 6 s epoch and lowest with the 6 min exponential moving average (EMA) in each group. The weighted mean proportions of participants meeting the PA guidelines in the whole sample were 99.3% with the 6 s epoch, 88.9% with the 1 min EMA and 68.0% with the 6 min EMA.

The proportions of participants adhering to the present PA guidelines using the relative, individual CRF-based thresholds are shown in Figure 3. The use of relative thresholds inverted the results and both men and women in the low CRF group had higher adherence to PA guidelines than those in the adequate CRF group except for the 6 min EMA, where the adherence of men was similar irrespective of the CRF group. The weighted mean proportions of participants meeting the PA guidelines in the whole sample were 46.6 % with the 6 s epoch, 33.2 % with the 1 min EMA and 20.4 % with the 6 min EMA.

Optimal cut-points for the accumulated weekly guideline PA time with absolute thresholds are shown in Table 2. The cut-points define the required weekly device-based PA time to achieve the positive outcome, estimated VO_2max ≥ 7.9 MET. The required time was highest for the 6 s epoch and lowest for the 6 min EMA with absolute thresholds. The area under curve (AUC) values regarding the CRF outcome were higher for men than women. The results for the relative thresholds are not shown because the low CRF group accumulated more guideline PA time than the adequate CRF group making the analysis of cut-points irrational.

Table 2
The optimal cut-points for device-based weekly guideline PA time. The AUC denotes for the area under the receiver operator characteristics curve and 95CI for the 95 % confidence intervals.

Group	Epoch	Cut-point (min/week)	Sensitivity	Specificity	AUC (95CI)
Device-based cut-points to achieve at least 7.9 MET VO_2max					
All	6 s epoch	491	67 %	65 %	0.708 (0.704–0.712)
	1 min EMA	289	63 %	69 %	0.702 (0,698–0,706)
	6 min EMA	156	69 %	58 %	0.679 (0.675–0.683)
Men	6 s epoch	491	67 %	65 %	0.782 (0.774–0.790)
	1 min EMA	278	66 %	65 %	0.776 (0.768–0.784)
	6 min EMA	156	69 %	58 %	0.750 (0.742–0.758)
Women	6 s epoch	518	63 %	69 %	0.680 (0.675–0.684)
	1 min EMA	293	63 %	66 %	0.676 (0.672–0.680)
	6 min EMA	208	62 %	68 %	0.672 (0.667–0.676)

3 Discussion

The proportion of adults meeting the current PA guidelines[4] varied from marginal 20 % to almost perfect 99 % depending on the analysis parameters. The lowest adherence to the PA guidelines was attained when the analysis was based on the 6 min EMA and relative cut-points. The highest, virtually perfect adherence was attained with the 6 s epoch, absolute cut-points. These contradictory findings can be very confusing to health care professionals, who are not necessarily familiar with the device-based measurements of PA, and particularly what is the impact of analysis parameters on the results. The present results are in line with previous studies showing that the choice of the analyzing parameters is critical and confers a substantial effect on the prevalence of meeting the PA guidelines.[25–27]

As the total volume of recommended PA, at least 150 min per week, stems from studies employing self-reported MVPA time,[2] it is expectable to have challenges with device-based methods.[27] Whereas the self-reports can provide information on the specific type of activity, the context of the activity, or location,[15,16]

the device-based methods provide more consistent results and capture all relevant movements or PA causing measurable acceleration irrespective of their duration.[12,28] Device-measured PA data have indicated that MVPA bouts of any length contribute to health benefits.[2] If at least 10 min bouts were required in this study population, the proportion of participants meeting this requirement with absolute thresholds was 14.8 % with the 6 s epoch, 29.0 % with the 1 min EMA and 45.0 % with the 6 min EMA, and correspondingly, with relative thresholds, the proportions were 6.6 %, 11.5 % and 14.8 % (data not shown). Although a perfect tool to examine PA does not exist, device-based methods, specific to the behaviors of interests, are recommended for examining PA in free-living environments.[11]

3.1 Physical activity intensity cut-points

Obviously a very low-fit person perceives already 3.0 MET physical exertion very hard while a high-fit person perceives even 6.0 MET exertion light. Accordingly, using the absolute cut-points, the adequate CRF group had higher adherence to PA guidelines and accumulated more guideline PA time. In contrast, the use of CRF-based relative cut-points inverted the results, and the low CRF group became paradoxically the most active one,[21] which does not serve the purpose of general PA recommendations for the population. This bizarre result suggests that high fitness can protect from excess or strenuous physical activity. Thus, participants in the low CRF group get physically stressed already in their daily routines whereas the participants with higher CRF engage in exercise on voluntary basis. [29]

In general, the use of absolute intensity cut-points will likely yield more reasonable results, since better fitness and higher PA are associated not only with higher adherence to the guidelines but also maintain the established associations with health outcomes.[21,30] The use of an individually determined relative intensity, in turn, may be more appropriate for individual exercise prescriptions in PA counseling. In PA counseling, the appropriate PA intensity needs to be tailored individually, while the goal is to find solutions to behavioral changes that are easy to adopt and sustain.[30] However, in the population-based samples and interventions, the use of relative intensity cut-points is likely problematic, when the varying intensity levels will have an impact on the amount of measured MVPA time in a confusing way.[21] The low VO_2max is also associated with higher body mass and BMI.[31] Thus, changes in body composition during interventions would have an effect on the VO_2max and individual intensity thresholds.

Altogether, we argue that physical fitness is primarily more important for health than physical activity. However, from the perspective of public health policy, it is more sensible to encourage individuals to become more physically active than improve their fitness.[32] Increasing PA at the population level will increase the overall fitness of the population and yield health benefits within the population.

3.2 Data smoothing

By definition, the 1 min EMA and 6 min EMA processing smooth the PA data collected in the 6 s epochs. These processing methods remove short, sporadic activities, and typically accumulate less total daily PA time than the 6 s epochs[21]. For activities performed at steady intensity, like jogging, smoothing does not

change the results. For an intermittent high-intensity activity, like ball games, the smoothed 1 min EMA and 6 min EMA can accumulate more PA time but at a lower intensity. The 6 s epoch is likely a better estimator to actual bodily movements produced by muscles whereas the smoothed data reflect better the time course of the metabolic and endocrine responses to muscle activity.[33,34] However, it is possible that neither the 6 s epoch, 1 min EMA, nor 6 min EMA alone is better than the others, but they just reflect different PA patterns and thus need different requirements for the accumulated time.

In this cross-sectional study, the optimal cut-point between the CRF groups was about two to three times higher with the 6 s epoch than with the 6 min EMA for both outcome types. The closest match between the optimal cut-points for the device-based weekly guideline PA time and the 150 min limit of the updated guideline was achieved with the 6 min EMA. Also, the differences between men and women are noteworthy and warrant further evaluation. However, it might not be possible to harmonize the outputs of different measurement methods or choose appropriate analysis parameters in a reasonable and consistent way. Various PA measurement methods have different sensitivities to a broad range of positive health outcomes.[2]

4 Materials And Methods

4.1 Participants

This study is based on a subsample of the population-based FinFit2017 study.[36] The sample comprised of 1645 participants (658 men, 987 women), aged 20-64 years, who completed 6MWT and had 24-hour daily wear time of the accelerometer at least for four days during seven consecutive days. Potential participants were drawn from the population registry in seven city-centered regions of Finland: 300 men and women from both Helsinki and Tampere regions and 150 men and women from each of Turku, Kuopio, Jyväskylä, Oulu, and Rovaniemi regions spread across five age groups (20–29, 30–39, 40–49, 50–59, and 60–69 years). Other inclusion or exclusion criteria were not used and participation in the study was voluntary. The coordinating ethics committee of the Regional Ethics Committee of the Expert Responsibility area of Tampere University Hospital gave the ethical approval for the study (R17030). All participants gave signed informed consent before participation. All methods were performed in accordance with relevant guidelines and regulations and all research was performed in accordance with the Declaration of Helsinki.

4.2 Measurements

The CRF was estimated using the 6MWT, where the participants were asked to walk back and forth along the 15m walking track as fast as possible for six minutes. The heart rate was recorded with a heart rate monitor (Polar M61, Polar Electro, Kempele, Finland). For men, the VO_2max (in METs) was predicted by the walking distance in six minutes, age, body mass index, body height, and heart rate at the end of the test. For women, the prediction was based on the distance walked in six minutes, body weight, and age. The accuracy of prediction is about 1 MET.[20] According to predicted VO_2max values, the participants

were divided into low and adequate CRF groups. The low CRF group comprised persons, whose estimated VO_2max values were less than 7.9 METs whereas the adequate CRF group comprised persons with estimated VO_2max values of at least 7.9 METs.[10]

A triaxial accelerometer (UKK RM42, UKK Terveyspalvelut Oy, Tampere, Finland) was used to measure participants' PA. The device was attached to a flexible belt with an instruction to wear the belt so that the accelerometer was on the right hip during waking hours and on the non-dominant wrist during bedtime for seven consecutive days, except during shower and other water activities. The acceleration signal was collected at 100 Hz sampling frequency, ±16 g acceleration range, and 0.004 g resolution. After the one-week measurement, the accelerometers were returned, and the raw data were stored on a hard disk for further analysis.

4.3 Data analysis

The raw accelerometer data was analyzed in 6 s epochs according to our standard procedure.[37–39] For each epoch, mean amplitude deviation (MAD) values of the resultant acceleration signal,[37,38] and mean amplitude deviation (MADxyz) values of the acceleration signal in each orthogonal direction[39] were calculated. The epoch-wise MAD values were converted to METs. The accuracy of the MET-estimation is about 1.2 MET for bipedal locomotion over a wide range of speed.[38] The MET values of the 6 s epochs were further smoothed by filtering the data with 1 min and 6 min exponential moving averages (EMA).[21] Presumably, the 6 s epochs capture all relevant bodily movements produced by skeletal muscles, whereas the longer 1 min and 6 min EMA simulate the metabolic responses to PA.[33, 34] The time course of the physiological responses is wide depending on the intensity and duration of the activity as well as the training status and fitness of the person.

The intensity of PA at each epoch time point was classified into combined moderate-to-vigorous PA (MVPA) and VPA using both absolute and individually determined relative cut-points. The absolute cut-points were the standard 3.0 MET and 6.0 MET and the relative cut-points 40 % and 60 % of the oxygen uptake reserve (VO_2R).[40] The days containing non-wear time were excluded from the analysis.[36] The adherence to the PA guidelines was estimated using both absolute and individually determined relative cut-points of PA intensity. The mean daily guideline PA time was calculated as the sum of MPA time and doubled VPA time. The weekly time was obtained by multiplying the mean daily time by seven. The participant was classified as sufficiently physically active if the weekly guideline PA time was at least 150 min. The classification was based on the MET values from the 6 s epochs as well as the 1 min and 6 min EMA MET values.

4.4 Statistical methods

Participants were weighted by the sample size in age groups for men and women (20-34 years, 35-49 years, and 50-64 years). It was assumed that at the population level, there is equal distribution of individuals in age groups. All the analysis were done for the weighted data. Participants' characteristics in CRF groups are presented as means and standard deviations (SD) for men and women. Differences

between CRF groups were tested with independent samples t-test. 95 % confidence intervals (CI) for the proportion of sufficiently physically active persons were calculated using the Clopper–Pearson exact method. The required, device-based, weekly guideline PA time was determined with the receiver operator characteristic (ROC) curve. The optimal cut-point was the point where the ROC curve was closest to the left-upper corner of the ROC space, and it denoted the minimum time required to achieve the VO_2max value greater than or equal to 7.9 MET.

All statistical analyses were conducted using IBM SPSS statistics software (IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp., New York, NY, USA).

Conclusion

Assessing the population-based adherence to the updated PA guidelines using device-based PA data appears a confusing task. The recommendation of the weekly volume stems from the subjective self-reports while the device-based methods are sensitive to analysis parameters. Although the relative intensity cut-points are more feasible for individual PA counseling, the absolute MET-based cut-points provide a more appropriate viewpoint to assess the adherence in population-based samples and interventions. Further, combination of different instruments (self-reports and devices) may provide a more holistic picture of PA.[35]

Declarations

Acknowledgments

Laboratory staff of the participating research centers are acknowledged for their help in the data collection.

Competing interests

The authors declare no competing interests

Contributions

All authors critically reviewed the manuscript, provided significant input and approved the final version. HV-Y drafted the manuscript, analyzed the data, and interpreted the data. HS and PH designed the data collection and revised the manuscript. KT did the statistical data analysis. AM, OH, JH, KM, KS and SK monitored the data collection. TV initiated the collaborative project and designed the data collection.

Data sharing Statement

The datasets of the current study are not publicly available due ethical reasons. Non-identifiable data are available for research purposes from the corresponding author upon reasonable request

Ethical approval information

The Regional Ethics Committee of the Expert Responsibility Area of Tampere University Hospital gave ethical approval for this study (R17030). All participants gave signed informed consent before participation.

Funding

The study is funded by the Finnish Ministry of Education and Culture and Lifestyles of Health and

Sustainability to Boost Sustainable Growth Consortium, Academy of Finland, Strategic Research Council (320400 and 320403).

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Figures

Figure 1

Weekly physical activity recommendation for 18-64-year-old adults in Finland.

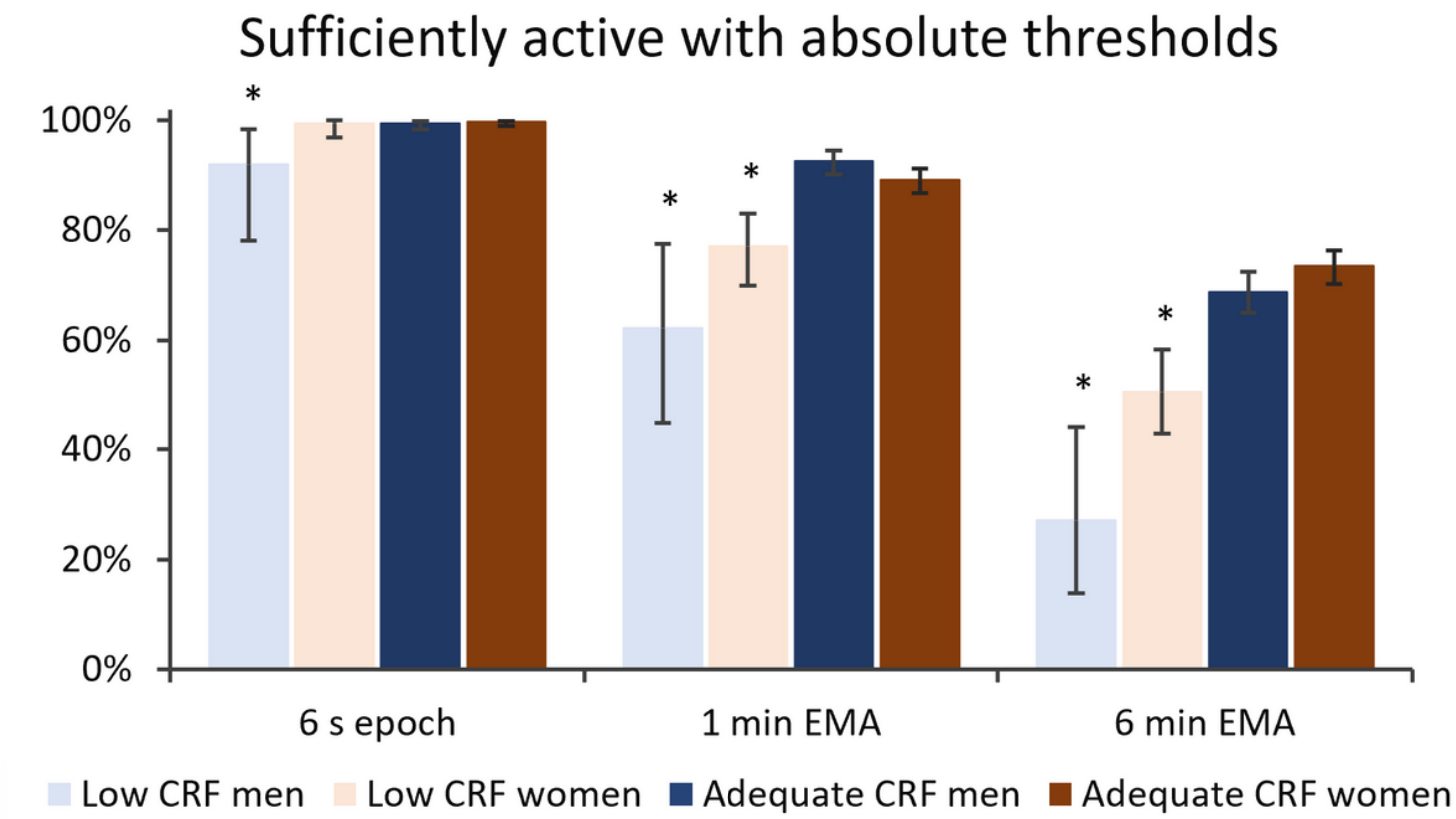

Figure 2

Proportions of the sufficiently physically active participants with absolute, 3.0 MET, and 6.0 MET thresholds. The sufficiently active participants accumulated at least 150 min a week. The error bars denote for 95 % confidence interval. The * denotes for significant ($p<0.05$) difference between the sex-specific CRF groups.

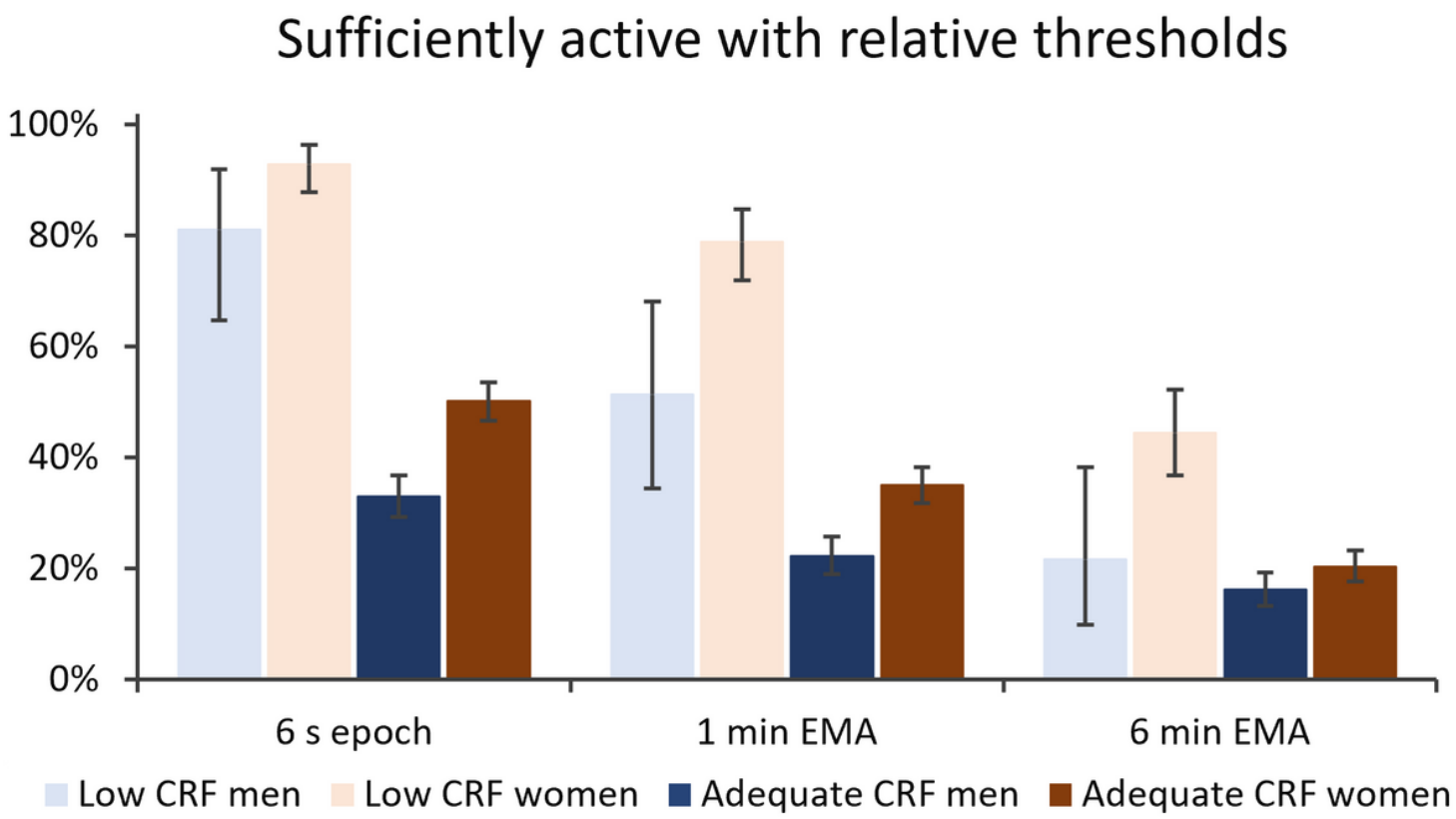

Figure 3

Proportions of the sufficiently physically active participants with relative 40 % and 60 % of the oxygen uptake reserve thresholds. The sufficiently active participants accumulated at least 150 min a week of guideline PA time. The error bars denote for 95 % confidence interval. The * denotes for significant ($p<0.05$) difference between the sex-specific CRF groups.