

PART F. CHAPTER 1. PHYSICAL ACTIVITY BEHAVIORS: STEPS, BOUTS, AND HIGH INTENSITY TRAINING

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INTRODUCTION

The *Physical Activity Guidelines Advisory Committee Report, 2008¹* demonstrated that moderate-to-vigorous physical activity is associated with a wide range of health benefits. Most of the literature on which the conclusions were based used survey and questionnaire data, where physical activity exposures were assessed using self-reported estimates of time spent in aerobic continuous moderate-to-vigorous physical activity accumulated in bouts of at least 10 minutes. In the 2008 Scientific Report, all other physical activity—sedentary behavior, light-intensity physical activity, and bouts of moderate-to-vigorous intensity physical activity of less than 10 minutes duration—was considered “baseline” physical activity. The physical activity that counted toward health benefits—moderate-to-vigorous physical activity in bouts of 10 minutes or more—was on top of baseline physical activity.

The conclusions of the 2008 Scientific Report¹ were solidly based on the existing scientific information, and the findings and conclusions of the *2018 Physical Activity Guidelines Advisory Committee Report* mostly extend the range of beneficial outcomes described in the 2008 Scientific Report. However, 10 additional years of scientific inquiry, aided by substantial advances in measuring physical activity, have improved and refined the understanding of the types of physical activity that influence health outcomes. These include topics such as:

- Are there simpler metrics—such as step counts—for estimating the volume of health-promoting behavior?
- Do short episodes of activity—bouts less than 10 minutes in duration—contribute to accumulated beneficial physical activity, such as parking distant from the entrance to a place of work (as suggested in most public health statements about physical activity); walking into the coffee shop instead of using the drive-through; getting up from chairs at work to walk around the office; getting up from the couch during the breaks in a TV program to do a chore; climbing a flight of stairs?
- How does the newly popularized high intensity interval training (HIIT) mode of exercise fit into health recommendations?
- What, if any, is the value of light-intensity physical activity?
- At any given volume of moderate-to-vigorous physical activity, does the composition of baseline physical activity influence health outcomes?

The Committee considered it important to address these questions and anticipate the ones that might arise following the publication of the 2018 Scientific Report by investigating the current data and further research needs of three particularly relevant issues: the role of daily step counts in the assessment of daily accumulated physical activity across all intensity levels, including light-intensity activity; the impact on health benefits of moderate-to-vigorous physical activity in bouts lasting less than 10 minutes; and the effect of and contribution of HIIT to the prescribed amount of weekly moderate-to-vigorous physical activity, and whether HIIT is associated with cardiometabolic health benefits.

All the dose-response data used to develop the physical activity targets for the 2008 Guidelines² were developed using epidemiologic data from longitudinal cohort studies with the condition as the outcome and moderate-to-vigorous physical activity as the exposure. One well-accepted limitation of reported data is the inability to incorporate light-intensity physical activity. With the advent of devices to

objectively measure physical activity of community-dwelling individuals during daily life activities in addition to exercise, it is becoming increasingly clear that light-intensity physical activity contributes to favorable health benefits, independent of those provided by moderate-to-vigorous physical activity.³

Since the 2008 Scientific Report,¹ several developments have occurred in the means by which physical activity and exercise are measured, quantified, and prescribed to individuals seeking exercise-associated health benefits. The proliferation and popularity of smart phones and other wearable devices containing accelerometers have facilitated the measurement of daily steps counts (see *Part F. Chapter 11. Promoting Regular Physical Activity* for additional details). Current consumer devices have three-dimensional accelerometers, which permit assessments of step cadence; this permits the assessment of physical activity as light intensity or as moderate-to-vigorous physical activity. It is now possible to assess the contribution of light-intensity physical activity to total step counts and, therefore, to better estimate total energy expenditure (see *Part C. Background and Key Concepts* for additional details). Because step counts incorporate both light-intensity and moderate-to-vigorous physical activity, the Subcommittee considered it important to better understand how the measurement of steps might fit into the assessment of daily or weekly physical activity exposures and its relationship to health outcomes.

The persistence of the seeming need to accumulate moderate-to-vigorous physical activity in episodes (bouts) of at least 10 minutes, which dates to the physical activity recommendations from the Centers for Disease Control and Prevention and the American College of Sports Medicine,⁴ has provided a barrier to research investigating how episodes of less than 10 minutes might contribute to the accumulation of the recommended moderate-to-vigorous physical activity. In addition, it creates dissonance with recommendations such as “take the stairs,” “move more, sit less,” and “park your car in the parking lot further from your place of work,” which can incorporate more physical activity into an individual’s lifestyle but typically take less than 10 minutes to execute. Therefore, the Subcommittee considered it important to examine data regarding whether accumulated episodes of less than 10 minutes have health benefits and whether those benefits are similar to those of accumulated episodes of greater than 10 minutes.

Since the 2008 Scientific Report, high intensity interval training (HIIT) has become a popular research topic. The media also presents HIIT as an alternative means by which individuals can achieve health benefits similar to those of classical continuous moderate-to-vigorous physical activity. Some have

suggested that HIIT may be a better alternative than traditional amounts of exercise because it consumes less overall time per week and might be more attractive as a long-term strategy by which to achieve the health benefits of regular physical activity. The Subcommittee considered it important to examine scientific evidence regarding the use of HIIT for health benefits, the sustainability of HIIT programs, and the rate of adverse events relative to classical continuous aerobic training.

REVIEW OF THE SCIENCE

Overview of Questions Addressed

This chapter addresses three major questions and related subquestions.

1. What is the relationship between step count per day and (1) all-cause and cardiovascular disease mortality, and (2) incidence of cardiovascular disease events and type 2 diabetes?
 - a) Is there a dose-response relationship? If yes, what is the shape of the relationship?
 - b) Does the relationship vary by age, sex, race/ethnicity, socioeconomic status, or weight status?
2. What is the relationship between bout duration of physical activity and health outcomes?
 - a) Does the relationship vary by age, sex, race/ethnicity, socioeconomic status, or weight status?
3. What is the relationship between high intensity interval training and reduction in cardiometabolic risk?
 - a) Is there a dose-response relationship? If yes, what is the shape of the relationship?
 - b) Does the relationship vary by age, sex, race/ethnicity, socioeconomic status, or weight status?

Data Sources and Process Used to Answer Questions

One search and triage process was conducted for existing reviews (systematic reviews, meta-analyses, pooled analyses, and reports) for all three questions. The Exposure Subcommittee determined that systematic reviews, meta-analyses, and pooled analyses provided sufficient literature to answer Question 3. The existing reviews did not provide sufficient evidence to answer Questions 1 and 2. Separate de novo searches for original research were conducted for Questions 1 and 2. For complete details on the systematic literature review process, see *Part E. Systematic Review Literature Search Methodology*.

Question 1. What is the relationship between step count per day and all-cause and cardiovascular disease mortality and (2) incidence for cardiovascular disease events and risk of type 2 diabetes?

- a) Is there a dose-response relationship? If yes, what is the shape of the relationship?
- b) Does the relationship vary by age, sex, race/ethnicity, or socio-economic status, and weight status?

Source of evidence: Original research articles

Conclusion Statements

Insufficient evidence is available to determine whether a relationship exists between step counts per day and all-cause and cardiovascular disease mortality. **PAGAC Grade: Not assignable.**

Limited evidence suggests that step count per day is associated with reduced incidence of cardiovascular disease events and risk of type 2 diabetes. **PAGAC Grade: Limited.**

Limited evidence suggests a dose-response relationship between the measure of steps per day and cardiovascular disease events and type 2 diabetes risk. **PAGAC Grade: Limited.**

Insufficient evidence is available to determine whether the relationship between the measure of steps per day and cardiovascular disease events and type 2 diabetes risk is influenced by age, sex, race/ethnicity, socioeconomic status, or weight status. **PAGAC Grade: Not assignable.**

Review of the Evidence

The committee reviewed evidence from nine manuscripts that reported on five original research studies. Of the nine reports, four used a cross-sectional design,⁵⁻⁸ four used a prospective design,⁹⁻¹² and one used a randomized controlled design where control and intervention groups were compared, as well as pooled, to examine steps per day in relationship to insulin resistance.¹³ The Navigator study, a multicenter trial of 9,306 individuals with impaired glucose recruited from 40 countries, provided four manuscripts (three longitudinal and one cross-sectional). All four Navigator papers examined health outcomes after pooling intervention and control groups. Therefore, the Navigator study design was considered cross-sectional⁵ or longitudinal prospective.^{9, 11, 12} Participants in all nine reviewed studies were middle-age or older. Males and females, multiple races and ethnicities, a continuum of body sizes, and diverse geographical areas were represented, supporting the generalizability of conclusions.

Cross-sectional studies cannot control for bi-directional relationships, i.e., the outcome causing the exposure as well as the exposure causing the outcome. Because it is likely that individuals with undiagnosed disease may take fewer steps per day than healthy individuals, the reviewed cross-sectional studies were used only to understand usual step counts per day across sample populations.

The longitudinal studies reported health outcomes that included blood glucose levels,^{10, 12, 13} metabolic syndrome,⁹ and a composite of CVD incidence, which included cardiovascular death, non-fatal myocardial infarction, or non-fatal stroke.¹¹

The baseline number of steps per day varied across studies but the median was approximately 5,000 steps per day. One report¹³ showed that 80 percent of the steps taken in a day were of light-intensity physical activity. Samples of older adults accumulated fewer daily steps than did younger middle-aged adults. An Australian sample of Tasmanian adults (mean age at baseline 50 years)¹⁰ accumulated nearly twice as many daily steps at baseline as other samples (approximately 10,000, whereas most study baseline steps per day were approximately 5,000).

Evidence on the Overall Relationship

No study was found that examined the relationship between step counts per day and all-cause or cardiovascular mortality. Therefore, the Subcommittee was unable to draw a conclusion about this relationship.

Several longitudinal studies examined the relationship between step counts per day and disease incidence or risk. One study examined cardiovascular disease events, defined as cardiovascular death, non-fatal myocardial infarction, or non-fatal stroke.¹¹ The other four longitudinal studies addressed type 2 diabetes risk.^{9, 10, 12, 13}

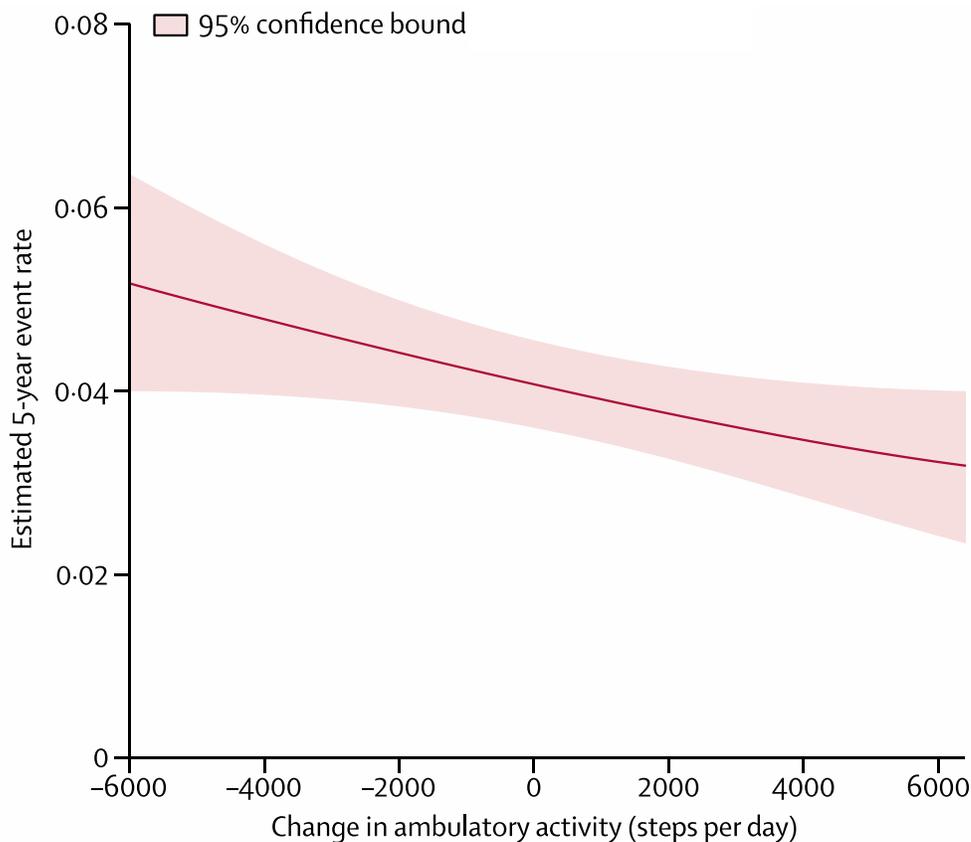
[Yates et al¹¹](#) provided evidence of the benefit of increasing steps per day to reduce cardiovascular event incidence as well as the effect of baseline step count on subsequent cardiovascular disease events. This study included more than 45,000 person-years of follow-up in which 531 cardiovascular events occurred. Change in steps per day and baseline steps were positively associated with reduced risk for cardiovascular disease events.

[Herzig et al,¹³](#) [Huffman et al,⁹](#) [Ponsonby et al,¹⁰](#) and [Yates et al¹²](#) focused on markers of type 2 diabetes risk. Following a 3-month intervention in which 78 participants who already had an abnormal glucose profile participated in 3 days a week of supervised walking or usual physical activity, step count per day for intervention and control groups were pooled.¹³ This measure was not associated with improved glucose profiles. [Huffman et al⁹](#) analyzed Navigator data and showed an incremental reduction in the 6-year metabolic syndrome score with baseline step count. Also using Navigator data, [Yates et al¹²](#) reported previous steps per day to be weakly and negatively associated with 2-hour glucose levels after

adjustment for glucose levels in the preceding 3 years. [Ponsonby et al¹⁰](#) followed 458 adults with a normal glucose profile and showed that higher steps per day at baseline were associated with a lower incidence risk for dysglycemia (impaired fasting glucose or impaired glucose tolerance) after 5 years.

Dose-response: In [Yates et al¹¹](#) a yearly 2,000 steps per day increase resulted in an 8 percent yearly reduction in cardiovascular event rate in individuals with impaired glucose tolerance. In addition, baseline level of steps per day was inversely associated with cardiovascular event incidence. Specifically, at baseline each 2,000 steps per day increment was associated with a 10 percent lower cardiovascular event rate (Figure F1-1).

Figure F1-1. Association Between Change in Daily Step Count and Cardiovascular Events in Individuals with Impaired Glucose Tolerance



Source: Reprinted with permission from Elsevier (The Lancet, Yates et al., 2014,¹¹ 383, 1059-1066).

[Huffman et al⁹](#) also analyzed Navigator data and showed for every incremental 2,000 step increase in baseline steps per day a 0.29 percent reduction in the 6-year metabolic syndrome score was expected.

[Ponsonby et al¹⁰](#) estimated that for any average daily step count, an additional 2,000 steps would be associated with a 25 percent reduction in developing incident dysglycemia over the succeeding 5 years.

Similar to the Navigator studies,^{9, 11} the relationship between step count per day and health outcome appeared linear in [Ponsonby et al.](#)¹⁰

Evidence on Specific Factors

Demographic factors and weight status: The difference in risk reduction reported in [Yates et al](#)¹¹ was not affected by weight status, sex, age, geographical region, or level of baseline steps per day. Despite these findings, the evidence on these factors was not sufficient enough for the Subcommittee to draw a conclusion about any relationship. Negative associations between steps and metabolic syndrome score reported in [Huffman et al](#)⁹ were independent of weight status. [Ponsonby et al](#)¹⁰ reported associations that were also independent of weight status when examining steps per day and dysglycemia.

For additional details on this body of evidence, visit: <https://health.gov/paguidelines/second-edition/report/supplementary-material.aspx> for the Evidence Portfolio.

Public Health Impact

Steps are a basic unit of locomotion and as such, provide an easy-to-understand metric of ambulation—an important component of physical activity. Measuring step counts has been shown to motivate diverse samples of individuals to increase physical activity levels (see *Part F. Chapter 11. Promoting Regular Physical Activity* for more details). Increasingly, the self-assessment of steps can be accomplished through device-based, readily obtainable technology such as pedometers, smartphones, and physical activity trackers. Unlike the measure of moderate-to-vigorous physical activity minutes per week, the metric of step counts per day provides a comparable measure to how caloric intake in most dietary guidance is standardized, i.e., per day. As a result, steps per day would provide a useful tool for researchers and the public to address a variety of health and physical activity issues. In addition, steps can be at light-, moderate-, and vigorous-intensity levels, providing a range of exertion choice to promote walking at all ages and for all levels of fitness. For these reasons, the measure of steps per day has the potential to significantly improve the translation of research findings into public health recommendations, policies, and programs.

Question 2. What is the relationship between bout duration of physical activity and health outcomes?

- a) Does the relationship vary by age, sex, race/ethnicity, socioeconomic status, or weight status?

Source of evidence: Original research articles

Conclusion Statements

Moderate evidence indicates that bouts of any length of moderate-to-vigorous physical activity contribute to the health benefits associated with accumulated volume of physical activity. **PAGAC Grade: Moderate.**

Insufficient evidence is available to determine whether the relationship between physical activity accumulated in bouts with a duration of less than 10 minutes and health outcomes varies by age, sex, race/ethnicity, or socioeconomic status. **PAGAC Grade: Not assignable.**

Historical Context

Physical activity recommendations have traditionally focused on moderate-to-vigorous physical activity performed in a continuous manner. The historical perspective of these recommendations was summarized in the U.S. Surgeon General's *Report on Physical Activity and Health*.¹⁴ In 1995, the Centers for Disease Control and Prevention and the American College of Sports Medicine provided the first contemporary recognition of the recommendation for moderate-to-vigorous physical activity to be "accumulated" in order to achieve a specific threshold of daily physical activity that, in turn, could result in health and fitness benefits.⁴ This recommendation stated that "intermittent bouts of physical activity, as short as 8 to 10 minutes, totaling 30 minutes or more on most days provided beneficial health and fitness effects." This resulted in a new paradigm, and the 2008 Guidelines continued to support this recommendation for adults, stating that "aerobic activity should be performed in episodes of at least 10 minutes".² However, free-living physical activity is also performed in episodes typically less than 10 minutes in duration; these shorter episodes of physical activity also may have health-related benefits. Thus, the Subcommittee was interested in examining the available scientific literature to determine whether physical activity episodes of less than 10 minutes in duration have health-related benefits; or, alternatively, if the benefits are only realized when the duration of physical activity episodes is at least 10 minutes.

Review of the Evidence

To answer this question, the Subcommittee reviewed evidence from 25 manuscripts that reported on 23 original research studies.¹⁵⁻³⁹ Two pairs of these studies reported on different outcomes from the same studies.¹⁶⁻¹⁹ Of the 23 studies, 11 used a cross-sectional design,^{18-21, 25-27, 30, 31, 35, 36, 38} 2 used a prospective design,^{22, 37} 9 used a randomized design,^{15-17, 23, 24, 28, 29, 32, 33, 38} and 1 used a non-randomized design.³⁴

These studies reported on either one or numerous outcomes. A variety of health outcomes were covered, including body weight or body composition,^{15-18, 20, 23-25, 27-35, 37, 38} blood pressure,^{16, 23, 24, 29, 31, 32, 37, 38} blood lipids,^{16, 19, 22, 23, 27, 31-33, 38, 39} glucose or insulin,^{16, 23, 26, 30, 38} metabolic syndrome,^{21, 30} inflammatory biomarkers,^{31, 38} or a composite of CVD risk.³⁶

The duration of intermittent bouts also varied across studies. Cross-sectional^{18-21, 25-27, 30, 31, 35, 36, 38} and prospective studies^{22, 37} reported on bouts of physical activity that were less than 10 minutes, whereas randomized studies^{15-17, 23, 24, 28, 29, 32-34, 39} reported only on intermittent bouts that were at least 10 minutes.

Evidence on the Overall Relationship

As reported in 11 manuscripts, 10 of the 23 unique studies examined used randomized designs that only included bouts of physical activity that were at least 10 minutes in duration.^{15-17, 23, 24, 28, 29, 32-34, 39} These studies demonstrated that intermittent bouts resulted in similar or enhanced effects when compared to continuous bouts of physical activity of longer duration for outcomes of weight and body composition,^{15-17, 23, 24, 28, 29, 32-34, 39} blood pressure,^{16, 23, 24, 29, 32} blood lipids,^{16, 23, 32, 33, 39} or glucose or insulin.^{16, 23} However, these studies do not provide information to evaluate bouts of physical activity of less than 10 minutes in duration.

Evidence of overall health benefits resulting from bouts of physical activity less than 10 minutes in duration is provided primarily by studies that used a cross-sectional design,^{18-21, 25-27, 30, 31, 35, 36, 38} with a few studies using a prospective design^{22, 37} (Table F1-1). This evidence supports that physical activity accumulated in bouts less than 10 minutes in duration is associated with body mass index (BMI) or body fatness,^{18, 20, 25, 27, 30, 31, 35, 37, 38} blood pressure,^{31, 37, 38} blood lipids,^{19, 22, 27, 31, 38} glycemic control,^{19, 26, 30, 31, 38} metabolic syndrome,^{21, 30} inflammatory markers,^{31, 38} or Framingham Cardiovascular Disease Risk Score.³⁶

Table F1-1. Summary of the Association Between Physical Activity Bout Duration and Health Outcomes from Prospective and Cross-Sectional Studies that Included Bouts of Less than 10-minute Duration

Citation	Study Type	Sample Size	Weight	BMI	Percent Body Fat, Body Composition	Visceral Adiposity	Blood Pressure	Total Cholesterol	HDL Cholesterol	LDL Cholesterol	Triglycerides	Fasting Glucose	Fasting Insulin	2-hour insulin during a glucose tolerance test	HbA1c	Metabolic Syndrome	CRP	Framingham CVD Risk Score
White et al., 2015 ³⁷	Prospective	2076		≥10			Both											
Di Blasio et al., 2014 ²²	Prospective	67							≥10									
Loprinzi and Cardinal, 2013 ³¹	Cross-Sectional	6321		Both	Both		Both	Both	Both	Both	Both	Both					Both	
Wolff-Hughes et al., 2015 ³⁸	Cross-Sectional	5668		≥10	<10		<10		<10		<10	<10	<10				<10	
Gay et al., 2016 ²⁶	Cross-Sectional	5302													<10			
Fan et al., 2013 ²⁵	Cross-Sectional	4511		Both														
Strath et al., 2008 ³⁵	Cross-Sectional	3250	≥10		≥10													
Glazer et al., 2013 ²⁷	Cross-Sectional	2109		Both	Both				Both		Both							

Part F. Chapter 1. Physical Activity Behaviors: Steps, Bouts, and High Intensity Training

Citation	Study Type	Sample Size	Weight	BMI	Percent Body Fat, Body Composition	Visceral Adiposity	Blood Pressure	Total Cholesterol	HDL Cholesterol	LDL Cholesterol	Triglycerides	Fasting Glucose	Fasting Insulin	2-hour insulin during a glucose tolerance test	HbA1c	Metabolic Syndrome	CRP	Framingham CVD Risk Score
Vasankari et al., 2017 ³⁶	Cross-Sectional	1398																1-5, 6-10, 11-15, 20-120 min
Clarke and Janssen, 2014 ²¹	Cross-Sectional	1119														1-9, 4-9, 7-9 min		
Jefferis et al., 2016 ³⁰	Cross-Sectional	1009		Both	Both								Both			Both		
Cameron et al., 2017 ²⁰	Cross-Sectional	298		<10	Both	Both												
Ayabe et al., 2013 ¹⁸	Cross-Sectional	42				>3 min												
Ayabe et al., 2012 ¹⁹	Cross-Sectional	42							≥32 sec			≥3 min						

Legend: BMI=body mass index, HDL=high-density lipoprotein, LDL=low-density lipoprotein, CRP=C-reactive protein, and Both=both bouts of greater than or equal to 10 minutes versus less than 10 minutes in duration showed an association.

Note: Values shown indicate the duration of physical activity bouts at which a significant association was shown with selected health outcomes. Empty cells indicate the outcome was not reported.

Obesity. One cohort study examined incidence of obesity.³⁷ This study reported that physical activity accumulated in bouts of at least 10 minutes in duration was associated with lower incidence of obesity, whereas physical activity accumulated in less than 10 minutes was not associated with lower incidence of obesity. For cross-sectional studies that examined BMI, two favored physical activity accumulated in bouts of at least 10 minutes compared to physical activity accumulated in bouts less than 10 minutes,^{31, 38} one favored physical activity accumulated in less than 10 minute bouts,²⁰ and three did not report a difference between physical activity accumulated in bouts less than 10 minutes versus bouts of at least 10 minutes.^{25, 27, 30} Of the seven cross-sectional studies that examined measures of body fatness, one favored physical activity accumulated in bouts of at least 10 minutes,³⁵ one reported that the association between total volume of physical activity was more strongly associated with cardiometabolic health than physical activity accumulated in bouts of at least 10 minutes,³⁸ and five studies showed no difference between physical activity accumulated in bouts of at least 10 minutes versus physical activity not accumulated in bouts of at least 10 minutes.^{18, 20, 27, 30, 31}

Resting Blood Pressure. For resting blood pressure, the Subcommittee reviewed one cohort study and two cross-sectional studies. The cohort study³⁷ demonstrated that physical activity in bouts of either at least 10 minutes or less than 10 minutes in duration was associated with lower incidence of hypertension. Both cross-sectional studies showed that physical activity accumulated in bouts less than 10 minutes was associated with lower resting blood pressure.^{31, 38}

Total Cholesterol. One cross-sectional study showed that physical activity accumulated in bouts of at least 10 minutes or less than 10 minutes in duration was associated with lower total cholesterol.³¹ The one cross-sectional study that examined low-density lipoprotein (LDL) cholesterol showed that both physical activity accumulated in bouts of at least 10 minutes in duration and in less than 10 minutes in duration were inversely associated with LDL cholesterol.³¹

HDL-cholesterol. For high-density lipoprotein (HDL) cholesterol, the one prospective study, which was only 14 weeks in duration, reported that physical activity accumulated in bouts of at least 10 minutes in duration predicted increase in HDL, whereas when the threshold was reduced to include bouts of at least 5 minutes this pattern of physical activity was not predictive of increase in HDL.²² Of the four cross-sectional studies reviewed, two showed similar associations between HDL and physical activity accumulated in bouts of at least 10 minutes and less than 10 minutes,^{27, 31} one showed that physical activity accumulated in bouts as short as 32 seconds was associated with higher HDL,¹⁹ and one showed

physical activity accumulated in bouts less than 10 minutes was more strongly associated with HDL than physical activity accumulated in at least 10 minutes.³⁸

Triglycerides. Three cross-sectional studies examined the association between physical activity and triglycerides. Two of these studies showed similar associations between triglycerides and physical activity accumulated in bouts of at least 10 minutes in duration or in bouts less than 10 minutes.^{27, 31} One of these studies showed physical activity accumulated in bouts of less than 10 minutes was more strongly associated with lower triglycerides than physical activity accumulated in bouts of at least 10 minutes.³⁸

Glucose Control Measures. Three cross-sectional studies examined the association between physical activity and fasting glucose,^{19, 31, 38} two with fasting insulin,^{30, 38} and one with Hemoglobin A1c (HbA1c).²⁶ For fasting glucose, one study showed that bouts of physical activity that were at least 3 minutes in duration were associated with lower fasting glucose,¹⁹ one study showed no difference in the association between fasting glucose and moderate-to-vigorous physical activity accumulated in bouts of less than 10 minute versus bouts of at least 10 minutes,³¹ and one study showed that physical activity accumulated in bouts of less than 10 minutes was more strongly associated with lower fasting glucose when compared to physical activity accumulated in bouts of at least 10 minutes.³⁸ For fasting insulin, one study showed no difference in the association when comparing moderate-to-vigorous physical activity accumulated in less than 10 minutes and at least 10 minutes,³⁰ and one study showed physical activity accumulated in bouts of less than 10 minutes was more strongly associated when compared to physical activity accumulated in bouts of at least 10 minutes in duration.³⁸ The one study that examined HbA1c showed that physical activity accumulated in bouts less than 10 minutes predicted lower HbA1c, whereas physical activity accumulated in bouts of at least 10 minutes in duration was not predictive of lower HbA1c.²⁶

Metabolic Syndrome. Two cross-sectional studies were reviewed that reported on the association between physical activity and metabolic syndrome.^{21, 30} One study showed that moderate-to-vigorous physical activity accumulated in bouts of either 1 to 9 minutes, 4 to 9 minutes, or 7 to 9 minutes in duration predicted lower odds of having metabolic syndrome independent of moderate-to-vigorous physical activity accumulated in bouts of at least 10 minutes.²¹ An additional study reported that the odds of having metabolic syndrome did not differ when comparing physical activity accumulated in bouts of less than 10 minutes versus at least 10 minutes.³⁰

C-reactive Protein. Two cross-sectional studies examined the association between physical activity and c-reactive protein.^{31, 38} One study showed no difference in the association between c-reactive protein and physical activity accumulated in bouts of less than 10 minutes in duration and bouts of at least 10 minutes.³¹ One study showed that physical activity accumulated in bouts of less than 10 minutes was more strongly associated with lower c-reactive protein when compared to physical activity accumulated in bouts of at least 10 minutes.³⁸

Framingham Cardiovascular Disease Risk Score. One cross-sectional study examined the association between physical activity and the Framingham Cardiovascular Disease Risk Score.³⁶ This study showed that physical activity accumulated in bouts of 1 to 5 minutes, 6 to 10 minutes, 11 to 15 minutes, or 20 to 120 minutes in duration and during total waking time were negatively associated with Framingham Cardiovascular Disease Risk Score.

Evidence on Specific Factors

Demographic factors and weight status: The literature examined included studies that included participants representing a range of ages, sex, race/ethnicity, and likely socioeconomic status. This literature also included participants representing a range of weight status. However, the results presented in this literature did not specifically present results from analyses to compare whether the association between physical activity that varied in bout duration varied by these demographic characteristics.

For additional details on this body of evidence, visit: <https://health.gov/paguidelines/second-edition/report/supplementary-material.aspx> for the Evidence Portfolio.

Public Health Impact

The *2008 Physical Activity Guidelines for Americans*² recommended that physical activity be accumulated in bouts of at least 10 minutes in duration to influence a variety of health-related outcomes. The evidence reviewed continues to support that physical activity accumulated in bouts of at least 10 minutes in duration can improve a variety of health-related outcomes. However, additional evidence, mostly from cross-sectional studies, suggests that physical activity accumulated in bouts that are less than 10 minutes is also associated with favorable health-related outcomes. Although published too late to include in our literature review, a recent study with device-based measures of physical activity and mortality as an outcome, demonstrates that bouts of less than even five minutes result in mortality benefits.⁴⁰ These findings are of public health importance because it suggests that engaging in

physical activity, regardless of length of the bout, may have health-enhancing effects. This is of particular importance for individuals who are unwilling or unable to engage in physical activity bouts that are at least 10 minutes in duration. Therefore, public health initiatives to enhance health should recommend including physical activity as an important lifestyle behavior regardless of the duration.

Question 3. What is the relationship between high intensity interval training (HIIT) and reduction in cardiometabolic risk?

- a) Is there a dose-response relationship? If yes, what is the shape of the relationship?
- b) Does the relationship vary by age, sex, race/ethnicity, socioeconomic status, or weight status?

Sources of evidence: Systematic reviews and/or meta-analyses

Conclusion Statements

Moderate evidence indicates that high intensity interval training can effectively improve insulin sensitivity, blood pressure, and body composition in adults. These high intensity interval training-induced improvements in cardiometabolic disease risk factors are comparable to those resulting from continuous, moderate-intensity aerobic exercise and are more likely to occur in adults at higher risk of cardiovascular disease and diabetes, compared to healthy adults. **PAGAC Grade: Moderate.**

Insufficient evidence is available to determine whether a dose-response relationship exists between the quantity of high intensity interval training and several risk factors for cardiovascular disease and diabetes. **PAGAC Grade: Not assignable.**

Insufficient evidence is available to determine whether the effects of high intensity interval training on cardiometabolic risk factors are influenced by age, sex, race/ethnicity, or socioeconomic status. **PAGAC Grade: Not assignable.**

Moderate evidence indicates that weight status influences the effectiveness of high intensity interval training to reduce cardiometabolic disease risk. Adults with overweight or obesity are more responsive than adults with normal weight to high intensity interval training's effects on improving insulin sensitivity, blood pressure, and body composition. **PAGAC Grade: Moderate.**

Review of the Evidence

The 2018 Advisory Committee based its conclusions on evidence published before May 2017, specifically from three existing systematic reviews and/or meta-analyses.⁴¹⁻⁴³ Participants were males and females

predominantly ages 18 years and older. The exposure was physical activity performed as high intensity interval training (HIIT).

For the purposes of this review, we used the following definition. HIIT is a form of interval training consisting of alternating short periods of intense anaerobic exercise with less intense aerobic recovery periods. There are no universally accepted lengths for either the anaerobic period, the recovery period, nor the ratio of the two; no universally accepted number of cycles for any HIIT session or the entire duration of the training bout; and no universally accepted relative intensity at which the intense anaerobic component should be performed.

The outcomes of interest were all-cause and CVD mortality, CVD and type 2 diabetes incidences, cardiorespiratory fitness, and cardiometabolic disease risk factors. The Subcommittee's assessment and evaluation specifically focused on outcomes related to cardiometabolic disease risk factors (e.g., blood pressure, fasting blood lipids and lipoproteins, fasting blood glucose and insulin, and BMI), due to a lack of information regarding mortality and cardiometabolic morbidities.

Evidence on the Overall Relationship

Results from these systematic reviews and/or meta-analyses of clinical intervention studies consistently support that HIIT can effectively improve cardiorespiratory fitness (increase VO_2 max) in adults with varied body weight and health status.⁴¹⁻⁴³ HIIT-induced improvements in insulin sensitivity,^{42, 43} blood pressure,^{41, 43} and body composition⁴¹⁻⁴³ more consistently occur in adults who have overweight or obesity with or without high risk of CVD and diabetes, especially if these individuals train for 12 or more weeks. These HIIT-induced improvements in cardiometabolic disease risk are comparable in magnitude to those achievable with continuous, moderate-intensity aerobic training.⁴² Healthy adults who have normal weight and lower risk of cardiometabolic disease do not typically show improvements in insulin sensitivity, blood pressure, and body composition with HIIT. Blood lipids and lipoproteins apparently are not influenced by HIIT.⁴¹

[Batacan et al⁴¹](#) reported findings based on 65 individual studies involving 2,164 participants (including 936 individuals who performed HIIT). Participants were predominantly ages 18 years and older. This meta-analysis included randomized controlled trials (RCTs) and non-randomized controlled trials and comparative studies in groups of individuals without (46 of 65 studies) or with (19 of 65 studies) a diagnosed, current medical condition. [Batacan et al⁴¹](#) defined high-intensity interval training “as

activities with intermittent bouts of activity that were performed at maximal effort, greater than or equal to 85% VO_2 max, greater than or equal to 85% heart rate reserve or the relative intensity of at least 90% heart rate max.” The modes of exercise included treadmill running, cycling, and swimming. The 65 studies were categorized with respect to exercise training intervention duration and participant BMI classification. Among groups of participants with normal weight (BMI 18.5–24.9 kg/m^2), short-term (<12 weeks) and long-term (≥ 12 weeks) HIIT interventions increased VO_2 max, but did not significantly or consistently influence clinical indexes of cardiometabolic disease risk (systolic and diastolic blood pressures; total cholesterol, HDL, LDL, and triglycerides; or fasting glucose and insulin). Among groups of participants classified as having overweight (BMI 25-29.9 kg/m^2) or obesity (BMI ≥ 30 kg/m^2), short-term and long-term HIIT significantly and consistently increased VO_2 max and decreased diastolic blood pressure and waist circumference. Long-term HIIT also decreased resting heart rate, systolic blood pressure, and body fat percentage among groups with overweight or obesity.

[Jelleyman et al⁴²](#) conducted a meta-analysis of 50 studies involving 2,033 participants (including 1,383 individuals who performed HIIT) to assess the effect of HIIT interventions on indexes of blood glucose control and insulin resistance, compared with continuous training or control conditions. Both controlled (N=36, 72%) and uncontrolled (N=14, 28%) studies were included. HIIT was defined as “at least two bouts of vigorous or higher intensity exercise interspersed with periods of lower intensity exercise or complete rest”.⁴² Participants were ages 18 years and older and the HIIT intervention was 2 weeks or longer. Subgroup analyses were performed after stratifying participants based on health characteristics: healthy (well-trained, recreationally active, or sedentary); weight status (overweight or obese); metabolic syndrome (metabolic syndrome or type 2 diabetes); or with another chronic disease. VO_2 max increased after HIIT by 0.30 liters per minute (95% CI: 0.25-0.35, $P < 0.001$), compared to baseline. The increase in VO_2 max was greater for HIIT than for non-exercising control conditions (weighted mean difference (WMD)=0.28 liters per minute, 95% CI: 0.12-0.44, $P = 0.001$) and attenuated but still significant compared with continuous training (WMD=0.16 liters per minute (95% CI: 0.07-0.25, $P = 0.001$). HIIT reduced body weight, compared to baseline, by 0.7 kg (95% CI: -1.19 to -0.25, $P = 0.002$). Compared to non-exercise control, the HIIT-induced weight loss was 1.3 kg (95% CI: -1.90 to -0.68, $P < 0.001$). HIIT-induced weight loss was not different than weight loss from continuous training. HIIT decreased fasting glucose, compared to baseline, by 0.13 mmol per liter (95% CI: -0.19 to -0.07, $P < 0.001$). This response over time was not statistically different compared with non-exercise control and continuous training. Subgroup analysis showed that for the groups of individuals with metabolic syndrome or type 2

diabetes, fasting glucose was reduced by HIIT, compared to non-exercise control, by 0.92 mmol per liter (95% CI: -1.22 to -0.63, $P < 0.001$). HIIT decreased fasting insulin from baseline by 0.93 μU per liter (95% CI: -1.39 to -0.48, $P < 0.001$), but this response was not different than the non-exercise control. HIIT decreased insulin resistance compared to baseline (change in Homeostasis Model Assessment of Insulin Resistance score, -0.33; 95% CI: -0.47 to -0.18, $P < 0.001$). Reduction in insulin resistance (results from multiple insulin resistance models combined) was greater for HIIT versus non-exercise control (-0.49; 95% CI: -0.87 to -0.12) and HIIT versus continuous training (-0.35; 95% CI: -0.68 to -0.02). Within the metabolic syndrome or type 2 diabetes grouping, HIIT did not change HbA1c, compared to baseline, among all 13 studies reporting these data. Subgroup analyses showed that HIIT reduced HbA1c by 0.25% (95% CI: -0.27 to -0.23, $P < 0.001$), compared to baseline. Among all studies, the HbA1c response over time (no change) was not statistically different between HIIT and control and continuous training groups. Subgroup analyses based on health (physical activity) status or other chronic diseases were either not significant or inconclusive due, in part, to limited available data.

[Kessler et al⁴³](#) conducted a quasi-systematic, qualitative review of 24 RCTs assessing the effects of HIIT interventions on changes in cardiometabolic disease risk factors. Fourteen of the 24 trials included a continuous moderate-intensity exercise control group, and the other 14 studies included a non-exercise control group. Participants had varied weight status (normal weight, overweight or obese) and health status (healthy (17 studies), CVD (5 studies), metabolic syndrome (1 study), type 2 diabetes (1 study)). Intervention durations ranged from two weeks to six months. HIIT was categorized into two subtypes: aerobic interval training (19 studies) and sprint interval training (5 studies). For the purpose of the Subcommittee's assessment, results only from aerobic interval training studies are described. This was done because of the low number of sprint interval training studies included in the [Kessler et al⁴³](#) review. Compared to baseline (i.e., changes over time), aerobic interval training increased VO_2 max (14 of 14 studies), increased insulin sensitivity (4 of 4 studies), and decreased blood pressure in participants not ingesting anti-hypertensive medication (5 of 5 studies with intervention periods ≥ 12 weeks). Other indexes of cardiometabolic disease risk were not influenced by aerobic interval training, including fasting glucose, total cholesterol, HDL, LDL, and triglycerides. Results for body weight, BMI, body fat percent, and waist circumference were mixed, with improvements observed more consistently for aerobic interval training interventions of 12 weeks or longer in participants with overweight or obesity. Collectively, these aerobic interval training responses were comparable with continuous moderate-

intensity exercise, except VO₂max, which was greater for aerobic interval training versus continuous moderate-intensity exercise.

Dose-Response: Among the three review articles the Committee systematically reviewed,⁴¹⁻⁴³ results were not presented from RCTs designed to assess dose-response relationships between duration of HIIT and changes in cardiometabolic disease risk factors. Using meta-regression techniques, [Batacan et al⁴¹](#) reported that VO₂max was predicted by longer HIIT intervention duration (β coefficient 0.77; 95% CI: 0.35-1.18) and BMI (β coefficient 0.84; 95% CI: 0.29-1.38), but not by total time performing HIIT (minutes) (β coefficient 0.0002; 95% CI: -0.0017-0.0021) among groups of participants with overweight or obesity. Intervention duration, total time performing HIIT, and BMI did not predict the improvements observed in systolic blood pressure and diastolic blood pressure among groups with overweight or obesity. Other cardiometabolic risk factors were not assessed due to lack of heterogeneity of responses. Regarding indexes of glucose control, [Jelleyman et al⁴²](#) (also using meta-regression techniques) reported that HIIT characteristics, interval intensity, and weekly high-intensity exercise did not predict the improvements (over time) in insulin resistance, fasting glucose, fasting insulin, or HbA1c.

Evidence on Specific Factors

Age, sex, race/ethnicity, socioeconomic status: Information on the race/ethnicity and socioeconomic status of participants was limited, inconsistently presented, and not statistically assessed. As a result, no conclusions about these relationships were possible.

Weight status: Weight status significantly influenced the effect of HIIT on several risk factors of cardiometabolic disease, with groups of adults classified as having overweight or obesity, but not normal weight, reducing blood pressure and body fat⁴¹ and improving insulin sensitivity.^{42, 43}

Evidence on Participant Safety

Participant safety is central to using HIIT as a tool to reduce the risk of cardiometabolic disease among adults, especially those who have overweight or obesity, with cardiometabolic disease risk factors, diagnosed CVD or type 2 diabetes, or another chronic disease. Although the Subcommittee did not address participant safety among adults performing HIIT, the issue is highly relevant with respect to using HIIT for health promotion. [Jelleyman et al⁴²](#) documented adverse events reported in the 50 studies included in their meta-analysis. Among the 19 total adverse events reported from the 17 studies (34% of the total) that included this type of information, 18 adverse events were attributable to musculoskeletal

injuries incurred with exercise, with 14 of 18 occurring with HIIT. None of the reported injuries was a serious adverse event or necessitated the participant to discontinue the intervention or drop out of the study. Perhaps consistent with the very low incidence of adverse events, mean participant dropout rate was 10 ± 10 percent among the 36 (72%) of studies that documented attrition. The health and disease characteristics of the participants who experienced an adverse event were not presented or discussed.

For additional details on this body of evidence, visit: <https://health.gov/paguidelines/second-edition/report/supplementary-material.aspx> for the Evidence Portfolio.

Public Health Impact

The Subcommittee has identified moderate evidence to indicate that HIIT can effectively improve insulin sensitivity, blood pressure, and body composition in adults. These HIIT-induced improvements in cardiometabolic disease risk factors are comparable to those resulting from continuous, moderate-intensity aerobic exercise and are more likely to occur in adults with overweight and obesity.

NEEDS FOR FUTURE RESEARCH

Question 1. Step Count Per Day and Question 2. Bout Duration

1. Conduct additional longitudinal research, either in the form of prospective studies or randomized controlled trials, to examine the dose-response relationship between:
 - a) Steps per day and health outcomes, and
 - b) Whether physical activity accumulated in bouts of less than 10 minutes in duration enhances health outcomes.

Rationale: This information is critical for setting target volumes of physical activity using steps per day as the metric and for firmly establishing that steps per day predicts the incidence of future disease outcomes. In this review, only one randomized controlled trial was identified and it did not include multiple arms to examine the effects of various doses of steps per day on outcomes.

The majority of studies reviewed supporting the health benefits of physical activity accumulated in bouts of less than 10 minutes in duration used a cross-sectional design, with none of the randomized studies reporting on the effects of physical activity accumulated in bouts of less than 10

minutes. Having this knowledge will inform potential cause and effect rather than simply associations.

2. Include measurement methods in prospective and randomized controlled studies that will examine:
 - a) Whether the rate of stepping and the length (bouts) of continuous steps influence the relationship between steps per day and disease outcomes
 - b) Whether physical activity performed in a variety of bout lengths has differential effects on health outcomes

Rationale: The studies reviewed used simple pedometers providing accumulated steps and could neither address patterns nor intensity of steps per day. Additional physical activity assessment methods collecting these data should provide a better target for recommending physical activity volume. Based on the studies reviewed, randomized studies did not report on physical activity accumulated in bouts less than 10 minutes in duration, and only two prospective studies were identified that reported on physical activity accumulated in bouts less than 10 minutes. This may be a result of the methods used to assess physical activity in randomized and prospective studies, and suggests the need to include physical activity assessment methods that allow for these data to be available for analysis.

Question 3. High Intensity Interval Training

1. Conduct longer-term randomized controlled trials to assess the adherence to and the effects of high intensity interval training, compared to other types of physical activity programs, on physiological, morphological, and cardiometabolic health outcomes. They should address issues of dose-response and be of at least 6 months in duration. These randomized controlled trials should include diverse groups of adults who have overweight or obesity and/or who are at high risk of cardiovascular disease or type 2 diabetes. They should systematically assess adverse events, including musculoskeletal injuries, attributable to high intensity interval training, compared to other types of exercise training, among adults with a wide variety of health and disease characteristics.

Rationale: Most high intensity interval training intervention periods are less than 12 weeks, which may be insufficient time to assess the magnitude and sustainability of clinically-important changes in some physiological, morphological, and cardiometabolic health outcomes. The willingness and

ability of individuals to adhere to high intensity interval training programs is currently unknown. Prescriptively designing these studies to include participants who have overweight or obesity and/or who are at high risk of cardiovascular disease or type 2 diabetes is important to inform health promotion practitioners and policy leaders on the utility of recommending high intensity interval training for health among a large proportion of the U.S. adult population. At present, evaluation of the safety of high intensity interval training among adults with varied health and disease characteristics is compromised by the limited data available, in part, due to the low proportion of studies reporting adverse events.

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