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Physical Activity, Injurious Falls, and Physical Function in Aging: An Umbrella Review

LORETTA DIPIETRO[1], WAYNE W. CAMPBELL[2], DAVID M. BUCHNER[3], KIRK I. ERICKSON[4], KENNETH E. POWELL[5], BONNY BLOODGOOD[6], TIMOTHY HUGHES[1], KELSEY R. DAY[1], KATRINA L. PIERCY[7], ALISON VAUX-BJERKE[7], and RICHARD D. OLSON[7], FOR THE 2018 PHYSICAL ACTIVITY GUIDELINES ADVISORY COMMITTEE*

[1]Milken Institute School of Public Health, The George Washington University, Washington, DC; [2]Department of Nutrition Science, Purdue University, West Lafayette, IN; [3]Department of Kinesiology and Community Health, University of Illinois at Urbana-Champaign, Champaign, IL; [4]Physical Activity and Weight Management Research Center, University of Pittsburgh, Pittsburgh, PA; [5]Centers for Disease Control and Prevention, Atlanta, GA; [6]ICF, Fairfax, VA; and [7]Office of Disease Prevention and Health Promotion, Office of the Assistant Secretary for Health, U.S. Department of Health and Human Services, Rockville, MD

ABSTRACT

DIPIETRO, L., W. W. CAMPBELL, D. M. BUCHNER, K. I. ERICKSON, K. E. POWELL, B. BLOODGOOD, T. HUGHES, K. R. DAY, K. L. PIERCY, A. VAUX-BJERKE, and R. D. OLSON, FOR THE 2018 PHYSICAL ACTIVITY GUIDELINES ADVISORY COMMITTEE. Physical Activity, Injurious Falls, and Physical Function in Aging: An Umbrella Review. *Med. Sci. Sports Exerc.*, Vol. 51, No. 6, pp. 1303–1313, 2019. **Purpose:** To review and update the evidence of the relationship between physical activity, risk of fall-related injury, and physical function in community-dwelling older people that was presented in the *2018 Physical Activity Guidelines Advisory Committee Scientific Report* (PAGAC Report). **Methods:** Duplicate independent screenings of 1415 systematic reviews and meta-analyses published between 2006 and 2016 identified from PubMed®, Cochrane Library, and CINAHL databases yielded 111 articles used for the PAGAC Report. The PAGAC Aging Subcommittee members graded scientific evidence strength based upon a five-criteria rubric and assigned one of four grades: strong, moderate, limited, or not assignable. An updated search of 368 articles published between January 2017 and March 2018 yielded 35 additional pertinent articles. **Results:** Strong evidence demonstrated that physical activity reduced the risk of fall-related injuries by 32% to 40%, including severe falls requiring medical care or hospitalization. Strong evidence also supported that physical activity improved physical function and reduced the risk of age-related loss of physical function in an inverse graded manner among the general aging population, and improved physical function in older people with frailty and with Parkinson's disease. Aerobic, muscle-strengthening, and/or multicomponent physical activity programs elicited the largest improvements in physical function in these same populations. Moderate evidence indicated that for older adults who sustained a hip fracture or stroke, extended exercise programs and mobility-oriented physical activity improved physical function. **Conclusions:** Regular physical activity effectively helps older adults improve or delay the loss of physical function and mobility while reducing the risk of fall-related injuries. These important public health benefits underscore the importance of physical activity among older adults, especially those living with declining physical function and chronic health conditions. **Key Words:** EXERCISE, FUNCTIONAL PERFORMANCE, GERIATRICS, MOBILITY

Address for correspondence: Loretta DiPietro, Ph.D., M.P.H., Milken Institute School of Public Health, 950 New Hampshire Ave, Suite 2, Washington, DC 20052; E-mail: ldp1@gwu.edu.
*The 2018 Physical Activity Guidelines Advisory Committee includes David M. Buchner, Wayne W. Campbell, Loretta DiPietro, Kirk I. Erickson, Charles H. Hillman, John M. Jakicic, Kathleen F. Janz, Peter T. Katzmarzyk, Abby C. King, William E. Kraus, Richard F. Macko, David X. Marquez, Anne McTiernan, Russell R. Pate, Linda S. Pescatello, Kenneth E. Powell and Melicia C. Whitt-Glover.
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Advances in public health and in health care are keeping people alive longer, and consequently, the proportion of older people in the global population is increasing rapidly. As of 2016, individuals ages 65 yr and older comprise about 13% of the United States population, and their numbers are projected to reach 72.1 million (19% of the total population) by the year 2030 (1). This represents a twofold increase compared with the older adult population in 2000. Moreover, the number of people 85 yr and older is projected to rise to 14.6 million by 2040 (1). Due to these growing demographic trends, the prevention of chronic disease, the maintenance of functional status, and the preservation of physical independence in aging present major challenges that have substantial personal and public health implications.

Physical activity is any bodily movement that results in increased energy expenditure and can be achieved by a variety of leisure-time, work or transportation-related activities (2). Exercise refers to physical activities that are planned, structured, repetitive, and intended to improve or maintain fitness, function, and health (2). Ample evidence now exists that regular physical activity is key to preventing and managing major chronic diseases common to older people (3). Physical activity is also important for preserving physical function and mobility, which can then delay the onset of major disability (4). Current physical activity guidelines for older people recommend at least 150 $\text{min}\cdot\text{wk}^{-1}$ of moderate-intensity aerobic activity, with muscle-strengthening activity performed on two or more days per week (5). Despite the known benefits of physical activity to health and physical function in aging, however, the proportion of older adults meeting recommended physical activity guidelines for aerobic activity remains low (27%), based on data from the 2011–2012 National Health and Nutrition Examination Survey (6). This low prevalence of physical activity has important implications because it is a modifiable behavior that contributes substantially to the burden of chronic disease mortality in the United States (7).

Since the *2008 Physical Activity Guidelines Advisory Committee (PAGAC) Scientific Report* (3), considerable evidence has emerged regarding the relative benefits of additional modes or combinations of physical activity to specific physical function outcomes (e.g., strength, gait speed, balance, activities of daily living [ADL] function). These additional physical activity interventions include progressive resistance training, multicomponent exercise, dual-task training, active video gaming, tai chi, yoga, and dance. In addition, the current research has begun to address the issues of the dose–response relationship between physical activity and physical function in aging. Similar to studies of pharmacologic agents, it is not only important to determine if a graded relationship exists but also to determine the shape of the relationship for specific health outcomes to establish a minimal effective dose and a maximal threshold dose for safety.

The 2018 PAGAC Scientific Report (8) expanded on the 2008 report by examining the relationship between physical activity and the risk of fall-related injuries, as well as the relationship between physical activity and physical function, in both the general aging population and in people living with specific chronic diseases (cardiovascular disease [CVD], chronic obstructive pulmonary disease (COPD), cognitive impairment, frailty, hip fracture, osteoporosis, Parkinson's Disease, stroke, and visual impairments). The 2018 PAGAC Scientific Report further leveraged current research in examining: 1) the dose–response relationship between exposure and outcome; 2) the mode of activity most beneficial to a specific functional outcome; and 3) whether the relationship between physical activity and physical function varied by age, race, sex, sociodemographic characteristics, or by body weight. This current article summarizes the evidence from the 2018 PAGAC Scientific Report and includes new evidence from an updated search of the effects of physical activity on fall-related injuries, and physical function in older people.

METHODS

Search strategy, study selection, and quality assessment. Table 1 provides the specific questions and subquestions addressed by the Aging Subcommittee of the 2018 PAGAC in their report. A first search was undertaken to include publications from 2006 to 2016. The searches were conducted in PubMed®, CINAHL, and Cochrane Library and supplemented through hand-searches of reference lists of included articles and are reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (9). The Subcommittee determined that systematic reviews (SR), meta-analyses (MA), pooled analyses, and reports provided a wealth of quality information to answer two of its three research questions. Thus, to increase work efficiency, the searches were limited to these types of reviews. For

TABLE 1. List of questions addressed by the aging subcommittee of the 2018 Physical Activity Guidelines Advisory Committee.

1. What is the relationship between physical activity and risk of injury due to a fall?
   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?
   c. What type(s) of physical activity are effective for preventing injuries due to a fall?
   d. What factors (e.g., level of physical function, existing gait disability) modify the relationship between physical activity and risk of injury due to a fall?
2. What is the relationship between physical activity and physical function among the general aging population?
   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?
   c. What type(s) of physical activity (single component, dual task, multicomponent) are effective for improving or maintaining physical function among the general aging population?
   d. What impairment(s) (e.g., visual impairment, cognitive impairment, physical impairment) modify the relationship between physical activity and physical function among the general aging population?
3. What is the relationship between physical activity and physical function in older adults with selected chronic conditions? These conditions are: 1) cardiovascular disease; 2) chronic obstructive pulmonary disease (COPD); 3) cognitive impairment; 4) frailty; 5) hip fracture; 6) osteoporosis and osteopenia; 7) Parkinson's disease; 8) stroke; and 9) visual impairment.

Question 1 (What is the relationship between physical activity and risk of injury due to a fall?*)*, the Subcommittee found that existing reviews (SR, MA, pooled analyses, and reports) covered only evidence from randomized controlled trials (RCT), and therefore a supplementary search for cohort and case–control studies was conducted to capture the most complete literature. Search terms included physical activity and sedentary time terms combined with physical function or falls and injuries terms. The full search strategies are available at https://health.gov/paguidelines/second-edition/report/supplementary_material/pdf/Aging_Q1_Risk_of_Injuries_Evidence_Portfolio.pdf and https://health.gov/paguidelines/second-edition/report/supplementarymaterial/pdf/Aging_Q2_Physical_Function_Evidence_Portfolio.pdf.

The inclusion criteria were predefined, and studies were considered potentially eligible if they were SR, MA, pooled analyses, or reports published in English from 2006 until February 2016 (also cohort studies published in English from 2006 until 2016 for risk of fall-related injuries) and investigated the association between all types and intensities of physical activity and physical function and/or risk of injuries from falls in the aging population. Studies of nonambulatory adults, hospitalized patients, or animals were excluded. Two reviewers independently screened titles, abstracts, and full-text of the identified articles. A third reviewer helped resolve disagreement between reviewers.

In March, 2018, two updated SR were undertaken to identify additional SR and MA published between January 2017 through February 2018 that assessed the relationship between 1) any type of physical activity and fall-related injury or 2) physical function in the aging population. The searches were also conducted in PubMed®, CINAHL, and Cochrane Library and supplemented through hand-searches of reference lists of included articles. The updated review followed an established protocol that was registered as two reviews with PROSPERO [CRD42018096687 (fall-related injuries) and CRD42018095776 (physical function)].

Evidence to inform each question was graded as strong, moderate, limited, or "not assignable" based on several grading criteria, including applicability, generalizability, risk of bias/study limitations, quantity and consistency of results across studies, and magnitude and precision of effect (8) (see Table, Supplemental Digital Content 1, 2018 Physical Activity Guidelines Advisory Committee Grading Criteria, http://links.lww.com/MSS/B523). Table 2 provides a summary of the relationships and level of evidence for each health outcome examined by the 2018 PAGAC Aging Subcommittee.

RESULTS

After duplicates were removed, a total of 1415 articles were identified from the original search process. Following full-text review, a total of four articles were deemed relevant to the question about fall-related injuries (question 1); 38 were relevant to physical function in the general aging population (question 2); and 63 were relevant to physical function in older people with specific chronic diseases (question 3). Quality for each SR, MA, or article was assessed using AMSTARExBP (10). Risk of bias, or internal validity, was assessed for each original study using an adapted version of the USDA Nutrition Evidence Library Bias Assessment Tool (11).

The updated systematic search for fall-related injury risk identified 38 unique SR and MA after duplicates were removed. Of these, 32 were excluded after a review of the titles and abstracts and five more were excluded after full-text review leaving one new review (Fig. 1). The updated search for physical function in the general aging population and in those with selected chronic conditions identified 330 SR and MA, of which 288 were excluded after review of titles, six were excluded after review of the abstracts, and two more excluded after full-text review leaving 34 new reviews (Fig. 2).

TABLE 2. Summary of the level of evidence for the relationship between physical activity, fall-related injuries, and physical function in older people: 2018 PAGAC Scientific Report.

	Overall Evidence	Dose–Response	Type of Activity Reported	Effect Modification by Demographic Factors, Weight, or Other Functional Factors
Fall-related injury	Strong	Limited (MVPA)	Moderate (multicomponent)	NOT ASSIGNABLE
Physical function in the general aging population	Strong	Strong (aerobic) Limited (strength and balance)	Strong (aerobic, strength, multicomponent) Moderate (balance) Limited (tai chi, dance, AVG, dual-task, functional) Not assignable (flexibility, yoga, qigong)	LIMITED/NOT ASSIGNABLE
Physical function in older people with specific chronic conditions*				
• Cardiovascular disease	Limited		Muscle-strengthening, tai chi, qigong, aerobic	
• COPD	Limited		Tia chi, qigong, walking, cycling, leg exercises	
• Cognitive impairment	Limited		Supervised multicomponent	
• Frailty	Strong		Multicomponent	
• Hip fracture	Moderate		Weight-bearing multicomponent	
• Osteoporosis	Limited		Muscle-strengthening, multicomponent	
• Parkinson's disease	Strong		Aerobic, resistance, dance, VRT, yoga, tai chi	
• Stroke	Moderate		Mobility-oriented, treadmill walking	
• Visual impairment	Insufficient			

The activities in parentheses refer to the level of evidence. For example among the general aging population, we found strong evidence linking aerobic, strength, and multicomponent activities to improvements in physical function.

*Question 3 did not examine dose–response or effect modification.

MVPA, moderate-to-vigorous intensity physical activity; AVG, active video gaming; VRT, virtual reality training.

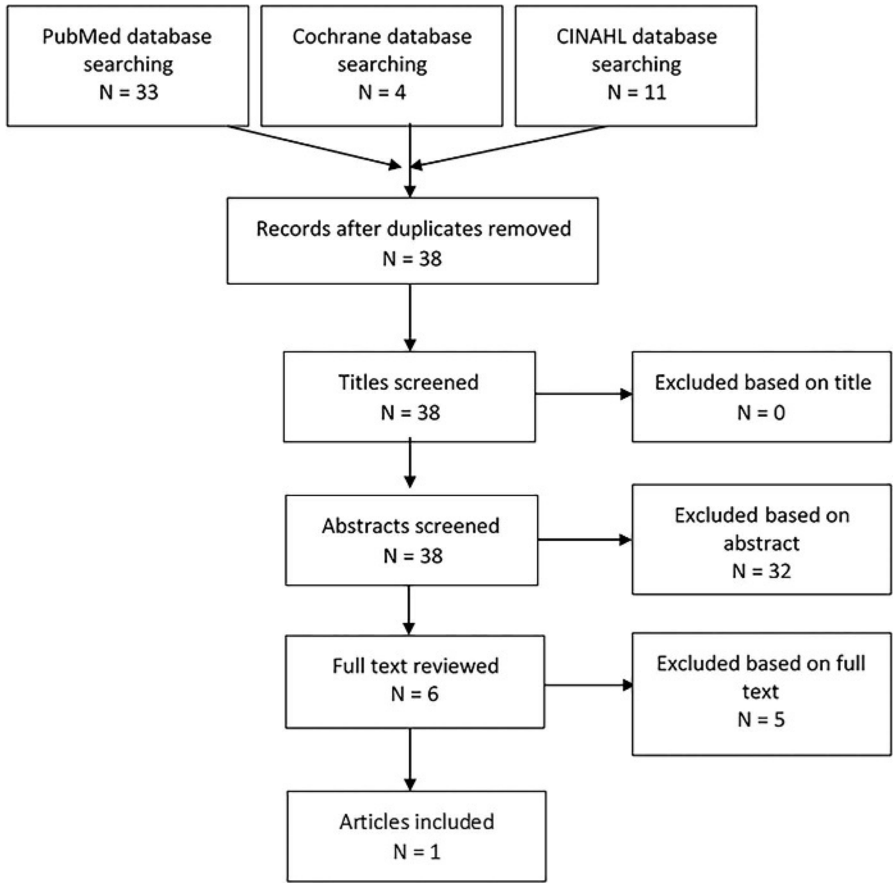

FIGURE 1—Risk of injuries from falls: SR, MA, pooled analyses, and report flow diagram of search strategy and study selection from the updated search, March 2018.

Physical Activity and Risk of Fall-Related Injury

The 2018 PAGAC Scientific Report cited strong and consistent evidence from RCT demonstrating that multicomponent physical activity (i.e., combinations of aerobic, muscle-strengthening, balance, and flexibility) significantly reduced the risk of fall-related injuries by about 32%–40%, including severe falls that result in bone fracture, head trauma, open wound soft tissue injury, or any other injury requiring medical care or admission to hospital (12–15). Moreover, the benefits of physical activity programs to reduce the risk of these four categories of fall-related injuries were similar between older adults identified as being at high risk of falling versus those who were at an unspecified risk (12). Also, fall prevention programs using multicomponent activity reduced the risk of fall-related bone fractures by 40% to 66% among older adults in community and home settings (12–15). These RCT findings were supported by data from three prospective cohort studies (16–18) and one case–control study (19).

The updated search identified one review that supported the evidence from the 2018 PAGAC Report (20). A MA of five RCT conducted in Asian countries reported that participation in physical activity programs (primarily tai chi) by community-dwelling older adults reduced the risk of fall-related injuries by 50% (relative risk [RR]. 0.50; 95% confidence interval [CI], 0.35–0.71).

Dose–response. There was some evidence in the 2018 PAGAC Scientific Report to suggest that a dose–response relationship exists between the amount of moderate-to-vigorous physical activity or home and group exercise and risk of fall-related injury and bone fracture; however, the small number of studies available and the diverse array of physical activities studied made it difficult to describe the shape of the relationship. Consistent results from four high-quality epidemiologic studies (three cohort and one case–control) suggested that adults age 65 yr and older who participated in physical activity of at least moderate-intensity for ≥30 min·d^{-1} (16) or engaging in high/very high levels of activity (i.e. a weekly physical activity index score ≥25) (17), reduced the risk of fall-related injury and bone fracture. Evidence also exists that even adults ages 85 yr and older obtained similar benefits from ≥60 min·wk^{-1} of home- or group-based physical activity (18). However, it is important to note that lower amounts of moderate-intensity physical activity (16,17) and walking (18) may not be sufficient to reduce the risk of fall-related injury and bone fracture in older age.

Physical activity type. The physical activity programs that effectively reduced the risk of fall-related injuries and bone fractures contained a variety of group- and home-based activities (12,14,15,18,19). Most programs were multicomponent and included various combinations of moderate-intensity

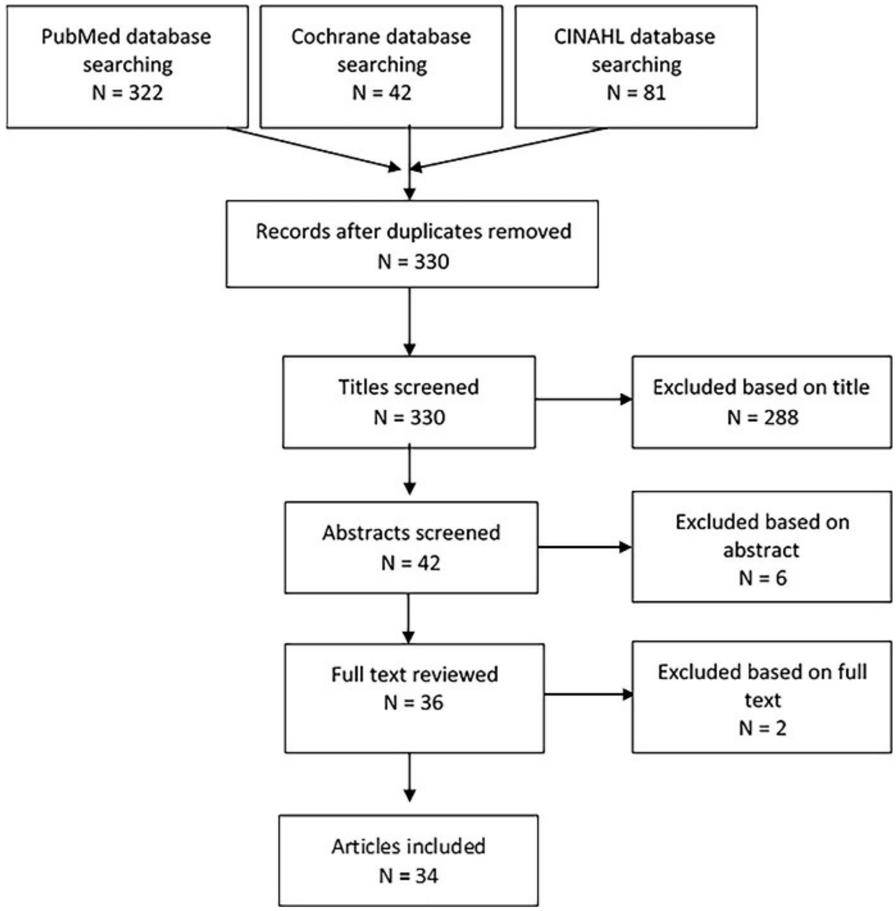

FIGURE 2—Physical function SR, MA, pooled analysis, and report flow diagram of search strategy and study selection from the updated search, March 2018.

balance, strength, endurance, gait, flexibility, and "physical function" training, as well as recreational activities (e.g., dancing, cycling, gardening, sports). Although the research was limited, it does not support the use of low-intensity walking as a primary mode of physical activity to reduce the risk of fall-related injuries and fractures among older adults (18,19), although walking may be included in multicomponent physical activity regimens. Unfortunately, insufficient information was available from the SR to determine the effects of individual elements (e.g., strength training, balance training) of the multicomponent training programs on the risk of fall-related injuries.

Effect modification by sociodemographic characteristics or preexisting disability. There was insufficient evidence available to determine whether the relationship between physical activity and risk of fall-related injuries and bone fractures varies by age, sex, race/ethnicity, socioeconomic status, or weight status or whether factors such as level of physical function ability and preexisting gait disability modify the relationship between physical activity and risk of injury due to a fall.

Physical activity and physical function in the general older population. The 2018 PAGAC Scientific Report cited strong evidence from RCT and cohort studies that aerobic, muscle-strengthening, balance, and/or multicomponent physical activity programs improved physical function and reduced risk of age-related loss of physical function in the general aging population (8). One high quality MA by Chase et al. (21) analyzed data from 28 RCT using objective composite measures of physical function, such as the short physical performance battery (SPPB), timed-up-and-go tests (TUG), the continuous scale physical performance test (CS-PPT), and the physical performance test (PPT). The summary effect size (ES) describing the magnitude of the relation between physical activity and physical function was 0.45 (95% CI: 0.27 to 0.64), with the higher quality studies reporting smaller effect sizes. The updated search identified nine SR/MA that supported the 2018 Scientific Report by also providing strong to moderate evidence demonstrating the benefits of physical activity to physical function in this population (22–30).

Dose–response. The 2018 PAGAC Scientific Report found strong evidence of an inverse dose–response relationship between volume of aerobic physical activity and risk of physical functional limitations in the general aging population. One review of 24 comparisons from prospective cohort studies with covariate adjustment classified dose of aerobic activity reported in cohort studies into four ordinal categories (0 = no activity; 1 = low activity; 2 = moderate activity; and 3 = vigorous activities and/or high activity volume) (31). With this analysis framework, virtually every study showed an inverse dose–response relationship of aerobic activity with risk of limitations in physical function (Fig. 3). The 2018 Scientific Report cited limited evidence of a dose–response relationship between either balance (32) or muscle-strengthening training and

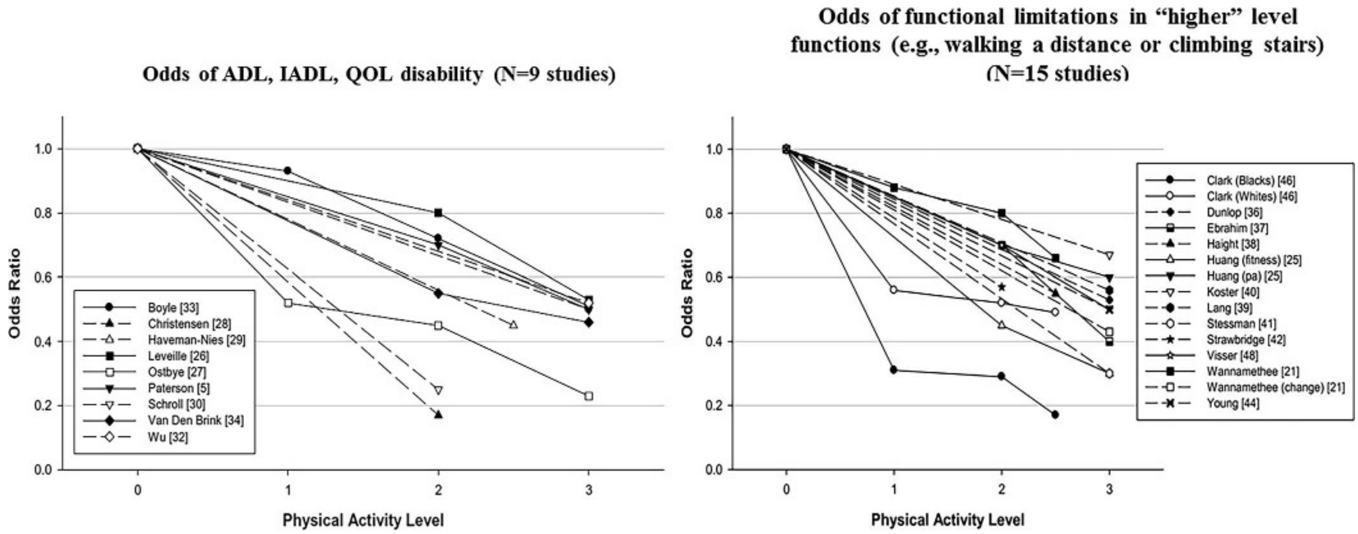

FIGURE 3—Results of a SR of the inverse dose–response relationship between volume of aerobic physical activity and risk of physical functional limitations in the general aging population. Categories of physical activity level were derived from prospective cohort studies with covariate adjustment: 0, no activity; 1, light activities only occasion walking or gardening; 2, moderate level of activity (volume = 3–5 d·wk^{-1} for 30 min·d^{-1}; and 3) = vigorous activities and/or high volume of systematic activity. The odds ratio is the odds of disability in the physical activity group relative to a comparison group. IADL, instrumental activities of daily living; QOL, quality of life score. Figure reproduced with permission from Paterson & Warburton, 2010.

physical function (21) in this same population. The updated search, however provided important additional information. Roberts et al. (29) examined the effects of different physical activity types and levels (determined from calculated MET-min and categorized as low, moderate, or high) on ADL function. Results from the pooled MA indicated that, compared with a control condition, there were beneficial effects of physical activity on ADL physical performance (standardized mean difference (SMD) = 0.72; 95% CI: 0.45 to 1.00; 29 studies) with the largest effects observed for moderate activity levels (SMD = 1.07; 95% CI: 0.44 to 1.70; nine studies), compared with low levels (SMD = 0.57; 95% CI:0.29 to 0.86; 20 studies). There were no studies of ADL performance that used high physical activity levels, and therefore a conclusion regarding their benefits could not be drawn. With regard to various levels of multitask activities (those activities that combine physical and mental tasks), the greatest difference in ADL performance between the exercise and the control groups were reported for the high level multitask group (SMD = 1.36; 95% CI: 0.46 to 2.26; six studies), followed by the moderate level group (SMD = 0.74; 95% CI: 0.41 to 1.06; 13 studies), and the low level group (SMD = 0.45; 95% CI: −0.01 to 0.91; eight studies).

Types of activity. The 2018 PAGAC Scientific Report cited strong evidence that, specifically, aerobic, muscle-strengthening, and multicomponent physical activity improved physical function in the general aging population, and moderate evidence indicating that balance training improved physical function in a dose–response manner among these same persons (8). The evidence linking physical activities such as tai chi exercise, dance training, active video gaming, and dual-task training to improvements in physical function in healthy aging were limited, however, due to the lack of studies at this time. Similarly, insufficient evidence was available to determine the effects of flexibility activity, yoga, and qigong exercise on physical function in the general aging population.

The updated search identified a MA by Farlie and colleagues (24) that examined the effects of four different types of balance training interventions [multidimensional (activities such as "functional exercises," tai chi, and ball games), control center of mass (COM), mobility, and reaching] on several dimensions of balance performance. Overall, the MA resulted in small to moderate effects in favor of programs that included multidimensional (SMD = 0.50; 95% CI: 0.36 to 0.65), reaching (SMD = 0.48; 95% CI: 0.33 to 0.64), COM (SMD = 0.42; 95% CI: 0.27 to 0.56) and mobility (SMD = 0.31; 95% CI: 0.20 to 0.43) balance training versus no balance training interventions. The authors noted, however, that there was substantial between-study heterogeneity among the interventions (I^2 range 50.4% to 80.6%).

Multitask activities with high levels of physical (speed, coordination, balance), mental and social demands (e.g., dancing, team sports, handball) appeared particularly effective in improving functional performance, relative to moderate or lower levels of such activities and compared with control conditions (29). Nordic walking also has demonstrated moderate effectiveness in improving dynamic balance (effect size (ES) = 0.30), functional balance (ES = 0.62), muscle strength of upper (ES = 0.66) and lower (ES = 0.43) limbs, and aerobic capacity (ES = 0.92) compared with no exercise comparison groups in healthy older people (23). An MA of 23 studies by Liu and colleagues (27) among community-dwelling older people with low physical function reported that progressive resistance exercise was effective in improving lower-body muscle strength and static standing balance; however multicomponent exercise was more effective in improving muscle strength, balance, and lower-body physical functioning, compared with progressive resistance exercise alone. Neither progressive resistance nor multicomponent exercise was effective in improving ADL, however.

Howe and colleagues (25) examined the effects of active computer gaming (ACG) on physical function in 1838 healthy people >65 yr of age. Their MA of 35 RCT reported significant moderate effects in favor of ACG over a control intervention on balance (SMD = 0.52; 95% CI: 0.24 to 0.79; 17 studies) and on functional exercise capacity when the volume of the ACG was >120 min·wk^{-1} (SMD = 0.53; 95% CI: 0.15 to 0.90; five studies). The authors noted, however, that the quality of the evidence for all comparisons was graded low or very low.

Finally, Weber et al. (30) reviewed 14 studies (six RCT) of interventions that integrated and embedded "functional exercise" into the daily activities of older people. The most frequently evaluated intervention in this review was the Lifestyle-integrated Functional Exercise (LiFE) program (33). "Functional exercises" are designed to improve lower-body strength, balance, and motor performance, as well as for increasing daily levels of physical activity. Examples of such include postures or walking with gradual reduction in the base of support (e.g., upgrading tandem stand to one-leg stand over time) and dynamic movements that perturb the center of gravity (stepping over obstacles). "Functional exercises" for improving lower-body strength include squatting, chair stands, and toe raises with a gradual increase to more intense and challenging activities (33). Importantly, the LiFE intervention has strategies for behavior change that are based on the habit reframing theory (34). Indeed, these exercises are linked to everyday tasks by using situational and environmental cues (e.g., tooth brushing, housework) as prompts to action, with the idea of performing the activities intentionally and consciously until they become a habit. Evidence from three RCT in the Weber et al. (30) review suggested that the LiFE intervention significantly improved balance, strength, and functional performance compared with either no intervention, low-intensity activities (e.g., walking), or structured exercise programs. Two of these RCT also reported a significant reduction in incident falls in participants in the LiFE group, compared with those in either a no intervention or a low-intensity activity group. Thus, although the data are limited, the LiFE approach appears to be a promising alternative or complement to traditional structured exercise programs.

In sum, our current findings pertaining to the effectiveness of different types of physical activity for improving physical function support those from the 2018 PAGAC Scientific Report, which cited strong evidence of the benefits of aerobic, muscle-strengthening, and multicomponent physical activity on improvements in physical function in the general aging population, and moderate evidence indicating that balance training improves physical function in these same persons. The evidence linking ACG (or active video gaming), Nordic walking, or functional exercise to improvements in physical function remains limited at this time.

Sociodemographic characteristics and weight status. Limited evidence from the 2018 PAGAC Scientific Report suggested that the relationship between physical activity and physical function did not vary by age, sex, or weight status in the general population of older adults (8). One MA reported sex and body mass index (BMI) were not significant effect modifiers of the relationship of physical activity on composite physical function scores (21). A MA of cohort studies reported the relationship between aerobic activity and ADL dependency did not differ significantly by age (75 yr and younger vs older than 75 yr) (35). The available evidence was insufficient to determine whether the relationship between physical activity and physical function varied by race/ethnicity and socioeconomic status in the general population of older adults. No relevant analyses were located in the updated search. We note, however, that several findings with "limited" evidence also have high public health importance. Adults age 75 yr and older have more age-related loss of physical function, are more likely to be women, and the majority have a BMI in the range of overweight-to-obese.

Effect modification by visual, cognitive, or physical impairments. None of the SR/MA identified in either search examined whether visual or cognitive impairments modified the effects of physical activity on physical function. Limited evidence suggested that physical activity has a stronger effect on physical function in older adults with limitations in physical function, compared with relatively healthy older adults. One MA compared the effect size in nonfrail adults (ES = 0.35; 95% CI: 0.17–0.54) with that in frail adults (ES = 1.09; 95% CI: 0.55–1.64) and found the effect size was significantly larger in frail adults ($P < 0.05$) (21). A MA identified from the updated search reported that the significant benefits of aerobic exercise training to improvements in peak aerobic capacity were observed in both healthy older people (MD = 1.72; 95% CI: 0.34 to 3.10; six studies) and in those with existing chronic conditions (MD = 1.47 (95% CI: 0.60 to 2.34; four studies) (22). This aerobic training involved walking, cycling, treadmill walking, walking/running on a mini-trampoline, or combinations of these activities performed three times per week over a range of 12 to 26 wk.

Physical Activity and Physical Function in Older People with Specific Chronic Conditions

This question builds upon Question 2 by addressing the relationship between physical activity and physical function in discreet populations of older people having selected chronic conditions. The chronic conditions were selected based on their prevalence in older age, as well as on the availability of published research linking physical activity to physical function within each condition (8).

Table 2 shows the level of evidence for the relationship between various types of physical activities and physical function in older people with specific chronic conditions from the 2018 PAGAC Scientific Report. The strongest evidence was observed for the benefits of multicomponent activities among people with frailty and with Parkinson's disease. Moderate evidence indicated that for community-dwelling older adults who sustain a hip fracture, extended exercise programs (which begin after formal hip fracture rehabilitation ends) was effective for improving physical function and that mobility-oriented physical activity improved walking function for individuals after a stroke.

Cardiovascular disease. In the 2018 PAGAC Scientific Report, there was limited evidence suggesting that physical activities such as muscle-strengthening and alternative/complementary exercises (tai chi, qigong, Baduanjin) improved physical function among older people with cardiovascular disease. The updated search identified no additional evidence of this relationship.

COPD. Limited evidence from the 2018 Report suggested that tai chi and qigong exercise improved one aspect of physical function (walking ability) in individuals with COPD (36,37). The updated search identified one SR/MA in people with severe COPD that supported the limited evidence reported in 2018 (38). This MA of 10 RCT reported that exercise training improved performance on the 6-min walk test (6MWT; SMD = 3.86; 95% CI: 2.04 to 5.67), compared with a control condition. The exercise training interventions comprised primarily leg exercises, cycling, and walking, with intensity of exercise ranging from 70% to 90% of maximal velocity achieved during incremental testing at baseline.

Cognitive impairment. Limited evidence from the 2018 PAGAC Scientific Report suggested that for individuals with cognitive impairment, physical activity programs improved physical function, including ADL measures. Two SR/MA examining the relationship between physical activity and physical function in older people with cognitive impairment were identified in the updated search (39,40). One of these MA (39) comprising 43 trials (N = 3988) reported significant differences between supervised exercise training and control conditions on improvements in performance on the 30-s sit-to-stand test (mean difference (MD) = 2.1 repetitions; 95% CI: 0.3 to 3.9; four trials), step length (MD = 5 cm; 95% CI: 2 to 8; five trials), Berg Balance Scale (MD = 3.6 points; 95% CI: 0.3 to 7.0; six trials), functional reach (MD = 3.9 cm; 95% CI: 2.2 to 5.5; six trials), TUG test (MD = −1 s; 95% CI: −2 to 0; 11 trials), walking speed (MD = 0.13 $m \cdot s^{-1}$; 95% CI: 0.03 to 0.24; seven trials), and the 6MWT (MD = 50 m; 95% CI: 18 to 81; seven trials) in this population. Importantly, about 45% of the training programs used multicomponent exercise with a resistance exercise component, while 23% relied on aerobic training.

Frailty. All of the 15 SR/MA included in the 2018 PAGAC Scientific Report cited that physical activity improved some or all measures of physical function in older people with frailty (8). A MA (41) of 19 RCT among community-dwelling older adults with frailty reported that overall, physical activity decreased the time needed to walk 10 m by 1.73 s. This has important clinical relevance for older people with frailty, as gait speed is a strong predictor of mortality risk and there is evidence that increments in speed as small as 0.1 $m \cdot s^{-1}$ significantly lowers that risk (42). The updated search identified five additional SR that support the strong evidence from the 2018 PAGAC Scientific Report (43–47). Most of these reviewed RCT and experimental studies examined multicomponent exercise involving resistance training, balance, gait, or endurance training (44–47). In a review of 16 studies involving 1350 frail older adults, Lopez and colleagues (45) reported that resistance training either alone or as part of multicomponent training improved maximal muscle strength between 6.6% and 37%. Similarly, the authors report gains in muscle mass (3.4% to 7.5%), muscle power (8.2%), and functional capacity (4.7% to 58.1%). Moreover, gait speed improved between 5.9% and 14.5%, as did score on the TUG (5.5% to 20.4%).

Hip fracture. Moderate evidence from the 2018 PAGAC Scientific Report indicated that older people who have sustained a hip fracture also benefitted from weight-bearing, multicomponent activity (8). The updated search identified only one SR/MA that investigated this relationship. The MA of RCT by Lee et al. (48) reported that progressive resistance exercise significantly improved overall physical function after hip fracture surgery compared with a control group (SMD = 0.408; 95% CI: 0.238 to 0.578; eight studies) and it was especially effective in improving mobility (SMD = 0.501; 95% CI: 0.297 to 0.705), ADLs (SMD = 0.238; 95% CI: 0.040 to 0.437), balance (SMD = 0.554; 95% CI: 0.310 to 0.797), lower-limb strength or power (SMD = 0.421; 95% CI: 0.101 to 0.741), and performance tasks (SMD = 0.841; 95% CI: 0.197 to 1.484).

Osteoporosis/osteopenia. Limited evidence from the 2018 PAGAC Scientific Report suggested that muscle-strengthening and agility activities performed on two or more days per week improved physical function in older people who are at risk of fragility fractures due to osteoporosis or osteopenia (8). The updated search identified one SR/MA examining this relationship that adds considerably to the level of evidence. Based on a MA of 25 RCT, Varaha et al. (49) reported that multicomponent exercise significantly improved timed mobility (SMD = −0.56; 95% CI: −0.81 to −0.32), balance (SMD = 0.50; 95% CI: 0.27 to 0.74), and self-reported functioning (SMD = −0.69: 95% CI: −1.04 to −0.34) compared with a control condition in 2,113 older people (95% of whom were women). Moreover, the results for multicomponent exercise (10 studies) were more pronounced than those for gait, balance, and functional tasks (four studies); strength/resistance training (nine studies); or tai chi (five studies) interventions, suggesting that multicomponent exercise was more effective in improving a broad range of functional outcomes in people with osteoporosis.

Parkinson's disease. The 2018 PAGAC Scientific Report cited strong evidence that physical activities, such as aerobic and resistance training, tango dancing, virtual reality training, yoga, and tai chi improved a number of physical function outcomes, including walking, balance, strength, and disease-specific motor scores in older people with Parkinson's disease, with effect sizes ranging from small (ES = 0.33; 95% CI: 0.17 to 0.49 for gait velocity) to moderate (ES = 0.72; 95% CI, 0.08–1.36 for the 6 min walk time) (8). Three additional SR on this relationship were identified in the updated search (50–52), two of which (51,52) included a MA. Overall, the newpapers supported the findings of the 2018 Report. One small MA (5 RCT; N = 159 participants) compared dance interventions (Tango or Irish) with other physical activity interventions (three RCT) or with no intervention (two RCT) (51). Dance practice at least three times per week promoted significant improvements in motor scores assessed with the Unified Parkinson's Disease Rating

Scale (UPDRS) III (SMD = −2.52; 95% CI: −4.59 to −0.45) and a significant decrease in TUG time (SMD = −1.15 s; 95% CI: −2.03 to −0.27 s) compared with other interventions. Dance also improved the UPDRS III score when compared with no intervention (SMD = −8.35; 95% CI: −13.79 to −2.91).

Stroke. In the 2018 PAGAC Scientific Report, moderate evidence indicated that mobility-oriented physical activity improved walking function for individuals after a stroke and that among stroke survivors, treadmill walking (especially with cadence cuing) improved walking speed by approximately 0.23 $m \cdot s^{-1}$ (8). Seven SR relating physical activity to improved physical function in people having had a stroke were identified from the updated search (53–59). Of these reviews, six included a MA (53–58). The interventions examined included aerobic exercise (54), circuit-based training (53), dual-task balance and mobility training (56), progressive task-oriented exercise (58), and treadmill training (57,59). Two novel MA examined the effects of circuit-based exercise (vs other types of exercise or no therapy) on various measures of physical function (53,55) and both reported that circuit-based training was equal or superior to other forms of therapy in improving measures of gait speed, balance, and functional mobility. In their MA (N = 10 studies; 835 participants), English and colleagues (55) reported that circuit training was superior to comparison interventions in improving walking capacity on the 6MWT (MD = 60.86 m; 95% CI: 44.50 to 77.17 m) and gait speed (MD = 0.15 $m \cdot s^{-1}$; 95% CI: 0.10 to 0.19 $m \cdot s^{-1}$). Interestingly, these same authors observed no difference in the effectiveness of circuit-training versus a control on walking endurance between stroke survivors who began training within 12 month of their stroke (MD = 46.56; 95% CI: 21.35 to 71.77) and those who started training 12 months or more after their stroke (MD = 71.15; 95% CI: 49.76 to 92.54). Additionally, superior benefits of circuit training were observed for scores on the TUG test and Activities of Balance Confidence, but not for the Berg Balance Score or the Step Test.

Visual impairments. Insufficient evidence was available from either search to determine the effects of physical activity on physical function in older adults with visual impairments.

DISCUSSION

This updated SR extends the findings of the 2018 PAGAC Scientific Report by providing new evidence that corroborates the benefits of physical activity to a lower risk of fall-related injuries, as well as to improved physical function among the general older population and among those with selected chronic conditions. The types of activities reviewed in the updated search are similar to those reviewed in the 2018 PAGAC Scientific Report with the addition of different types of balance training interventions, functional exercises that become embedded in everyday lifestyle activities, Nordic walking, and circuit-based training. Perhaps the most convincing evidence from the 2018 PAGAC Report, along with that from the updated search, relates to the greater benefits of multicomponent, relative to single-component, exercise to the prevention of fall-related injuries and to improvements in physical function in older age. Moreover, multicomponent and multitask activities that are incorporated into the daily routine may be a promising alternative to structured, single-task exercise programs for older adults.

One in four individuals ≥65 yr falls in the United States every year (60). Furthermore, falls are the leading cause of fatal injury and the most common cause of nonfatal trauma-related hospital admissions among older adults (60). Physical activity programs that emphasize combinations of moderate-intensity balance, strength, endurance, gait, and physical function training appear most effective in reducing the risk of fall-related injuries and fractures in older adults. Thus, the effectiveness of these programs (that were performed in community settings or at home) for risk reduction has significant public health relevance in older age, due to the high prevalence of falls and fall-related injuries and fractures among older adults, as well as the consequent morbidity, disability and reduced quality of life.

Age-related limitations in physical function are prevalent in older adults. The National Health Interview Survey ascertained the prevalence of physical limitations in 2001 to 2007, with limitations defined as great difficulty doing (or inability to do) basic tasks of life (e.g., walk a quarter of a mile, lift a 10-pound bag of groceries) (61). At that time, 22.9% of older adults ages 60 to 69 yr and 42.9% of adults ages ≥80 yr reported functional limitations. Older adults with lower levels of physical function generally have higher health care expenditures (60). In addition, about 80% of adults ≥60 yr of age have at least one chronic condition, and 77% have at least two. Moreover, approximately 20% to 30% of adults older than age 65 yr suffer from either mild cognitive impairment or dementia (60). Chronic diseases account for 75% of health care spending in the United States (60). Low levels of daily physical activity often co-exist with chronic disease, thereby accelerating the risk of functional decline, disability, and mortality. Ample evidence now indicates that physical inactivity is among the strongest predictors of physical disability in older people (4). Aerobic, muscle-strengthening, and multicomponent physical activity appear to have the strongest relationship to improvements in physical function in the general aging population, as well as among those with chronic conditions. Thus, such activities may delay or improve mobility disability, frailty, and loss of independence in aging.

Both the 2018 Scientific Report (8) and this umbrella review underscore the need for future research in several areas. For example, the relationship between the minimal effective dose of activity (150 $min \cdot wk^{-1}$ of moderate intensity activity) and health has been described in detail (3,8). There still is, however, a need to examine greater volumes and intensities of physical activity to establish safety thresholds for older people — especially for those with preexisting conditions or limitations. To accomplish this, studies need to examine several levels of activity and to monitor and report adverse events. Also, the feasibility and benefits of alternative and complimentary activities, rigorous multitask activities, as well as novel interventions that integrate "functional exercises" into everyday tasks, need to be examined further. Moreover, the effectiveness of any new intervention needs to be examined across different socioeconomic strata to address existing disparities in prevention strategies and in health among older people. Given the rapidly increasing trends in aging demographics in the United States, preventing or delaying fall-related injuries and loss of physical function and mobility has important public health benefits, and this may be especially so for older people with already established chronic conditions.

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This article is being published as an official pronouncement of the American College of Sports Medicine. This pronouncement was reviewed for the American College of Sports Medicine by members-at-large and the Pronouncements Committee. This article serves as an update to the topics covered in the 2009 ACSM position stand, "Exercise and Physical Activity for Older Adults" [*Med. Sci. Sports Exerc*. 2009;41(7):1510–30]. *Disclaimer:* Care has been taken to confirm the accuracy of the information present and to describe generally accepted practices. However, the authors, editors, and publisher are not responsible for errors or omissions or for any consequences from application of the information in this publication and make no warranty, expressed or implied, with respect to the currency, completeness, or accuracy of the contents of the publication. Application of this information in a particular situation remains the professional responsibility of the practitioner; the clinical treatments described and recommended may not be considered absolute and universal recommendations.

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