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# Trends in adherence to the muscle-strengthening activity guidelines in the US over a 20-year span

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ABSTRACT

*Purpose:* Purpose to evaluate the prevalence and temporal trends in adherence to muscle-strengthening activity (MSA) guidelines among the US population from 1997 to 2018 (pre-Covid 19).
*Methods:* We used nationally representative data from the National Health Interview Survey of the US (NHIS; a cross-sectional household interview survey). We pooled data from 22 consecutive cycles (1997 to 2018) and estimated prevalence and trends of adherence to MSA guidelines among adults aged 18–24 years, 25–34 years, 35–44 years, 45–64 years, and ≥ 65 years.
*Results:* A total of 651,682 participants (mean age 47.7 years [SD = 18.0], 55.8% women) were included. The overall prevalence of adherence to MSA guidelines significantly increased ($p < .001$) from 1997 to 2018 (19.8% to 27.2%, respectively). Adherence levels significantly increased ($p < .001$) for all age groups from 1997 to 2018. Compared with their white non-Hispanic counterparts, the odds ratio for Hispanic females was 0.5 (95% CI = 0.4–0.6).
*Conclusions:* It is over a 20-year span, adherence to MSA guidelines increased across all age groups, although the overall prevalence remained below 30%. Future intervention strategies to promote MSA are required with a particular focus on older adults, women, Hispanic women, current smokers, those with low educational levels, and those with functional limitations or chronic conditions.

## 1. Introduction

Accumulating research evidence positions muscle-strengthening activity (MSA) as a cornerstone to improve health as well as for chronic disease management and prevention [1,2]. Engaging in MSA has been shown to improve physical function and quality of life [3], and reduce depressive [4] and anxiety symptoms [5] in adults. In a recent meta-analysis of cohort studies, MSA was associated with a 10–17% lower risk of cardiovascular disease, cancer, diabetes, lung cancer and all-cause mortality among adults [1]. In fact, engaging in MSA as little as once a week shows a strong inverse association with mortality risk [6]. For these reasons, public health guidelines have adopted MSA recommendations since 2007 [7].

The World Health Organization (WHO) [8] and the Physical Activity Guidelines for Americans [9] advise adults to engage in MSA two or more days a week. While public health organizations have invested enormous efforts in promoting and tracking adherence to the aerobic component of physical activity guidelines [10], there is sparse evidence concerning the adherence to MSA guidelines. Prior studies have focused primarily on investigating the prevalence of general or aerobic-type

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physical activities [10,11], showing higher adherence to these than for MSA [12,13]. The only previous report of annual trends in adherence to MSA guidelines among different age groups in a nationally representative sample from the US National Health Interview Survey (NHIS) showed a significant increase among women from 1998 to 2004.[14] More recent prevalence data from NHIS indicate that only one in five US adults meet MSA guidelines [13]. Considering the limited findings, there is a need for more research with nationally representative samples and that examine a more extensive timeframe across different age groups. This information may be relevant to inform strategies that target at-risk subpopulations, a critical measure given the evident suboptimal adherence levels to MSA guidelines in the US [1,13].

Capitalizing on representative samples from the NHIS, we aimed to assess the prevalence and trends in adherence to the MSA guidelines among the US population from 1997 to 2018 across different ages and sex.

## 2. Methods

### 2.1. Study design and sample

We retrieved and pooled data from 22 consecutive cycles of the NHIS conducted between 1997 and 2018. The NHIS is a nationally representative survey of the noninstitutionalized population living in the US. The Centers for Disease Control and the Prevention's National Center for Health Statistics conducted this survey annually, which also includes the ethical approval [15]. In brief, trained interviewers conducted personal interviews in selected households derived from random clusters through a stratified, complex multistage sampling approach. Thereupon, a sample of adults was randomly selected from these households to answer a health-related survey [15].

From an eligible sample of 671,696 participants, we discarded those with missing data on MSA questions ($n$ = 20,014, 3%), leaving a final sample size of 651,682 adults (≥18 years) for the present study. The reporting of this study followed the guidelines of the Observational Routinely collected health Data Statement [16].

### 2.2. MSA recommendations

Meeting the MSA recommendations was ascertained through the following question: *"How often do you do physical activities specifically designed to strengthen your muscles, such as lifting weights or doing calisthenics?"* According to the recommended physical activity guidelines for Americans [17], we categorized individuals into two groups: meeting the recommended (≥2 times/week) and not meeting recommended guidelines (<2 times/week).

### 2.3. Covariates

According to prior research [14], participants were categorized into the following age groups: 18–24 years, 25–34 years, 35–44 years, 45–64 years, and ≥ 65 years. Moreover, we also considered other self-reported demographic and lifestyle related-variables such as age as continuous variable (years), gender (men/women), race (non-Hispanic white/non-Hispanic black/Hispanic/Other, non-Hispanic), education (lower than high school degree/high school degree/higher than high school degree), smoking status (never/former/current smoker), number of prevalent major cardiometabolic conditions (diabetes, hypertension, coronary heart disease, angina pectoris, heart attack, stroke, cancer, emphysema, and/or asthma), body mass index (body weight in kilograms divided by height in meters squared), functional limitations defined as having any degree of difficulty while performing a specific physical task (i.e., walking a quarter of a mile, walking up ten steps, standing for two hours, sitting for two hours, carrying a ten pound object, overhead arm reach, stooping, bending, kneeling, pushing a large object or grasping an object), or engaging in social activities and recreation (i.e., relaxing, going shopping, attending club meetings, visiting friends, sewing, reading, visiting a doctor's office or going to parties) without the assistance of another person or using special equipment (no/yes), as well as survey year (1997 to 2018).

### 2.4. Statistical analysis

Statistical analyses were conducted between October 2022 and December 2022 using Stata software version 16.1. Survey analysis procedures were used to account for sample weights and the complex sampling design of NHIS. The crude weighted prevalence and 95% CIs of MSA recommendations were estimated by survey year and age group. The overall crude linear trends in meeting the MSA recommendations were examined using linear regression models across survey years and to estimate the regression coefficients and 95% CIs for annual change. *P*-values for trends were calculated using the survey year as a continuous variable, whereas absolute differences in the estimated prevalence of meeting the MSA recommendations were estimated by comparing the 2018 survey with the 1997 survey. In addition, crude trends in meeting the MSA recommendations were visually illustrated. Logistic regressions were used to model the prevalence of meeting the MSA recommendations and to estimate the Odds Ratios (ORs). Participants with missing data in any of the examined covariates were excluded from the regression analyses ($n$ = 29,817) (4.6%). All statistical tests were two-sided, and statistical significance was set at $p < .05$.

## 3. Results

A total of 651,682 participants (mean age 47.7 years [SD = 18.0], 55.8% women) were included in the study. The sample size per survey ranged from 20,898 to 35,806. Table 1 shows the unweighted sample sizes from the 2018 survey for each age group and related covariates. Supplement eTable 1 shows the weighted survey-specific sample size for the 2018 survey and eTable 2 shows weighted logistic regression models of adherence to current recommendations for MSA examining race stratified by sex.

Table 2 displays the crude weighted prevalence of adherence to MSA guidelines from 1997 to 2018 among the US population. The overall prevalence of adherence to MSA guidelines significantly increased ($p <$ .001) from 1997 to 2018 (19.8% to 27.2%, respectively). The prevalence of adherence to MSA guidelines significantly increased (p < .001) for all age groups from 1997 to 2018: 18–24 years, 8.2% (95% CI = 4.8–11.5); 25–34 years, 9.4% (95% CI = 7.2–11.7); 35–44 years, 8.7% increase (95% CI = 6.5–10.8); 45–64 years, 7.1% (95% CI = 5.6–8.6); and 65 years or older, 9.1% (95% CI = 7.7–10.5).

Fig. 1 shows the crude weighted trends in adherence to MSA guidelines for all age groups throughout 1997 to 2018, with a consistent overall trend toward increasing adherence. Across all survey years, younger adults showed higher adherence levels to MSA guidelines than older adults.

Table 3 shows weighted ORs of adherence to MSA recommendations in the US. Compared with women, men were more likely to adherent to MSA recommendation in all age groups (18–24 years: 1.5, 95% CI = 1.5–1.5; 25–34 years: 2.3, 95% CI = 2.2 to 2.4; 35–44 years; 1.7, 95% CI = 1.7–1.8; 45–64 years, 1.3, 95% CI = 1.3–1.4; 65 and older: 1.2, 95% CI = 1.1–1.2). Compared with their white non-Hispanic counterparts, the OR for black non-Hispanic participants aged 18–24 years was 0.8 (95% CI = 0.7–0.8), 0.9 (95% CI = 0.8–0.9) for those aged 35–44 years, 0.8 (95%CI = 0.7–0.8) for those aged 45–64 years and 0.7 (95% CI = 0.6–0.7) for participants aged 65 and older. Compared with their white non-Hispanic counterparts, the OR for Hispanic participants aged 18–24 and 25–34 years was 0.7 (95% CI = 0.6–0.7), 0.6 (95% CI = 0.6–0.6) for those aged 35–44 years, 0.6 (95%CI = 0.6–0.7) for those aged 45–64 years and 0.7 (95% CI = 0.6–0.7) for participants aged 65 and older. Compared with their white non-Hispanic counterparts, the OR for other non-Hispanic race were 0.9 (95% CI = 0.8–0.9), 0.8 (95% CI = 0.7–0.9)

**Table 1**
Sample Size for muscle strengthening activity recommendations in the US Population by Sociodemographic and Lifestyle Characteristics, National Health Interview Survey 2018[a].

| | No. of Participants by Age Subgroup (Unweighted %) | | | | |
|---|---|---|---|---|---|
| | 18–24 y | 25–34 y | 35–44 y | 45–64 y | ≥65 y |
| **Overall** | 1840 | 3836 | 3848 | 8240 | 7013 |
| **Weighted *N*** | 29,009,373 | 43,818,033 | 40,422,711 | 81,036,303 | 49,533,280 |
| **Sex** | | | | | |
| Female | 915(49.7) | 2060(53.7) | 2085(54.2) | 4387(53.2) | 4061(57.9) |
| Male | 925(50.3) | 1776(46.3) | 1763(45.8) | 3853(47.8) | 2952(42.1) |
| **Race** | | | | | |
| White, non-Hispanic | 1037(56.3) | 2368(61.7) | 2389(62.1) | 5903(71.6) | 5449(77.6) |
| Black, non-Hispanic | 238(12.9) | 489(12.8) | 476(12.4) | 962(11.7) | 728(10.4) |
| Hispanic | 390(21.2) | 658(17.2) | 662(17.2) | 882(10.7) | 493(7.2) |
| Other, non-Hispanic | 175(9.5) | 321(8.4) | 321(8.3) | 493(6.0) | 343(4.9) |
| **Education** | | | | | |
| <High school | 211(11.5) | 298(7.8) | 380(9.9) | 795(9.7) | 1013(14.4) |
| High school | 34(1.9) | 115(3.0) | 117(3.0) | 231(2.8) | 165(2.4) |
| >High school | 1593(86.6) | 3413(89.0) | 3341(86.8) | 7180(87.1) | 5793(82.6) |
| Missing | 2(0.1) | 10(0.3) | 10(0.3) | 34(0.4) | 42(0.6) |
| **Smoking** | | | | | |
| Never smoker | 1558(84.7) | 2636(68.7) | 2409(62.6) | 4722(57.3) | 3640(51.9) |
| Former smoker | 107(5.8) | 550(14.3) | 748(19.4) | 1996(24.2) | 2715(38.7) |
| Current smoker | 172(9.4) | 645(16.8) | 686(17.8) | 1511(18.3) | 645(9.2) |
| Missing | 3(0.2) | 5(0.1) | 5(0.1) | 11(0.1) | 138(0.2) |
| **Chronic conditions, mean (SD)** | 0.3(0.6) | 0.3(0.6) | 0.5(0.8) | 1.0(1.2) | 1.8(1.5) |
| Missing n(%) | 4(0.2) | 9(0.2) | 11(0.3) | 54(0.7) | 90(1.3) |
| **BMI ($kg/m^2$), mean (SD)** | 25.9(6.2) | 27.8(6.6) | 28.6(6.6) | 28.9(6.6) | 27.7(5.8) |
| Missing n(%) | 34(1.8) | 78(2.0) | 107(2.8) | 245(3.0) | 202(2.9) |
| **Functional limitation** | | | | | |
| No | 1557(84.6) | 3094(80.7) | 2874(74.6) | 4590(55.7) | 2222(31.6) |
| Yes | 283(15.4) | 742(19.3) | 974(25.3) | 3650(44.3) | 4791(68.2) |
| Missing | 1(0.1) | 0(0.0) | 4(0.1) | 4(0.1) | 12(0.2) |

BMI, body mass index.
[a] Participant characteristics were presented by age group.

and 0.8 (95% CI = 0.7–0.8) for participants aged, 25–34, 35–44 and 45–64 years respectively. Compared with their white non-Hispanic counterparts, the OR for non-Hispanic black males was 1.7 (95% CI = 1.5–2.0) while the OR for Hispanic females was 0.5 (95% CI = 0.4–0.6). Compared to participants with no high school education, a higher OR was observed for participants with high school education: 1.6 (95% CI = 1.5–1.8) for participants aged 25–34 years; 1.7 (95% CI = 1.5–1.8) for participants aged 35–44 and 45–64 years; 1.4 (95% CI = 1.2–1.5) for participants aged 65 and older. Compared with those without high school education, higher OR was shown for those with more than high school education: 1.6 (95% CI = 1.5–1.7) for participants aged 18–24 years; 3.1 (95% CI = 2.9–3.3) for participants aged 25–34 years; 3.3 (95% CI = 3.1–3.6) for participants aged 35–44 years; 3.7 (95% CI = 3.5–4.0) for participants aged 45–64 years; 3.1 (95% CI = 3.0–3.3) for participants aged 65 years and older. Compared with never smokers, the OR for former smokers was 1.1 (95% CI = 1.1–1.2) for participants aged 25–34 years, 1.1 (95% CI = 1.1–1.2) for participants aged 35–44 years and 1.2 (95% CI = 1.1–1.2) for participants aged 65 years and older. Compared with never smokers, the OR for current smokers was 0.7 (95% CI = 0.7–0.7) for participants aged 18–24 years, 0.7 (95% CI = 0.7–0.7) for participants aged 25–34 years, 0.6 (95% CI = 0.5–0.6) for participants aged 35–44 years, 0.5 (95% CI = 0.5–0.5) for participants aged 45–64 years and 0.5 (95% CI = 0.4–0.5) for participants aged 65 years and older. Compared with non-limitation, the OR for functional limitation was 0.8 (95% CI = 0.7–0.8) for participants aged 18–24 years, 0.7 (95% CI = 0.7–0.7) for participants aged 25–34 years, 0.7 (95% CI = 0.7–0.7) for participants aged 35–44 years, 0.6 (95% CI = 0.6–0.6) for participants aged 45–64 years and 0.6 (95% CI = 0.6–0.7) for participants aged 65 years and older. The OR for number of chronic conditions was 0.9 (95% CI = 0.9–0.9) for participants aged 35–44 years, 0.8 (95% CI = 0.8–0.8) for participants aged 45–64 years and 0.9 (95% CI = 0.9–0.9) for participants aged 65 years and older.

## 4. Discussion

In this nationally representative sample of the US population, adherence to MSA guidelines exhibited an upward trend from 1997 through 2018 in all age groups and overall, yet remained critically low at below 30%. Adherence was especially low among women, non-white, people with lower education, smokers, and people with functional limitations and chronic conditions.

We found that overall prevalence of adherence to MSA guidelines significantly increased from 1997 to 2018 (19.8% to 27.2%, respectively). Our study aligns with findings from a 2004 study examining temporal trends in the US using data from the NHIS. In 2004, adherence to the MSA guidelines were 21.9% and 17.5% for men and women, respectively.[14] The corresponding combined figure for 2014 was 20.4% [13], although no temporal trends were provided. The observed levels of adherence in the former study aligned with our findings; however, we noted a slower rate of overall increase from 1997 to 2018 (8.5% on average), which exhibited a particular deceleration during the last decade. This trend could be attributed to a more limited window of opportunity after a larger upswing in adherence during the late 2000s. Interestingly, the American College of Sports Medicine (ACSM) and the American Heart Association (AHA) recommended MSA in 2007 for the first time, in order to promote and maintain good health and physical independence among adults [7]. According to the ACSM and AHA, the Physical Activity Guidelines for Americans in 2008 included MSA guidelines that were expanded to children, adolescents and adults with disabilities. In addition, these recommendations were also largely adopted by the WHO in its global physical activity guidelines published in 2010 [18]. Our findings suggest that the inclusion of MSA in the aforementioned guidelines could have positively influenced MSA participation, especially among adults aged 35 years and older. Public health organizations should undertake greater endeavours to attain further progress in the future. Moreover, the disengagement from sports

**Table 2**
Crude weighted trends among the US population across survey years, National Health Interview Survey 1997–2018.[a,b] Prevalence of adherence to current recommendations for muscle strengthening activity in the US (two or more strength training sessions per week), Weighted % (95% CI).

| Age, y | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Overall | 19.8 (19.2–20.3) | 18.2 (17.6–18.8) | 18.5 (17.8–19.1) | 18.5 (17.8–19.2) | 20.7 (20.0–21.3) | 20.9 (20.3–21.6) | 20.8 (20.1–21.6) | 20.0 (19.1–20.7) | 20.5 (19.8–21.2) | 19.7 (18.9–20.6) | 20.2 (19.4–21.0) | 22.4 (21.6–23.2) | 22.8 (22.0–23.5) |
| 18–24 | 29.6 (27.6–31.5) | 28.1 (26.2–29.9) | 28.4 (26.2–30.6) | 27.5 (25.5–29.5) | 30.2 (28.1–32.2) | 29.1 (27.0–31.2) | 29.7 (27.6–31.9) | 28.0 (25.9–30.1) | 29.1 (27.0–31.2) | 26.6 (24.2–29.1) | 28.4 (25.6–31.2) | 29.4 (26.7–32.0) | 29.1 (26.6–31.6) |
| 25–34 | 24.6 (23.3–25.8) | 23.1 (21.8–24.4) | 22.8 (21.4–24.1) | 23.0 (21.6–24.4) | 26.1 (24.7–27.5) | 26.4 (25.0–27.8) | 25.3 (23.8–26.7) | 24.1 (22.6–25.6) | 23.3 (21.9–24.6) | 24.7 (22.7–26.7) | 23.0 (21.5–24.5) | 26.8 (25.0–28.6) | 27.2 (25.6–28-9) |
| 35–44 | 20.7 (19.6–21.9) | 19.1 (17.9–20.2) | 20.1 (18.9–21.3) | 18.8 (17.6–19.9) | 22.4 (21.2–23.6) | 22.3 (21.1–23.5) | 21.5 (20.2–22.8) | 20.1 (18.8–21.4) | 22.2 (20.9–23.5) | 20.9 (19.3–22.4) | 20.9 (19.4–22.3) | 22.9 (21.2–24.6) | 24.2 (22.5–25.9) |
| 45–64 | 16.6 (15.7–17.5) | 14.6 (13.6–15.6) | 14.8 (13.9–15.8) | 15.8 (14.8–16.8) | 16.9 (16.0–17.9) | 17.9 (16.8–18.9) | 18.3 (17.3–19.3) | 17.8 (16.9–18.8) | 18.4 (17.4–19.4) | 17.6 (16.4–18.8) | 18.8 (17.5–20.1) | 20.5 (19.4–21.5) | 20.6 (19.5–21.7) |
| ≥65 | 10.0 (9.2–10.8) | 9.1(8.2–10.0) | 9.5(8.6–10.4) | 10.4 (9.4–11.3) | 11.1 (10.1–12.2) | 11.8 (10.7–12.9) | 12.4 (11.3–13.5) | 12.8 (11.8–13.9) | 12.3 (11.3–13.4) | 11.3 (10.0–12.7) | 12.4 (11.2–13.7) | 15.0 (13.5–16.5) | 15.7 (14.3–17.1) |
| **Age, y** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | **β (95% CI)[c]** | ***P* for Trend[c]** | **2018 vs. 1997 survey, Difference (95% CI)** | |
| Overall | 24.4 (23.6–25.0) | 24.3 (23.6–25.1) | 23.9 (23.2–24.6) | 24.2 (23.4–24.9) | 24.3 (23.6–25.1) | 24.7 (24.0–25.4) | 25.8 (24.9–26.7) | 27.3 (26.4–28.2) | 27.2 (26.4–28.1) | 0.4(0.4–0.4) | $p < .001$ | 7.5(6.4–8.5) | |
| 18–24 | 32.9 (30.6–35.2) | 33.0 (30.9–35.1) | 32.1 (29.8–34.4) | 33.4 (31.2–35.5) | 33.8 (31.2–36.4) | 33.0 (30.4–35.6) | 34.4 (31.9–36.8) | 36.6 (33.8–39.4) | 37.7 (35.1–40.4) | 0.4(0.3–0.5) | $p < .001$ | 8.2(4.8–11.5) | |
| 25–34 | 29.8 (28.2–31.3) | 29.1 (27.6–30.7) | 30.1 (28.6–31.7) | 29.2 (27.4–30.9) | 29.9 (28.3–31.4) | 30.1 (28.5–31.8) | 32.8 (30.9–34.6) | 33.6 (31.6–35.6) | 34.0 (32.1–36.0) | 0.5(0.4–0.6) | $p < .001$ | 9.4(7.2–11.7) | |
| 35–44 | 25.4 (23.9–26.8) | 25.6 (24.2–27.1) | 24.5 (23.1–26.0) | 24.4 (23.1–25.8) | 25.5 (24.1–27.0) | 26.0 (24.4–27.5) | 26.8 (25.1–28.5) | 30.5 (28.6–32.3) | 29.4 (27.6–31.2) | 0.4(0.4–0.5) | $p < .001$ | 8.7(6.5–10.8) | |
| 45–64 | 21.8 (20.6–23.1) | 21.4 (20.4–22.4) | 21.1 (19.9–22.2) | 21.6 (20.6–22.7) | 21.3 (20.2–22.4) | 22.1 (21.1–23.1) | 23.0 (21.8–24.3) | 24.0 (22.7–25.2) | 23.7 (22.5–24.9) | 0.4(0.4–0.5) | $p < .001$ | 7.1(5.6–8.6) | |
| ≥65 | 16.0 (14.7–17.4) | 16.7 (15.5–17.8) | 16.7 (15.6–17.9) | 17.2 (16.0–18.5) | 16.9 (15.7–18.1) | 17.9 (16.6–19.2) | 18.1 (16.8–19.2) | 18.9 (17.6–20.1) | 19.1 (18.0–20.3) | 0.5(0.4–0.5) | $p < .001$ | 9.1(7.7–10.5) | |

[a] Sample sizes for individual cells ranges from 1798 to 11,451.
[b] All estimates accounts for the weights and complex survey design of the National Health Interview Survey to be nationally representative.
[c] The estimate β, 95% CI, and P for trend are calculated using linear regression that includes the year of each National Health Interview Survey as a continuous variable. The estimate β can be interpreted as the average annual percentage point change of prevalence.

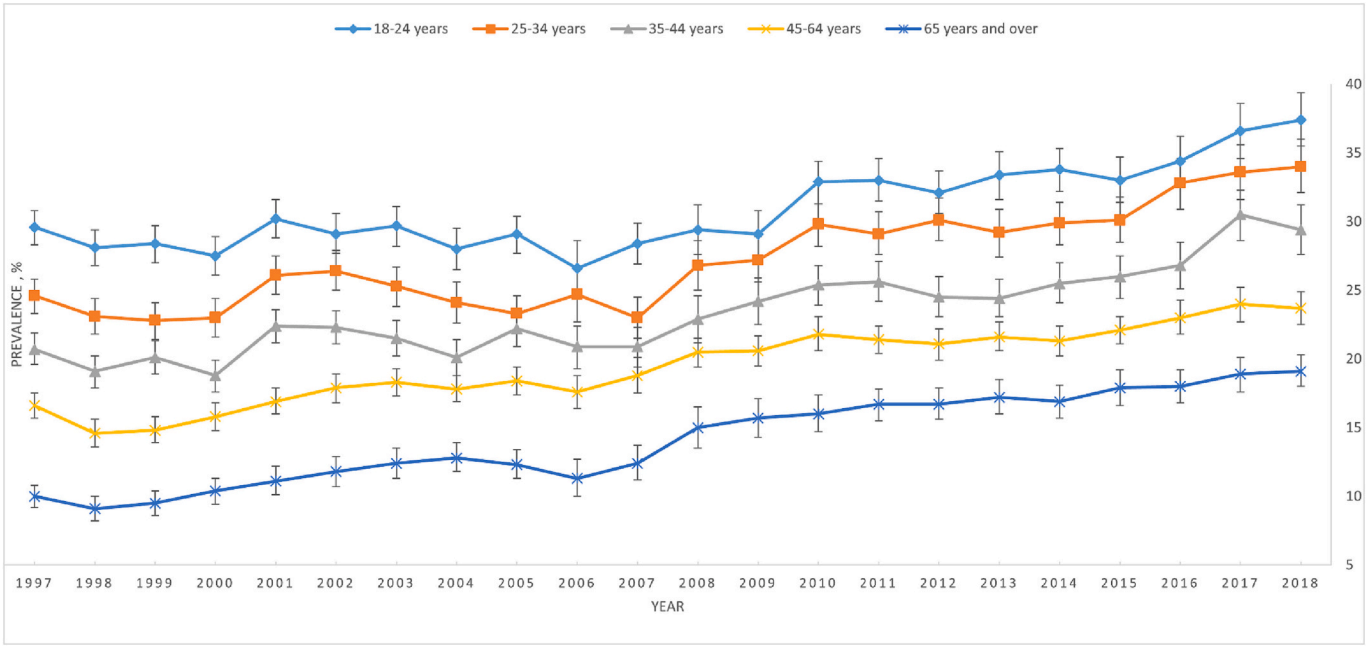


**Fig. 1.** Crude weighted trends in adherence to recommended muscle strengthening activity among US adults, 1997–2018, by age subgroup (prevalence and 95% CIs)[a].

[a]All estimates accounted for the weights and complex survey design of the National Health Interview Survey to be nationally representative. Error bars indicate 95% CIs.

over time observed among American adults toward other activities with less emphasis in extrinsic motivational factors (e.g., the need to win) [19], may also play an important role in increasing MSA adherence. Interestingly, among different types of physical activities in the US, weight lifting increased the most during the last decades. [19] In this regard, novel MSA modalities such as CrossFit have garnered increased popularity in recent years [20]. Nevertheless, these facts do not necessarily entail adherence to MSA guidelines (e.g., perform two or more days/week of MSA).

Age seems a crucial factor reducing adherence to MSA guidelines. We found that younger participants showed higher adherence levels to MSA recommended guidelines than older adults across all the survey years, which is consistent with previous findings on physical activity [13,14] and inactivity [21]. In addition, as age increases, the odds for insufficient MSA increase among men, non-Hispanic blacks and Hispanics, current smokers and those with functional limitations or chronic conditions. Our findings on the age difference is particularly important as the association between insufficient MSA and all-cause mortality is stronger in those aged 60 years or older [13]. Concerning this issue, a recent systematic review highlighted that the need for exercise individualization and negative beliefs (e.g., risk of heart attack or looking too muscular) are relevant barriers to MSA among older adults [22]. We also found that men had higher adherence to MSA guidelines at every age group which is consistent with the existing literature [23]. In this sense, a systematic review identified a number of barriers for women's adherence to MSA guidelines, including lack of social support from family or friends, slow progress, boredom, poor knowledge, poor accessibility in gyms, lack of supervision or routine, and difficulty in balancing work, time, family life, and other commitments [24]. Likewise, those with the highest educational attainment (i.e., beyond high school) had higher adherence to MSA guidelines in every age group, in agreement with previous evidence [23]. People with higher education demonstrated a greater number of healthy behaviors such as reduced total sitting time [25], reduced physical inactivity levels [21], and reduced prevalence of smoking or obesity [26]. In fact, a large prospective study including 415,764 US adults found an association between low educational attainment and increased mortality risk [26]. In the present study, smoking, functional limitations and for those aged 35 years and older, the number of chronic conditions were also associated with lower MSA adherence. Smoking increases the risk of morbidity and mortality from a wide range of diseases [27], and together with the higher likelihood of having other unhealthy risk behaviors [28] could compromise the participation in MSA. Several factors could partially explain why functional limitations or chronic conditions are barriers for MSA including a greater need for social support, conductive environments or negative beliefs [22], and greater difficulty for exercising depending on their physical/mental health status. In fact, it is likely that not adhering to MSA guidelines could lead (at least in long-term) to functional limitations/chronic conditions. An additional factor associated with suboptimal adherence to MSA guidelines, is race. In general, non-Hispanic blacks and Hispanics had lower adherence than non-Hispanic whites, especially as age increases, with Hispanics reporting the categories with the lowest adherence from 35 to 44 and 45 to 64 years old. However, our analysis examining MSA trends for different race and stratified by sex showed that interestingly, non-Hispanic black males and other non-Hispanic had greater odds for adhering guidelines than non-Hispanic whites. In addition, Hispanic females had lower odds for adhering MSA guidelines than non-Hispanic whites, while the differences between the latter and Hispanic males disappeared. Interestingly, racial/ethnic disparities in the prevalence of adherence to MSA are less frequent than for aerobic activity [29]. Previous data from NHIS showed that Hispanics have the lowest adherence to MSA guidelines, in accordance with our findings. Furthermore, similar values were observed between non-Hispanic white and black adults regardless of income level [29]. However, it should be considered that authors [29] analysed two time periods (1998–2000 and 2016–2018) and without categorizing in different age groups. In line with our general results, Hispanics and non-Hispanic blacks have reported higher prevalence of physical inactivity than non-Hispanic whites among US adults aged 50 and older [21] and non-Hispanic blacks have also showed higher prevalence of prolonged sitting watching television at all ages [25]. Likewise, the Behavioral Risk Factor Surveillance System [30] reported that overall, Hispanics had the highest prevalence of physical inactivity (31.7%), followed by non-Hispanic blacks (23.4%). A national study

**Table 3**
Weighted Logistic Regression Models of adherence to current recommendations for muscle strengthening activity in the US (two or more strength training sessions per week), Adjusted for Sociodemographic and Lifestyle characteristics, National Health Interview Survey 1997-2018[a].

| | Odds Ratio (95%CI)[b] | | | | |
|---|---|---|---|---|---|
| Age subgroup | 18–24 y | 25–34 y | 35–44 y | 45–64 y | ≥65 y |
| **No.** | 63,527 | 115,846 | 116,886 | 198,376 | 127,230 |
| **Age**[c] | 1.0(1.0–1.0) | 1.0(1.0–1.0) | 1.0(1.0–1.0) | 1.0(1.0–1.0) | 1.0(1.0–1.0) |
| **Sex** | | | | | |
| Female | 1(reference) | 1(reference) | 1(reference) | 1(reference) | 1(reference) |
| Male | 2.3(2.3–2.5) | 1.7(1.7–1.8) | 1.3(1.3–1.4) | 1.2(1.1–1.2) | 1.3(1.3–1.4) |
| **Race** | | | | | |
| White, non-Hispanic | 1(reference) | 1(reference) | 1(reference) | 1(reference) | 1(reference) |
| Black, non-Hispanic | 0.8(0.7–0.8) | 0.9(0.9–1.0) | 0.9(0.8–0.9) | 0.8(0.7–0.8) | 0.7(0.6–0.7) |
| Hispanic | 0.7(0.6–0.7) | 0.7(0.6–0.7) | 0.6(0.6–0.6) | 0.6(0.6–0.7) | 0.7(0.6–0.7) |
| Other, non-Hispanic | 1.0(0.9–1.1) | 0.9(0.8–0.9) | 0.8(0.7.-0.9) | 0.8(0.7–0.8) | 1.0(0.9–1.2) |
| **Education** | | | | | |
| <High school | 1(reference) | 1(reference) | 1(reference) | 1(reference) | 1(reference) |
| High school | 0.9(0.9–1.0) | 1.6(1.5–1.8) | 1.7(1.5–1.8) | 1.7(1.6–1.8) | 1.4(1.2–1.5) |
| >High school | 1.6(1.5–1.7) | 3.1(2.9–3.3) | 3.3(3.1–3.6) | 3.7(3.5–4.0) | 3.1(3.0–3.3) |
| **Smoking** | | | | | |
| Never smoker | 1(reference) | 1(reference) | 1(reference) | 1(reference) | 1(reference) |
| Former smoker | 0.9(0.9–1.0) | 1.1(1.1–1.2) | 1.1(1.1–1.2) | 1.0(1.0–1.0) | 1.2(1.1–1.2) |
| Current smoker | 0.7(0.7–0.7) | 0.7(0.7–0.7) | 0.6(0.5–0.6) | 0.5(0.5–0.5) | 0.5(0.4–0.5) |
| **Functional limitation** | | | | | |
| No | 1(reference) | 1(reference) | 1(reference) | 1(reference) | 1(reference) |
| Yes | 0.8(0.7–0.8) | 0.7(0.7–0.7) | 0.7(0.7–0.7) | 0.6(0.6–0.6) | 0.6(0.6–0.7) |
| **BMI (kg/m$^2$)**[c] | 1.0(1.0-1.0) | 1.0(1.0–1.0) | 1.0(1.0–1.0) | 1.0(0.9–1.0) | 1.0(1.0–1.0) |
| **Number of chronic conditions**[c] | 1.0(1.0–1.0) | 1.0(0.9–1.0) | 0.9(0.9–0.9) | 0.8(0.8–0.8) | 0.9(0.9–0.9) |
| **Survey** | | | | | |
| 1997 | 1(reference) | 1(reference) | 1(reference) | 1(reference) | 1(reference) |
| 1998 | 0.9(0.8–1.1) | 0.9(0.8–1.0) | 0.9(0.8–1.0) | 0.9(0.8–0.9) | 0.9(0.8–1.0) |
| 1999 | 0.9(0.8–1.1) | 0.9(0.8–1.0) | 1.0(0.9–1.1) | 0.9(0.8–1.0) | 1.0(0.8–1.1) |
| 2000 | 0.9(0.8–1.0) | 0.9(0.8–1.0) | 0.9(0.8–1.0) | 0.9(0.9–1.0) | 1.0(0.9–1.2) |
| 2001 | 1.0(0.9–1.2) | 1.1(1.0–1.2) | 1.1(1.0–1.2) | 1.0(0.9–1.1) | 1.1(1.0–1.3) |
| 2002 | 1.0(0.9–1.2) | 1.1(1.0–1.2) | 1.1(1.0–1.2) | 1.1(1.0–1.2) | 1.2(1.1–1.4) |
| 2003 | 1.0(0.9–1.2) | 1.0(0.9–1.2) | 1.1(1.0–1.2) | 1.1(1.0–1.2) | 1.3(1.1–1.5) |
| 2004 | 0.9(0.8–1.1) | 1.0(0.9–1.1) | 1.0(0.9–1.1) | 1.1(1.0–1.2) | 1.4(1.2–1.5) |
| 2005 | 1.0(0.9–1.1) | 0.9(0.9–1.0) | 1.1(1.0–1.2) | 1.1(1.0–1.2) | 1.3(1.1–1.4) |
| 2006 | 0.9(0.8–1.0) | 1.1(1.0–1.3) | 1.0(0.9–1.1) | 1.1(0.9–1.2) | 1.2(1.0–1.4) |
| 2007 | 1.0(0.8–1.1) | 0.9(0.8–1.0) | 1.0(0.9–1.1) | 1.2(1.0–1.3) | 1.3(1.1–1.5) |
| 2008 | 1.0(0.9–1.2) | 1.1(1.0–1.3) | 1.1(1.0–1.3) | 1.3(1.2–1.4) | 1.6(1.4–1.9) |
| 2009 | 1.0(0.8–1,1) | 1.2(1.0–1.3) | 1.2(1.1–1.4) | 1.3(1.2–1.5) | 1.7(1.5–2.0) |
| 2010 | 1.2(1.0–1.3) | 1.3(1.2–1.4) | 1.3(1.2–1.4) | 1.4(1.3–1.5) | 1.7(1.5–2.0) |
| 2011 | 1.2(1.0–1.3) | 1.3(1.1–1.4) | 1.3(1.2–1.5) | 1.4(1.2–1.5) | 1.8(1.6–2.0) |
| 2012 | 1.1(1.0–1.3) | 1.3(1.2–1.4) | 1.2(1.1–1.4) | 1.3(1.2–1.5) | 1.8(1.6–2.1) |
| 2013 | 1.2(1.0–1.4) | 1.3(1.1–1.4) | 1.3(1.2–1.4) | 1.4(1.3–1.5) | 1.8(1.6–2.1) |
| 2014 | 1.2(1.0–1.4) | 1.3(1.2–1.4) | 1.3(1.2–1.4) | 1.4(1.2–1.5) | 1.8(1.6–2.1) |
| 2015 | 1.2(1.0–1.4) | 1.3(1.2–1.5) | 1.3(1.2–1.5) | 1.4(1.3–1.6) | 2.0(1.7–2.2) |
| 2016 | 1.2(1.1–1.4) | 1.nnnnn(1.3–1.7) | 1.4(1.2–1.6) | 1.5(1.4–1.7) | 2.0(1.8–2.3) |
| 2017 | 1.4(1.2–1.6) | 1.5(1.4–1.7) | 1.7(1.5–1.9) | 1.6(1.4–1.7) | 2.1(1.9–2.4) |
| 2018 | 1.4(1.2–1.7) | 1.6(1.4–1.8) | 1.6(1.4–1.8) | 1.6(1.4–1.7) | 2.1(1.9–2.4) |
| ***P* for Trend**[d] | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

BMI, body mass index.
[a] All estimates accounted for the weights and complex survey design of the National Health Interview Survey to be nationally representative. Participants with missing values (n = 29,817) (4.6%) were removed from the analyses.
[b] For categorical variables, the odds ratios (ORs) represent the change in odds expected in each category in relation to the reference group.
[c] The ORs in this row represent the change in odds expected from a 1-year increase in age within this age group.
[d] *P* for Trend over survey was calculated using the National Health Interview Survey years as a continuous variable.

suggested that minorities more often live in places with less facilities that enable and promote physical activity [31]. In fact, a study conducted among African-American and Hispanic or Latina women showed that higher quality physical activity resources helped in maintaining or increasing physical activity regardless of neighbourhood income [32]. Interestingly, data from the Exploring Health Disparities in Integrated Communities-Southwest Baltimore study and the NHIS revealed that disparities in physical inactivity based on race were eradicated among individuals of black and white ethnicity who reside in a shared social context [33]. This suggests that the differences observed in prior studies could be ascribed to divergent social and environmental exposures [33], which could help to explain regional differences across the US. For instance, within the Northeast, South, and West, black men had lower odds of adhering to recommendations for physical activity compared to white men whereas there were no differences at the Midwest [34]. Future studies are warranted to further understand whether certain groups may be affected disproportionally by lower MSA adherence and identify specific facilitators and barriers to engaging MSA.

### 4.1. Strengths and limitations

We pooled data from 22 cycles of US nationally representative sample in the NHIS survey and accounted for specific weights and methodology for this study. The main limitation of the current study is that MSA adherence was self-reported by participants, which can lead to a recall and misclassification bias. Nevertheless, self-reported MSA has been used several times on previous epidemiological studies [13,14,35], and is unlikely that measurement errors can represent a critical issue in a

study investigating secular trends. Finally, since our data is representative from US, the generalisability to populations of other races and ethnicities outsides the US should be made with caution.

In conclusion over a 20-year span, adherence to MSA guidelines increased across all age groups, although the average adherence level remained low (below 30%). Achieving higher compliance with MSA guidelines is an essential yet challenging objective that public health organizations must prioritize. Future population intervention strategies to promote MSA are required with a particular focus on older adults, women, Hispanic women, current smokers, those with low educational levels, and those with functional limitations or chronic conditions.

## Author's contributions

Dr. López-Bueno has full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Concept and design: Calatayud, López-Bueno, Andersen. Acquisition, analysis, or interpretation of data: All authors. Drafting of the manuscript: Calatayud, López-Bueno. Critical revision of the manuscript for important intellectual content: All authors. Statistical analysis: López-Bueno. Supervision: All authors.

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## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The used dataset is publicly available athttps://www.cdc.gov/nchs/nhis/index.htm

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.genhosppsych.2023.06.016.

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