**Assessment of muscle-strengthening exercise adult participation in public health surveillance: A systematic review**

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Shakespear-Druery, J., De Cocker, K., Biddle, S. J. H., Gavilán-Carrera, B., Segura-Jiménez, V., & Bennie, J. (2021). Assessment of muscle-strengthening exercise in public health surveillance for adults: A systematic review. *Preventive Medicine, 148*, 106566. doi:10.1016/j.ypmed.2021.106566

**ABSTRACT**

There is strong scientific evidence that muscle-strengthening exercise (i.e. use of weight machines, push‐ups, sit-ups) is independently associated with a reduced risk of multiple chronic diseases (e.g. diabetes, hypertension, cardiovascular disease). However, prevalence rates for meeting the muscle-strengthening exercise guideline (≥2 times/week) are significantly lower (~20%) than those reported to meet the aerobic physical activity guideline (e.g. walking, jogging, cycling) (~50%). It is therefore important to understand public health surveillance approaches to assess muscle-strengthening exercise. The aim of this review was to describe muscle-strengthening exercise assessment in public health surveillance. Informed by the PRISMA guidelines, an extensive keyword search was undertaken across 7 electronic data bases. We identified 86,672 possible articles and following screening (*n =* 1,140 in full-text) against specific inclusion criteria (adults aged ≥18 years, English, studies containing <1000 participants), extracted data from 156 manuscripts. Fifty-eight different survey systems were identified across 17 countries. Muscle-strengthening exercise frequency (85.3%), duration (23.7%) and intensity (1.3%) were recorded. Muscle-strengthening exercise questions varied significantly, with some (11.5%) requiring a singular ‘yes’ vs ‘no’ response, while others (7.7%) sought specific details (e.g. muscle groups targeted). Assessments of duration and intensity were inconsistent. Very few studies measured the validity (0.6%) and reliability (1.3%) of muscle-strengthening exercise questions. Discrepancy exists within the current assessment systems/surveys used to assess muscle-strengthening exercise in public health surveillance. This is likely to impede efforts to identify at risk groups and trends within physical activity surveillance, and to accurately assess associations between muscle-strengthening exercise and health-related outcomes.

**Keywords**: assessment, measurement, muscle-strengthening exercise, public health surveillance

**INTRODUCTION**

Regular participation in physical activity is key in the prevention and management of non-communicable diseases (NCDs: diabetes, hypertension, cardiovascular disease, etc.). 1 Physical activity guidelines describe various types, frequencies and quantities of physical activity or exercise that all individuals can undertake for health benefits. 2 Public health-focused recommendations for physical activity were initially established in the U.S. in 1995, 3 with these recommendations centred on aerobic physical activity (e.g., *adults should accumulate 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of the week*). 3 Over the past decade, muscle-strengthening exercise (MSE) was also included within the U.S. guidelines. 4 The new 2020 World Health Organization’s (WHO) ‘*Guidelines on physical activity and sedentary behaviour*’ state that for “*additional health benefits*” adults (18–64 years) should engage in muscle-strengthening exercise “*at moderate or greater intensity”* including “*all the major muscle groups*”andshould be completed *“on two or more days a week*”. 2 While the new 2020 WHO guidelines have expanded on the 2010 guidelines by including recommendations regarding muscle-strengthening exercise intensity, there is no recommendation made for time (duration). 2, 5

While most of the research on the health benefits of physical activity has focussed on aerobic moderate-to-vigorous intensity physical activity (MVPA: brisk walking, jogging, cycling), 6 the evidence from epidemiological and controlled experimental studies is growing in support of undertaking muscle-strengthening exercise to reduce the risks and morbidity associated with chronic disease within adult populations. 7 In brief, evidence from systematic reviews links the independent benefits of undertaking muscle-strengthening exercise with a reduced risk of mortality, 8 enhanced cardiometabolic health, 9 and lower levels of depression and anxiety. 10 In spite of this evidence, compared to the public health promotion of aerobic MVPA, the promotion of muscle-strengthening exercise has largely been forgotten. 11 Moreover, muscle-strengthening guidelines are often overlooked in physical activity surveillance. 12

In comparison to the decades of research on the assessment of aerobic MVPA, 13 research on the assessment of muscle-strengthening exercise is limited. 14 Currently, muscle-strengthening exercise is assessed in public health surveillance exclusively through self-reported questionnaires. 15 Prevalence rates are typically measured against the guideline of ≥2 times/week. 14 Globally, reported muscle-strengthening exercise prevalence rates, based on data from large population studies, range from about 10% to 30%. 11, 16-19 The inconsistencies in the way muscle-strengthening exercise is assessed across countries are likely to explain this discrepancy in prevalence rates. The use of accurate assessments 20 of muscle-strengthening exercise, is essential for establishing health effects, tracking trends, and assessing the effectiveness of interventions. 11, 12 Therefore, applying a standardised approach to the collection and analysis of data concerning population-level physical activity engagement is essential. 20 However, since there has been no systematic review of the systems/surveys used to assess muscle-strengthening exercise in public health surveillance, little is known about the description of the items contained within the surveys, or the reliability and validity of surveys used.

The aim of this study, therefore, is to conduct the first systematic review of muscle-strengthening exercise surveillance systems/surveys used within large adult-population-based studies. Specifically, this review will:

1. Describe the types and frequency of surveillance systems/surveys used within public health surveillance of muscle-strengthening exercise;
2. Report on the reliability and validity of the identified systems/surveys.

**METHODS**

**Study inclusion and exclusion criteria**

Studies were included if meeting the following inclusion criteria:

1. The aim of the study was to measure muscle-strengthening exercise, in the context of leisure-time physical activity;
2. The system/survey under study was a self-reported questionnaire, either self-administered or administered by a researcher in the form of an interview (face to face, computer-assisted telephone interview (CATI), online, telephone);
3. The questionnaire measured muscle-strengthening activities/exercise;
4. A study was accepted as a full-text original article in a peer-reviewed journal until 19 June 2019;
5. The article was published in English;
6. The sample population was predominantly adults aged 18 years and over;
7. The sample population was ≥1000 free-living participants. This threshold was set to encompass studies that included population-representative samples.

Studies were excluded if meeting the following exclusion criteria:

1. All studies with a clinical population;
2. Abstracts only, those reporting statistics only or muscle-strengthening activities/exercise not reported separately from e.g., aerobic/stretching exercise;
3. Occupational, household, transport-related physical activity or aerobic physical activity;
4. Accelerometer measures or measures of physical strength.

**Search strategy**

Informed by the PRISMA guidelines 21 an extensive keyword search was undertaken across 7 electronic databases between 18-19 June 2019: (i) Cumulative Index to Nursing and Allied Health Literature (CINAHL); (ii) EBSCOhost academic search ultimate; (iii) PsychInfo; (iv) Scopus; (v) SportDiscus; (vi) Web of science; and (vii) Proquest (for grey literature, theses, and dissertations). All data were imported into Endnote. 22 Appendix A has a description of the final search terms. Additionally, an ancestry search was completed on the reference lists of all the included articles, with this data also imported into Endnote (Clarivate, Camelot UK Bidco Limited, Philadelphia, PA, USA). 22

**Study selection**

A review of the title and abstract was conducted by the principal author (JSD). Full-text articles were independently screened by the principal author (JSD) and co-authors (BGC, VSJ) against the specific inclusion/exclusion criteria, with any disagreement discussed and resolved with the last co-author (JAB). An ancestry search (a visual screening of each reference list from all the included articles to identify any additional articles for inclusion, this process has also been described as snowballing within the literature)23 was conducted (JSD) resulting in 6 additional articles, following an agreement with co-authors (JAB, KDC) (see Figure 1).



Figure 1

**Data extraction**

For each included article data extraction was undertaken by the main investigator (JSD), and included: author/year; study design and sample characteristics; muscle-strengthening exercise questions (including key exercise prescription components); assessed participation and prevalence rates; and reliability and validity measures (a summary of each article is included in Online Supplementary Table 1).

**Risk of Bias**

We did not complete a risk of bias assessment for the included articles as the focus of the study was on adult large population health surveillance of muscle strengthening exercise with exclusion of intervention studies and randomised controlled trials. The authors limited the risk of outcome bias through the large scale/scope of search terms, the number of databases included in the search in addition to the ancestry (snowballing) search conducted on all included articles.

**Approach for narrative synthesis of the data**

The following data were extracted for each of the included articles: Country, Continent, Author, Year, Study design and sample characteristics (age, sex, data year (start), participant numbers), Surveillance system, Measurement tool, Question/s, Yes/No only response required, Number of questions, Timeframe assessed, Reported percentage meeting muscle-strengthening exercise guideline, Reported percentage of participation in muscle-strengthening exercise, Frequency measure (yes/no), Intensity Measure (yes/no), Type (terminology), Time measure (yes/no), Correlates, Included correlates (yes/no), Reliability, Reliability discussed (yes/no), Validity, Validity discussed (yes/no), Notes (see Online Supplementary Table 1).

Due to the diverse way in which muscle-strengthening exercise was assessed, and the age/age groups of participants, across the included articles a meta-analysis was not able to be performed.

**RESULTS**

**Search results and study selection**

We identified 86,672 possible articles and following removal of duplicates (*n =* 34,915) the title and abstract of 51,757 articles were reviewed. Of these, 1,140 articles were then reviewed in full. Seven articles from ancestry searches (*n =* 6,191) were reviewed in full. A total of 156 articles were included in our analysis (see Figure 1).

**Study characteristics**

The 156 included articles analysed data collected from years 1969-2015. Data collection from U.S. participants was identified in 65.4% of the included articles. The other studies were conducted in Australia (8.3%), Korea (5.1%), Canada (4.5%), United Kingdom (4.5%), Japan (4.5%), Brazil (1.3%) and one each in Finland, Guatemala, Ireland, Israel, Italy, Libya, Pakistan, South Korea, Sweden and Taiwan. Participant sample size ranged from 1,051 24 to 497,967. 25, 26 Most articles included participants aged 18 years and older (for example: ≥18 years, 26.9%; >20 years, 9.0%; >65 years, 9.0%; and 20-85 years, 4.5%) with some articles only providing mean age data (5.8%). Most (95.5%) included both male and female data (149 articles), the remaining data was reflected as single sex i.e. female (2.6%) or male (1.9%).

**Systems/surveys including the assessment of muscle-strengthening exercise**

A total of 58 different systems/surveys (see Table 1) were identified across 17 countries. The U.S.-based National Health and Nutrition Examination Survey (25.0%), National Health Interview Survey (15.4%) and Behavioral Risk Factor Surveillance System (10.3%) are the most commonly reported items.

| **Table 1:** Surveillance system/survey (n=58) identified per country. | | |
| --- | --- | --- |
| Country | Surveillance system/survey used | Reference |
| **Australia** | Active Australia survey | 27 |
| Australian Diabetes, Obesity and Lifestyle study | 28 |
| Central Queensland Social Survey | 29 30 31 |
| Concord Health and Aging in Men Project | 32 |
| Exercise, Recreation and Sport Survey | 16 33 34 35 |
| National Nutrition and Physical Activity Survey | 19 36 |
| New South Wales Fall Prevention telephone survey | 37 |
| **Brazil** | Surveillance System of Risk Factors and Protection for Chronic Noncommunicable Diseases | 38 |
| Brazilian Living Standards Measurement Survey | 39 |
| **Canada** | Canadian Community Health Survey | 40 |
| Canadian Longitudinal Study on Aging | 41 42 |
| General Social Survey | 43 |
| National College Health Assessment | 44 |
| National Population Health Survey | 45 46 |
| **Finland** | Finnish Regional Health and Well-being Study | 18 |
| **Guatemala** | Nutritional supplementation trial | 47 |
| **Ireland** | North/South Ireland Food Consumption Survey | 48 |
| **Israel** | Social Survey | 49 |
| **Italy** | Longevity check-up 7+ | 50 |
| **Japan** | Not disclosed | 24 51 |
| COMMUNIty-wide CAmpaign To promote Exercise study | 52 53 54 |
| Japan Epidemiology Collaboration on Occupational Health Study | 55 |
| SSF National Sports-Life Survey | 56 |
| **Korea** | Korea National Health and Nutrition Examination Survey | 57 58 59 60 61 62 63 64 |
| **Libya** | General Student Health Survey | 65 |
| **Pakistan** | 7 Day recall | 66 |
| **South Korea** | Korean Survey on Citizens’ Sports Participation | 67 |
| **Sweden** | PEAK-25 Cohort - Self-administered questionnaire | 68 |
| **Taiwan** | Taiwanese version of the International Physical Activity Questionnaire-long version (IPAQ-LV) | 69 |
| **United Kingdom** | British Regional Heart Study | 70 |
| General Student Health Survey | 71 |
| Health Survey for England | 72 73 |
| MRC National Survey of Health and Development | 74 |
| Scottish Health Survey | 11 75 73 |
| **United States** | Aerobics Center Longitudinal Study | 76 77 78 |
| American Time Use Survey | 79 |
| Behavioral Risk Factor Surveillance System | 80 17 81 82 83 84 85 86 25 26 87 88 89 90 91 92 |
| Cardiovascular Health Study | 93 |
| College Student Health Survey | 94 |
| Education and Research Towards Health Study | 95 |
| Go for the Gold” employee wellness program | 96 |
| Health Information National Trends Survey | 97 |
| Health Professionals Follow-up Study | 98 |
| Health risk survey | 99 |
| HealthStyles Survey | 100 101 |
| Millennium Cohort Study | 102 |
| Modified CHAMPS questionnaire | 103 |
| National College Health Assessment | 104 |
| National Health and Nutrition Examination Survey | 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 91 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 |
| National Health Interview Survey | 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 91 92 |
| National Physical Activity Survey | 92 |
| National Physical Activity and Weight Loss Survey | 165 166 |
| New York City Neighborhood and Mental Health in the Elderly Study II | 167 168 |
| New York County Health Census | 169 |
| Nurses' Health Study | 170 |
| Nurses’ Health Study II | 170 |
| Structured questionnaire | 171 |
| VITamins And Lifestyle study | 172 |
| Women’s Health Study | 173 174 |

Table 1: Surveillance system/survey (n=58) identified per country

**Variation of questions for frequency, duration and intensity**

Assessments of frequency (85.3%), intensity (1.3%) and duration (23.7%) were recorded across the 58 systems/surveys.

**Frequency**

For frequency, some asked one simple ‘did you do/do you do’ style question, eliciting a dichotomous ‘yes’ vs ‘no’ response (11.5%) for undertaking muscle-strengthening exercise. Additionally, half (50.6%) asked multiple questions (e.g. *did you do any physical activities specifically designed to strengthen your muscles*, and *how many times did you do these activities designed to strengthen your muscles*). Within these, 7.7% were asking for more detailed responses (e.g. *inclusion of muscle group(s)*;101 *location of muscle-strengthening activities performed*; 101 *what is your main reason for engaging in*;39 and asked to *specify seasonal variations* 68) (see Table 2 for an example, also see Online Supplementary Table 2 and Online Supplementary Table 3 for a full list of the questions identified within the included articles). However, some of the included articles did not describe the muscle-strengthening exercise assessment methods (7.1%), with the remaining 30.8% asking: ‘how many times; how much time spent; how often; or type’ styled questions. Most (67.9%) of the systems/surveys asked participants to reflect on their ‘past’ muscle-strengthening exercise behaviours, however the time period of these varied considerably with: *past 30* days (16.8%); *previous month* (11.2%); *weekly* (11.2%); and *past week* (8.9%) the most frequently identified. Other muscle-strengthening exercise behaviour periods included: c*urrent activity*; *periodically; regular engagement;* and *usual behaviour*, however these appeared less frequently.

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| **Table 2:** Example of depth and richness of data sought within the included studies. |
| **Simple ‘yes/no’ questions** |
| 1. ‘In the last week, did you do any gym-based resistance training’? 30 |
| 1. Participants reported whether they performed ‘any physical activity designed to strengthen muscles such as weight-lifting, push-ups or sit-ups, over the past 30 days’. 109 |
| **Complex closed questions used in a single system/survey** |
| * “Do you currently perform any strength based training to build or maintain muscle? This could include activities such as training at home or the gym using barbells, dumbbells, hand weights or weight machines.” * “How many days each week do you perform strength based training activities?” * “When you perform the activities to build or maintain muscle, how many different exercises do you perform?” * “On average how many repetitions do you perform in each set?” and * “Thinking about the weight that you lift during your muscle strengthening sessions, we would like you to categorise the intensity of this weight on a scale of 1–10, where 1 means that it is no effort at all, 5 is moderate effort and 10 is the weight you can only lift once.” 31 |

Table 2: Example of depth and richness of data sought within the included studies.

**Duration**

Within the 37 articles (23.7%) that reported an assessment of duration, there were differences in the way responses (minutes/hours) were ascertained from participants. Questions included for example: “*the average exercise duration (minutes) for each session of muscle-strengthening physical activity using either free weights or weight training machines over the past 3 months”*;76 “*the average duration of each session: 1 to 15 minutes, 16 to 30 minutes, 31 to 60 minutes, or more than one* hour”; 40 *“how many hours a week?” with six response options (<1, 1–2, 3–4, 5–6, 7–8, and ≥9 hr)*;103 and *“when you took part in this activity, for how many minutes or hours did you usually keep at it?”*.88

**Intensity**

While two articles (1.3%) included the reporting of muscle-strengthening exercise intensity, how each was assessed differed. Harada et al 51 applied a perceived intensity of *light, moderate, or high*,and excluded data from participants who indicated light intensity as they were regarded as non-performers of muscle-strengthening exercise at this level of effort. In Humphries et al 31 respondents were asked to *categorise the intensity of this weight on a scale of 1–10, where 1 means that it is no effort at all, 5 is moderate effort and 10 is the weight you can only lift once.* The applied scale was reportedly based upon ACSM guidelines for resistance training.

**Modalities of included muscle-strengthening exercise**

While most surveillance systems/surveys provide respondents with examples of muscle-strengthening exercises, there is inconsistency in the terms used to describe muscle-strengthening exercise. Within the included articles we identified 44 different modalities (terms/terminology) used as examples to identify muscle-strengthening exercise. The 5 most frequent modalities identified were: push-ups (12.5%); sit-ups (12.5%); lifting weights (11.2%); calisthenics (8.4%); and weight lifting (8.7%). However less common terms/exercise modalities including ‘keep fit’, 72 ‘neuromuscular training’, 18 ‘military exercise’, ‘power team’, and ‘prime movers’. 16

**Participation and prevalence rate of muscle-strengthening exercise**

Rates of participation (‘yes’ or ‘no’) in muscle-strengthening exercise (>0 times/week) were reported within over half of the studies (55.8%) with rates varying from as low as 1.1% 70 to 76.9%. 110 Prevalence rates, assessed against the muscle-strengthening exercise guideline (≥2 times/week), were reported in 78 (50.0%) of the articles and varied from 3.2% 144 to 69.9%. 102 Twenty articles (12.8%) reported rates of participation (‘yes’ or ‘no’) and prevalence (≥2 times/week). 11, 16, 17, 31, 37, 56, 58, 73, 75, 76, 96, 104, 111, 117, 124, 126, 130, 146, 155, 170

**Validity and reliability of self-reported measures of muscle-strengthening exercise**

Most articles (69.9%) did not report on the validity of the survey ,with only one (0.6%) independently assessing internal validity. 39 The remaining 29.5% referenced previous research that had cited validity. Of the 46 articles citing validity, two U.S. surveillance systems/surveys were the most frequent. They are the National Health and Nutrition Examination Survey (NHANES, 32.6%) and the Behavioral Risk Factor Surveillance System (BRFSS, 13.0%). For NHANES, the study by Loprinzi et al 138 was referenced 53.3% of the time for the convergent validity of the muscle-strengthening exercise questions. For the BRFSS, two studies were referenced, first, Loprinzi et al 138 (50.0% of the time) and second Yore et al 175 (concurrent validity) was identified once (16.7%). In Yore et al 175, it was reported moderate validity inferences (κ = 0.40–0.52), for the strengthening measure, when comparing a physical activity log against the survey questions.

For reliability, 80.1% were unreported, with two articles (1.3%) independently assessing reliability, 53, 68 the remaining 18.6% (29 articles) referenced previous research. The results for Kamada et al 52 assessment of test-retest reliability was reported as moderate and acceptable (ρ = 0.75)for muscle-strengthening exercise, whereas Callréus et al 68 found no significant difference (*p* value range 0.13–1.0) when conducting the Sign Test on the responses to the two administrations of their questionnaire. Of the 29 articles that cited reliability, the BRFSS was the most frequently identified surveillance system/survey, with the study by Yore et al 175 referenced 66.7% of the time for test-retest reliability. Yore et al 175 reported excellent test-retest reliability (κ = 0.85-0.92) for the muscle-strengthening exercise measure when comparing the results of the first administration of the survey against the second and third survey administrations.

**DISCUSSION**

To our knowledge, this systematic review provides the first synthesis of muscle-strengthening exercise participation assessment systems/surveys used in public health surveillance. The key findings were that there is large heterogeneity in the measures used and that the validity and reliability of muscle-strengthening exercise questions are rarely assessed.

This review has identified that globally there is a multitude of different surveillance systems/surveys, used between and within countries. This finding is similar to that by Milton et al 12 in their recent review of the Global Observatory of Physical Activity (GoPA) ‘country cards’ where they observed 42 different surveillance systems/surveys within 44 countries. However, their analysis included systems/surveys that measured aerobic MVPA (*n =* 34) alone, with only 4 systems/surveys (Health Survey for England; Scottish Health Survey; Health Survey for Northern Ireland; and the BRFSS) that sought specific muscle-strengthening exercise data. 12

While many aspects of the surveillance systems/surveys, identified within our review, may be similar, individual nuances are most likely to limit the ability to formally compare results across studies. A key future research question is concerning the time period being assessed (e.g., past or current activity) and, when the results are compared against recommended muscle-strengthening exercise guideline, are they comparable periods or is average data being used (e.g. past 7 days or past year)? A further potential point of consideration needs to consider whether the questionnaire seeks to explore the participant’s ability to recall activities or whether the systems/surveys seeks information that is typical of the respondents’ usual exercising behaviours. Consistency in the period under review will aid researchers in understanding actual participant behaviour and assist comparability of muscle-strengthening exercise data across surveillance systems/surveys and various populations/countries.

Another finding was the inconsistency in the terminologies used within muscle-strengthening exercise surveillance systems/surveys. This may influence the accuracy of participation, especially from responders who have limited physical activity literacy. Furthermore, our review showed that the examples of muscle-strengthening exercise modalities within the questionnaires were highly varied, with 44 different terms identified. This difference in the number and/or type of modalities could lead to inconsistency in participant responses, with some not providing a positive response if, for example, they know the exercise by a different name. 92 Participant responses may therefore be influenced by their level of physical activity literacy and other factors, including cultural influences, such as language, cultural norms, and ethnicity. 176, 177 In the review by Ham et al 92 they discuss the influence that differing examples, used to describe muscle-strengthening exercise, may have on reported prevalence rates between individual surveillance systems/surveys. Therefore, the ability to accurately compare prevalence rates between different populations may also be hindered.

Our review shows the clear need for further research is needed to understand the impact that cultural influences may have on muscle-strengthening exercise participation, building on the earlier work in this area on aerobic physical activity by Tudor-Locke et al 176 Additionally, we suggest that existing global surveillance tools, such as the Global Physical Activity Questionnaire (GPAQ) 178 could be expanded to include the assessment of muscle-strengthening exercise (i.e. including visual examples of muscle-strengthening exercise within their show cards), along with the WHO providing examples of muscle-strengthening exercise within their physical activity guidelines. 2 Furthermore, the categorisation of muscle-strengthening exercises specifically undertaken to improve or maintain muscle strength requires further research. The paper by Strain et al 11 highlights the inclusion of activities such as horse riding and lawn bowls as muscle-strengthening activities. However, it remains unclear as to what extent that these activities may influence health-related outcomes or the global efforts to reduce NCD’s.

The current physical activity guidelines do not include recommendations regarding muscle-strengthening exercise duration, therefore, it is not surprising that less than one-quarter of articles within our review included an assessment of duration. The present study also showed that, regardless of the way that muscle-strengthening exercise duration is assessed, there needs to be a unified approach in measuring the actual time spent exercising. For example, a respondent may indicate that they undertake 30 minutes of muscle-strengthening exercise, however, what is not known is how much of that time is actually spent lifting/lowering/pushing/pulling. A portion of the time indicated may be allocated to setting up their weights/machine and or taking rest periods between each exercise group/set (which is a recommended component of muscle-strengthening exercise). 179 Further research is needed to identify the most feasible and practical approach to assess actual muscle-strengthening exercise duration and apply this approach within large population surveillance.

Our paper highlights a distinct gap in obtaining responder exercise intensity data, with only two surveillance systems/surveys including this. While there is limited research on the influence that muscle-strengthening exercise intensity may have on reducing the risks associated with chronic disease, 180 it is still considered an important component to track within public health surveillance. 158 However, equally, it is acknowledged that the accurate assessment of muscle-strengthening exercise intensity will present a challenge for public health surveillance. Clinical measures of intensity (e.g., the use of weights equipment based accelerometers/linear transducers) do not currently appear to be financially or physically viable on such large scale studies.

A further key finding was that there is a clear lack of reference to both the validity and reliability of the systems/surveys used to measure muscle-strengthening exercises within large population surveillance. Within our review, two articles 138, 175 were the most commonly cited within the surveillance systems/surveys, when reporting on the methods used to assess muscle-strengthening exercise. However, the comparison between even these two is difficult as only Yore et al 175 has assessed both aerobic MVPA and muscle-strengthening exercise questions. For concurrent validity of aerobic MVPA, Yore et al 175 reported poor to fair validity - using accelerometry (κ = 0.17-0.22), and moderate validity - using physical activity logs (κ = 0.40-0.51) for the recommended activity when comparing against the survey questions. Similar validity was found for muscle-strengthening exercise (κ = 0.40-0.52) 175 using physical activity logs. For test-retest reliability, Yore et al 175 reported substantial reliability (κ = 0.67-0.84) for the recommended aerobic MVPA measure when comparing the results of the first administration of the survey against the second and third survey administrations. However, the results for reliability were significantly stronger for muscle-strengthening exercise (κ = 0.85-0.92). 175

Additionally, while it is acknowledged that obtaining data through self-reported methods can increase the risk of bias (e.g., where respondents may answer in terms of what they think is socially desirable), 181 there are currently no alternate forms of assessment for muscle-strengthening exercise participation. This is in contrast to aerobic MVPA (were the use of accelerometers is common). Limited research has been conducted, and only within clinical/laboratory settings, on the use of devices such as wrist 182 or hip 183 worn accelerometers to accurately identify muscle-strengthening exercise performance. Alternate assessment tools for large population surveillance, such as through the use of personal physical activity tracking devices or mobile phone applications, are currently restricted due to technology limitations. 184

**Recommendations for future research**

Our results clearly show that a consistent approach is required to accurately analyse and compare data between surveillance systems/surveys globally. Further research is needed to identify the most feasible and practical approach to assess muscle-strengthening exercise intensity within large population surveillance. Researchers will then understand the importance of obtaining/tracking this data or, be comfortable that on a large population scale that obtaining this information is as a greater cost to participants (e.g., responder fatigue) than the benefit that the data currently provides. Based on our review, we conclude that no single surveillance system/survey contains the optimum set of questions to assess and report on muscle-strengthening exercise behaviour and, that a combination of several existing surveillance approaches is necessary to create a new comprehensive questionnaire. Most systems/surveys do not obtain data for each recommended component (e.g., frequency, intensity, time, type, repetitions, sets) 179 of muscle-strengthening exercise and the research gap regarding the importance of these individual components remains. This is an opportunity for future research to build upon. While research into the independent benefits of undertaking muscle-strengthening exercise (against health-related conditions/outcomes, and in comparison to global physical activity recommendations) is ongoing, one approach to bridge the surveillance gap may be to review and update the current global surveillance tools, such as the GPAQ or the International Physical Activity Questionnaire (IPAQ) to include component measures for muscle-strengthening exercise. Importantly, the reviewed system/survey should incorporate specificity regarding the: frequency (specific days muscle-strengthening exercise is completed); intensity (using a perceived rating scale); time (actual time spent completing muscle-strengthening exercises) type (name or description of the exercise/muscle groups used); and the number of, exercises, sets and repetitions for each exercise. The reviewed system/survey would optimally be also tested for validity and reliability.

Additionally more research into the testing of the reliability and validity of future surveys is needed. While it is acknowledged that varying the questions contained within national population surveillance questionnaires may pose additional burden on both researchers (comparability) and responders (fatigue) it is equally if not more important to obtain additional muscle-strengthening exercise behaviour information in order to better understand the relationship with health, and guide future health promotion messages. A simple do you do, and how often do you do it (both frequency based questions) approach is no longer sufficient. We recommend the minimum should include some basic ‘program’ parameters i.e. frequency (days per usual week), intensity (scaled from very light to very hard), type (specific exercise mode) and, time (duration per session), with a further/future expansion of the questions to include an understanding about the muscle groups used.

A key strength of this study is that it is the first systematic review of muscle-strengthening exercise surveillance systems/surveys used in large population-based studies with an adult population. Due to the volume of articles obtained during the ‘identification’ phase, the eligible study sample size was reviewed. Following an agreement with the co-authors, the inclusion/exclusion criteria were refined to include only those studies with ≥1000 participants, as studies containing less than this number may not be considered ‘surveillance’ studies. Therefore, there is a risk that some data were lost and not included in this review. There is also a risk that data was lost due to the exclusion of unpublished works and those not published in the English language.

**CONCLUSION**

This review shows that there is large heterogeneity within the systems/surveys currently used to assess muscle-strengthening exercise in public health surveillance. This may impede efforts to identify at risk groups, trends and accurately assess improvements in health within large populations. Despite the growing evidence of the health benefits of undertaking muscle-strengthening exercise 7 prevalence rates (≥2 times/week) are globally low. Prevalence and participation rates may be influenced by the surveillance system/survey question structure, and the physical activity literacy of respondents. Greater emphasis and consistency is required in the communication of muscle-strengthening exercise recommendations globally. With the accurate assessment and comparability of physical activity behaviour data required to effectively track health trends and identify population subgroups most at risk of low participation levels.

**Conflict of interest statement**

The authors declare that they have no competing interests.

**Authors’ contributions**

JSD, KDC, SJHB, and JAB conceptualised the study and developed the research plan. JSD conducted the search strategy and data extraction. JSD, BGC, and VSJ conducted the study selection. JSD drafted the initial manuscript. JAB, KDC, and SJHB provided guidance on the study and critically reviewed the manuscript. All authors read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

**Acknowledgements**

This research has been supported by an Australian Government Research Training Program Scholarship and a University of Southern Queensland Research Training Program Stipend Scholarship. The authors wish to also thank Dr Tricia Kelly for her support and guidance in the search strategy phase of this review.

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**Appendix A**

We used the search terms, “strength training" OR "resistance training" OR “muscle strengthening exercise” OR “muscle strengthening activity” OR “muscle strengthening activities” OR "weight training" OR "weight lifting" OR "muscle strengthening" OR "muscular strengthening" OR "muscle training" OR "muscle toning" OR "weight bearing training" OR "weight bearing strengthening" OR toning OR exercise OR “resistance band” OR “anaerobic” OR “muscular conditioning” OR “muscle strength” OR “elastic band exercise” OR “Weight-Bearing Exercise Program” OR “Weight-Lifting Exercise Program” OR “Weight-Lifting Strengthening Program” OR Calisthenics OR “resistance bands” OR “weight machines” OR “free weights” OR “handheld weights” AND “Public health surveillance” OR “Public health” OR surveillance OR Population OR Prevalence OR Correlate? OR Assess\* OR Measure\* OR “physical activity epidemiology” OR adherence OR Guideline? ANDAdult?

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Date** | **Search Strategy** | **Database** | **Number of results** | **Field** | **Notes** |
| 18.6.19 | TITLE-ABS-KEY ( ( ( "strength training" OR "resistance training" OR "muscle strengthening exercise" OR "muscle strengthening activity" OR "muscle strengthening activities" OR "weight training" OR "weight lifting" OR "muscle strengthening" OR "muscular strengthening" OR "muscle training" OR "muscle toning" OR "weight bearing training" OR "weight bearing strengthening" OR toning OR exercise OR "resistance band" OR "anaerobic" OR "muscular conditioning" OR "muscle strength" OR "elastic band exercise" OR "Weight-Bearing Exercise Program" OR "Weight-Lifting Exercise Program" OR "Weight-Lifting Strengthening Program" OR calisthenics OR "resistance bands" OR "weight machines" OR "free weights" OR "handheld weights" ) AND ( "Public health surveillance" OR "Public health" OR surveillance OR population OR prevalence OR correlate? OR assess\* OR measure\* OR "physical activity epidemiology" OR adherence OR guideline? ) AND adult? ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) ) | Scopus | 25871 | Title, Abstract, Keyword | limited to English language |

**Online Supplementary Table 1**. Studies assessing strength-training activities - Individual study characteristics

| **Country** | | **Surveillance system/survey used** | **Ref.** | **Population** | **Data year** | **Time Frame a** | **MSA % b** | **MSA c** | **Freq d** | **Int. e** | **Type f (Mode)** | **Dur g** | **Rel h** | **Val i** | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Australia | | Active Australia Survey | 27 | ≥18 years  42% M | ~ | P12m | ✘ | ✘ | ✔ | ✘ | 3 | ✔ | ≞ | ≞ | |
| Australian Diabetes, Obesity and Lifestyle Study | 28 | Mean age 56.0 ± 12.7 years  55% F | 2004-2005 | PW | 16.5% M 14.8% W | ✔ | ✔ | ✘ | 4 | ✔ | ✘ | ✘ | |
| Central Queensland Social Survey | 29 | ≥18 years  50.7% F | 2010 | P6m | ✘ | ✔ | ✔ | ✘ | 1 | ✘ | ≞ | ≞ | |
| 30 | ≥18 years | 2006 | PW | ✘ | ✔ | ✘ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 31 | ≥18 years  49.9% F | ~ | DPW | 5.2%  6.5% M 3.6% F | ✔ | ✔ | ✔ | 4 | ✘ | ✘ | ✘ | |
| Concord Health and Aging in Men Project | 32 | ≥70 years  100% M | 2005-2007 | P7d | ✘ | ✔ | ✔ | ✘ | 1 | ✘ | ✘ | ≞ | |
| Exercise, Recreation and Sport Survey | 16 | 15-98 years  49.4% M | 2001-2010 | P2w/PY | 10.4% P2w  9.3% PY | ✔ | ✔ | ✘ | 10 | ✔ | ≞ | ✘ | |
| 33 | ≥ 65 years  58.9% F | 2001-2009 | P12 m | ✘ | ✔ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 34 | ≥15 years | 2010 | P12m/P2w | ✘ | ✔ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 35 | ≥15 years  53.6% F | 2006 | PY/P2w | ✘ | ✔ | ✔ | ✘ | 1 | ✔ | ✘ | ✘ | |
| National Nutrition and Physical Activity Survey | 19 | 18-85 years  54.1% F | 2011-2012 | PW | 18.6% | ✘ | ✔ | ✘ | 2 | ✘ | ≞ | ✘ | |
| 36 | ≥18 years  45.9% M | 2011-2012 | PW | 17.9% 19.7% M  16.1% F | ✘ | ✔ | ✘ | 4 | ✔ | ≞ | ✘ | |
| New South Wales Fall Prevention telephone survey | 37 | ≥65 years | 2009 | PW | 9.4% | ✔ | ✔ | ✘ | 4 | ✘ | ✘ | ✘ | |
| Brazil | | Surveillance System of Risk Factors and Protection for Chronic Noncommunicable Diseases | 38 | ≥18 years | 2014 | P3m | ✘ | ✔ | ✔ | ✘ | 1 | ✔ | ✘ | ✘ | |
| Brazilian Living Standards Measurement Survey | 39 | ≥20 years  47.4% M | 1996-1997 | D/W | ✘ | ✔ | ✔ | ✘ | 2 | ✔ | ✘ | ✔I | |
| Canada | | Canadian Community Health Survey | 40 | 12-79 years | 2007-2011 | P3m | ✘ | ✔ | ✔ | ✘ | 1 | ✔ | ✘ | ✘ | |
| Canadian Longitudinal Study on Aging | 41 | ≥60 years | 2012-2015 | PW | ✘ | ✔ | ✔ | ✘ | 6 | ✘ | ≞ | ≞ | |
| 42 | 45-85 years | 2012-2015 | P7d | ✘ | ✘ | ✔ | ✘ | 1 | ✔ | ≞ | ≞ | |
| General Social Survey | 43 | ≥65 years | 2010 | D | ✘ | ✔ | ✘ | ✘ | 1 | ✔ | ✘ | ✘ | |
| National College Health Assessment | 44 | Mean age 22.11 ± 5.24 years  71.60% F | 2013 | PW | 36.4 % M 19.9% F | ✘ | ✔ | ✘ | 2 | ✘ | ≞ | ≞ | |
| National Population Health Survey | 45 | 20-79 years | 1996-1997 | P3m | ✘ | ✔ | ✘ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 46 | ≥18 years  48.8% M | 1994-2011 | P3m | ✘ | ✔ | ✔ | ✘ | 1 | ✔ | ✘ | ✘ | |
| Finland | | Finnish Regional Health and Well-being Study | 18 | 18-98 years  52% F | 2013-2014 | PY | 17.2% | ✘ | ✔ | ✔ | 3 | ✘ | ≞ | ✘ | |
| Guatemala | | Nutritional supplementation trial | 47 | 24-49 years  54.6% F | 1969-1977 | PY | ✘ | ✔ | ✔ | ✘ | 1 | ✔ | ✘ | ✘ | |
| Ireland | | North/South Ireland Food Consumption Survey | 48 | 18-64 years  47.9% M | 1997-1999 | PY | ✘ | ✔ | ✔ | ✘ | 1 | ✘ | ✘ | ≞ | |
| Israel | | Social Survey | 49 | 20-65 years. | 2010 | P3m | ✘ | ✔ | ✘ | ✘ | 3 | ✘ | ✘ | ✘ | |
| Italy | | Longevity check-up 7+ | 50 | 18-98 years  57% F | 2015-2017 | PY | ✘ | ✔ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| Japan | | Not disclosed | 24 | 40–69 years  47.57% F | 2011 | W | 13.6% 15.2% M 11.8% F | ✘ | ✔ | ✘ | ` | ✘ | ✘ | ✘ | |
| 51 | 65–74 years  49.6% F | 2011 | DPW | 9.2% E 26.2% B | ✘ | ✔ | ✔ | 8 | ✘ | ✘ | ✘ | |
| COMMUNIty-wide CAmpaign To promote Exercise study | 52 | 40-79 years  46.4% M | 2009-2014 | DPW | 38% Cb 37.7% Ib 34.9% Cf5 37.2% If5 | ✘ | ✔ | ✘ | 1 | ✘ | ≞ | ✘ | |
| 53 | 40-79 years  46.4% M | 2009-2010 | DPW | 38% Cb 37.7% Ib 32.5% Cf1 24.2% If1 | ✘ | ✔ | ✘ | 1 | ✘ | ✔ T | ✘ | |
| 54 | 40 - 79 years | 2012 | DPW | 38% Cb 37.7% Ib 32.8% Cf3 35.8% If3 | ✘ | ✔ | ✘ | 1 | ✘ | ≞ | ✘ | |
| Japan Epidemiology Collaboration on Occupational Health Study | 55 | 30–64 years | 2006-2013 | Re | ✘ | ✔ | ✔ | ✘ | 1 | ✔ | ✘ | ✘ | |
| SSF National Sports-Life Survey | 56 | ≥20 years, 52.1% F | 2006 | PY | 3.9% A  0.6% -9.9% R | ✔ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| Korea | | Korea National Health and Nutrition Examination Survey | 57 | 20-80 years  50.3% F | 2014-2015 | Pe | 6% | ✘ | ✔ | ✘ | 3 | ✘ | ≞ | ≞ | |
| 58 | >20 years  40.4% M | 2008-2009 | DPW | 18.9% 29.5% M 11.68% F | ✔ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 59 | ≥65 years  45.2% M | 2008 - 2011 | PW | 22.2% M 6.1% F | ✘ | ✔ | ✘ | 4 | ✘ | ✘ | ✘ | |
| 60 | 18-64 years  50% M  older adults aged ≥65  44.4% M | 2014 – 2015 | PW | 30.8% M, 14.4% F 30.6% OM  8.9% OF | ✘ | ✔ | ✘ | 1 | ✘ | ≞ | ≞ | |
| 61 | 19-60 years,  43% M | 1999-2012 | CW | ✘ | ✘ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 62 | ≥ 65 years  43.4% M | 2014 | PW | ✘ | ✔ | ✔ | ✘ | 4 | ✘ | ✘ | ✘ | |
| 63 | adults with MetS  ≥ 20 years  44.5% M | 2014 | PW | ✘ | ✔ | ✔ | ✘ | 4 | ✘ | ✘ | ✘ | |
| 64 | ≥65 years  40.4% M | 2007 - 2008 | DPW | ✘ | ✔ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| Libya | | General Student Health Survey | 65 | Mean age 20.9 ±2.4 years  66.2% F | 2008-2009 | P7d | 43.7% 33.9% F 62.9% M | ✘ | ✔ | ✘ | 3 | ✘ | ≞ | ✘ | |
| Pakistan | | 7 Day recall | 66 | Junior doctors ≤ 30 years  Senior doctors > 30 years  41.3% M | 2013 | P7d | ✘ | ✔ | ✘ | ✘ | 1 | ✘ | ✘ | ✘ | |
| South Korea | | Korean Survey on Citizens’ Sports Participation | 67 | 18-64 years  45.8% F | 2015 | DpM | ✘ | ✔ | ✔ | ✘ | 3 | ✘ | ✘ | ✘ | |
| Sweden | | PEAK-25 Cohort Self-administered questionnaire | 68 | 25 years  100% F | 1999-2004 | CA | ✘ | ✔ | ✔ | ✘ | 1 | ✔ | ✔ T | ✘ | |
| Taiwan | | Taiwanese version of the International Physical Activity Questionnaire-long version (IPAQ-LV) | 69 | ≥65 years | ~ | PW | 25.4% | ✘ | ✔ | ✘ | 1 | ✘ | ≞ | ≞ | |
| United Kingdom | | British Regional Heart Study | 70 | 40-59 years | ~ | PM | ✘ | ✔ | ✔ | ✘ | 2 | ✘ | ✘ | ✘ | |
| General Student Health Survey | 71 | University students  77.8% F | 2007–2008 | P7d | 19.4% F  38.3% M | ✘ | ✔ | ✘ | 3 | ✘ | ✘ | ✘ | |
| Health Survey for England | 72 | >16 years  55.3% F | 1997-2006 | P4w | ✘ | ✔ | ✔ | ✘ | 4 | ✔ | ✘ | ≞ | |
| Health Survey for England **+**  Scottish Health Survey | 73 | ≥30 years | 1994–2008 | P4w | 3.4% | ✔ | ✔ | ✘ | 5 | ✔ | ✘ | ✘ | |
| MRC National Survey of Health and Development | 74 | 36 years  50.3% F | 1982 | PrM | ✘ | ✔ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| Scottish Health Survey | 11 | ≥16 years | 2012–2014 | P28d | 31% M  24% F | ✔ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 75 | ≥16 years | 2012-2015 | P28d | 31% M  24% F | ✔ | ✔ | ✘ | 1 | ✘ | ≞ | ≞ | |
| United States | | Aerobics Center Longitudinal Study | 76 | Mean age 46 ± 9.5 years  19% F | 1987-2006 | P3m | 35% | ✔ | ✔ | ✘ | 4 | ✔ | ✘ | ✘ | |
| 77 | ≥40 years  79.9% M | 1980-1992 | P3m | ✘ | ✔ | ✘ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 78 | 20-81 years  83.4% M | 2005 | CI | ✘ | ✔ | ✘ | ✘ | 4 | ✘ | ✘ | ✘ | |
| American Time Use Survey | 79 | ≥21 years  52% M | 2003–2006 | PD | ✘ | ✔ | ✔ | ✘ | 2 | ✔ | ✘ | ✘ | |
| Behavioral Risk Factor Surveillance System | 80 | ≥18 years | 2015 | M/W | 30.2% | ✘ | ✔ | ✘ | 7 | ✘ | ≞ | ≞ | |
| 17 | 18-80 years  51.5% F | 2015 | M/W | 30.2% | ✔ | ✔ | ✘ | 6 | ✘ | ≞ | ≞ | |
| 81 | 18-85 years  47.9% M | 2015 | PrM | 9.6% | ✘ | ✔ | ✘ | 7 | ✘ | ≞ | ≞ | |
| 82 | ≥18 years  50.2% M | 2015 | ✘ | 10.1% | ✘ | ✔ | ✘ | 1 | ✘ | ≞ | ≞ | |
| 83 | ≥18 years | 2013 | PrM | 7.7% | ✘ | ✔ | ✘ | 6 | ✘ | ✘ | ✘ | |
| 84 | ≥18 years  67.2% F | 1989 | M/W | ✘ | ✔ | ✔ | ✘ | 1 | ✔ | ✘ | ✘ | |
| 85 | ≥18 years  50.1% M | 2000 | PrM | ✘ | ✔ | ✔ | ✘ | 2 | ✔ | ≞ | ≞ | |
| 86 | ≥18 years  39.2% M | 2011 | DPW | 7.1% | ✘ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 25 | ≥18 years | 2011 | PrM | 13.4% M  10.5% F WD | ✘ | ✔ | ✘ | 5 | ✘ | ✘ | ✘ | |
| 26 | ≥18 years | 2011 | PrM | 9.5% NH 7.3% H | ✘ | ✔ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 87 | ≥18 years  52.7% F | 2011 | PrM | 27.7% | ✘ | ✔ | ✘ | 6 | ✘ | ≞ | ≞ | |
| 88 | ≥18 years  52% F | 2013 | PrM | 16.06% | ✘ | ✔ | ✘ | 1 | ✔ | ✘ | ✘ | |
| 89 | 18-99 years  51.9% F | 2000 | PrM | ✘ | ✔ | ✘ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 90 | ≥45 years  53.1% F | 2011 | PrM | 23.7% 25.9% M 21.9% F | ✘ | ✔ | ✘ | 6 | ✘ | ✘ | ✘ | |
| Cardiovascular Health Study | 93 | ≥65 years | 1989-1990  1992-1993 | P2W | ✘ | ✔ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| College Student Health Survey | 94 | 15-99 years  37.8% M | 2007 | P7d | ✘ | ✔ | ✘ | ✘ | 4 | ✔ | ✘ | ✘ | |
| Education and Research Towards Health Study | 95 | 18-94 years  37.5% M | 2004 | PrM | ✘ | ✔ | ✔ | ✘ | 2 | ✔ | ✘ | ≞ | |
| Go for the Gold” employee wellness program | 96 | Mean age 41.2 ± 10.8 years  68.1% F | 2003-2012 | CA | 29.7% (2003) | ✔ | ✘ | ✘ | 4 | ✘ | ✘ | ✘ | |
| Health Information National Trends Survey | 97 | ≥18 years  51.6% F | 2011-2014 | TW | ✘ | ✘ | ✘ | ✘ | 2 | ✘ | ✘ | ≞ | |
| Health Professionals Follow-up Study | 98 | Mean age 58 ± 7 years  100% M | 2008 | Py | ✘ | ✔ | ✔ | ✘ | 4 | ✔ | ✘ | ≞ | |
| Health risk survey | 99 | Mean age 24.2 ± 5.9 years  39% M | 2004 | PW | ✘ | ✔ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| HealthStyles Survey | 100 | ≥18 years  61.9% F | 2004 | Re | ✘ | ✔ | ✘ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 101 | ≥18 years  50.8% F | 2009 | UW/PrM | 37.1%  34% M  29.5% F  6% MG  5.7% M/MG  6.2% F/MG | ✘ | ✔ | ✘ | 7 | ✘ | ✘ | ✘ | |
| Millennium Cohort Study | 102 | 19-39 years  68% M | 2007-2008 | Tw | 69.9% 49.1% M 20.8% F | ✘ | ✔ | ✘ | 4 | ✘ | ✘ | ✘ | |
| Modified CHAMPS questionnaire | 103 | ≥18 years  34.2% M | 2003 | PrM | ✘ | ✔ | ✔ | ✘ | 1 | ✔ | ✘ | ✘ | |
| National College Health Assessment | 104 | 18-24 years  70.3% F | 2008 | P7d | 32.4% | ✔ | ✔ | ✘ | 1 | ✘ | ≞ | ≞ | |
| National Health and Nutrition Examination Survey | 105 | ≥20 years  50.2% M | 1999-2004 | P30d | 34.4% M 36.5% F | ✘ | ✔ | ✘ | 3 | ✘ | ✘ | ✘ | |
| 106 | ≥60 years  42.8% M | 1997 | PrM | ✘ | ✔ | ✘ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 107 | 20-85 years  48.2% M | 2003-2006 | P30d | 21.7% | ✘ | ✔ | ✘ | 3 | ✘ | ✘ | ≞ | |
| 108 | 18-80 years  53.5% F | 1999-2000, 2005-2006  (pooled) | P30d | ✘ | ✔ | ✔ | ✘ | 7 | ✘ | ✘ | ✘ | |
| 109 | ≥18 years  53.5% F | 1999-2006 | P30d | ✘ | ✔ | ✔ | ✘ | 6 | ✘ | ✘ | ✘ | |
| 110 | 20 -79 years  48.9% M | 1999-2004  (pooled) | P30d | ✘ | ✔ | ✔ | ✘ | 3 | ✘ | ✘ | ✘ | |
| 111 | ≥20 years  51.% M | 1999-2006  (pooled) | P30d | 20.3% | ✔ | ✔ | ✘ | 3 | ✘ | ✘ | ✘ | |
| 112 | ≥20 years  50.5% M | 1999–2004 (pooled) | P30d | 43.9% Ds  28.3% Ig  37.9% H  37.3% Aw | ✘ | ✔ | ✘ | 3 | ✘ | ✘ | ✘ | |
| 113 | ≥20 years | 1988-1994 | PrM | ✘ | ✔ | ✔ | ✘ | 3 | ✘ | ✘ | ✘ | |
| 114 | 20-74 years | 2005-2006 | P30d | ✘ | ✔ | ✘ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 115 | ≥20 years old  50.6% M | 2003-2006 | P30d | ✘ | ✘ | ✔ | ✘ | 3 | ✘ | ✘ | ≞ | |
| 116 | ≥50 years old  52.6% F | 1999-2002 | P30d | 14.7% | ✘ | ✔ | ✘ | 3 | ✘ | ✘ | ≞ | |
| 117 | ≥20 years  52.7% F | 2003-2006 | P30d | 16.6% | ✔ | ✔ | ✘ | 3 | ✘ | ✘ | ≞ | |
| 118 | 20-85 years old  51.6% F | 2003-2006 | P30d | 21.6% | ✘ | ✔ | ✘ | 3 | ✘ | ✘ | ≞ | |
| 119 | ≥20 years,  51% M | 2003-2006 | P30d | 8.9% | ✘ | ✔ | ✘ | 3 | ✘ | ✘ | ≞ | |
| 120 | ≥50 years  50.4% F | 1999-2002 | P30d | 13.8% | ✘ | ✔ | ✘ | 3 | ✘ | ✘ | ≞ | |
| 121 | 18-65 years | 1988-1994 | PrM | ✘ | ✔ | ✔ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 122 | 20 -85 years  52.0% F | 1999-2006 | P30d | 22.2% | ✘ | ✔ | ✘ | 3 | ✘ | ✘ | ≞ | |
| 123 | 50 -85 years  51.2% F | 1999-2002  (pooled) | ✘ | 13.3% | ✘ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 124 | ≥40 years  54.6% F | 2003-2006 | PrM | 19.2% | ✔ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 125 | ≥18 years  48% M | 2003-2004 | PrM | ✘ | ✘ | ✔ | ✘ | 5 | ✘ | ✘ | ✘ | |
| 126 | ≥17 years  52.1% F | 1988-1994 | PrM | 8.7% | ✔ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 127 | ≥18 years  49.7% M | 2003-2004 | P30d | ✘ | ✔ | ✔ | ✘ | 1 | ✔ | ✘ | ✘ | |
| 128 | 20-74 years | 2005-2006 | P30d | ✘ | ✔ | ✔ | ✘ | 1 | ✔ | ✘ | ✘ | |
| 129 | ≥18 years  49.1% M | 1999-2002 | P30d | ✘ | ✔ | ✔ | ✘ | 1 | ✔ | ✘ | ✘ | |
| 130 | 20-49 years  51.3% M. | 1999-2000, 2001-2002, 2003-2004  (pooled) | D/W/M | 30.4% M 20.3% F | ✔ | ✔ | ✘ | 3 | ✘ | ✘ | ≞ | |
| 131 | 50–85 years  52.6% F | 1999–2002 | P30d | ✘ | ✔ | ✘ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 132 | 60-85 years  54.9% F | 1999-2002 | P30d | 13.3% | ✘ | ✔ | ✘ | 4 | ✘ | ✘ | ≞ | |
| 133 | 20-85 years | 2003–2006 | P30d | ✘ | ✘ | ✔ | ✘ | 4 | ✘ | ✘ | ≞ | |
| 134 | 20-85 years | 2005-2006 | P30d | ✘ | ✔ | ✔ | ✘ | 3 | ✘ | ✘ | ≞ | |
| 135 | 20-85 years  51.1% F | 1999-2002 | P30d | ✘ | ✔ | ✘ | ✘ | 3 | ✘ | ✘ | ✘ | |
| 136 | 20-85 years  60.9% F | 2003-2006 | P30d | 15.8% | ✘ | ✔ | ✘ | 3 | ✘ | ✘ | ≞ | |
| 137 | 20-39 years  56.1% F | 1999-2004 | P30d | ✘ | ✘ | ✔ | ✘ | 3 | ✘ | ✘ | ≞ | |
| 138 | ≥20 years  48.6% M | 2003-2006 | P30d | ✘ | ✔ | ✔ | ✘ | 3 | ✘ | ✘ | ≞ | |
| 139 | 20-84 years | 1999-2002 | P30d | ✘ | ✔ | ✘ | ✘ | 3 | ✘ | ✘ | ✘ | |
| 140 | ≥20 years  50.5% M | 1999-2004 | P30d | ✘ | ✔ | ✘ | ✘ | 3 | ✘ | ✘ | ✘ | |
| 141 | 18-50 years | 1999-2006 | P30d | ✘ | ✔ | ✔ | ✘ | 1 | ✔ | ✘ | ✘ | |
| 142 | ≥20 years  51.5% M | 1999-2004 | P30d | 17.66% | ✘ | ✔ | ✘ | 3 | ✘ | ✘ | ✘ | |
| National Health Interview Survey | 143 | ≥18 years | 2002-2004 | UB | 28.1% M 21.4% F | ✘ | ✔ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 144 | 18-64 years (employed) | 2008-2014  (pooled) | CA | 3.2% | ✘ | ✔ | ✘ | 3 | ✘ | ✘ | ✘ | |
| 145 | ≥18 years | 1998-2008  (pooled) | D/W/M/Y | 17.7% (1998)  21.9% (2008) | ✘ | ✔ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 146 | ≥18 years | 2003 | W | 20.8% | ✔ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 147 | ≥65 years  44% M | 2011 | W/M | 18.8% M  14% F | ✘ | ✔ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 148 | ≥65 years  42.4% M | 1997-2001 | W/M | 9.6% | ✘ | ✔ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 149 | ≥18 years | 1998-2004 | W | 17.7% - 1998  19.6% - 2004  21.9% M 17.5% F | ✘ | ✔ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 150 | ≥50 years  46.5% M | 2001 | W | 13.7% 15.3% M 12.4% F | ✘ | ✔ | ✘ | 2 | ✘ | ✘ | ≞ | |
| 151 | ≥50 years | 2005 | D/W/M/Y | 16.7% HW/M  17.2% OW/M  11.4% OB/M  18.3% HW/F  13.1% OW/F  11.0% OB/F | ✘ | ✔ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 152 | ≥18 years  37.5% M | 2015 | UW | 20.7% M 18.5% F | ✘ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 153 | ≥18 years  48.2% M | 2005–2007 | UB | ✘ | ✔ | ✔ | ✘ | 3 | ✘ | ✘ | ✘ | |
| 154 | ≥18 years | 1999–2001 | UB | ✘ | ✔ | ✔ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 155 | ≥18 years  48.3% M | 2008–2010 - | UB | 23%  27% M 19.1% F | ✔ | ✔ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 156 | ≥18 years | 1997-2004 | ✘ | 3.4% | ✘ | ✔ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 157 | ≥65 years  56% F | 2011 | W/PM | 16.1% 18.8% M 14% F | ✘ | ✔ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 158 | ≥18 years | 1998–2009 | W | 20.4% | ✘ | ✔ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 159 | ≥18 years | 1999–2001 | W | ✘ | ✔ | ✔ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 160 | ≥45 years | 2014 | W | ✘ | ✘ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 161 | ≥18 years  61.6% F | 1999–2009 | ✘ | 4.3% 4.2% M 4.4% F | ✘ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| 162 | ≥18 years  46.9% M | 2012 | ✘ | ✘ | ✔ | ✘ | ✘ | 2 | ✘ | ✘ | ✘ | |
| 163 | ≥18 years  60.9% F | 2015-2016 | ✘ | 3.4% IBD  3.5% xIBD | ✘ | ✘ | ✘ | ✘ | ✘ | ✘ | ✘ | |
| 164 | ≥65 years  64.3% F | 1990 | P2w | ✘ | ✔ | ✔ | ✘ | 2 | ✔ | ✘ | ✘ | |
| National Health Interview Survey +  Behavioral Risk Factor Surveillance System +  National Health and Nutrition Examination Activity Survey | 91 | adult population,  ≥65 years  37.2% M | 2013  2013  2011-2012 | TpW | 6.7%  17.4% M 16.2% F (NHIS)  21.6% 24.7% M 19.9% F (BRFSS) | ✘ | ✔ | ✘ | 1 | ✘ | ✘ | ✘ | |
| National Health Interview Survey +  Behavioral Risk Factor Surveillance System +  National Physical Activity Survey | 92 | ≥18 years  42.3% male | 2000  1999  1999-2000 | ✘  UW  UW | 18.2% (NHIS),  28.1% (BRFSS),  34.5% (NPAS) | ✘ | ✔ | ✘ | 5 | ✘ | ≞ | ≞ | |
| National Physical Activity and Weight Loss Survey | 165 | ≥18 years  56% F | 2002 | W | 38% 55.3% M 44.7% F | ✘ | ✔ | ✘ | 3 | ✘ | ✘ | ✘ | |
| 166 | ≥18 years  43.4% M | 2002 | UW | 40% M  34% F | ✘ | ✔ | ✘ | 4 | ✘ | ✘ | ✘ | |
| New York City Neighborhood and Mental Health in the Elderly Study II, longitudinal study | 167 | 65–75 years  39% M | 2011-2013 | PW | ✘ | ✔ | ✔ | ✘ | 3 | ✔ | ≞ | ≞ | |
| 168 | 65–75 years at baseline | 2011 | PW | ✘ | ✔ | ✔ | ✘ | 3 | ✔ | ✘ | ≞ | |
| New York County Health Census | 169 | ≥17 years | 1992 | PW | ✘ | ✔ | ✔ | ✘ | 3 | ✘ | ≞ | ≞ | |
| Nurses' Health Study  PLUS  Nurses’ Health Study II | 170 | 53–81 years  36–55 years  100% F | 2000–2008  2001–2009 | W | 20.43% | ✔ | ✔ | ✘ | 6 | ✔ | ✘ | ≞ | |
| Structured questionnaire | 171 | ≥20 years  100% M |  | W | ✘ | ✔ | ✔ | ✘ | 2 | ✔ | ✘ | ✘ | |
| VITamins And Lifestyle study | 172 | 53-57 years  51.2% F | 2000-2002 | W/Y/P10y | ✘ | ✔ | ✔ | ✘ | 1 | ✔ | ≞ | ≞ | |
| Women’s Health Study | 173 | Mean age 62.2 ± 6.8 years  100% F | 1992 -2004 | PrM | ✘ | ✔ | ✘ | ✘ | 2 | ✔ | ≞ | ≞ | |
| 174 | Mean age 62.6 ± 6.9 years  100% F | 1992-2004 | Py | ✘ | ✔ | ✘ | ✘ | 2 | ✔ | ≞ | ≞ | |
|  | | | | | | | | | | | | | | |
| Time frame a | ✘ = not disclosed; CA = current activity; CI = currently involved; CW = current week; D = day/s; DpM = days per month; DPW = days per week; M = month/ly; P10y = previous 10 years; P12m = past 12 months; P28d = past 28 days; P2w = past 2 weeks; P30d = past 30 days; P3m = past 3 months; P4w = past 4 weeks; P6m = past 6 months; P7d = past 7 days; PD = previous day; Pe = periodically; PM = per month; PrM = previous month/past month; PW = past week; PY = past year; Re = regular engagement/participation; TpW = times per week; TW = typical week; UB = usual behaviour; UW = usual week; W = week/ly; Y = year | | | | | | | | | | | | | |
| MSA % b | Met muscle-strengthening exercise guideline of ≥ 2 times each week - ✘ = not reported  A = average; Au = augmented waist circumference; B = body weight; Cb = control baseline; Cf = control follow-up; Ds = dyslipidaemia; E = using equipment; F = female; H = hypertensive; HW = healthy weight; Ib = intervention baseline; If = intervention follow-up; Ig = impaired fasting glucose; IBD = with irritable bowel disease; M = male; MG = muscle groups; NH = non-hypertensive; OB = obese; OF = older female; OM = older male; OW = overweight; R = range; WD = with diabetes; xIBD = without irritable bowel syndrome | | | | | | | | | | | | | |
| MSA c | ✘ = participation rate not reported, ✔ = participation rate reported | | | | | | | | | | | | | |
| Freq. d | ✘ = Frequency assessment not reported, ✔ = Frequency assessment reported | | | | | | | | | | | | | |
| Int.  e | ✘ = Intensity assessmentnot reported, ✔ = Intensity assessmentreported | | | | | | | | | | | | | |
| Type f | Number of different modalities used to describe muscle-strengthening exercises | | | | | | | | | | | | | |
| Dur  g | ✘ = Duration assessmentnot reported, ✔ = Duration assessmentreported | | | | | | | | | | | | | |
| Rel h | ✘ = Reliability not reported, ≞ = Reliability referenced, ✔T = Reliability tested (test retest) | | | | | | | | | | | | | |
| Val i | ✘ = Validity not reported, ≞ = Validity referenced, ✔I = Validity tested (internal validity) | | | | | | | | | | | | | |

|  |  |  |  |
| --- | --- | --- | --- |
| **Online Supplementary Table 2:** Chronological order of questions assessing muscle-strengthening exercise behaviours within the included studies. | | | |
| **Year** | **Surveillance system/survey** | **Question/s contained within each included article [additional notes]** | **Ref** |
| 1969 | Nutritional supplementation trial (Physical activity questionnaire) | Field workers administered a physical activity questionnaire asking about the frequency and duration of activities performed over the preceding year on a typical workday | 47 |
| 1978 | British Regional Heart Study | How often they participated in sport/exercise. Men reporting frequent sport/exercise participation were also asked to state the type of sport/exercise they engaged in. | 70 |
| 1980 | Aerobics Center Longitudinal Study | Self-reported resistance exercise was assessed in the medical history questionnaire. Participants were asked about the weekly frequency and average exercise duration (minutes) for each session of muscle-strengthening PA using either free weights or weight training machines over the past 3 months. | 77 |
| 1982 | MRC National Survey of Health and Development (Minnesota leisure time physical activity questionnaire) | Sports and recreational activities:  List of 27 activities (eg, …………..., exercises such as press ups at home,……. | 74 |
| 1987 | Aerobics Center Longitudinal Study | Self-reported resistance exercise was assessed in the medical history questionnaire. Participants were asked about the weekly frequency and average exercise duration (minutes) for each session of muscle-strengthening PA using either free weights or weight training machines over the past 3 months. | 76 |
| 1988 | National Health and Nutrition Examination Survey | Participants were asked to specify their frequency of LTPA during the past month for the following: ….. calisthenics or floor exercises, and weight lifting.  "In the past month, did you lift weights?" Participants who responded "yes" were then asked, "In the past month, how often did you lift weights?" | 113 126 |
|  |  | Using standard NHANES questions, participants reported types of leisure time physical activity they performed in the past month (e.g. jogging, biking, swimming) and the number of times they performed each activity. For example, “We are interested in exercise, sports, physically active hobbies that you may do in your leisure time. In the past month did you . . . jog or run? How many times during the month?” | 121 |
| 1989 | Behavioral Risk Factor Surveillance System | ~ | 84 |
| 1989 | Cardiovascular Health Study | ~ [duration per session × number of sessions in the last 2 weeks/2.] | 93 |
| 1990 | National Health Interview Survey | The Health Promotion and Disease Prevention supplement includes questions about physical activity. Regular LTPA was defined as participation for 30 minutes or more at least 3 times a week during the past 2 weeks in 1 or more of the following physical activities: ......., calisthenics, .... weight lifting, ....... or up to 2 unspecified other activities. | 164 |
| 1992 | Women’s Health Study | During the past month, what was your approximate time per week spent at each of the following recreational activities? Weight lifting/strength training. | 173 |
|  |  | During the past year, what was your approximate time per week spent at each of the following recreational activities? Weight lifting/strength training. | 174 |
| 1994 | National Population Health Survey | It is based on responses to questions asking respondents if they had participated in any of 23 activities in the past 3 months specified in the NPHS questionnaire and, if so, their duration and frequency of participation in these activities. For Cycle 1, the listed activities were: ........., weight training,........, and up to three other activities. | 46 |
|  | Health Survey for England + Scottish Health Survey | Physical activity was assessed using a questionnaire that inquired about participation in sports and exercises during the 4 weeks prior to the interview. Participants were shown a card. For each positive response, participants were asked whether they had participated in the activity for at least 15 minutes, the frequency of activity (number of occasions), and the duration of activity per occasion. | 73 |
| 1996 | National Population Health Survey | Forms of LTPA were assessed by asking respondents whether they had participated in the past 3 months in LTPA, that is, activities not related to work. The interviewer read from a list of 20 such activities (i.e., walking for exercise, gardening or yardwork, swimming) and also inquired on any other activity not listed. | 45 |
|  | Brazilian Living Standards Measurement Survey | The questionnaire included six questions: (1) Do you engage in any physical exercise or sport?; (2) What kind of exercise or sport do you perform? (Please mark the most frequent group: .............., gym/muscular exercise, ....., other sports.); (3) Do you perform exercise or a sport every week?; (4) How many days per week? (Please include all exercise and sports.); (5) How many minutes or hours in each day? (Please include all exercise and sports.); (6) What is your main reason for engaging in exercise or sport? (recreation, health/medical counseling, esthetics/ beauty, other reason). | 39 |
| 1997 | National Health and Nutrition Examination Survey | During the past month, did you …………….., do calisthenics, or do other exercises or sports? | 106 |
|  | National Health Interview Survey | “How often do you do leisure-time physical activities specifically designed to strengthen your muscles, such as lifting weight or doing calisthenics?” Participant responses included both the number of times strength training  was performed and the unit of time (i.e. “per week,”“per month”) | 148 |
|  | North/South Ireland Food Consumption Survey (NSIFCS based on the validated Minnesota Leisure Time Activity Questionnaire) | Levels of customary physical activity were assessed by a self-administered questionnaire that was developed at the Institute of Public Health, University of Cambridge. In each case, questions were closed rather than open-ended, to make them easy to complete and to facilitate large-scale data entry. Respondents were asked to identify the frequency and duration of their participation in 36 named recreational pursuits, including sports and gardening activities. For each activity, respondents indicated the number of times they performed the activity in the past year and the average duration per episode. | 48 |
|  | National Health Interview Survey | (5) How often do you do LEISURE-TIME physical activities specifıcally designed to STRENGTHEN your muscles such as lifting weights or doing calisthenics? | 156 |
|  | Health Survey for England | Sport and exercise participation was measured by showing respondents a card listing common activities such as, gym workout,., keep-fit, and calisthenics. | 72 |
| 1998 | National Health Interview Survey | Respondents were also asked about their participation in leisure-time physical activities specifıcally designed to strengthen their muscles, such as lifting weights or doing calisthenics. Respondents were classifıed as meeting the muscle-strengthening guideline if they reported engaging in muscle-strengthening activity two or more times/week. | 145 |
|  |  | “How often do you do physical activities designed to strengthen your muscles, such as lifting weights or doing calisthenics?” | 149 |
|  |  | “How often do you do leisuretime physical activities specifically designed to strengthen your muscles such as lifting weights or doing calisthenics?” | 158 |
| 1999 | Korea National Health and Nutrition Examination Survey | used five answers from IPAQ, which for that week of the survey identified the number of days the participants did vigorous physical activity, moderate physical activity, walking, strength, and flexibility, for at least 10 min at a time. | 61 |
|  | National Health and Nutrition Examination Survey | Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups? Include all such activities even if you have mentioned them before in the past 12 months; Over the past 30 days, how often did you do these activities? [Activities designed to strengthen your muscles such as lifting weights, push-ups or sit-ups]. | 105 |
|  |  | “any physical activity designed to strengthen muscles such as lifting weights, push-ups or sit-ups, over the past 30 days” 75, and by asking what specific leisure time strength training activity they performed over the past 30 days 76 | 108 |
|  |  | Participants reported whether they performed ‘any physical activity designed to strengthen muscles such as weight-lifting, push-ups or sit-ups, over the past 30 days’. | 109 |
|  |  | “Over the past 30 days, how often did you do any physical activities designed to strengthen your muscles such as lifting weights, push-ups, or sit-ups? Include all such activities even if you have mentioned them before.” | 110 |
|  |  | ‘Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?’ ‘Over the past 30 days, how often did you do these physical activities?’ Activities designed to strengthen your muscles such as lifting weights, push-ups or sit-ups. | 111 112 |
|  |  | “During the past 30 days, did you do any PAs specifically designed to strengthen your muscles, such as weight lifting, push-ups, or sit-ups?”, “During the past 30 days, how many times did you do these MSAs (eg, weight lifting, push-ups, or sit-ups)?” | 116 |
|  |  | "During the past 30 days, did you do any physical activities specifically designed to strengthen your muscles, such as weight lifting, push-ups, or sit-ups?” and if so “During the past 30 days, how many times did you do these muscle strengthening activities (e.g., weight lifting, push-ups, or sit-ups)?”. | 120 |
|  |  | 1) “Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?” (response option: yes or no), and 2) “Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, push-ups, or sit-ups?” | 122 |
|  |  | ~ [self-report of meeting muscle-strengthening activities guidelines (yes/no; ≥2 sessions per week)] | 123 |
|  |  | ‘‘[Over the past 30 d], did you do moderate activities for at least 10 min that caused only light sweating or a slight to moderate increase in breathing or heart rate? Some examples are brisk walking, bicycling for pleasure, golf, or dancing.’’ Individuals who reported that they had engaged in moderate-intensity activity were asked to report the frequency and duration of any of the 32 moderate activities. | 129 |
|  |  | “Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups, or sit-ups?” “How often did you do these physical activities?” | 130 |
|  |  | ‘Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?’ (response yes/no). | 131 |
|  |  | (1) ‘‘Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, pushups or sit-ups?’’ (response option: yes or no) and (2) among those answering yes to this first question, they were asked, ‘‘Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, push-ups, or sit-ups?’’ | 132, 137 |
|  |  | “Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?” | 135 139 |
|  |  | ‘‘Over the past 30 days, did you do any physical activity specifically designed to strengthen your muscles such as LW, push-ups or sit-ups?’’ | 140 |
|  |  | Participants were asked which vigorous activities from a list of examples they performed over the past 30 days. Vigorous activity was defined as those “that caused heavy sweating, or large increases in breathing or heart rate?” VPA activities were defined as a having corresponding metabolic equivalent level (MET) level of 6.0. For each activity reported, the number of times performed over the past 30 days and the average duration in minutes was collected. The same process was used to collect the frequency and duration of moderate activities performed over the past 30 days, defined as activities “that caused light sweating or a slight to moderate increase in your heart rate or breathing.” MPA activity was defined by NHANES as an activity with a corresponding MET level of 3.0–5.9. | 141 |
|  |  | (1) “Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?” and (2) “Over the past 30 days, how many times did you do these physical activities?” | 142 |
|  | National Health Interview Survey | AHB.130 How often do you do physical activities specifically designed to STRENGTHEN your muscles such as lifting weights or doing calisthenics? (Include all such activities even if you mentioned them before.) [Asked of all adults.] | 154 |
|  |  | How often do you do physical activities specifically designed to strengthen your muscles such as lifting weights or doing calisthenics? (NCHS, 2003b, p. 365) | 159 |
|  |  | ~ | 161 |
|  | National Health Interview Survey + Behavioral Risk Factor Surveillance System + National Physical Activity Survey | The NHIS used examples of strengthening activities (e.g., lifting weights, calisthenics).  The BRFSS used examples of activities for strengthening (e.g., lifting weights, pull-ups, push-ups, sit-ups).  The NPAS terms were identical to the BRFSS study | 92 |
|  | PEAK-25 Cohort Self-administered questionnaire (Questionnaire) | The subjects were asked to grade their own overall activity level; to describe the types of exercise they performed; to estimate the amount of time spent on each specific activity; and to specify seasonal variations in their activity. | 68 |
| 2000 | Behavioral Risk Factor Surveillance System | “During the past month, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?” Those who answered affirmatively then were asked to provide information about the type, frequency, and duration of up to two activities. | 85 |
|  |  | What type of physical activity or exercise did you spend the most time doing during the past month? and What other type of physical activity gave you the next most exercise during the past month?, providing their two most common activities. | 89 |
|  | Nurses' Health Study + Nurses’ Health Study II | each participant reported her average weekly amount of resistance exercise, lower intensity exercise (yoga, stretching, toning), and aerobic physical activities. | 170 |
|  | VITamins And Lifestyle study (Questionnaire) | Respondents were instructed to only report activities carried out regularly, defined as at least once per week for at least 1 y in the previous 10y. Participants reported the number of years in the last 10 that they did each activity, along with the days per week and the minutes per day. | 172 |
| 2001 | Exercise, Recreation and Sport Survey | participation in leisure-time physical activity, defined as; ‘any physical activity done for exercise, recreation or sport in the past 12 months’. Respondents were asked to exclude ‘any physical activity associated with work, household or garden chores’.  Those who indicated participation were asked to list the types of leisuretime physical activity undertaken, whether each activity was organised or non-organised, and the number of times they participated in each activity during the previous 12 months. From 2005 onwards, participants were also asked about the frequency and average session duration in the past two weeks. | 16 |
|  |  | participants were asked about any physical activity done for exercise, recreation or sport in the past 12 months. | 33 |
|  | National Health Interview Survey | “How often do you do physical activities specifically designed to strengthen your muscles, such as lifting weights or doing calisthenics?” | 150 |
| 2002 | Modified CHAMPS questionnaire | The participants were first asked whether they had done each of these activities in a typical week during the last month (yes/no). Those who answered no were referred to the next item. Those who answered yes then responded to the frequency question “how many times a week?” and the duration question “how many hours a week?” with six response options (<1, 1–2, 3–4, 5–6, 7–8, and ≥9 hr). | 103 |
|  | National Health Interview Survey | "How often do you do physical activities specifically designed to STRENGTHEN your muscles such as lifting weights or doing calisthenics? (Include all such activities even if you mentioned them before.) [Asked of all adults.]" | 143 |
|  | National Physical Activity and Weight Loss Survey | Respondents were asked whether they participated in any activities designed to increase muscle strength or tone in a usual week, and if so, how many days per week did they participate in such resistance-type activities | 165 |
|  |  | “In a usual week, do you do any activities designed to increase muscle strength or tone, such as lifting weights, pull-ups, push-ups, or sit-ups?” Those who said yes were asked, “How many days per week do you do these activities?” | 166 |
| 2003 | American Time Use Survey | Respondents were asked to sequentially describe each activity and its duration for the 24-h period beginning at 4:00 a.m. Follow-up questions assessed where and with whom each activity occurred. Each interview lasted approximately 15 to 20 min | 79 |
|  | Go for the Gold” employee wellness program (the Wellsource Concise Assessment Plus Personal Wellness Profile) | Engaging in strength exercising (sit-ups, pushups, or use weight training equipment) How many times per week do you do strength building exercises such as situps, pushups, or use weight training equipment? | 96 |
|  | National Health and Nutrition Examination Survey | i) ‘Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?’ (response option: yes or no), and (ii) among those answering yes to this first question, they were asked, ‘Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, push-ups, or sit-ups?’ | 107 136 |
|  |  | (1) “Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?” and, if so, (2) “Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?” | 115 117 |
|  |  | (1) “Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weight, push-ups or sit-ups?” and if yes (2) “Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?” | 118 |
|  |  | (1) ‘‘Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weight, push-ups, or sit-ups?’’, (2) ‘‘Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, pushups, or sit-ups?’ | 119 |
|  |  | ~ [Strengthening ≥2 times/week 1 time/week None] | 124 |
|  |  | ~ [All PA  3) Type of PA: number of sessions per month cardio strengthening Flexibility  Total MeT-minutes cardio strengthening Flexibility] | 125 |
|  |  | The PA questionnaire data consisted of participants' responses to whether or not they participated in leisure-time MVPA and activities in other PA domains (e,g,, transportation related or domesfic PA), and if yes, what were the type, frequency, and duration of fhe specific activities participants performed in the past 30 d | 127 |
|  |  | Participants were asked two questions related to engagement in MSA: (1) ‘Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?’ (response option: yes or no), and (2) among those answering yes to this first question, they were asked, ‘Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, pushups, or sit-ups?’ | 133, 138 |
|  | National Health Interview Survey | respondents were asked to report the frequency of ‘‘physical activities specifically designed to strengthen your muscles such as lifting weights or doing calisthenics.’’ | 146 |
| 2004 | Australian Diabetes, Obesity and Lifestyle study | ‘‘How many times have you done any activities designed to increase muscle strength or tone, such as lifting weights, pull-ups, push-ups, or sit-ups?’’ In a separate question, ST duration was evaluated by asking, ‘‘What do you estimate was the total time that you spent in these activities in the last week?’’ | 28 |
|  | Education and Research Towards Health Study (Questionnaire) | Questions about activities that are less frequently performed (traditional activities, leisure activities, and occupational activities) were asked in the manner of the Taylor questionnaire; participants chose from a list of individual activities and specified the length of time and frequency at which they were performed, for all activities, participants were asked to include only those lasting more than 10 minutes at a time, specify the days per week (or per month as applicable) of the activity, and specify the average time spent on each activity. | 95 |
|  | Health risk survey | Using survey items similar to those included in national surveillance systems,...Students also self-reported the number of days in the past week in which they engaged in stretching and/or strengthening exercises. | 99 |
|  | HealthStyles Survey | Respondents were also asked to report all physical activities/sports they engage in from a list of 18 specific activities: "Which of the following physical activities/sports do you participate in regularly?" These items included …., lifting weights | 100 |
| 2005 | Aerobics Center Longitudinal Study | Participants were asked to provide yes/no answers to 4 separate questions:  (1) “Are you currently involved in a muscle-strengthening programme?”  (2) Can you specify the muscle-strengthening activity as “Callisthenics”, “Free Weights”, “Weight Training Machines” or “Other”?  (3) “Are you currently involved in exercises to maintain or improve your joint flexibility?”  (4) Can you specify the flexibility activity as “Stretching”, “Callisthenic”, “Exercise Class”, “Yoga” or “Other”? | 78 |
|  | Concord Health and Aging in Men Project (PASE) | Participants reported the frequency and time spent in the past 7 days in muscle strengthening exercise. | 32 |
|  | National Health and Nutrition Examination Survey | Participants were also asked if they participated in specific physical activities (not in the workplace) in the previous 30 days including …….., and muscle strengthening activities. | 114 |
|  |  | Participants were also asked if they participated in specific physical activities (not in the workplace) in the previous 30 days including ...........muscle strengthening activities. If they answered yes, they were asked about the frequency and the average duration of time they engaged in those activities | 128 |
|  |  | 1) “Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?” (response option: yes or no), and 2) among those answering yes to this first question, they were asked, “Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, push-ups, or sit-ups?” | 134 |
|  | National Health Interview Survey | Respondents were asked to report the frequency they engaged in strength training (per day, week, month, or year). | 151 |
|  |  | AHB.130 How often do you do LEISURE-TIME physical activities specifically designed to STRENGTHEN your muscles such as lifting weights or doing calisthenics? (Include all such activities even if you mentioned them before.) [Asked of all adults.] | 153 |
| 2006 | Central Queensland Social Survey | ‘In the last week, did you do any gym-based resistance training’? | 30 |
|  | Exercise, Recreation and Sport Survey | Respondents were asked if they participated in any physical activity for exercise, recreation and sport during the last 12 months, excluding activities that were part of work or household and garden chores. Those who indicated participation were asked to list up to 10 specific activities that were coded by the interviewer against a list of 166 activities (including two “other” options). Respondents reported the number of sessions they engaged in each activity over the previous 12 months. For the three activities with the highest frequency of participation over the previous 12 months, respondents also reported the number of sessions and average minutes per session of each activity during the previous 2 weeks. | 35 |
|  | Japan Epidemiology Collaboration on Occupational Health Study | Participants were asked if they regularly engaged in any physical activity during leisure time including muscle strength training, | 55 |
|  | SSF National Sports-Life Survey | Questions 1 and 2 of the questionnaire were utilized for the engagement of strength training. | 56 |
| 2007 | Canadian Community Health Survey (CHMS household questionnaire) | Respondents aged 12 or older were asked if they had engaged in any of the following activities in the previous three months: , home exercises, weight-training, or any other. For each activity reported, respondents were asked the frequency in the past three months, and the average duration of each session: 1 to 15 minutes, 16 to 30 minutes, 31 to 60 minutes, or more than one hour. | 40 |
|  | College Student Health Survey | In the past 7 days, how many hours did you spend doing the following activities? (C) Exercises to strengthen or tone your muscles | 94 |
|  | General Student Health Survey  [United Kingdom] | “On how many of the past 7 days did you do exercises to strengthen or tone muscles (push-ups, sit-ups, or weight lifting)?” | 71 |
|  | Korea National Health and Nutrition Examination Survey | how many days per week the individual spends on strengthening or stretching activity | 64 |
|  | Millennium Cohort Study | "In a typical week, how much time do you spend participating in strength training or work that strengthens your muscles (such as lifting/pushing/pulling/weights)?” | 102 |
| 2008 | General Student Health Survey  [Libya] | “On how many of the past 7 days did you do exercises to strengthen or tone your muscles, such as push-ups, sit-ups, or weight lifting?” Participants answered 0–7 days | 65 |
|  | Health Professionals Follow-up Study | Participants were asked to report the average time spent per week in the previous year in each……. Calisthenics…., weightlifting/ weight machine….. | 98 |
|  | National College Health Assessment | On how many of the past 7 days did you do 8 to 10 strength training exercises (such as resistance training weight machines) for 8 to 12 repetitions each? | 104 |
|  | Korea National Health and Nutrition Examination Survey | ~ [after adjustment for factors known to affect osteoporosis, such as age, gender, BMI, serum 25(OH) vitamin D level, menstruation status, hormone supplement use, menopausal status, and the number of days per week of muscular strength exercise.] | 58 |
|  |  | Participants also recorded the frequency of resistance exercises such as push-ups, sit-ups, or training using dumbbells, weights, or a horizontal bar in the past week. | 59 |
|  | National Health Interview Survey | ‘How often do you do leisure-time muscle-strengthening activities (‘‘such as lifting weights or doing calisthenics’’) | 144 |
|  |  | AHB.130 How often do you do LEISURE-TIME physical activities specifically designed to STRENGTHEN your muscles such as lifting weights or doing calisthenics? (Include all such activities even if you mentioned them before.) [Asked of all sample adults.] | 155 |
| 2009 | COMMUNIty-wide CAmpaign To promote Exercise study (Questionnaire) | Respondents were asked about the weekly number of days performed was asked for muscle-strengthening activity. | 52 |
|  |  | The weekly number of days engaged in muscle-strengthening activity was assessed by asking “Do you usually do activities to maintain and/or improve muscles and/or muscle strength (e.g., sit-ups, squats, knee extensions)?” | 53 |
|  | HealthStyles Survey | Respondents were asked about muscle-strengthening participation (yes/no), frequency (days per week), inclusion of muscle group(s) (i.e., shoulders, arms, back, chest, abdomen, legs, and hips), and type and location of muscle strengthening activities performed during a usual week in the past month. | 101 |
|  | New South Wales Fall Prevention telephone survey (Questionnaire) | Participants were asked if in the past week they did “strength or resistance training such as lifting weights or push ups”. | 37 |
| 2010 | Central Queensland Social Survey (Based on the Active Australia Survey) | ‘Have you ever consistently, at least two times per week for at least six months, performed strength-based training to build or maintain muscle?’ If yes, participants were asked to report how long ago they strength trained, with one of the category choices being, ‘I currently strength train’. | 29 |
|  | Exercise, Recreation and Sport Survey | Interviewers asked respondents if they had participated in any LTPA for exercise, recreation or sport in the last 12 months (as opposed to PA associated with employment, housework or garden chores). If the response was ‘yes’, respondents were then asked to report what activities they had participated in during this time period (up to a maximum of 10 activities).  Respondents were also asked how many times (sessions or episodes) they had participated in each of their nominated types of activity during the previous 12 months. | 34 |
|  | General Social Survey | gather information regarding daily time-use by asking participants to estimate the number of minutes spent engaging in various leisure and work-related activities during a designated day of the week. | 43 |
|  | Social Survey (Social Survey Questionnaire) | “Physical exercise to strengthen muscles is exercise intended to strengthen and build muscles, for example gymnastics, bodybuilding, and weightlifting. In the last three months, did you engage in exercise to strengthen muscles? | 49 |
| 2011 | Behavioral Risk Factor Surveillance System | Respondents’ PA levels were determined using six items on the BRFSS that assessed ………….. the frequency of engaging in muscle strengthening exercises | 86 |
|  |  | 2) the frequency of physical activities or exercises to strengthen their muscles (excluding aerobic activities but including yoga, sit-ups, push-ups, and exercises using weights or elastic bands). | 25 |
|  |  | They also reported, during the past month,.  (2) the frequency of physical activities or exercises to strengthen their muscles | 26 |
|  |  | ‘During the past month, how many times per week or per month did you do physical activities or exercises to STRENGTHEN your muscles? Do NOT count aerobic activities like walking, running, or bicycling. Count activities using your own body weight like yoga, situps or push-ups and those using weight machines, free weights, or elastic bands.’ | 87 90 |
|  | Health Information National Trends Survey | “In a typical week, outside of your job or work around the house, how many days do you do leisure-time physical activities specifically designed to strengthen your muscles such as lifting weights or circuit training (do not include cardio exercise such as walking, biking, or swimming)?” | 97 |
|  | National Health Interview Survey + Behavioral Risk Factor Surveillance System + National Health and Nutrition Examination Activity Survey | NHANES only assessed muscle strengthening behaviors in 1999–2006, thus we did not report on these values due to the lack of recent data points. NHIS questionnaires included strength training from 1998 to 2013, BRFSS assessed strength training in 2011 and 2013. | 91 |
|  | National Health Interview Survey | “How often do you do leisure-time physical activities specifically designed to strengthen your muscles such as lifting weights or doing calisthenics?” Participant responses included both the number of times ST was performed and the unit of time (i.e. “per week,”“per month”) | 147 |
|  |  | “How often do you do leisuretime physical activities specifically designed to strengthen your muscles such as lifting weights or doing calisthenics?” | 157 |
|  | National Nutrition and Physical Activity Survey | “Including any activities already mentioned, in the last week did you do any strength or toning activities?”. If they answered positively, they were further asked: “How many times did you do any strength or toning activities in the last week?”. | 19 |
|  |  | “In the last week, did you do any strength or toning activities? (For example; lifting weights, pull-ups, push-ups, or sit-ups)”. If they answered ‘yes’ they were then asked, “How many times did you do any strength or toning activities in the last week?” and “What was the total time that you spent doing strength or toning activities in the last week?” | 36 |
|  | New York City Neighborhood and Mental Health in the Elderly Study II, longitudinal study (Physical Activity Scale for the Elderly (PASE)) | All subjects who were followed up successfully were asked at each wave about past-week physical activity using 16 items derived from the Physical Activity Scale for the Elderly (PASE) (26–28) | 167 |
|  |  | PASE asks subjects to recall past-week engagement in ……. muscle-strengthening | 168 |
|  | Not disclosed (Questionnaire) | ~ [Strength training was defined as all exercises that serve to enhance muscular strength and endurance, with regular strength training defined as 2 days or more per week. Respondents were categorized into two groups: those who engaged in regular strength-training behavior and those who did not. In addition, for those who reported regular training, the location (facility or home) was requested.] [Japan] | 24 |
|  |  | Respondents were asked to report how many days they participated in each type of activity during a typical week [Japan] | 51 |
| 2012 | Canadian Longitudinal Study on Aging (CLSA - modified Physical Activity Scale for Elderly (PASE)) | participants were asked how often they engaged in exercises specifically to increase muscle strength and endurance | 41 42 |
|  | COMMUNIty-wide CAmpaign To promote Exercise study (Questionnaire) | The weekly number of days performed was asked for muscle-strengthening activity. | 54 |
|  | National Health Interview Survey | How often do you do leisure-time activities specifically designed to strengthen your muscles such as lifting weights or doing calisthenics? | 162 |
|  | Scottish Health Survey | Respondents were asked to report the frequency (in the 28 days prior to interview) and average duration of any sport and exercise activities that they undertook. “During the past four weeks, was the effort of (name of activity) usually enough to make your muscles feel some tension, shake or feel warm?” | 11 |
|  |  | For certain activities an additional question was asked to identify whether the activity could be classed as muscle strengthening. IF WhtAct, WhtAcB or OactQ = cycling, workout at a gym, aerobics, any other type of dancing, running/jogging, football/rugby, badminton/tennis, squash, exercises, ten pin bowling, yoga/pilates, aquarobics/aquafit, martial arts/Tai Chi, basketball, netball, lawn bowls, golf, hill walking/rambling, cricket, hockey, curling, ice skating, shinty, surf/body boarding, volleyball THEN [cyclemus to Vollmus]  During the past four weeks, was the effort of (name of activity) usually enough to make your muscles feel some tension, shake or feel warm? 1 Yes 2 No  IF WhtAct = Exercises (e.g. press-ups, sit-ups) AND (Age>=65) THEN [ExMov]2 Did these exercises involve you standing up and moving about? 1 Yes 2 No | 75 |
| 2013 | 7 Day recall | Do you do exercise as a part of your daily routine? | 66 |
|  | Behavioral Risk Factor Surveillance System | All individuals who indicated any activity in the past month also were asked whether in the past month they had engaged in physical activity, such as yoga, sit-ups, push-ups, and using weight machines, free weights, and elastic bands, to strengthen their muscles, and how many times per week or month they engaged in those activities. | 83 |
|  |  | Meeting the muscle strengthening recommendations was assessed by asking  participants “what type of physical activity or exercise did you spend the most time doing during the past month?” followed up by “how many times per week or per month did you take part in this activity during the past month?” and followed up by “and when you took part in this activity, for how many minutes or hours did you usually keep at it?” | 88 |
|  | Finnish Regional Health and Well-being Study | (a) “think about the past year (12 months)”; (b) “consider all regular weekly physical activity which lasts at least 10 minutes/session”; and (c) “select all alternatives that correspond to their physical activity habits”. The frequency (days/week) and duration (hours and minutes/ week) of the following four physical activity- related behaviors were assessed: (iii) “Neuromuscular training (for example keep-fit circuit training or muscular strength training in a gym, and including exercises for the main muscle groups with 8-12 repetitions)” | 18 |
|  | National College Health Assessment | Participation in strength training activity was also assessed, using the question: In the past seven days, how many days did you exercise to strengthen muscles doing eight to ten repetitions? | 44 |
| 2014 | Korea National Health and Nutrition Examination Survey | ‘Over the past 7 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups, or situps?’. Those who reported ‘yes’ were asked to report their MSE frequency (times/week). Based on the Korean guidelines | 57 |
|  |  | Based on the Global Physical activity questionnaire. And the frequency of participating in MSE (1 item) were also self-reported. | 60 |
|  |  | Subjects who performed resistance exercise were defined as those who performed exercises such as push-ups, crunches, or chin-ups for 1 day or more in the past week | 62, 63 |
|  | National Health Interview Survey | ~ | 160 |
|  | Surveillance System of Risk Factors and Protection for Chronic Noncommunicable Diseases | “have you practiced any kind of physical exercise or sport during the last three months? Yes/No/Which?” “on the day you exercise or practice a sport, how long does this activity last?” | 38 |
| 2015 | Behavioral Risk Factor Surveillance System | “During the past month, how many times per week or per month did you do physical activities or exercises to strengthen your muscles?”. “Do not count aerobic activities like walking, running, or bicycling. Count activities using your own body weight like yoga, sit-ups or push-ups and those using weight machines, free weights, or elastic bands” | 17, 80, 81 |
|  |  | ~ | 82 |
|  | Korean Survey on Citizens’ Sports Participation (2015 Survey on Citizens’ Sports Participation) | "How often do you participate in structured/ nonstructured physical activity?" | 67 |
|  | Longevity check-up 7+ (lifestyle interview/questionnaire) | ~ [Information and data: - habitual physical activity] | 50 |
|  | National Health Interview Survey | Respondents reporting participation in leisure time physical activities specifically designed to strengthen their muscles (e.g., lifting weights, doing calisthenics) two or more times weekly were classified as meeting the muscle strengthening guideline. | 152 |
|  |  | Morbidity and Mortality Weekly Report [looking at the actual questionnaire :-AHB.130\_01.000: Strength activity freq: # of units | 163 |
| Unclear | Active Australia survey | Respondents who reported any activity were asked to list their three main types of physical activities (unprompted) and how often they had engaged in each of 14 specific recreational physical activities over the previous 12 months (never, once every 6 months, once a month, once every 2 weeks, once a week and more than once a week). | 27 |
|  | Central Queensland Social Survey | “Do you currently perform any strength based training to build or maintain muscle? This could include activities such as training at home or the gym using barbells, dumbbells, hand weights or weight machines.”  “How many days each week do you perform strength based training activities?”  “When you perform the activities to build or maintain muscle, how many different exercises do you perform?”  “On average how many repetitions do you perform in each set?” and  “Thinking about the weight that you lift during your muscle strengthening sessions, we would like you to categorise the intensity of this weight on a scale of 1–10, where 1 means that it is no effort at all, 5 is moderate effort and 10 is the weight you can only lift once.” | 31 |
|  | New York County Health Census (derived from Paffenbarger et al.'s16 original physical activity questionnaire) | "At least once a week, do you engage in any regular activity like brisk walking, jogging, bicycling, etc. long enough to work up a sweat? (No, Yes) If yes, how many times a week? \_\_ Activity." | 169 |
|  | Structured questionnaire | Frequency and duration (i.e., quantity) of participation in strength training and 20 other physical activities, such as jogging, rowing, stair stepping, or swimming, were assessed with the quantitative ~ history method) | 171 |
|  | Taiwanese version of the International Physical Activity Questionnaire-long version (IPAQ-LV) | Those who reported engagement in MS activities were asked whether they had done any MS activities in the previous week other than MVPA. If they answered affirmatively, they were further asked: “How many times did you do MS activities last week?” | 69 |
| ~ [ ] Where the specific muscle-strengthening exercise questions were not explicitly detailed within the included articles we have included additional text, located within each respective manuscript, to indicate how the exercise was measured. | | | |

**Online Supplementary Table 2**: Chronological order of questions assessing muscle-strengthening exercise behaviours within the included studies.

|  |  |  |  |
| --- | --- | --- | --- |
| **Online Supplementary Table 3:** Chronological order of questions assessing muscle-strengthening exercise behaviours within the included studies. | | | |
| **Surveillance system/survey** | |  |
| **Year** | **Question/s contained within each included article [additional notes]** | **Ref** |
| Nutritional supplementation trial (Physical activity questionnaire) | |  |
| 1969 | Field workers administered a physical activity questionnaire asking about the frequency and duration of activities performed over the preceding year on a typical workday | 47 |
| British Regional Heart Study | | |
| 1978 | How often they participated in sport/exercise. Men reporting frequent sport/exercise participation were also asked to state the type of sport/exercise they engaged in. | 70 |
| Aerobics Center Longitudinal Study | | |
| 1980 | Self-reported resistance exercise was assessed in the medical history questionnaire. Participants were asked about the weekly frequency and average exercise duration (minutes) for each session of muscle-strengthening PA using either free weights or weight training machines over the past 3 months. | 77 |
| 1987 | Self-reported resistance exercise was assessed in the medical history questionnaire. Participants were asked about the weekly frequency and average exercise duration (minutes) for each session of muscle-strengthening PA using either free weights or weight training machines over the past 3 months. | 76 |
| 2005 | Participants were asked to provide yes/no answers to 4 separate questions:  (1) “Are you currently involved in a muscle-strengthening programme?”  (2) Can you specify the muscle-strengthening activity as “Callisthenics”, “Free Weights”, “Weight Training Machines” or “Other”?  (3) “Are you currently involved in exercises to maintain or improve your joint flexibility?”  (4) Can you specify the flexibility activity as “Stretching”, “Callisthenic”, “Exercise Class”, “Yoga” or “Other”? | 78 |
| MRC National Survey of Health and Development (Minnesota leisure time physical activity questionnaire) | | |
| 1982 | Sports and recreational activities:  List of 27 activities (eg, , exercises such as press ups at home | 74 |
| National Health and Nutrition Examination Survey | | |
| 1988 | Participants were asked to specify their frequency of LTPA during the past month for the following: ….. calisthenics or floor exercises, and weight lifting.  "In the past month, did you lift weights?" Participants who responded "yes" were then asked, "In the past month, how often did you lift weights?" | 113 126 |
|  | Using standard NHANES questions, participants reported types of leisure time physical activity they performed in the past month (e.g. jogging, biking, swimming) and the number of times they performed each activity. For example, “We are interested in exercise, sports, physically active hobbies that you may do in your leisure time. In the past month did you . . . jog or run? How many times during the month?” | 121 |
| 1997 | During the past month, did you , do calisthenics, or do other exercises or sports? | 106 |
| 1999 | Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups? Include all such activities even if you have mentioned them before in the past 12 months; Over the past 30 days, how often did you do these activities? [Activities designed to strengthen your muscles such as lifting weights, push-ups or sit-ups]. | 105 |
|  | “any physical activity designed to strengthen muscles such as lifting weights, push-ups or sit-ups, over the past 30 days” 75, and by asking what specific leisure time strength training activity they performed over the past 30 days 76 | 108 |
|  | Participants reported whether they performed ‘any physical activity designed to strengthen muscles such as weight-lifting, push-ups or sit-ups, over the past 30 days’. | 109 |
|  | “Over the past 30 days, how often did you do any physical activities designed to strengthen your muscles such as lifting weights, push-ups, or sit-ups? Include all such activities even if you have mentioned them before.” | 110 |
|  | ‘Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?’ ‘Over the past 30 days, how often did you do these physical activities?’ Activities designed to strengthen your muscles such as lifting weights, push-ups or sit-ups. | 111 112 |
|  | “During the past 30 days, did you do any PAs specifically designed to strengthen your muscles, such as weight lifting, push-ups, or sit-ups?”, “During the past 30 days, how many times did you do these MSAs (eg, weight lifting, push-ups, or sit-ups)?” | 116 |
|  | "During the past 30 days, did you do any physical activities specifically designed to strengthen your muscles, such as weight lifting, push-ups, or sit-ups?” and if so “During the past 30 days, how many times did you do these muscle strengthening activities (e.g., weight lifting, push-ups, or sit-ups)?”. | 120 |
|  | 1) “Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?” (response option: yes or no), and 2) “Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, push-ups, or sit-ups?” | 122 |
|  | ~ [self-report of meeting muscle-strengthening activities guidelines (yes/no; ≥2 sessions per week)] | 123 |
|  | ‘‘[Over the past 30 d], did you do moderate activities for at least 10 min that caused only light sweating or a slight to moderate increase in breathing or heart rate? Some examples are brisk walking, bicycling for pleasure, golf, or dancing.’’ Individuals who reported that they had engaged in moderate-intensity activity were asked to report the frequency and duration of any of the 32 moderate activities. | 129 |
|  | “Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups, or sit-ups?” “How often did you do these physical activities?” | 130 |
|  | ‘Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?’ (response yes/no). | 131 |
|  | (1) ‘‘Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, pushups or sit-ups?’’ (response option: yes or no) and (2) among those answering yes to this first question, they were asked, ‘‘Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, push-ups, or sit-ups?’’ | 132, 137 |
|  | “Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?” | 135 139 |
|  | ‘‘Over the past 30 days, did you do any physical activity specifically designed to strengthen your muscles such as LW, push-ups or sit-ups?’’ | 140 |
|  | Participants were asked which vigorous activities from a list of examples they performed over the past 30 days. Vigorous activity was defined as those “that caused heavy sweating, or large increases in breathing or heart rate?” VPA activities were defined as a having corresponding metabolic equivalent level (MET) level of 6.0. For each activity reported, the number of times performed over the past 30 days and the average duration in minutes was collected. The same process was used to collect the frequency and duration of moderate activities performed over the past 30 days, defined as activities “that caused light sweating or a slight to moderate increase in your heart rate or breathing.” MPA activity was defined by NHANES as an activity with a corresponding MET level of 3.0–5.9. | 141 |
|  | (1) “Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?” and (2) “Over the past 30 days, how many times did you do these physical activities?” | 142 |
| 2003 | i) ‘Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?’ (response option: yes or no), and (ii) among those answering yes to this first question, they were asked, ‘Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, push-ups, or sit-ups?’ | 107 136 |
|  | (1) “Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?” and, if so, (2) “Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?” | 115 117 |
|  | (1) “Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weight, push-ups or sit-ups?” and if yes (2) “Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?” | 118 |
|  | (1) ‘‘Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weight, push-ups, or sit-ups?’’, (2) ‘‘Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, pushups, or sit-ups?’ | 119 |
|  | ~ [Strengthening ≥2 times/week 1 time/week None] | 124 |
|  | ~ [All PA  3) Type of PA: number of sessions per month cardio strengthening Flexibility  Total MeT-minutes cardio strengthening Flexibility] | 125 |
|  | The PA questionnaire data consisted of participants' responses to whether or not they participated in leisure-time MVPA and activities in other PA domains (e,g,, transportation related or domesfic PA), and if yes, what were the type, frequency, and duration of fhe specific activities participants performed in the past 30 d | 127 |
|  | Participants were asked two questions related to engagement in MSA: (1) ‘Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?’ (response option: yes or no), and (2) among those answering yes to this first question, they were asked, ‘Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, pushups, or sit-ups?’ | 133, 138 |
| 2005 | Participants were also asked if they participated in specific physical activities (not in the workplace) in the previous 30 days including …….., and muscle strengthening activities. | 114 |
|  | Participants were also asked if they participated in specific physical activities (not in the workplace) in the previous 30 days including ...........muscle strengthening activities. If they answered yes, they were asked about the frequency and the average duration of time they engaged in those activities | 128 |
|  | 1) “Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?” (response option: yes or no), and 2) among those answering yes to this first question, they were asked, “Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, push-ups, or sit-ups?” | 134 |
| Behavioral Risk Factor Surveillance System | | |
| 1989 | ~ | 84 |
| 2000 | “During the past month, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?” Those who answered affirmatively then were asked to provide information about the type, frequency, and duration of up to two activities. | 85 |
|  | What type of physical activity or exercise did you spend the most time doing during the past month? and What other type of physical activity gave you the next most exercise during the past month?, providing their two most common activities. | 89 |
| 2011 | Respondents’ PA levels were determined using six items on the BRFSS that assessed ………….. the frequency of engaging in muscle strengthening exercises | 86 |
|  | 2) the frequency of physical activities or exercises to strengthen their muscles (excluding aerobic activities but including yoga, sit-ups, push-ups, and exercises using weights or elastic bands). | 25 |
|  | They also reported, during the past month,  (2) the frequency of physical activities or exercises to strengthen their muscles | 26 |
|  | ‘During the past month, how many times per week or per month did you do physical activities or exercises to STRENGTHEN your muscles? Do NOT count aerobic activities like walking, running, or bicycling. Count activities using your own body weight like yoga, situps or push-ups and those using weight machines, free weights, or elastic bands.’ | 87 90 |
| 2013 | All individuals who indicated any activity in the past month also were asked whether in the past month they had engaged in physical activity, such as yoga, sit-ups, push-ups, and using weight machines, free weights, and elastic bands, to strengthen their muscles, and how many times per week or month they engaged in those activities. | 83 |
|  | Meeting the muscle strengthening recommendations was assessed by asking  participants “what type of physical activity or exercise did you spend the most time doing during the past month?” followed up by “how many times per week or per month did you take part in this activity during the past month?” and followed up by “and when you took part in this activity, for how many minutes or hours did you usually keep at it?” | 88 |
| 2015 | “During the past month, how many times per week or per month did you do physical activities or exercises to strengthen your muscles?”. “Do not count aerobic activities like walking, running, or bicycling. Count activities using your own body weight like yoga, sit-ups or push-ups and those using weight machines, free weights, or elastic bands” | 17, 80, 81 |
|  | ~ | 82 |
| Cardiovascular Health Study | | |
| 1989 | ~ [duration per session × number of sessions in the last 2 weeks/2.] | 93 |
| National Health Interview Survey | | |
| 1990 | The Health Promotion and Disease Prevention supplement includes questions about physical activity. Regular LTPA was defined as participation for 30 minutes or more at least 3 times a week during the past 2 weeks in 1 or more of the following physical activities: ......., calisthenics, .... weight lifting, ....... or up to 2 unspecified other activities. | 164 |
| 1996 | “How often do you do leisure-time physical activities specifically designed to strengthen your muscles, such as lifting weight or doing calisthenics?” Participant responses included both the number of times strength training was performed and the unit of time (i.e. “per week,”“per month”) | 148 |
|  | (5) How often do you do LEISURE-TIME physical activities specifıcally designed to STRENGTHEN your muscles such as lifting weights or doing calisthenics? | 156 |
| 1998 | Respondents were also asked about their participation in leisure-time physical activities specifıcally designed to strengthen their muscles, such as lifting weights or doing calisthenics. Respondents were classifıed as meeting the muscle-strengthening guideline if they reported engaging in muscle-strengthening activity two or more times/week. | 145 |
|  | “How often do you do physical activities designed to strengthen your muscles, such as lifting weights or doing calisthenics?” | 149 |
|  | “How often do you do leisuretime physical activities specifically designed to strengthen your muscles such as lifting weights or doing calisthenics?” | 158 |
| 1999 | AHB.130 How often do you do physical activities specifically designed to STRENGTHEN your muscles such as lifting weights or doing calisthenics? (Include all such activities even if you mentioned them before.) [Asked of all adults.] | 154 |
|  | How often do you do physical activities specifically designed to strengthen your muscles such as lifting weights or doing calisthenics? (NCHS, 2003b, p. 365) | 159 |
|  | ~ | 161 |
| 2001 | “How often do you do physical activities specifically designed to strengthen your muscles, such as lifting weights or doing calisthenics?” | 150 |
| 2002 | "How often do you do physical activities specifically designed to STRENGTHEN your muscles such as lifting weights or doing calisthenics? (Include all such activities even if you mentioned them before.) [Asked of all adults.]" | 143 |
| 2003 | respondents were asked to report the frequency of ‘‘physical activities specifically designed to strengthen your muscles such as lifting weights or doing calisthenics.’’ | 146 |
| 2005 | Respondents were asked to report the frequency they engaged in strength training (per day, week, month, or year). | 151 |
|  | AHB.130 How often do you do LEISURE-TIME physical activities specifically designed to STRENGTHEN your muscles such as lifting weights or doing calisthenics? (Include all such activities even if you mentioned them before.) [Asked of all adults.] | 153 |
| 2008 | ‘How often do you do leisure-time muscle-strengthening activities (‘‘such as lifting weights or doing calisthenics’’) | 144 |
|  | AHB.130 How often do you do LEISURE-TIME physical activities specifically designed to STRENGTHEN your muscles such as lifting weights or doing calisthenics? (Include all such activities even if you mentioned them before.) [Asked of all sample adults.] | 155 |
| 2011 | “How often do you do leisure-time physical activities specifically designed to strengthen your muscles such as lifting weights or doing calisthenics?” Participant responses included both the number of times ST was performed and the unit of time (i.e. “per week,”“per month”) | 147 |
|  | “How often do you do leisuretime physical activities specifically designed to strengthen your muscles such as lifting weights or doing calisthenics?” | 157 |
| 2012 | How often do you do leisure-time activities specifically designed to strengthen your muscles such as lifting weights or doing calisthenics? | 162 |
| 2014 | ~ | 160 |
| 2015 | Respondents reporting participation in leisure time physical activities specifically designed to strengthen their muscles (e.g., lifting weights, doing calisthenics) two or more times weekly were classified as meeting the muscle strengthening guideline. | 152 |
|  | Morbidity and Mortality Weekly Report [looking at the actual questionnaire :-AHB.130\_01.000: Strength activity freq: # of units | 163 |
| Women’s Health Study | | |
| 1992 | During the past month, what was your approximate time per week spent at each of the following recreational activities? Weight lifting/strength training. | 173 |
|  | During the past year, what was your approximate time per week spent at each of the following recreational activities? Weight lifting/strength training. | 174 |
| National Population Health Survey | | |
| 1994 | It is based on responses to questions asking respondents if they had participated in any of 23 activities in the past 3 months specified in the NPHS questionnaire and, if so, their duration and frequency of participation in these activities. For Cycle 1, the listed activities were: . , weight training, , and up to three other activities. | 46 |
| 1996 | Forms of LTPA were assessed by asking respondents whether they had participated in the past 3 months in LTPA, that is, activities not related to work. The interviewer read from a list of 20 such activities (i.e., walking for exercise, gardening or yardwork, swimming) and also inquired on any other activity not listed. | 45 |
| Health Survey for England + Scottish Health Survey | | |
| 1994 | Physical activity was assessed using a questionnaire that inquired about participation in sports and exercises during the 4 weeks prior to the interview. Participants were shown a card. For each positive response, participants were asked whether they had participated in the activity for at least 15 minutes, the frequency of activity (number of occasions), and the duration of activity per occasion. | 73 |
| Brazilian Living Standards Measurement Survey | | |
| 1996 | The questionnaire included six questions: (1) Do you engage in any physical exercise or sport?; (2) What kind of exercise or sport do you perform? (Please mark the most frequent group: , gym/muscular exercise, , other sports.); (3) Do you perform exercise or a sport every week?; (4) How many days per week? (Please include all exercise and sports.); (5) How many minutes or hours in each day? (Please include all exercise and sports.); (6) What is your main reason for engaging in exercise or sport? (recreation, health/medical counseling, esthetics/ beauty, other reason). | 39 |
| North/South Ireland Food Consumption Survey (NSIFCS based on the validated Minnesota Leisure Time Activity Questionnaire) | | |
| 1996 | Levels of customary physical activity were assessed by a self-administered questionnaire that was developed at the Institute of Public Health, University of Cambridge. In each case, questions were closed rather than open-ended, to make them easy to complete and to facilitate large-scale data entry. Respondents were asked to identify the frequency and duration of their participation in 36 named recreational pursuits, including sports and gardening activities. For each activity, respondents indicated the number of times they performed the activity in the past year and the average duration per episode. | 48 |
| Health Survey for England | | |
| 1996 | Sport and exercise participation was measured by showing respondents a card listing common activities such as, gym workout,., keep-fit, and calisthenics. | 72 |
| Korea National Health and Nutrition Examination Survey | | |
| 1999 | used five answers from IPAQ, which for that week of the survey identified the number of days the participants did vigorous physical activity, moderate physical activity, walking, strength, and flexibility, for at least 10 min at a time. | 61 |
| 2007 | how many days per week the individual spends on strengthening or stretching activity | 64 |
| 2008 | ~ [after adjustment for factors known to affect osteoporosis, such as age, gender, BMI, serum 25(OH) vitamin D level, menstruation status, hormone supplement use, menopausal status, and the number of days per week of muscular strength exercise.] | 58 |
|  | Participants also recorded the frequency of resistance exercises such as push-ups, sit-ups, or training using dumbbells, weights, or a horizontal bar in the past week. | 59 |
| 2014 | ‘Over the past 7 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups, or situps?’. Those who reported ‘yes’ were asked to report their MSE frequency (times/week). Based on the Korean guidelines | 57 |
|  | Based on the Global Physical activity questionnaire. And the frequency of participating in MSE (1 item) were also self-reported. | 60 |
|  | Subjects who performed resistance exercise were defined as those who performed exercises such as push-ups, crunches, or chin-ups for 1 day or more in the past week | 62, 63 |
| National Health Interview Survey + Behavioral Risk Factor Surveillance System + National Physical Activity Survey | | |
| 1999 | The NHIS used examples of strengthening activities (e.g., lifting weights, calisthenics).  The BRFSS used examples of activities for strengthening (e.g., lifting weights, pull-ups, push-ups, sit-ups).  The NPAS terms were identical to the BRFSS study | 92 |
| PEAK-25 Cohort Self-administered questionnaire (Questionnaire) | | |
| 1999 | The subjects were asked to grade their own overall activity level; to describe the types of exercise they performed; to estimate the amount of time spent on each specific activity; and to specify seasonal variations in their activity. | 68 |
| Nurses' Health Study + Nurses’ Health Study II | | |
| 2000 | each participant reported her average weekly amount of resistance exercise, lower intensity exercise (yoga, stretching, toning), and aerobic physical activities. | 170 |
| VITamins And Lifestyle study (Questionnaire) | | |
| 2000 | Respondents were instructed to only report activities carried out regularly, defined as at least once per week for at least 1 y in the previous 10y. Participants reported the number of years in the last 10 that they did each activity, along with the days per week and the minutes per day. | 172 |
| Exercise, Recreation and Sport Survey | | |
| 2001 | participation in leisure-time physical activity, defined as; ‘any physical activity done for exercise, recreation or sport in the past 12 months’. Respondents were asked to exclude ‘any physical activity associated with work, household or garden chores’.  Those who indicated participation were asked to list the types of leisuretime physical activity undertaken, whether each activity was organised or non-organised, and the number of times they participated in each activity during the previous 12 months. From 2005 onwards, participants were also asked about the frequency and average session duration in the past two weeks. | 16 |
|  | participants were asked about any physical activity done for exercise, recreation or sport in the past 12 months. | 33 |
| 2006 | Respondents were asked if they participated in any physical activity for exercise, recreation and sport during the last 12 months, excluding activities that were part of work or household and garden chores. Those who indicated participation were asked to list up to 10 specific activities that were coded by the interviewer against a list of 166 activities (including two “other” options). Respondents reported the number of sessions they engaged in each activity over the previous 12 months. For the three activities with the highest frequency of participation over the previous 12 months, respondents also reported the number of sessions and average minutes per session of each activity during the previous 2 weeks. | 35 |
| 2010 | Interviewers asked respondents if they had participated in any LTPA for exercise, recreation or sport in the last 12 months (as opposed to PA associated with employment, housework or garden chores). If the response was ‘yes’, respondents were then asked to report what activities they had participated in during this time period (up to a maximum of 10 activities).  Respondents were also asked how many times (sessions or episodes) they had participated in each of their nominated types of activity during the previous 12 months. | 34 |
| Modified CHAMPS questionnaire | | |
| 2002 | The participants were first asked whether they had done each of these activities in a typical week during the last month (yes/no). Those who answered no were referred to the next item. Those who answered yes then responded to the frequency question “how many times a week?” and the duration question “how many hours a week?” with six response options (<1, 1–2, 3–4, 5–6, 7–8, and ≥9 hr). | 103 |
| National Physical Activity and Weight Loss Survey | | |
| 2002 | Respondents were asked whether they participated in any activities designed to increase muscle strength or tone in a usual week, and if so, how many days per week did they participate in such resistance-type activities | 165 |
|  | “In a usual week, do you do any activities designed to increase muscle strength or tone, such as lifting weights, pull-ups, push-ups, or sit-ups?” Those who said yes were asked, “How many days per week do you do these activities?” | 166 |
| American Time Use Survey | |  |
| 2003 | Respondents were asked to sequentially describe each activity and its duration for the 24-h period beginning at 4:00 a.m. Follow-up questions assessed where and with whom each activity occurred. Each interview lasted approximately 15 to 20 min | 79 |
| Go for the Gold” employee wellness program (the Wellsource Concise Assessment Plus Personal Wellness Profile) | | |
| 2003 | Engaging in strength exercising (sit-ups, pushups, or use weight training equipment) How many times per week do you do strength building exercises such as situps, pushups, or use weight training equipment? | 96 |
| Australian Diabetes, Obesity and Lifestyle study | | |
| 2004 | ‘‘How many times have you done any activities designed to increase muscle strength or tone, such as lifting weights, pull-ups, push-ups, or sit-ups?’’ In a separate question, ST duration was evaluated by asking, ‘‘What do you estimate was the total time that you spent in these activities in the last week?’’ | 28 |
| Education and Research Towards Health Study (Questionnaire) | | |
| 2004 | Questions about activities that are less frequently performed (traditional activities, leisure activities, and occupational activities) were asked in the manner of the Taylor questionnaire; participants chose from a list of individual activities and specified the length of time and frequency at which they were performed, for all activities, participants were asked to include only those lasting more than 10 minutes at a time, specify the days per week (or per month as applicable) of the activity, and specify the average time spent on each activity. | 95 |
| Health risk survey | | |
| 2004 | Using survey items similar to those included in national surveillance systems,  Students also self-reported the number of days in the past week in which they engaged in stretching and/or strengthening exercises. | 99 |
| HealthStyles Survey | | |
| 2004 | Respondents were also asked to report all physical activities/sports they engage in from a list of 18 specific activities: "Which of the following physical activities/sports do you participate in regularly?" These items included …., lifting weights | 100 |
| 2009 | Respondents were asked about muscle-strengthening participation (yes/no), frequency (days per week), inclusion of muscle group(s) (i.e., shoulders, arms, back, chest, abdomen, legs, and hips), and type and location of muscle strengthening activities performed during a usual week in the past month. | 101 |
| Concord Health and Aging in Men Project (PASE) | | |
| 2005 | Participants reported the frequency and time spent in the past 7 days in muscle strengthening exercise. | 32 |
| Central Queensland Social Survey | | |
| 2006 | ‘In the last week, did you do any gym-based resistance training’? | 30 |
| unclear | “Do you currently perform any strength based training to build or maintain muscle? This could include activities such as training at home or the gym using barbells, dumbbells, hand weights or weight machines.”  “How many days each week do you perform strength based training activities?”  “When you perform the activities to build or maintain muscle, how many different exercises do you perform?”  “On average how many repetitions do you perform in each set?” and  “Thinking about the weight that you lift during your muscle strengthening sessions, we would like you to categorise the intensity of this weight on a scale of 1–10, where 1 means that it is no effort at all, 5 is moderate effort and 10 is the weight you can only lift once.” | 31 |
| 2010 | ‘Have you ever consistently, at least two times per week for at least six months, performed strength-based training to build or maintain muscle?’ If yes, participants were asked to report how long ago they strength trained, with one of the category choices being, ‘I currently strength train’. | 29 |
| Japan Epidemiology Collaboration on Occupational Health Study | | |
| 2006 | Participants were asked if they regularly engaged in any physical activity during leisure time including muscle strength training, | 55 |
| SSF National Sports-Life Survey | | |
| 2006 | Questions 1 and 2 of the questionnaire were utilized for the engagement of strength training. | 56 |
| Canadian Community Health Survey (CHMS household questionnaire) | | |
| 2007 | Respondents aged 12 or older were asked if they had engaged in any of the following activities in the previous three months: , home exercises, weight-training, or any other. For each activity reported, respondents were asked the frequency in the past three months, and the average duration of each session: 1 to 15 minutes, 16 to 30 minutes, 31 to 60 minutes, or more than one hour. | 40 |
| College Student Health Survey | | |
| 2007 | In the past 7 days, how many hours did you spend doing the following activities? (C) Exercises to strengthen or tone your muscles | 94 |
| General Student Health Survey | | |
| 2007 | “On how many of the past 7 days did you do exercises to strengthen or tone muscles (push-ups, sit-ups, or weight lifting)?” [United Kingdom] | 71 |
| 2008 | “On how many of the past 7 days did you do exercises to strengthen or tone your muscles, such as push-ups, sit-ups, or weight lifting?” Participants answered 0–7 days [Libya] | 65 |
| Millennium Cohort Study | | |
| 2007 | "In a typical week, how much time do you spend participating in strength training or work that strengthens your muscles (such as lifting/pushing/pulling/weights)?” | 102 |
| Health Professionals Follow-up Study | | |
| 2008 | Participants were asked to report the average time spent per week in the previous year in each……. Calisthenics…., weightlifting/ weight machine….. | 98 |
| National College Health Assessment | | |
| 2008 | On how many of the past 7 days did you do 8 to 10 strength training exercises (such as resistance training weight machines) for 8 to 12 repetitions each? [United States] | 104 |
| 2013 | Participation in strength training activity was also assessed, using the question: In the past seven days, how many days did you exercise to strengthen muscles doing eight to ten repetitions? [Canada] | 44 |
| COMMUNIty-wide CAmpaign To promote Exercise study (Questionnaire) | | |
| 2009 | Respondents were asked about the weekly number of days performed was asked for muscle-strengthening activity. | 52 |
|  | The weekly number of days engaged in muscle-strengthening activity was assessed by asking “Do you usually do activities to maintain and/or improve muscles and/or muscle strength (e.g., sit-ups, squats, knee extensions)?” | 53 |
| 2012 | The weekly number of days performed was asked for muscle-strengthening activity. | 54 |
| New South Wales Fall Prevention telephone survey (Questionnaire) | | |
| 2009 | Participants were asked if in the past week they did “strength or resistance training such as lifting weights or push ups”. | 37 |
| General Social Survey | | |
| 2010 | gather information regarding daily time-use by asking participants to estimate the number of minutes spent engaging in various leisure and work-related activities during a designated day of the week. | 43 |
| Social Survey (Social Survey Questionnaire) | | |
| 2010 | “Physical exercise to strengthen muscles is exercise intended to strengthen and build muscles, for example gymnastics, bodybuilding, and weightlifting. In the last three months, did you engage in exercise to strengthen muscles? | 49 |
| Health Information National Trends Survey | | |
| 2011 | “In a typical week, outside of your job or work around the house, how many days do you do leisure-time physical activities specifically designed to strengthen your muscles such as lifting weights or circuit training (do not include cardio exercise such as walking, biking, or swimming)?” | 97 |
| National Health Interview Survey + Behavioral Risk Factor Surveillance System + National Health and Nutrition Examination Activity Survey | | |
| 2011 | NHANES only assessed muscle strengthening behaviors in 1999–2006, thus we did not report on these values due to the lack of recent data points. NHIS questionnaires included strength training from 1998 to 2013, BRFSS assessed strength training in 2011 and 2013. | 91 |
| National Nutrition and Physical Activity Survey | | |
| 2011 | “Including any activities already mentioned, in the last week did you do any strength or toning activities?”. If they answered positively, they were further asked: “How many times did you do any strength or toning activities in the last week?”. | 19 |
|  | “In the last week, did you do any strength or toning activities? (For example; lifting weights, pull-ups, push-ups, or sit-ups)”. If they answered ‘yes’ they were then asked, “How many times did you do any strength or toning activities in the last week?” and “What was the total time that you spent doing strength or toning activities in the last week?” | 36 |
| New York City Neighborhood and Mental Health in the Elderly Study II, longitudinal study (Physical Activity Scale for the Elderly (PASE)) | | |
| 2011 | All subjects who were followed up successfully were asked at each wave about past-week physical activity using 16 items derived from the Physical Activity Scale for the Elderly (PASE) (26–28) | 167 |
|  | PASE asks subjects to recall past-week engagement in ……. muscle-strengthening | 168 |
| Not disclosed (Questionnaire) | |  |
| 2011 | ~ [Strength training was defined as all exercises that serve to enhance muscular strength and endurance, with regular strength training defined as 2 days or more per week. Respondents were categorized into two groups: those who engaged in regular strength-training behavior and those who did not. In addition, for those who reported regular training, the location (facility or home) was requested.] [Japan] | 24 |
|  | Respondents were asked to report how many days they participated in each type of activity during a typical week [Japan] | 51 |
| Canadian Longitudinal Study on Aging (CLSA - modified Physical Activity Scale for Elderly (PASE)) | | |
| 2012 | participants were asked how often they engaged in exercises specifically to increase muscle strength and endurance | 41 42 |
| Scottish Health Survey | | |
| 2012 | Respondents were asked to report the frequency (in the 28 days prior to interview) and average duration of any sport and exercise activities that they undertook. “During the past four weeks, was the effort of (name of activity) usually enough to make your muscles feel some tension, shake or feel warm?” | 11 |
|  | For certain activities an additional question was asked to identify whether the activity could be classed as muscle strengthening. IF WhtAct, WhtAcB or OactQ = cycling, workout at a gym, aerobics, any other type of dancing, running/jogging, football/rugby, badminton/tennis, squash, exercises, ten pin bowling, yoga/pilates, aquarobics/aquafit, martial arts/Tai Chi, basketball, netball, lawn bowls, golf, hill walking/rambling, cricket, hockey, curling, ice skating, shinty, surf/body boarding, volleyball THEN [cyclemus to Vollmus]  During the past four weeks, was the effort of (name of activity) usually enough to make your muscles feel some tension, shake or feel warm? 1 Yes 2 No  IF WhtAct = Exercises (e.g. press-ups, sit-ups) AND (Age>=65) THEN [ExMov]2 Did these exercises involve you standing up and moving about? 1 Yes 2 No | 75 |
| 7 Day recall | | |
| 2013 | Do you do exercise as a part of your daily routine? | 66 |
| Finnish Regional Health and Well-being Study | | |
| 2013 | (a) “think about the past year (12 months)”; (b) “consider all regular weekly physical activity which lasts at least 10 minutes/session”; and (c) “select all alternatives that correspond to their physical activity habits”. The frequency (days/week) and duration (hours and minutes/ week) of the following four physical activity- related behaviors were assessed: (iii) “Neuromuscular training (for example keep-fit circuit training or muscular strength training in a gym, and including exercises for the main muscle groups with 8-12 repetitions)” | 18 |
| Surveillance System of Risk Factors and Protection for Chronic Noncommunicable Diseases | | |
| 2014 | “have you practiced any kind of physical exercise or sport during the last three months? Yes/No/Which?” “on the day you exercise or practice a sport, how long does this activity last?” | 38 |
| Korean Survey on Citizens’ Sports Participation (2015 Survey on Citizens’ Sports Participation) | | |
| 2015 | "How often do you participate in structured/ nonstructured physical activity?" | 67 |
| Longevity check-up 7+ (lifestyle interview/questionnaire) | | |
| 2015 | ~ [Information and data: - habitual physical activity] | 50 |
| Active Australia survey | | |
| Unclear | Respondents who reported any activity were asked to list their three main types of physical activities (unprompted) and how often they had engaged in each of 14 specific recreational physical activities over the previous 12 months (never, once every 6 months, once a month, once every 2 weeks, once a week and more than once a week). | 27 |
| New York County Health Census (derived from Paffenbarger et al.'s16 original physical activity questionnaire) | | |
| Unclear | "At least once a week, do you engage in any regular activity like brisk walking, jogging, bicycling, etc. long enough to work up a sweat? (No, Yes) If yes, how many times a week? \_\_ Activity." | 169 |
| Structured questionnaire | | |
| Unclear | Frequency and duration (i.e., quantity) of participation in strength training and 20 other physical activities, such as jogging, rowing, stair stepping, or swimming, were assessed with the quantitative ~ history method) | 171 |
| Taiwanese version of the International Physical Activity Questionnaire-long version (IPAQ-LV) | | |
| Unclear | Those who reported engagement in MS activities were asked whether they had done any MS activities in the previous week other than MVPA. If they answered affirmatively, they were further asked: “How many times did you do MS activities last week?” | 69 |
| ~ [ ] Where the specific muscle-strengthening exercise questions were not explicitly detailed within the included articles we have included additional text, located within each respective manuscript, to indicate how the exercise was measured. | | |

**Online Supplementary Table 3:** Chronological order of questions assessing muscle-strengthening exercise behaviours within the included studies.