Review Article

What are the health benefits of muscle and bone strengthening and balance activities across life stages and specific health outcomes?

Melvyn Hillsdon[1], **Charlie Foster**[2]

[1]University of Exeter, Sport & Health Sciences, Exeter, UK; [2]University of Bristol, Exercise Nutrition and Health Sciences, Social Science Complex, Bristol, UK

Abstract

Many activities of daily living require muscular strength and power as well as balance. Consequently, preserving musculoskeletal function is a prerequisite for maintaining mobility and independent living during ageing. Estimates suggest that the prevalence of physical activity guidelines for strength and balance is low. Review of reviews of: a) observation studies of the prospective association between measures of musculoskeletal fitness and health outcomes and b) randomised controlled trials of resistance, balance and skeletal impact training exercises on bone health, risk of falls, physical function, motor and cognitive function, quality of life and activities of daily living. Preserving muscular strength/power in middle and older age is associated with a reduced risk of all-cause and cardiovascular mortality. Impaired muscular strength/power and balance is associated with an increased risk of falls and lower bone mineral content. Regular supervised exercise incorporating high intensity resistance training, vertical impacts and a balance challenge are most likely to be beneficial to health and wellbeing, bone health and reduce the risks of falls. Adults in late middle and older age would benefit from a regular program of exercise that incorporates high intensity resistance training, impact exercises and balance challenges.

Keywords: Strength, Power, Balance, Exercise, Bone, Physical Activity

Introduction

Many activities of daily living require muscular strength and power as well as balance. Lifting and holding heavy objects such as shopping, raising the bodyweight while using a handrail on the stairs or when boarding a bus, carrying out heavy gardening or housework all require hand grip strength. Similarly, most weight bearing activities and locomotion require strength/power in the large lower limb muscles. Balance is necessary to undertake all activities of daily living to reduce the risk of tripping and falling. Consequently, preserving musculoskeletal function via physical activity and exercise is a prerequisite for maintaining mobility and independent living during ageing. UK physical activity guidelines recommend that adults aged 19-64 should "undertake physical activity to improve muscle strength on at least two days a week" and adults age 65 years and older who are at risk of falls should in addition "incorporate physical activity to improve balance and co-ordination on at least two days a week"[1]. Although surveillance of adherence to these specific aspects of physical activity guidance is not routinely undertaken, estimates suggest that they are low. In Scotland, 31% of men and 24% of women adhered to the muscle strengthening recommendation and 19% of men and 12% of women aged 65 and over met the balance and co-ordination recommendation[2].

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Corresponding author: *Melvyn Hillsdon, University of Exeter, Sport & Health Sciences, St Luke's Campus, Heavitree Road, Exeter UK, EX1 2LU*

E-mail: *m.hillsdon@exeter.ac.uk*

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Methods

A review of reviews of: a) observation studies of the prospective association between measures of musculoskeletal fitness and health outcomes including mortality, morbidity, mental wellbeing and risk of falls and b) randomised controlled trials of resistance, balance and skeletal impact training exercises on bone health, risk of falls, physical function, motor and cognitive function, quality of life and activities of daily living.

A purposive review was undertaken to search and identify review level relevant literature on the association between objective measures of muscular strength, power and balance and health outcomes as well as review level literature on the effectiveness of muscle, bone and balance training on health outcomes, physical function and activities of daily living in non-diseased adults. The search focused on review level evidence searching PubMed and the Cochrane Library. We used a broad set of MeSH terms (Medical Subject Headings) including “muscle”, “bone’, “balance” AND “function” AND “adults”. We also searched for international evidence reviews of physical activity used to construct national physical activity guidelines and recommendations (published since 2010) using Google, targeting public health bodies (i.e. National Centre for Health and Clinical Excellence, Centre for Disease Control). Reference lists of all identified reviews were examined to identify reviews not found from electronic searches. Finally, we also contacted international experts to identify further examples of relevant reviews.

Narrative systematic reviews were included as well as meta-analyses. Where two reviews addressed the same research question the most recent review was included and meta-analyses were preferred over narrative reviews.

Measures of musculoskeletal fitness

In observational studies and clinical trials, in community dwelling populations, both direct and indirect measures of musculoskeletal fitness were commonly employed.

The most common direct measure of muscular strength was grip strength measured using a handgrip dynamometer. In some studies the highest value achieved was recorded whereas in others the average of a number of attempts was recorded. Indirect measures of muscular strength, endurance and power include gait speed, chair rising and the timed get up and go. Gait speed was measured as the time taken from a standing start to complete distances of between 8 feet to 6 meters. Sometimes the fastest time was recorded and other times self paced ‘normal’ speed was recorded. The fastest time taken to rise from a chair to a standing position and back to sitting position 5 or 10 consecutive times was the most common measure of muscular power, although lower limb power is correlated with gait speed[3]. Occasionally, the timed get up and go was used which measures the time taken to rise from a chair, walk 3 meters and return to sitting. Balance was most commonly measured using the longest time (up to 30 seconds) that a person could stand on one leg, either with eyes closed or open.

Results

Measures of musculoskeletal fitness and mortality, morbidity, mental wellbeing and risk of falls

Mortality

Two narrative reviews and one meta-analyses examined associations between measures of musculoskeletal fitness and all-cause and cause specific mortality. Chainani et al.[4], reviewed 19 prospective studies that examined the association between objective measures of hand grip strength and gait speed on the risk of cardiovascular mortality. Twelve studies measured hand grip strength and seven gait speed. The average length of follow up was 5.1 years and the mean age of male and female participants ranged from 59-80 years. The majority of studies showed that higher hand grip strength was associated with a reduced risk of cardiovascular mortality (hazard ratios ranged from 0.22 to 0.90 per unit change in strength with some confidence intervals crossing 1.00). Slower gait speeds were associated with the risk of cardiovascular mortality. Hazard ratios varied from as high as 11.55 in highest versus lowest quartile comparisons (95% confidence intervals 2.30 to 58.04) to 2.92 (95% confidence intervals 1.46 to 5.84) with a number of confidence intervals again crossing 1.00 . Cardiorespiratory fitness, an important confounding variable, was not controlled for.

In 2015 Volaklis et al.[5], undertook a narrative review of 15 observational studies and 8 clinical trials of the relationship between muscular strength and all-cause and cause specific mortality. The studies included males and females with an age range from 20-89 years although most people were aged 50 years and older. Measures of muscular strength included hand grip strength, maximum leg strength and maximum bench press (upper body strength). The review found that muscular strength was consistently inversely associated with all-cause mortality even after adjustment for confounding factors including comorbidity (relative risks ranged from 1.35 to 2.34 in low versus high comparisons with some confidence intervals crossing 1.00). One observational study was also able to adjust for cardiorespiratory fitness without reducing associations to null. The protective effect of muscular strength was seen in both younger and older ages. The association between muscle strength and cardiovascular and cancer mortality was less consistent.

Cooper et al.[6], undertook a systematic review and meta-analysis of 28 observational studies of the association between direct and indirect measures of musculoskeletal fitness (referred to by the authors as physical capability) and all-cause mortality. Most studies involved adults aged 60 years and older but age range was broader in studies of hand grip strength. The relative risk of all-cause mortality associated with a 1 kg increase in grip strength was 0.97 (95% confidence interval 0.96 to 0.98) for both males and females and younger and older age groups. Comparisons between sex specific quartiles of grip strength showed a graded inverse association between grip strength and all-cause mortality. The overall relative risk of mortality was 1.67 (95% confidence interval 1.45 to 1.93) for the weakest quartile compared to the strongest quartile after adjustment for age, sex and body size.

There was a consistent, inverse and graded association between gait speed and all cause mortality. The relative risk of mortality in the slowest quartile compared to the fastest quartile was 2.99 (95% confidence interval 2.24 to 4.00).

The fastest time for 5 consecutive chair rises was also inversely associated with all-cause mortality. The overall relative risk was 1.96 (95% confidence interval 1.56 to 2.45) after adjustment for age, sex and body size. Residual confounding by factors such as comorbidity, physical activity, cardiovascular fitness and socioeconomic position cannot be ruled out.

Morbidity

One systematic review examined the association between musculoskeletal fitness and outcomes including cardiovascular disease, hospitalisation and institutionalisation. One narrative review examined the association between muscular strength, incident cardio-vascular disease and cardiovascular disease risk factors.

Cooper et al.[7], systematically reviewed 24 studies examining the association between physical capability and future health outcomes. Outcomes relating to incident cardiovascular disease along with hospitalisation and institutionalisation will be considered in this section with other outcomes considered in other sections. Due to the heterogeneity of included studies pooled analysis was not undertaken. Three studies examined the association between measures of musculoskeletal fitness and incident cardiovascular disease (2 reported incident stroke and 1 any fatal or non-fatal cardiovascular disease) in adults typically aged 65 years and older living in the community. One study focused on younger adults aged 18-25 years. For measures of grip strength and chair rises, hazard ratios were not always reported preventing accurate comment on effect size. Gait speed was inversely associated with risk of cardiovascular disease (hazard ratios ranged from 1.63 to 2.59 and confidence intervals from 1.16 to 4.64 in slowest versus fastest speed comparisons).

Four studies examined the association between measures of musculoskeletal fitness and hospitalisation and institutionalization. Results were equivocal.

Artero et al.[8], undertook a narrative review of the effects of muscular strength on cardiovascular risk factors including both cross-sectional and longitudinal studies preventing pooling of data. The risk factors examined included obesity, hypertension, metabolic syndrome, dyslipidemia and inflammatory markers. The authors of the review surmised that muscular strength was inversely and independently associated with obesity, risk of hypertension and incidence of the metabolic syndrome although many associations were attenuated to the null when adjustment was made for the confounding effects of cardiorespiratory fitness. The interpretation should be treated with caution given that the review was narrative and the number of studies considered for each risk factor was small and varied in study population and design.

Mental wellbeing

Cooper et al.[9], combined data from five UK cohort studies and examined the relationship between hand grip strength, walking speed, timed get up and go, chair rise speed and mental wellbeing. The age range of the combined studies was 53 to 82 years and included males and females with follow up times between 5 and 10 years. Mental wellbeing was measured with the Warwick and Edinburgh Mental Wellbeing Scale (https://warwick.ac.uk/fac/med/research/platform/wemwbs/). For walking speed and chair rise speed a 1 standard deviation increase in baseline value was associated with an increase in WEMWBS between baseline and follow up (regression coefficients ranged from 0.54 to 0.60) after adjustment for a range of covariates. For timed up and go and grip strength confidence intervals crossed 1.00 in fully adjusted models. The large sample size, consistency of measures and covariates are a strength of this study, but it was not a systematic review of all possible studies.

Risk of falls

A meta-analysis of the association between muscle weakness and the risk of falls reviewed 13 prospective studies[10] of the association between muscle weakness and risk of falls in both community dwelling and institutionalised adults aged 55 years and older. The follow up period was >1 year in 7/13 studies. Muscle strength/weakness in the lower body was predominantly measured via knee extension, ankle dorsiflexion or timed chair rises. In the upper body the main measure was hand grip strength with some manual muscle testing. Muscle weakness was computed as a dichotomous measure to permit the calculation of odds ratios. The combined odds ratio of any fall (new or recurrent) was 1.76 (95% confidence interval 1.31 to 2.37) in people classified as having lower extremity muscle weakness versus those who were not. The combined odds ratio of a recurrent fall was 3.06 (95% confidence interval 1.86 to 5.04). The risk of a fall that led to an injury was 1.52 (95% confidence interval 1.05 to 2.20) times higher in those classified with lower extremity muscle weakness compared to those who were not. Comparable figures for upper extremity muscle weakness were 1.53 (95% confidence interval 1.01 to 2.32) and 1.41(95% confidence interval 1.25 to 1.59). No figures were reported for injurious falls with upper extremity muscle weakness. It should be pointed out that the confounding variables adjusted for varied between studies but always included history of falls, physical activity, balance, sensory deficits, psychological factors, environmental factors, medical conditions and medication use.

A systematic review and meta-analysis examined the association between measures of balance and the subsequent risk of falls[11]. Twenty-three prospective studies with at least 1-year of follow up were included. Participants were community dwelling and had a mean age of 65 years and all were >60 years of age. Balance was measured in clinics and values were dichotomised as a balance impairment or not. Measures included the one leg stand, tandem stand and tandem walk. The relative risk of falling during the follow up period was 1.42 (95% confidence interval 1.08 to 1.85) in groups with a balance impairment compared to those without.

Randomised controlled trials of resistance, balance and skeletal impact training exercises on bone health, risk of falls, physical function, motor and cognitive function, quality of life and activities of daily living

Bone Health

Five meta-analyses contribute to this section, three that focused on postmenopausal women and one on premenopausal women. In 2017, Zhao et al.[12], undertook a meta-analysis of 11 randomised controlled trials of the effect of a combination of high intensity resistance training and impact exercises (e.g., running, jumping, skipping) on changes in bone mineral density (BMD) in healthy, sedentary, postmenopausal women (mean age 55.3 years, SD 6.3). Interventions were primarily supervised exercise sessions undertaken 2-6 times per week and the study durations varied from 8-30 months. BMD was measured in g/cm^2 and change scores were expressed as the standardised mean difference (SMD). Positive effects were observed at the lumbar spine, femoral neck, total hip and total body. In women <60 years of age there was no effect on the lumbar spine and in women ≥60 years there was no effect on the femoral neck.

An earlier review of 24 trials examined the effect of high intensity resistance training alone, or in combination with impact exercises (e.g., jogging, skipping, hopping), undertaken 2-6 days per week in healthy, sedentary, postmenopausal women aged 50-69 years on changes in BMD in the femoral neck and lumbar spine[13]. Study duration varied between 6 months and 12 years in one case. Training involved resistance exercises for the major muscle groups at an intensity of 80% of the one repetition maximum. Compliance ranged from 65-90%. Nineteen of the trials were randomised controlled trials and the others non-randomised controlled trials. Changes on the BMD of the femoral neck was 0.30 (95% confidence interval 01.3 to 0.48) and the lumbar spine was 0.31 (0.12 to 0.51) but a subgroup analysis of interventions that included resistance training alone showed no effect on preserving the BMD of the femoral neck and lumbar spine.

Two further reviews, 1 in pre and 1 in postmenopausal women, compared a combination of high intensity resistance training and impact exercises with impact exercises alone[14,15]. In the review (10 randomised and 5 non-randomised controlled trials) in postmenopausal women, impact exercises alone did not alter BMD at the hip or lumber spine but when combined with other lower impact exercises such as stairclimbing and walking beneficial effects on BMD were seen at both sites. In premenopausal women (aged from 20 years to late 40s) results from 6 randomised and 3 non-randomised controlled trials indicated that high impact exercise preserved BMD in the femoral neck but had no effect on the lumbar spine.

In 2014 Zhao et al.[16], undertook a meta-analysis of 6 randomised and non-randomised controlled trials, of at least 6 months duration, on the effectiveness of jumping exercise on BMD in the hip and lumbar spine in premenopausal, sedentary women aged 18-50 years. Interventions were a mix of between 1-6 weekly supervised jumping sessions supplemented by home exercise. The mean difference in BMD between intervention and control groups on measures at the femoral neck was 0.017 (95% confidence interval 0.014 to 0.020) and the trochanter was 0.021 (95% confidence interval 0.018 to 0.024). Effects on measures at the lumbar spine were non-significant.

Risk of falls

A meta-analysis of the effect of exercise on the risk of injurious falls in community dwelling older adults (aged ≥65 years) including 88 randomised controlled trials, mostly in community dwelling adults[17]. Exercise programmes included combinations of balance, resistance, flexibility and endurance training and 52% of studies achieved adherence rates of >50%. The mean follow up was 52 weeks. In the community programmes the relative risk of a fall in intervention versus control groups was 0.79 (95% confidence interval 0.73 to 0.85). Meta-regression of individual programme components revealed that when the exercise programme included a 'high balance challenge' and at least 3 rather than 2 hours a week of training effects were greater.

One meta-analysis examined the effect of Tai-Chi on the incidence of falls and time to first fall in adults aged 56 to 98 years compared to usual care or other interventions in 10 randomised controlled trials[18]. Interventions were typically of 1-hour duration and delivered at a frequency of 1-3 times per week for 12-26 weeks. Outcomes were measured immediately after the intervention or up to 70 weeks post intervention. Follow up periods (baseline measure to follow up measure) were classified as short term (<12 months) or long term (≥12 months). The relative risk of a fall in longer term studies was 0.87 (95% confidence interval 0.77 to 0.99) and in shorter term studies was 0.57 (95% confidence interval 0.46 to 0.70).

Physical function

A Cochrane review of 121 trials examined the effects of progressive resistance training on multiple measures of physical function[19]. Interventions included a wide range of resistance training methods including elastic band exercises. Outcomes included self-report and objective measures of physical function. This review will be limited to objective measures reflecting those reported in the observational section of this paper. Studies included males and females (mean age ≥60 years) with and without comorbidities. Most exercise programmes were supervised but some included a mix of supervised and home based exercises and 10 programmes were home based only. Resistance training was usually high intensity and undertaken 2-3 times per week. Programmes were typically 8-12 weeks in duration. Positive effects of resistance training (significant difference between intervention and control groups in pooled analysis) were reported for gait speed, timed up and go, timed chair rise and timed stairclimbing.

A meta-analysis of the dose-response relationship between resistance training and various physical function outcomes included a total of 29 randomised controlled trials[20]. The mean age of participants was 65-81 years. Comparisons between low and high intensity training revealed no difference for stair climbing, gait speed or the timed get up and go. However, caution should be used in interpreting the results as in these analyses only 1 or 2 trials were included. In further analysis, any intensity of progressive resistance training was compared with power training (resistance training carried out at higher velocities). In these analyses, power training was superior to progressive resistance training on chair rise time and stairclimbing but not walking speed or the timed get up and go. Again, all analysis were undertaken on 1-3 studies only.

Motor and Cognitive Function

One narrative review of 19 longitudinal studies, with at least one comparison group, examined the association between a mixture of exercise interventions on cognitive and motor outcomes[21]. Studies included a mix of male and female participants (aged 55-97 years) free of cognitive disease and other degenerative diseases. Interventions were categorised as either aerobic, strength, balance, dance, combined (aerobic and strength component) and physical-cognitive (a combination of some physical exercise with cognitive training). Training programmes were typically 6-12 weeks long and averaged 24 training sessions. A wide range of outcome measures were reported including four motor outcomes: "functional lower limb mobility; gait characteristics; static and/or dynamic balance; muscle strength and psychomotor tasks", as well as five cognitive outcome measures including: "processing speed; working memory inhibition; attention; and dual- task cost." Due to the heterogeneity of interventions and measures no quantitative synthesis was undertaken but rather a vote counting method was employed (counting the number of positive and negative outcomes) to summarise results. Study quality, sample size, or effect size were not accounted for. The authors concluded that multi-component interventions, especially those with cognitive tasks were associated with a number of positive outcomes. Too few studies with small sample sizes prevented any conclusions being drawn about the independent effects of strength training or balance training.

Quality of Life

Although there is review level evidence of the benefit of multi-component exercise interventions on self-reported measures of quality of life[22], it was not possible to separate out the independent effects of musculoskeletal fitness exercise or balance exercise. However, as part of a Cochrane review[18] of the effects of resistance training in older adults (see Physical Function section for details) one analysis compared the effects of resistance training versus a control group on the Vitality measure of the SF-36 in 10 randomised controlled trials and reported no difference between groups. In a further sub-group analysis of 2 trials, high intensity resistance training did have a positive effect on Vitality compared to low intensity training.

Activities of daily living

As part of a wider Cochrane review[18] of the effects of resistance training in older adults (see Physical Function section for details) results from three randomised controlled trials on the effect of resistance training on self-reported activities of daily living were pooled. No significant differences were observed.

Discussion

Preserving muscular strength and power in middle and older age is associated with a reduced risk of mortality from all causes and cardiovascular mortality. There is some evidence to suggest that gait speed in older adults is associated with a reduced risk of incident cardiovascular disease and hospitalisation. There is only weak evidence suggesting an association between muscular strength and obesity, hypertension and the metabolic syndrome. Higher levels of muscular strength and power in older adults is associated with higher levels of mental wellbeing with lower levels and poor balance associated with an increased risk of a first fall, recurrent falls and falls that lead to injury.

Supervised exercise interventions, undertaken at least twice per week, that include a combination of high intensity resistance training and impact exercises (e.g., running, jumping), lead to higher levels of bone mineral content in the hip and spine in middle aged and older women who are either pre or post-menopausal. High intensity resistance training alone appears to be less effective and the effects of impact only training seem to be restricted to the hip. It is unclear whether the prescribed exercises associated with positive effects on bone health in supervised exercise programs can be achieved in home based exercise programs as too few studies have examined this question.

Supervised exercise interventions undertaken 1-3 times per week, that include a combination of high intensity resistance training and exercises that promote improved balance are associated with a reduced risk of falls in older males and females. Further, Tai-Chi classes undertaken 1-3 times per week are also associated with a reduced risk of falls in middle-aged and older males and females.

High intensity resistance training undertaken at least twice per week is associated with physical function in older males and females. There is some evidence to suggest that when the concentric phase of resistance training is undertaken at high velocity (power training) effects are improved. The effect of muscular strength or balance training alone on measures of motor and cognitive function are unclear. Only limited evidence is available to suggest there may be an association between strength or balance training on one dimension of self-reported quality of life (vitality) and there is insufficient evidence to draw conclusions about the effect of strength and balance training on activities of daily living.

Strength and limitations

Twenty systematic reviews, covering observation studies and randomised controlled trials, represent a substantial body of evidence supporting the value of preserving levels of muscular strength, power and balance as we age. Many of the studies reviewed include objective exposure and outcome measures.

In observation studies objective exposure measures were frequently the same allowing for greater certainty about what measures of strength, power and balance offer protective effects on health. The main limitation in observation studies was the variance in the number of potential confounding factors controlled for. In particular, when mortality or morbidity was the outcome the possibility of residual confounding by physical activity that did not involve musculoskeletal exercise, and cardiorespiratory fitness could not be ruled out. Further, few attempts were made to address the possibility of reverse causality. The review was tasked with addressing effects over the lifespan but apart from a few studies the bulk of the evidence was undertaken in adults at least aged 60 years and older.

In trials of the effects of different strength, power, impact and balance exercises the heterogeneity in the exercise prescription, the length of programs and follow up periods makes it impossible to identify an 'optimum' exercise prescription. Although a broader range of ages were represented in the included studies results are still mostly applicable to adults over the age of 50 years with clear benefits for the very old. The major limitation of trials included in the reviews was the lack of intention to treat analysis. Most studies were restricted to per protocol analysis that often required a high level of adherence to the exercise prescription and some studies had a high loss to follow up. Consequently, the results reported in the cited reviews may be exaggerated compared to what would be observed in routine community programs. Many of the included reviews combined randomised and non-randomised trials and there was some evidence that results from randomised controlled trials were closer to null compared to non randomised controlled trials.

This review of reviews excluded individual cohort studies and randomised controlled trials that may have added important new knowledge, especially where there are gaps in the evidence in existing reviews.

Recommendations

Based on the review level evidence reported in this study middle aged and older adults should:

Undertake a program of exercise at least twice per week that includes high intensity resistance training, some impact exercise (running, jumping, skipping etc.) and balance training. The specific exercises included and the volume of exercise per session should be tailored to individual fitness and physical capabilities.

The study by Strain et al.[2], attempted to estimate the prevalence of strength and balance training by inferring from sports, recreational exercise and activities of daily living that require varying levels of muscular strength, power, vertical impact or balance depending on the intensity there are undertaken and the age, fitness and health of the participant. The search strategy for this review did not provide any review level evidence of the relationship between specific types of physical activity and objective measures of muscular strength, power, bone health or balance, that would inform an estimate of the prevalence of muscle strength and balance based on physical activity behaviours. Although the surveys from which prevalence was estimated in the Strain study included one or two questions about participation in gym based activity, the surveys do not specifically enquire about the frequency of participation in resistance training by intensity level, impact exercises or balance exercises. However, time spent in moderate to vigorous intensity physical activity (from all types of physical activity), measured by self-report and accelerometer is both cross-sectionally and prospectively associated with grip strength, chair rise time and standing balance[23-25]. This suggests that existing measures of physical activity included in population surveillance may provide sufficient estimates of who is at risk for deficits in muscle strength and balance and the associated health outcomes.

Given the presence of common measures of muscular strength, power and balance in many UK birth cohorts and studies of ageing, there may be considerable value in supplementing existing surveillance studies of physical activity with a small number of objective measures that are cheap and quick to do such as hand grip strength, chair rise time and standing balance. The objectivity of these measures would avoid the misclassification associated with estimates based on self-reports of behaviours. Further, combining prevalence data with data from epidemiological studies would allow for estimates of the health gain associated with population changes in these measures.

Consideration should also be given to the reintroduction of objective measures of physical activity to national surveys. Objective measurement of physical activity via wrist worn accelerometers, either in parallel with self-reports or as a stand-alone measure, is now commonplace in national surveillance such as the US NHANES[26] study and epidemiological studies such as UK Biobank[27], Whitehall II[28] and the National Survey of Health and Development[29]. Incorporation of accelerometer measurement into national surveillance, alongside the strength and balance measures described above, would permit the identification of specific volumes, patterns and intensities of physical activity that were associated with the measures of physical capabilities. Such data could lead to better prevalence estimates and more tailored physical activity guidelines for preserving muscular strength and power, balance and bone health. Analysis from UK Biobank accelerometer data has already identified specific types of activity associated with bone health in pre and post-menopausal women[26].

The results of this review mostly relate to structured, supervised, high intensity resistance training, impact exercise and balance training programs but there was insufficient review level evidence to suggest that the same outcomes could be achieved in home based exercise alone or via routine day-to-day activities. Although the physical infrastructure exists to provide programmes (fitness industry membership stands at around 9 million), accessing 2-3 hours per week of personal training for all eligible adults represents a substantial public health challenge with major resource implications.

If the aim of the HALCyon study group to identify screening values for their physical capability measures is achieved, it may be possible to screen people with most to gain from a program of supervised musculoskeletal fitness training if the simple measures above were incorporated into national surveillance, primary care for those at risk of falls and frailty and prior to hospital discharge for those attending with fall related injuries.

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