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How many adults have sufficient muscle-strengthening exercise and the associated factors: A systematic review consisting of 2,629,508 participants

Zhanbing Ren [a,1], Yanjie Zhang [b,**,1], Clemens Drenowatz [c], Narelle Eather [d,e], Jintao Hong [f], Lei Wang [g], Jin Yan [d,e], Sitong Chen [a,*]

[a] School of Physical Education and Sport, Shenzhen University, Shenzhen, China
[b] Physical Education Unit, School of Humanities and Social Science, The Chinese University of Hong Kong—Shenzhen, Shenzhen, China
[c] Division of Sport, Physical Activity and Health, University of Education Upper Austria, 4020, Linz, Austria
[d] Centre for Active Living and Learning, University of Newcastle, Callaghan, NSW, Australia
[e] College of Human and Social Futures, University of Newcastle, Callaghan, NSW, Australia
[f] Shanghai Research Institute of Sports Science (Shanghai Anti-Doping Agency), Shanghai, China
[g] School of Physical Education and Sport Training, Shanghai University of Sport, Shanghai, China

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ABSTRACT

Purpose: The aim of this systematic review was to (1) estimate the prevalence of adhering to the MSE guidelines (at least 2 times/days a week) among adults; and (2) synthesize evidence on the correlates of adhering to the MSE guidelines.

Methods: Five electronic databases were searched (March 2022), with a total of 30 observational studies consisting of 2,629,508 participants meeting the eligibility criteria. A meta-analysis was conducted to pool the prevalence of adhering to the MSE guidelines using the results of 21 eligible studies (study aim 1); and data reporting correlates of adhering to the MSE guidelines using 12 eligible studies were synthesized and categorized based on the Socioecological Model Framework (study aim 2).

Results: Overall, 22.8 % (95%CI: 18.18 % — 27.77 %) of adults adhered to the MSE guidelines, and 23 potential correlates at five levels were examined. Five variables (i.e., sex, age, education level, socioeconomic status) at the sociodemographic level and two variables (i.e., body mass index, self-rated health) at the physical related level were identified as consistent correlates, but displaying weak to moderate association strengths.

Conclusions: Less than a quarter of adults meet the MSE guidelines and multidimensional correlates are associated with the adherence to the guidelines, particularly sociodemographic correlates (e.g., sex, age, and educational level). Findings highlight the need to further promote the importance of engaging in MSE among adults and investing effective interventions that not only provide opportunities for MSE for adults, but also facilitate the development of skills and confidence to engage in MSE.

1. Introduction

Regular participation in physical activity (PA) is protective against all-cause mortality, cardiovascular disease, cancer, obesity and mental health problems.[1–4] Hence, national and global health guidelines recommend that adults engage in at least 150 min of moderate physical activity a week.[5,6] However, data shows that adherence to the 150-min--recommendation is very low.[7] In addition to the 150 min recommendation, it is recommended that people aged 18 years and above engage in muscle-strengthening exercise (MSE) twice a week for additional health benefits.[6,8] As has been shown for general PA, regular MSE has been associated with lower risks of developing physical and mental health problems,[9,10] including reduced risk of obesity,[11,12] cardiometabolic health problems,[13] chronic diseases,[14] depressive symptoms,[15,16] reduced sleep health quality[17] and psychological distress.[18] MSE is therefore important for populational public health.

Although somewhat limited, recent cross-sectional national data reporting the prevalence of adhering to the MSE guidelines indicates

* Corresponding author.
** Corresponding author.
E-mail addresses: zhangyanjie@cuhk.edu.cn (Y. Zhang), sitong.chen@live.vu.edu.au (S. Chen).
[1] Both are the first author.

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that adherence rate is even lower. For example, a study consisting of 383,928 U S. adults highlighted that only 9.9 % of the participants met the MSE guidelines.[19] Data from the Korea National Health and Nutrition Examination Survey (2014–2015) indicated that adherence to MSE guidelines was approximately 6.3 % among Korean adults[13]; and from a survey of English adults, De Cocker et al.[18] found that only 1.3 % of the sample adhered to the MSE guidelines. Across 28 European countries in 2021, the pooled prevalence of adhering to the MSE guidelines was 17.3 % among adults.[11] Although there is a noticeable variation in the prevalence of adhering to the MSE guidelines across the countries, the available data highlights a lack of engagement in MSE among adults and warrants attention from relevant researchers and practitioners.

Given the low prevalence of adhering to the MSE guidelines among adults, identifying potential barriers and facilitators would help inform interventional strategies addressing this problem. The work of Bennie et al.[20] and the other related studies[21–23] showed that being female, older age, lower educational status, poorer self-rated health and unhealthy weight status were negative correlates of adhering to the MSE guidelines. Although focusing only on resistance training— a means of engaging in MSE, a systematic review by Rhodes et al.[24] also identified that education levels, poor perceived health status, and some intrapersonal (e.g., affective judgements) and interpersonal factors (e.g., subjective norms) were associated with engagement. Given the increasing number of studies reporting MSE guideline adherence in the past five years, there is a need for an updated review of the evidence and a synthesis of factors that influence engagement in MSE among adults.

Additionally, no meta-analysis has been published which examines adherence to the MSE guidelines for adults. There is also, no research that summarized the factors of adhering to the MSE guidelines using systematic approaches. This evidence is needed to inform and guide behaviour change and health promotion intervention research targeting MSE. The Behavioural Epidemiology Framework highlights the importance of identifying and targeting correlates of health-related behaviours for successful behaviour change interventions.[25] To fill the research gaps and advance the knowledge regarding MSE among adults, this systematic review and meta-analysis contains two study aims: (1) to report the prevalence of adhering to the MSE guidelines and (2) to synthesize the associated correlates of the adhering to the MSE guidelines.

2. Methods

This systematic review and meta-analysis was registered in the International Prospective Register of Systematic Reviews (CRD42022335199) and processed in line with the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines.[26]

2.1. Eligible criteria

As the study aims were twofold, two sets of inclusion and exclusion criteria were used for study selections. For study aim 1, eligible studies met the following criteria: (1) study participants were healthy adults with a mean age of 18 years or above; (2) prevalence (%; unweighted results) of adhering to the MSE guidelines was reported; (3) study design was observational; (4) study was published in a peer-reviewed journal. If two or more studies were based on the same data, the publication with the larger sample size was included. For study aim 2, eligible studies met the following criteria: (1) study participants were healthy adults with a mean age of 18 years or above; (2) correlates of adhering to the MSE guidelines were reported; (3) study design was observational study; (4) study was published in a peer-reviewed journal. The exclusion criteria for study aim 1 and 2 consisted of: (1) unhealthy study participants (e.g., diagnosed physical health problem/s or mental disorder/s; (2) intervention studies or systematic review and/or meta-analysis, case study, degree thesis or dissertation, and studies not published in English; (3) weighted sample size was used.

2.2. Literature search strategy and study selection

Five literature databases (Web of Science, Scopus, Medline, SPORTDiscus and CINAHL) were used in the search for articles from inception to March 2022, without any date limits on articles. As stated by the Participants, Intervention, Comparison, Outcomes and Study (PICOS) framework, the combination of four groups of search terms was performed, according to our study aims: (1) "adult*"; (2) "muscle" OR "resistance" OR "weight" OR "strengthen*" OR "muscle strengthen*"; (3) "guideline" OR "recommendation"; (4) "factor" OR "correlate" OR "determinant". The literature search was performed by two authors (YZ and LW) and any disagreements were resolved by a third author (SC). Two authors (YZ and LW) did the study selection process independently and screened every title and abstract to identify eligible article, then full texts were located and assessed for eligibility. Finally, the bibliographies of relevant review studies were manually searched to identify additional potential studies. Any disagreements during the above stages were resolved by a third author (SC).

2.3. Data extraction

The following information was extracted: Study aim 1: author, year, analytical sample, country, measures of muscle-strengthening exercise, the definition of adhering to the muscle-strengthening exercise guidelines, cases of adhering to the muscle-strengthening exercise guidelines and prevalence of adhering to the muscle-strengthening exercise guidelines; Study aim 2: author, year, study design, analytical sample, country, measures of muscle-strengthening exercise, operationalized definition of adhering to the muscle strengthening exercise guideline, and factors examined. In the extraction process, if there was a disagreement between authors, a third author joined in the discussion to reach a consensus (JH).

2.4. Quality assessment

The quality assessment of included studies was conducted by two authors using the *Quality Assessment Tool for Observational Cohort and Cross-sectional Studies*.[27] This assessment tool consists of 14 items for longitudinal studies, of which 11 items can be employed to assess the quality of cross-sectional studies (not including items 7, 10 and 13). The 14 items were as follows: (1) research question; (2 and 3) study population; (4) groups recruited from the same population and uniform eligibility criteria; (5) sample size justification; (6) exposure assessed prior to outcome measurement; (7) sufficient timeframe to see an effect; (8) different levels of the exposure of interest; (9) exposure measures and assessment; (10) repeated exposure assessment; (11) outcome measures; (12) blinding of outcome assessors; (13) follow-up rate; and (14) statistical analyses. The assessment score was 1 point (Yes) or 0 points (No) for each item. Since items 7, 10 and 13 are for second measurement of variables, these items are thus not suitable for cross-sectional studies, the total score ranged from 0 to 14 points for a longitudinal study, while 0 to 11 points for cross-sectional studies. The scores were classified as 3 quality levels for longitudinal studies: "high quality" ($\geq$10 points), "medium quality" (5–9 points), "low quality" ($\leq$4 points); and for cross-sectional studies: "high quality" ($\geq$8 points), "medium quality" (4–7 points), "low quality" ($\leq$3 points). Two authors assessed the included studies independently and any disagreements were resolved by a third author.

2.5. Statistical analysis for meta-analysis

The Stata 15.0 (StataCorp., College Station, TX, USA) and *metaprop* method was employed to calculate the prevalence of adhering to the MSE guidelines in this meta-analysis. The pooled prevalence was calculated by using a random-effects model with a 95 % confidence interval (CI), and a Freeman-Tukey transformation was applied to

normalize the results before computing the aggregate prevalence. Heterogeneity across selected studies was determined using the I^2 statistic and its p-value in the process of the *Metaprop* test. The Doi plot and the Luis Furuya-Kanamori (LFK) index were used to examine publication bias.[28] LFK indices of ±1, between ±1 and ± 2, and outside ±2 were regarded as no asymmetry, minor asymmetry, or major asymmetry, respectively.[29] Subgroup analysis was performed by the following categories: survey region (i.e., North America, East Asia, and Europe), study quality (high, medium; no studies were rated as low quality), measure of MSE (i.e., weekly and monthly) and publication year (i.e., 2008 to 2014 and 2015 to 2021). Only significant results for subgroup analysis were presented. Of note, when conducting subgroup analysis by survey region, it was found that most studies included were US based, which may introduce low generalization of the overall results. Accordingly, a subgroup analysis between US based and non-US based studies was further conducted. The significance level of the subgroup analysis was set up as $p < 0.05$.

2.6. Analysis and synthesis of results for systematic review

For study aim 2, meta-analyses can not be performed because of the high heterogeneity of data and measurements across the included studies. Consequently, narrative syntheses of research findings were made to determine potential correlates of adhering to the MSE guidelines, which was adapted from Lee et al.'s[30] previous systematic review study. Based on the Socioecological Models (SEM) framework[31] and studies included for achieving study aim 2, the potential correlates were grouped into demographic, physical, behavioural, cognitive and environmental levels. The direction of the association between potential correlates and adhering to the MSE guidelines was indicated as positive (+), negative (−), or null (Ø). However, for those directionless correlates, such as region or race/ethnicity, significant association was indicated using asterisk (*). Research findings based on statistical adjustments were preferred but unadjusted findings were used when adjusted findings were not available. Only adhering to the MSE guidelines entered as dependent or outcome variable in directional statistical techniques (e.g., linear or logistic regression) were eligible and included in the synthesis. Only statistically significant results based on hypothesis testing with an alpha level <0.05 were considered in determining important correlates.

Similar to previous reviews examining correlates of physical activity or its associated components,[30,32,33] the consistency of the association concerning each of the potential correlates was established based on the percentage reported. The hypothesized association was assessed by dividing the number of studies supporting the association by the total number of studies where the association was examined. Percentages ranging between 0 and 33 % were considered as "no evidence (coded as 'Ø)", 34–59 % as "undetermined evidence (coded as '?')", and 60–100 % as "mostly positive or negative (coded as '+' or '−' based on the direction of the association)". To indicate the strength of evidence, the result was coded as 'ØØ,' '++,' or '−−' when four or more observations existed (considered as *consistent* evidence). A single symbol was used if there were three or fewer observations. Slightly adapted from Lee et al.,[30] to be considered as correlate supported by *weak* evidence, the evidence had to be based on only one study, while correlate supported by *limited* evidence had to be based on 2−3 studies, regardless of the consistency(%). Owing to the limited number of studies reporting results by age, sex/-gender, or other groups, subgroup analyses were not made. All studies, regardless of the quality rating, were included in analyses and discussed the overall review findings and sensitivity analyses.

Based on the consistent correlates that this review summarized ahead, we further assessed the strength of the associations between the consistent correlates and adherence to the MSE guidelines. Owing to the high heterogeneity in statistical analyses and operationalized definitions of the similar variable (e.g., age group), it was impossible to conduct a meta-analysis for quantitively determining the strength of the associations. For this reason, we extracted effect size for each association between consistent correlate and the adherence to the MSE guidelines. Across the included studies examining the correlate of adhering to the MSE guidelines, effect size was mostly assessed by odd ratio (OR); accordingly, we extracted OR as a measure to assess the strength of associaiton in each single study. If OR was less than 1, it was converted to transform OR more than 1. Rosenthal's[34] criteria was used to determine the strength (i.e., 1.5 or less: weak; 2.5 to 1.6: moderate; 4 to 2.6: strong; 10 to 4.1: very strong) of association presented in each included study. We finally summarized the strengths of association between consistent correlate and adherence to the MSE guidelines based on the extracted results.

3. Results

3.1. Study selection

Fig. 1 presents the flowchart of selection for included studies examining the prevalence and correlates of meeting the MSE guidelines in this systematic review and meta-analysis. A total of 17,542 records were retrieved from the databases. After screening for duplicates (N = 8076), 9466 records remained. A total of 67 records were identified for further confirmation after screening the title and abstracts. After reviewing the full texts 37 records were excluded, which resulted in 30 studies that met the inclusion criteria and were included in the systematic review and meta-analysis. Of these 30 studies 21 were analysed in the meta-analysis to address aim 1 and 12 studies were summarized to address aim 2 due to three duplicated studies.[11,35] Collectively, this review study consisted of 2,629,508 study participants.

3.2. Study characteristics

Table S1 (supplementary material 1) shows the characteristics of included studies reporting the prevalence of adherence to the MSE guidelines. Eighteen of the included studies were cross-sectional studies and 3 studies were longitudinal studies. The included studies were published between 2008 and 2021, with data collection occurring in China (n = 2),[35,36] USA (n = 11),[37–47] England or Scotland (n = 2),[18,48] Germany (n = 1),[17] Korea (n = 1),[13] Japan (n = 2),[49,50] Canada (n = 1)[51] and European countries (combined data; n = 1).[11] The prevalence of adhering to the MSE guidelines ranged from 1.3 %[18] to 76.2 %[50] across the included studies. A total of 2,412,407 participants aged 18 or over were included in this systematic review. Concerning the measurements of MSE, all included studies used self-reported measures (one single question to assess frequency, times or days of MSE in a given period, such as past week or usual month), but there were large variations across measurements in terms of which kind of activities can be assessed. All the studies (n = 21) used the definition of at least 2 days/week of MSE to assess whether study participants adhered to the MSE guidelines.

Table S2 (Supplementary material 2) shows the characteristics of included studies (n = 12) for correlates of adhering to the MSE guidelines. Eleven studies were cross-sectional studies, and one study was a longitudinal study. The included studies were published between 2014 and 2021, with data collected in Libya (n = 1),[52] Australia (n = 2),[21,53] Finland (n = 1),[22] China (n = 2),[35] USA (n = 3),[23,54,55] Germany (n = 1),[56] Croatia (n = 1),[57] and the European region (n = 1, consisting of 28 countries).[58] In sum, a total of 501,847 study participants were included for addressing study aim 2.

3.3. Quality assessment

The quality assessment (n = 21) for studies reporting the prevalence of meeting the MSE guidelines is summarized in Table S3 (supplementary material 3). Ten of the included studies were recognized as "high quality", and 11 were recognized as "medium quality". In terms of the sample, only six studies met the participation rate of eligible persons

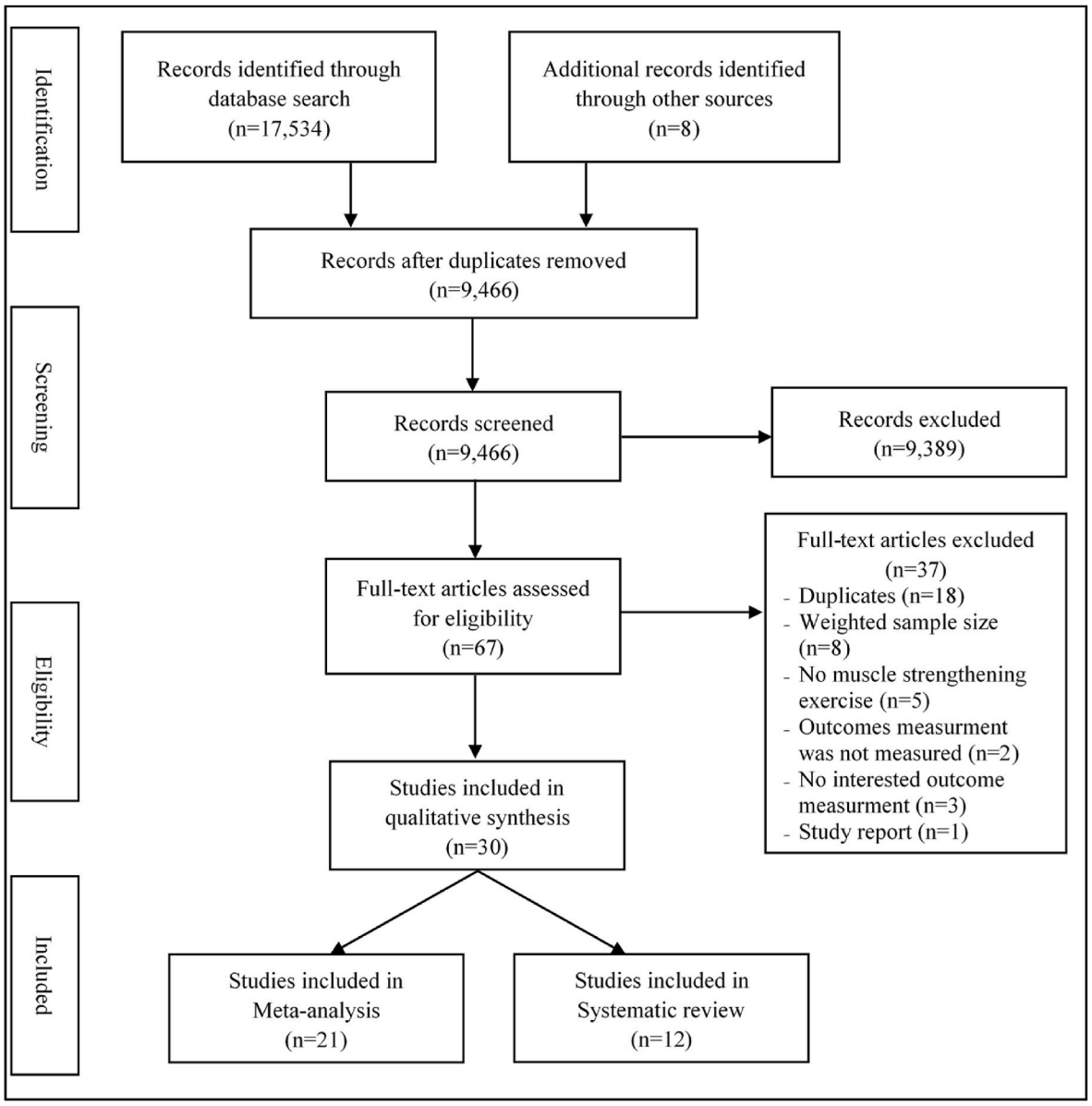

Fig. 1. Literature selection flow chart for studies included in this article.

greater than 50 % (item 3), and 3 studies reported the sample size justification (item 5). Because most included studies (n = 18) were cross-sectional, baseline measures and exposure time of the intervention were not considered (item 6, item 7). 3 studies assessed the exposures more than once over time (item 10). No studies used the blinding method to assess the outcomes (item 12) and identified the loss of participants in the follow-up (item 13). In the rest of the items, all studies met the corresponding criteria (items 1, 2, 4, 8, 9, 14). The results of quality assessment (n = 12) for studies examining the correlates of adhering to the MSE guidelines are shown in Table S4 (supplementary material 4). Seven out of 12 studies were rated as high quality.

3.4. Results of the pooled prevalence of adhering to the MSE guidelines

Fig. 2 shows that overall adherence to the MSE guidelines was 22.8 % (95 % CI: 18.18 %–27.77 %, $p < 0.001$; $I^2 = 99.98$ %) in the included participants. The LFK index for the Doi plots revealed a major asymmetry, suggesting a major risk of publication bias (LFK = 6.42) (Fig. 3). In terms of the subgroup analyses according to survey region (including country-based comparison), study quality, measure of MSE by recall duration and publication year, only the adherence rate by different measures of MSE was significant ($p = 0.001$), with an overall rate of 22.8 % (95%CI: 18.18–27.77 %, $p = 0.00$). The adherence rate of studies assessing MSE over the past or usual week was 29.53 % (95%CI: 20.14–39.90, $p < 0.01$, $I^2 = 99.98$ %) and studies assessing MSE over the past or usual month 11.43 % (95%CI: 7.38–16.22, $p < 0.01$, $I^2 = 99.94$ %).

3.5. Results of factors of adhering to the MSE guidelines

Table 1 summarises the synthesized results of factors of adhering to the MSE guidelines. Of the 12 included studies examining the factors of adhering to the MSE guidelines, 23 potential factors were identified, and these factors were divided into sociodemographic, physical, behavioural, cognitive and environmental domains. Sex/gender (n = 12), age (n = 10) and education level (n = 9) were the three most examined factors in the included studies. Seven studies examining socioeconomic status, employment status and body mass index; six studies measured self-rated health, and four studies measured location (state or territory or region. For other examined factors, such as living residence, current

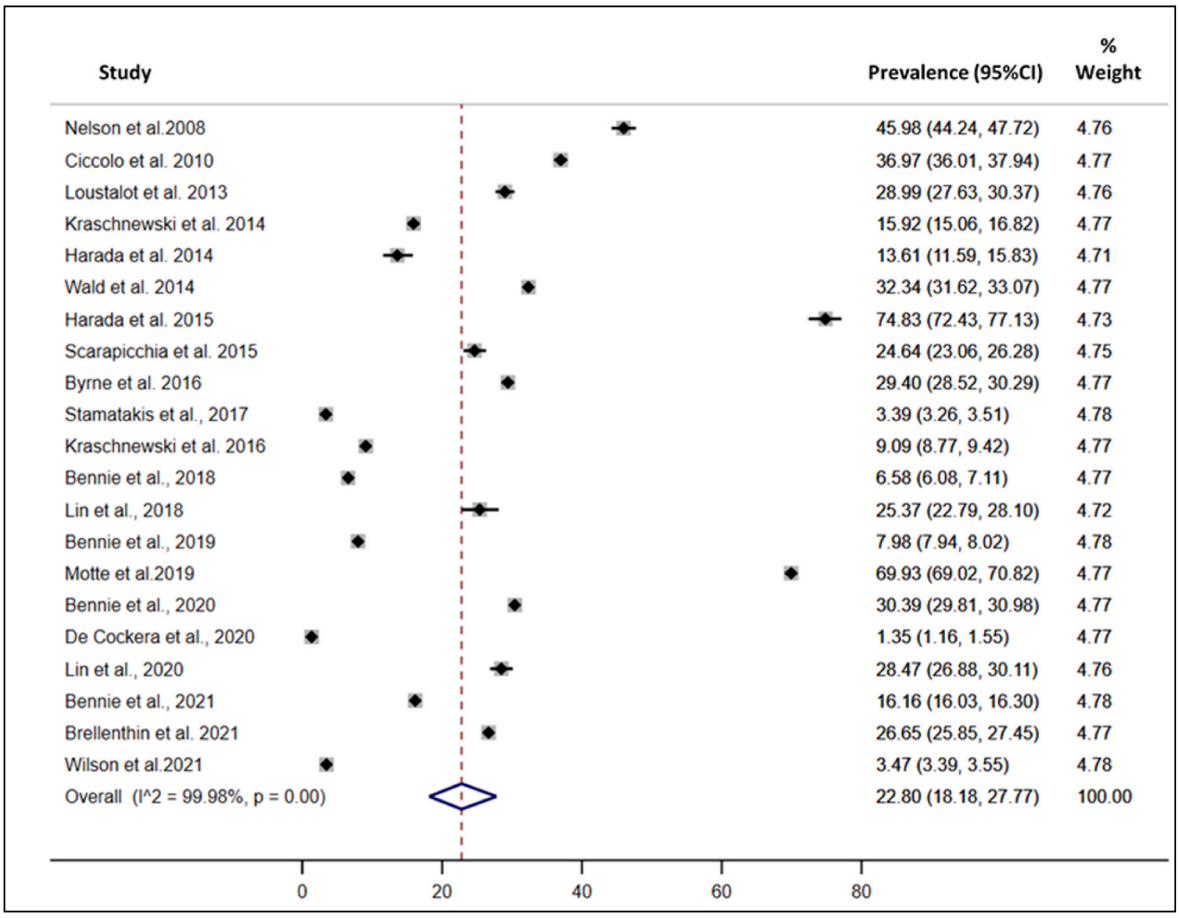

Fig. 2. Forest plot of prevalence of adhering to the muscle-strengthening exercise guidelines.

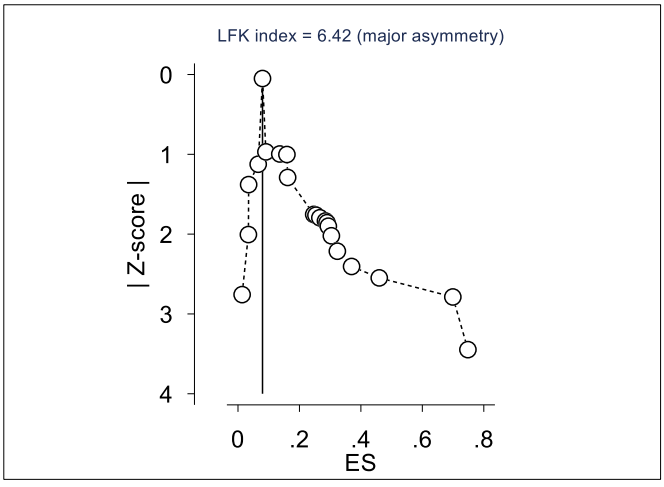

Fig. 3. Asymmetry index of adhering to the muscle-strengthening exercise guidelines.

smoking status, urbanisation level and academic performance, less than three studies assessed the association with adhering to the MSE guidelines.

Eight factors, including sex, age, education level, socioeconomic status, state or territory or region, employment status, body mass index and self-rated health were consistent correlates of adhering to the MSE guidelines. Put another work, being male, younger age, having higher education levels, better socioeconomic status and reporting better self-rated health were associated with a greater likelihood to adhere to the MSE guidelines. Compared with adults with normal body mass index, adults categorized as overweight or obese were less likely to adhere to the MSE guidelines. State or territory or region and employment status were also significantly consistent correlates of adhering to MSE guidelines.

Race/ethnicity (n = 2), living/area residence (n = 3), marital status (n = 3), current smoking status (n = 3), physical activity (n = 3) and urbanisation level (n = 2) were limited correlates of adhering to the MSE guidelines. Minority race/ethnicity was a limited correlate (cannot determine direction) and living in urban areas was a positively limited correlate associated with adhering to the MSE guidelines. Adults who were not current smokers were also more likely to adhere to the MSE guidelines. Adhering to the aerobic physical activity guidelines was also positively associated with adherence to the MSE guidelines in adults. Urbanisation level was a positive correlate of adhering to the MSE guidelines. Marital status was a significant correlate. However, the association between family composition (the number of children adults had) and adhering to the MSE guidelines cannot be determined.

Regarding factors that were examined by only one study, including nationality, living status, eye health, limitations due to health, chronic disease, physical effort during working, alcohol intake and academic performance, mixed results are shown. Nationality, living status, chronic disease and alcohol intake were not associated with adhering to the MSE guidelines. Eye health and academic performance were positive factors of adhering to the MSE guidelines, while physical effort during work and limitations due to health were negative factors. Owing to the limited number of studies, the evidence on the associations between these factors and adhering to the MSE guidelines cannot be confidently generated.

Table 1
Synthesis of the correlates of adhering to the muscle-strengthening exercise guidelines in adults.

Factors within socioecological models examined	Associations		Evidence synthesis		
	Studies	Direction	Consistency %	Summarized direction	Evidence summary
Sociodemographic					
Sex/gender (n = 12; ref = female)					
	[35,65]	Ø	2/12 = 17 %	+ +	Consistent
	[22,23,36,52–58]	+ (male)	10/12 = 83 %		
Age (n = 10; ref = oldest)					
	[36]	Ø	1/10 = 10 %	+ +	Consistent
	[22,23,35,54–58,65]	+ (younger)	9/10 = 90 %		
Education level (n = 9; ref = lowest)					
	[36]	Ø	1/9 = 11 %	+ +	Consistent
	[22,23,35,54,55,57,58,65]	+ (higher)	8/9 = 89 %		
Socioeconomic status[$] (n = 7; ref = lowest)					
	[36,22]	Ø	2/7 = 28.6 %	+ +	Consistent
	[23,54,56,58,65]	+ (higher)	5/7 = 71.4 %		
Race/ethnicity (n = 2; ref = dominant)					
	[23,55]	* (minority)	2/2 = 100 %	*	Limited
Living/area residence (n = 3; ref = outer/rural)					
	[36]	Ø	1/3 = 33 %	+	Limited
	[53,65]	+ (urban)	2/3 = 67 %		
Nationality (n = 1; ref = domestic)					
	[56]	Ø (immigrant)	1/1 = 100 %	**Ø**	Weak
Marital status (n = 3)					
	[35]	Ø	1/3 = 33 %	*	Limited
	[53,55]	*	2/3 = 67 %		
Living status (n = 1; ref = living with others)					
	[35]	Ø (living alone)	1/1 = 100 %	**Ø**	Weak
Family composition (n = 2; ref = single child)					
	[36]	+ (multiple child)	1/2 = 50 %	**?**	Undetermined
	[53]	- (multiple child)	1/2 = 50 %		
State or territory or region (n = 4)					
	[52,54,58,65]	*	4/4 = 100	* *	Consistent
Employment status (n = 7; ref = full time)					
	[35,36]	Ø	2/7 = 28.6 %	* *	Consistent
	[22,23,54,56,58]	* (not full-time)	5/7 = 71.4 %		
Physical					
Weight status according to body mass index (n = 7; ref = normal)					
	[36]	Ø	1/7 = 14.3 %	- -	Consistent
	[22,23,55–58]	- (unhealthy[#])	6/7 = 85.7 %		
Eye health (n = 1; ref = some extent)					
	[52]	+ (healthy)	1/1 = 100 %	+	Weak
Limitations due to health problems (n = 1; ref = not at all)					
	[58]	- (with limitations)	1/1 = 100 %	-	Weak
Chronic disease (n = 1; ref = no)					
	[55]	Ø (yes)	1/1 = 100 %	**Ø**	Weak
Self-rated health (n = 6; ref = poor)					
	[22,23,53,55–57]	+ (better)	6/6 = 100 %	+ +	Consistent
Physical effort during working (n = 1; ref = mostly sitting or standing)					
	[58]	- (heavy labour effort)	1/1 = 100 %	-	Weak

Behavioural	Association		Evidence synthesis		
	Studies	Direction	Consistency %	Summarized direction	Strength of evidence
Current smoking status (n = 3; ref = current smoker)					
	[57]	Ø	1/3 = 33 %	+	Limited
	[23,56]	+ (non-current smoker)	2/3 = 67 %		
Alcohol intake (n = 1; ref = never or rarely consumer)					
	[57]	Ø (current smoker)	1/1 = 100 %	**Ø**	Weak
Physical activity (n = 3; ref = insufficient or low level)					
	[23,53,58]	+ (physically active)	3/3 = 100 %	+	Limited
Cognitive					
Academic performance (n = 1; ref = worse)					
	[52]	+ (better)	1/1 = 100 %	+	Weak
Environmental					
Urbanisation level (n = 2; ref = low)					
	[57,58]	+ (higher)	2/2 = 100 %	+	Limited

Ref: reference group.
Ø: null significant associaiton.
+: positive association.
-: negative association.
?: undetermined.
$: across the included studies, different measures of socioeconomic status were used.
#: unhealthy weight status includes underweight, overweight and obesity.
Double symbols: ≥60 % of at least four observations for one specific association, suggesting the strength of evidence at moderate or above.

3.6. Strength of factors of adhering to the MSE guidelines

Table 2 illustrates range of effect size of the strengths of associations between different consistent correlates and adherence to the MSE guidelines across different studies included in the analysis. Among the eight consistent correlates of adhering to the MSE guidelines, the included studies indicated that the strength of the association between weight status and adherence to the MSE guidelines was weak (OR range: 1.15 to 2.26). In terms of sex/gender, socioeconomic status and self-rated health, the included studies showed that the strengths of their associations with adherence to the MSE guidelines ranged from weak to moderate (OR for sex/gender range: 1.10 to 3.32; OR for socioeconomic status range: 1.05 to 2.50; OR for self-rated health range: 1.11 to 3.67). For the remaining four correlates — age, education level, state/region, and employment status — the strengths of the associations presented as weak to strong. However, for these associations, a very limited number of studies found a strong association (age: n = 2; education level: n = 2; state/region: n = 1; employment status: n = 1). In general, the majority of include studies presented weak to moderate associations between consistent correlates and the adherence to the MSE guidelines.

4. Discussion

4.1. Main findings

This systematic review and meta-analysis aimed to examine the global prevalence of adhering to the MSE guidelines among adults and to determine the associated factors. Our research findings firstly demonstrate that among adults, the adherence rate to the MSE guidelines is 22.8 %. Secondly, we find strong evidence demonstrating male, younger adults, with higher education levels, and better socioeconomic status are more likely to adhere to the MSE guidelines; that state or territory or region and employment status are associated with adhering to the MSE guidelines among adults; and when compared with adults with normal weight status, those who are overweight and obese are less likely to adhere to the MSE guidelines.

4.2. Interpretations of findings

Recently increasing research attention has been put on MSE related studies,[9] given the accumulating evidence on the associations between MSE and physical/mental health benefits.[9] However, data regarding adherence to the MSE guidelines at the populational level is sparse.[9] The current study adds to the literature by providing a global estimate of the prevalence of adhering to the MSE guidelines in adults, showing that only 22.8 % of adults reach recommended participation in MSE. In general, low adherence to the MSE guidelines has public health implications in the short and long term. Thus, promoting participation in MSE in adults is a pressing matter.[9]

Only subgroup analysis according to the measures of MSE (different recall periods) was significant. When looking at the adherence rate according to different measures of MSE (weekly or monthly recall), it was found that the adherence rate estimated from the weekly recall measures was significantly higher than it pooled from the monthly recall measures. A possible reason is that weekly recall measure could provide more accurate information regarding MSE whereas monthly recall measures cannot do because of greater memory bias,[59] which further has influence on the adherence to the operationalized definition (at least two times or days of MSE per week) of adhering to the MSE guidelines. Based on this, future studies should be more cautions when considering measurement of MSE according to the study objective.

In addition to the different recall periods, another important point should be mentioned. Across the included studies for pooled prevalence of meeting the MSE guidelines, there was a large variation in terms of the operationalized definition of MSE. This finding has been confirmed by a previous review summarizing and analysing the surveys of MSE at the population level.[59] This review found that the questions to assess MSE varied largely across the identified surveys, which may be an influencing factor of the accuracy when respondents were recalling the frequency of MSE, especially for those who had limited physical activity related literacy.[59] Our results also showed that the examples or explanations that help respondents understand MSE of the included studies were greatly varied. This discrepancy in the modalities of MSE may cause inconsistency in responses to the survey questions, which thus could be a factor influencing the estimated prevalence of meeting the MSE guidelines among individuals.[59]

To increase adults' participation in MSE, it is necessary to understand why some adults do more MSE than others.[9] This information may identify vulnerable populations or those who warrant special attention regarding the promotion of MSE. Some sociodemographic factors were determined as consistent correlates of adhering to the MSE guidelines, including being male, being younger, having higher education levels and having better socioeconomic status. A similar systematic review partly supports our research findings, which suggested that age and educational level are two factors influencing resistance training.[24] Since sufficient studies included in our review focused on the associations between the above four factors and adherence to the MSE guidelines, a high certainty for consistent and positive associations can be confirmed.

Geographical location, and employment status are significant correlates of adhering to the MSE guidelines, which is consistent with previous studies examining the correlates of overall physical activity.[60,61] However, geographical location and employment were treated as nominal variable, therefore the direction of the associations of these two variables with adherence with the MSE guidelines cannot be confidently determined in this review. This interpretation can also be applicable to another factor of adhering to the MSE guidelines, that is marital status. Adults of minority of race/ethnicity or living in urban areas had a higher likelihood of adhering to the MSE guidelines. There is evidence implying that MSE is a popular exercise form among minority population subgroups.[23] For those living in urban areas, it might be easier to access facilities or equipment for participations in MSE.[21] However, regarding living status and family composition (number of children adults had), large uncertainties remain owing to mixed evidence from insufficient studies.

This study highlights that body mass index and self-rated health are consistent correlates of adherence to the MSE guidelines. These two factors are related to physical health. It is possible that participation in MSE is greater among adults who have enhanced health awareness of participating in or maintaining healthier lifestyles. For example, individuals with higher self-rated health would have better health status

Table 2
Summarized strength of consistent correlate of adhering to the muscle-strengthening exercise guidelines.

Consistent correlate	Studies	Range of effect size	Summarized strength
Sex/gender (ref = female)	[22,23,36,52–58]	1.10 to 3.32	Weak to moderate
Age (ref = oldest)	[22,23,35,54–57,65]	1.13 to 5.56	Weak to strong
Education level (ref = lowest)	[22,23,35,54,55,57,58,65]	1.06 to 6.25	Weak to strong
Socioeconomic status[$] (ref = lowest)	[22,36]	1.05 to 2.50	Weak to moderate
State or territory or region	[52,54,58,65]	1.03 to 9.09	Weak to strong
Employment status (ref = full time)	[22,23,54,56,58]	1.06 to 4.55	Weak to strong
Weight status according to body mass index (ref = normal)	[22,23,55–58]	1.15 to 2.26	Weak
Self-rated health (ref = poor)	[22,23,53,55–57]	1.11 to 5.56	Weak to strong

Ref: reference group.
Effect size was assessed using odd ratio; strength of odd ratio was determined using Rosenthal's[34] criteria.

and be permitted more MSE.[53] This finding informs that researchers or policymakers could make use of the observed associations to help identify populations with "insufficient" MSE for future interventions. Of note, in physical activity research, many set body mass index and self-rated heath as outcome[62,63] instead of exposure, which is different from the current review. This suggests that in MSE related studies, outcomes can be body mass index and self-rated health. As these studies were cross-sectional, the associations of body mass index and self-rated health with MSE may be bidirectional. Thus, future studies should determine the direction of these associations. Evidence on eye health, limitations due to health problems, chronic disease and physical effort during work remains rare, which does not enable us to draw any reliable conclusions on their associations with MSE.

At the behavioural level, not smoking currently and meeting the aerobic physical activity guidelines are two limited positive correlates of adhering to the MSE guidelines. Evidence from a systematic review conducted Kaczynski et al. (2008) by indicated a negative association between PA and smoking,[64] which suggests that current non-smokers are generally more health conscious and therefore are more likely to meet MSE guidelines. Meeting the PA recommendation of 150 min/-week of moderate-to-vigorous physical activity is a positive correlate of adhering to the MSE guidelines in adults in this review. This highlights the importance of aerobic exercise or activity. Given the positive association between greater aerobic PA and adherence to MSE guidelines, adults doing more aerobic exercise could generally be potentially incorporating strength-related activities.[53]

At the environmental level, higher urbanisation levels are a positive correlate of adhering to guidelines in adults, because higher urbanisation levels could make adults access more muscle-strengthening exercise programmes an easier approach.[57] This would be an incentive to promote adults engage in more MSE. Higher urbanisation level could promote adults MSE participations through providing more accesses to MSE, such as facilities and gyms; but this assumption should be examined further. However, participating in MSE can be achieved through individual's own weight, such as push-ups. We do not neglect the potentially beneficial roles of higher urbanisation on adults MSE, but how to promote intrinsic motivation for participating in MSE is a further question. It is worthwhile to mention that in the current review, living in urban areas is somewhat similar to urbanisation. As a matter of a fact, they are two different concepts, as living residence refers to individuals' location in which they live, while urbanisation is a comprehensive measure to reflect the extent to the population shift from rural to urban areas. For this regard, when interpreting the associations of living residence and urbanisation with adherence to the MSE guidelines, more information, especially study respondents' surrounding attributes, is needed.

As we discussed before, studies on the correlate of adhering to the MSE guidelines can help develop strategies on promoting muscle-promoting activity in the population. Although most of the correlates supported by consistent certainty are not modifiable factors (i.e., sociodemographic characteristics), the levels of evidence certainty varied owing to different number of included studies that examined the different correlates. It is possible that consistent correlates supported by more observations are more reliable compared with those supported by weaker evidence when designing interventions aimed to promote MSE in the population. For this regard, researchers should focus on evidence certainty when designing evidence guided MSE interventions. In addition to sociodemographic factors, there were two consistent correlates at physical-related domain: body mass index and self-rated health. Theoretically, these two factors are more likely to be health outcome of MSE because in PA epidemiology, one of the main research topics is to determine the health impacts of specific types of PA. Therefore, such correlates should not be prioritized for intervention design and implementation.

Furthermore, results of this study demonstrate that, for the consistent correlates, the included studies presented weak to moderate associations with adherence to the MSE guidelines, even though a few studies showed strong effect size in some specific associations. This finding suggests that these consistent correlates (e.g., sex/gender, age) summarized in this review may not lead to practical implications given their limited magnitude of the associations. For this reason, in conjunction with the above analysis, it is to target these correlates when design interventions. This further suggests that more studies are needed to determine clinically strong correlates of adhering to the MSE guidelines for effective interventions development and implementation.

4.3. Study strengths and limitations of this review

Some study strengths are worthwhile to mention. The current study pooled data based on more than two million of samples and offers an estimated prevalence of adhering to MSE guidelines in adults (mainly from high-income countries), with a wider research generalisability in some similar contexts. Also, this review provides insight into factors influencing MSE from a synthesized perspective. These messages help to inform the design of efficient interventions aimed at promoting MSE in adults. Results of study quality assessment of the studies included were mostly high or medium. This research finding suggests that synthesized evidence based on the current review is largely reliable. However, in light of a better understanding of our research findings, some inherent study limitations should be mentioned. Firstly, the literature search included only studies published in English, which might increase bias due to the exclusion of potentially eligible studies published in other languages. Second, due to the heterogeneity across the studies examining correlates of MSE, a meta-analysis was not appropriate and the associations between the influencing factors and adhering to MSE guidelines failed to be quantifiable. Third, some factors (e.g., academic performance, alcohol intake) examined in the current review were limited in number of observations and their associations with adherence to the MSE guidelines cannot be determined. Finally, studies included in this review were largely based on populations in high-income countries, including Australia, North American (e.g., the US) and European regions (e.g., England); so, research findings may not be highly generalised to the other countries with different characteristics (e.g., low-income countries).

5. Conclusions

This systematic review provides evidence that most adults fail to meet the MSE guidelines – placing them "at-risk" of ill-health. Comprehensive and effective public health strategies and interventions are needed to encourage population-level MSE participation. Furthermore, specific sub-populations should be prioritized, such as females and those with lower education levels, as they exhibit particularly low adherence to MSE guidelines; but these associations were weak to moderate, generating limited the clinical importance. Our findings are of particular importance for informing future research regarding participation in MSE among adults.

Given that many studies were conducted in high-income countries/regions, more studies should focus on low- and middle-income countries/regions in the world. Moreover, considering the nature of cross-sectional study, researchers are encouraged to assess the determinants of adherence to the MSE guidelines, and more efforts should be place on interpersonal, environmental and policy factors. Future studies need to develop more comprehensive measures to collect more information on MSE (e.g., intensity and duration). It is worthwhile to address these gaps in the future and this knowledge can help advance PA epidemiology research.

Authors' contributions

SC conceptualised and designed the study. SC, YZ and LW were responsible for the literature search. SC, YZ, LW and JH participated in

data extraction and synthesis. ZR, YZ and SC drafted, and NE, CD and JY reviewed and edited the manuscript.

Declaration of competing interest

The authors declare that they have no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jesf.2024.06.002.

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