Muscle-Strengthening Exercise and Depression in Chinese Young Adults

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Abstract

Studies based on western population have indicated that muscle-strengthening exercise (MSE) has positive roles against mental disorders, but little is known about that in Chinese adults. This study, thus, aimed to explore the association between MSE and depression in Chinese university students (aged 18-24 years). A convenient sample of 1794 university students (mean age: 20.67 years) were recruited into this study. A self-reported questionnaire was used to collect information on participants’ sociodemographic information (e.g., sex, body mass index) and MSE. Physical activity and sleep were measured using the International Physical Activity Questionnaire-Short Form and Pittsburgh Sleep Quality Index. Study participants’ depression severity was assessed using the Patient Health Questionnaire-9. A multivariate linear regression was performed to examine the association between MSE and depression. Only 24.87% of study participants met the World Health Organization MSE guidelines of more than 2 days/week. The mean score of depression was 6.80 (± 5.19). More days for MSE (0-7 days) was negatively associated with depression (beta = -0.17, 95%CI: -0.31 – -0.03, p = 0.015). Students who did not meet MSE guidelines were more likely to have higher risks for depression (beta = 0.63, 95%CI: 0.09-0.19, p = 0.027). The results indicate that engaging in MSE could be related to decreased depression in Chinese young adults. Interventions aiming at reducing depression could incorporate MSE as a strategic component.

1 Background

Depression is characterized by sadness, loss of interest or pleasure, feelings of guilt or low self-worth, disturbed sleep and/or appetite, feelings of tiredness, and poor concentration [1, 2]. Depression is one of the leading mental health problems in the global population [2, 3] with more than 264 million people living with depression around the world [2]. As a common mental health disorder, depression has adverse negative effects on physical health and overall mental wellbeing [4–6], often contributing to deaths by suicide [2]. More recent data shows that depression is the third cause of global disease burden (first in developed countries) and is expected to become the first cause of disease burden worldwide by 2030, with related suicide rates more likely to increase [7].

According to the World Health Organization (WHO), depression has become the second largest killer of humans after cancer [2]. Many young adults (18–25 years) have been diagnosed with depressive symptoms across the world; one of the 10 diseases leading to death in this age group [8–10]. Several multidimensional factors interact to increase the vulnerability of young adults to depression [11, 12]. The prevalence of depression in Chinese university students (young adults) is of great concern [13, 14]. Depression as an individual and public health issue has attracted a large amount of attention from policymakers, scholars, and practitioners. For example, in September 2020, the Chinese General Office of the National Health Commission issued the “Working Plan for Exploring Special Services for the Prevention and Treatment of Depression”. The policy requires depression screening to be included in student health examination at universities.

In light of the increasing prevalence and health burden of depression, researchers are encouraged to identify various risk factors of depression [15, 16], resulting in more effective interventions aiming at reducing depression. Several studies have considered sufficient physical activity (PA) as a protective factor against depression in young adults [17–20]. However, those studies focused on overall volume of PA instead of one specific modality of PA, which may inhibit more nuanced understanding the role of PA in preventing depression. Recently, some research has investigated association between muscle-strengthening exercise (MSE) and depression because of MSE’s emerging role in promoting health [21]. For example, Bennie et al. [22] recently published a cross-sectional study of a nationally representative sample of German adults, finding that MSE might be a protective factor against depression. Based on the epidemiological evidence, it is likely that MSE can play a positive role in preventing depression in adults. However, more studies are encouraged to replicate or negate evidence regarding associations between MSE and mental health indicators, especially in varying ethnic and age groups [21].

Although previous research is promising in this area, several important limitations should be noted. One major limitation is that most previous studies were based on Western populations while, to our knowledge, little is known about the roles of MSE on depression in Chinese populations. Another study limitation involves in a lack of measuring or accounting for confounders when assessing the association between MSE and depression. Specifically, two studies by Bennie et al. [22, 23] omitted two important confounders, such as sedentary behavior and sleep duration, that have been recognized as correlates of depression in young adults. Sleep and sedentary behaviour are important considerations that can contribute to understanding potential moderators of the relationship between MSE and depression [24].

The present study aimed to address the gaps in the literature and explore the association between MSE and depression in young adults (i.e., a sample of Chinese university students) in China. This research provides a basis for identifying similarities with previous research as well as designing effective interventions and informing policies for depression prevention in Chinese young adults.

2 Methods

2.1 Study design and participants

Our study originated from a longitudinal study survey (ongoing) to assess the impacts of the coronavirus disease (COVID-19) outbreak on Chinese university students’ mental health [25]. We intended to conduct at least 4 consecutive surveys (starting February 2020 and performing the surveys at a three-month intervals) among students from 10 universities in southern China. In wave 3, we assessed MSE using the survey. The survey was sent to study participants who agreed to join in wave 3 (provide consent in wave 2). In wave 3, 1159 study participants responded to the questionnaire. To increase the sample size, we invited additional study participants to complete the same measurements. In brief, 714 participants responded and submitted the questionnaire. Both of the surveys were conducted from August 21~31, 2020. Of all the study participants (N = 1873), 1793 study participants provided valid data pertaining to all the variables included in this study (response rate = 95.73%). All the study participants provided informed consent to participate in this study prior to data collection.

2.2 Procedure and data collection
The survey was conducted online for both convenience and safety reasons in light of the COVID-19 outbreak. Over a period of 10 days, students were invited to participate in the survey (hosted at wenjuanxing [wjx.cn], Ranxing Information and Tech Company, Changsha, China) via Tencent’s QQ, WeChat, Weibo, and college-related websites (e.g., university association websites and bulletin board system forums). The survey took approximately 15 minutes to complete, and participants were given 10 RMB (Chinese currency) via online payment (equivalent to 1.5 U.S. dollars at the current rate). Recruitment and data collection procedures were approved by the Human Research Ethics Committee (No:2020005) of Shenzhen University.

2.3 Measures

(1) Muscle-strengthening exercise (MSE)

Each study participant was asked to report engagement in MSE by responding to the question “how many days did you do MSE over the past week?” In this context, MSE was defined as “activities involving major muscle groups [26], like push-ups, weightlifting, curl-ups or pull-ups”. Responses for study participants ranged from 0 to 7 days. Similar questions had been used in studies based on US [27–29] and Australian [30–32] as well as Chinese [33] populations, which showed acceptable reliability. In accordance with WHO and consistent with past studies (two or more days for MSE as a cut-off) [26], participants were classified as meeting the MSE guidelines if they reported having participated in MSE two or more times per week. In the statistical analyses, the variable of MSE days was treated as continuous while the variable of meeting MSE guidelines or not was treated as binary outcome.

(2) Depression (PHQ-9)

Participants’ depressive symptoms were assessed by the Patient Health Questionnaire-9 consisting of 9 items (PHQ-9) assessing self-report of major depressive symptoms (e.g., little interest and bad feeling from the survey) relative to the last two weeks where participants responded from 0 = not at all to 3 = almost every day [34]. A previous study found that the reliability and validity of the PHQ-9 (Chinese version) in university students was acceptable [35], and can be used in epidemiological surveys. In our analyses, the scores of PHQ-9 were treated as a continuous variable.

(3) Socio-demographic variables and other control variables

Based on previously published studies [22, 23], the variables of sex (male or female), age (years), body mass index (BMI; calculated by self-reported height [cm] and weight [kg]), siblings (single or two or more), residence (urban or rural), family structure (full, divorced or other), parental educational level (middle school or below, high school, college or university, master or above), estimated number of close friends (none, 1–2, 3–5, 6 or more), perceived family affluence and physical activity behavior were assessed. Perceived family affluence was assessed by a scale (from 0 to 10) developed by Nancy et al. [36], which higher scores indicate more perceived family affluence.

Physical activity behavior was assessed by the International Physical Activity Questionnaire-short form (IPAQ-SF), its reliability and validity has been reported in Chinese populations [37], indicating the IPAQ-SF was acceptable to capture Chinese adults’ physical activity and sedentary behavior. In brief, study participants were required to recall their physical activity (e.g., vigorous, moderate and light) and sedentary behavior (e.g., sitting during leisure time and transportation time) over the past 7 days. Minutes of physical activity and sedentary time per week were calculated based on the published guidelines by the IPAQ expert group [38]. Study participants’ sleep duration (hours) was assessed by Pittsburgh Sleep Quality Index (PSQI) that has been validated in Chinese populations [39]. In the statistical analyses, age, BMI, perceived family affluence, physical activity, sedentary behavior and sleep duration were treated as continuous variables while other potential confounding/ moderating variables were included as categorical variables.

2.4 Statistical analyses

All the statistical analyses were conducted using SPSS version 25.0. Descriptive statistics calculated were frequency and percentage (%) of categorical variables (e.g., sex, residence, days for MSE) as well as mean and standard deviation of continuous variables (e.g., age, BMI). Pearson’s chi square was used to examine sex differences across all the categorical variables and student t test was used to examine sex differences across all the continuous variables. Pearson correlation coefficients were calculated to determine bivariate associations among study variables. A multilevel linear model (also known as hierarchical linear model; HLM) was used to estimate the association between MSE and depression. This technique takes into account the dependency of observations within multiple clusters (in this case, individual characteristics were nested within city). A multilevel linear regression controls for confounding variables on the micro-level (individual), as well as the macro-level (cities). Based on our data structure in this study, we fitted our data as a two-level structure (level 2: city, level 1: individual), which then uses the Linear Mixed Models function with Restricted Maximum Likelihood Estimation (REML) to examine the associations between MSE and depression. To thoroughly explore the association between MSE and depression, two models were established (model 1: MSE days as independent variable; model 2: MSE guidelines as independent variable) and controlled for all the sociodemographic and control variables. Adjusted beta estimates with corresponding 95% confidence intervals (95% CI) are described in the results. Statistical significance was defined as $p < 0.05$ (two sided).

3 Results

Socio-demographic characteristics of the study sample and variables are outlined in Table 1. In Total, 1793 participants (63.58% female) were included in this study, the average of BMI was 20.27 ± 2.86 kg/m². 34.18% of participants were only-child, and the percentage of participants living in urban area was 69.21%. Education level of most of participants’ parents were high school or below (M: 82.48%, F: 89.18%). 52.2% of participants reported that they have 3–5 friends. In total, participants accumulated time spent in physical activity 126.98 ± 120.98 min/week, sedentary time was 384.53 ± 222.20 min/day, and sleep was 443.57 ± 91.52 min/day. Moreover, 72.6% of respondents reported zero days of MSE per week, and the proportions in male and female were 58.04% and 80.09%, respectively. Overall, 24.8% of respondents met the MSE guidelines, and the percentage of meeting guidelines in males was more than twice that of the females. In addition, the mean score of depression in females (7.24 ± 5.17) was significantly higher that in males (6.04 ± 5.13).
Table 2 and Table 3 show the bivariate correlation coefficients among the variables included in this study. Significant relationships were found between depression and MSE days ($r = -0.11$, $p < 0.001$), and depression and MSE guidelines ($r = -0.11$, $p < 0.001$). Multilevel regression models were estimated to determine the association between MSE days and depression (Table 4). In total, a negative relationship between MSE days ($\beta = -0.17$, 95%CI = -0.31 to -0.03) and depression was found. The relationship between meeting MSE guidelines and depression can be found in Table 5. We found a positive relationship between not meeting MSE guidelines ($\beta = 0.63$, 95%CI = 0.07 to 1.19) and depression compared to meeting the MSE guidelines.

4 Discussion

The purpose of this research was to examine the associations between MSE and depression among Chinese young adults while accounting for important third variables such as sleep and sedentary behavior. We found that about a quarter (24.87%) of Chinese young adults (university students) engaged in at least 2 days of MSE per week. Importantly, more days spent engaging in MSE or meeting the MSE guidelines were significantly negatively related to depression severity (assessed by PHQ-9). To our knowledge, this is the first study to investigate the prevalence of MSE and its potentially protective role in preventing depression among Chinese young adults, which can advance understandings of mental well-being promotion.

Although MSE has been an imperative component of the well-recognized PA guidelines by the World Health Organization and other national public health sectors (e.g., America and Canada), research focusing on MSE and mental health benefits in various populations remains scarce [21]. This deficiency is a barrier to better understanding physical activity in a way that is comprehensive and inclusive of various populations. The prevalence of meeting the MSE guidelines in our sample is lower (24.87% vs 28.50%) compared with one previously published study consisting of adults (from Hubei, China) over 30 years of age [33]. This small discrepancy may be owing to different sample characteristics, such as age, and survey time (e.g., spring, summer). When evaluating the level of MSE in Chinese young adults compared with results based on Western (e.g., America, Australia) study samples, the prevalence of meeting MSE guidelines is generally lower for Chinese samples. For example, Bennie et al. [31] found that 29.2% of Australian adults aged 18–24 years complied with the MSE guidelines. In the US, a trend analysis on data from 2011 to 2017 indicated that over 40% of adults of 18–24 years met the MSE guidelines regardless of survey year [29]. Taken together, the prevalence of meeting the MSE guidelines among Chinese young adults is lower compared to Western samples, pointing to the importance of intervention in young adults in order to encourage the development of lifelong healthy behaviors in this population [40–45].

Regardless of how we measured MSE in our study (e.g., days or meeting the guidelines), more days of participation in MSE or meeting the guidelines were independently related to lower risks for depression in Chinese young adults. In other words, participation in MSE could be a protective factor against depression. This research finding is consistent with prior research by Jason et al. [22, 23]. Specifically, one study based on German adults aged over 18 years (N = 23, 635) indicated that increases in MSE would be a beneficially preventive approach to treating depression. Researchers have offered some explanations as to the mechanisms that may help explain MSE's role in decreasing depression severity or symptoms. First, more engagements in MSE can increase muscle strength that has been viewed as a health indicator and component of fitness, which improves individuals' physical function and quality of life [46–48] resulting in decreased depression. Another mechanism examined are myokines produced by MSE that may act as a biological inhibitor against depression [49]. In addition to these more biological mechanisms, as a form of PA, MSE could change individual psychosocial (e.g., self-esteem) and neurobiological (e.g., cerebral blood flow) factors that may both lower depression in adults [50]. However, the mechanism associating MSE and depression should be further clarified in future research. Importantly, because our study adopted a cross-sectional design, it is unreasonable to draw conclusions related to causality. Longitudinal or experimental trials to confirm the association between MSE and depression among young adults should be conducted. Altogether, this study suggests that MSE is likely a beneficial factor against depression among Chinese young adults.

Our research findings foster some important practical implications and future research recommendations to inform depression prevention. MSE is a feasible and efficient approach to preventing depression in Chinese young adults. MSE is one form of physical activity that needs few environmental supports (e.g., equipment, playgrounds). For example, individuals can conduct MSE without any equipment or instruments or perform MSE in a small space. The restrictions put in place to prevent the spread of COVID-19 in many countries, such as closing indoor gym spaces, is a testament to the versatility of MSE which many have continued or taken up in their homes. This kind of physical activity has its own merits regarding accessibility over other forms of physical activity, like swimming (need a pool) or ball sports (need balls or mates). Importantly, little is known about correlates/determinants of MSE in Chinese young adults [33] which is a critical component when generating campaigns to encourage young adults to conduct MSE. Future research should examine and identify components of effective interventions to promote MSE in this population.

A major strength of this study is that we used a large sample to augment evidence on the association between MSE and depression among Chinese young adults, and contributed to the evidence base for depression prevention/treatment in Chinese young adults. Another strength is that our study controlled for more variables compared with previous studies, including family-related factors, socioeconomic parameters and behavioral variables (e.g., sedentary behavior and sleep duration). However, some inherent study limitations should be mentioned. The cross-sectional study design is one limitation, which cannot fully answer the cause-and-effect association between MSE and depression. The second limitation is the use of self-reported questionnaires, which may result in recall bias. Our study sample was mainly from southern provinces in China and the generalizability of research findings into wider regions should be approached with caution. The final limitation concerns measurement, which the questionnaire to assess PA (IPAQ) did not require study participants to distinguish moderate to vigorous physical activity and MSE. This implies that IPAQ may capture MSE to some extent. However, the correlation coefficient between moderate to vigorous physical activity and MSE was 0.28 (weak correlation), indicating they are likely not measuring the same thing. Future studies should explicitly distinguish these physical activity types.

5 Conclusions

This study is the first to assess the prevalence of MSE and its association with depression in Chinese young adults. Only about a quarter of Chinese young adults met the MSE guidelines (more than 2 days per week). We found that more engagement in MSE may help protect against depression. Future studies are...
encouraged to confirm or negate these research findings using more improved study designs (e.g., follow-up studies or experimental studies). Despite this, our study provides preliminary evidence for depression prevention in Chinese young adults.

Declarations

-Ethics approval and consent to participate

The administration committees of the surveyed colleges and universities approved the study and data collection, as did the Human Research Ethics Committee of Shenzhen University.

All students in the selected classes were invited to participate in this study (N = 1,200), and students who agreed to participate signed consent forms before the questionnaire was administered.

-Consent to publish

Not applicable

-Availability of data and materials

The datasets used and/or analyzed during the current study are available from the first author on reasonable request.

-Competing interests

The authors declare that they have no competing interests.

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-Author contributions

Study design: Xinli Chi and Si-Tong Chen.

Data collection: Xinli Chi, Liuyue Huang, Yanjie Zhang and Can Jiao

Data analysis: Xinli Chi, Liuyue Huang and Si-Tong Chen.

Manuscript draft: Xinli Chi and Si-Tong Chen.

Critical revision: Kimberley Curtin, Kaja Kastelic, Cain Clark, Liye Zou

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### Tables
|                                | Total     | Male       | Female     | p for sex difference |
|--------------------------------|-----------|------------|------------|----------------------|
| **N**                          | 1793      | 100        | 1140       | -                    |
| **%**                          |           | 36.42      | 63.58      | -                    |
| **Sex**                        |           |            |            |                      |
| **Male**                       |           | 653        | 1140       |                      |
| **Female**                     |           | 1090       | 520         |                      |
| **p for sex difference**       |           | 0.110      | 0.000      |                      |
| **Age (mean ± SD) [years]**    |           | 20.75 ± 1.63 | 20.63 ± 1.60 | 0.110               |
| **BMI (mean ± SD) [kg/m²]**    |           | 20.27 ± 2.86 | 21.44 ± 3.12 | 0.000               |
| **Siblings**                   |           |            |            |                      |
| **Single**                     |           | 613        | 336        | 0.000                |
| **Two or more**                |           | 1180       | 804        |                      |
| **Residence**                  |           |            |            |                      |
| **Urban**                      |           | 1241       | 811        | 0.020                |
| **Rural**                      |           | 552        | 329        |                      |
| **Family structure**           |           |            |            |                      |
| **Full**                       |           | 1261       | 1028       | 0.600                |
| **Divorced**                   |           | 109        | 70         |                      |
| **Other**                      |           | 63         | 42         |                      |
| **Perceived family affluence** |           |            |            | 0.000                |
| **(mean ± SD)**                |           | 5.71 ± 1.64 | 5.86 ± 1.59 |                      |
| **Father education level**     |           |            |            |                      |
| **Middle school or below**     |           | 867        | 539        | 0.291                |
| **High school**                |           | 612        | 391        |                      |
| **College or university**      |           | 250        | 174        |                      |
| **Master or above**            |           | 64         | 36         |                      |
| **Mother education level**     |           |            |            | 0.245                |
| **Middle school or above**     |           | 1055       | 652        |                      |
| **High school**                |           | 544        | 362        |                      |
| **College or university**      |           | 152        | 103        |                      |
| **Master or above**            |           | 42         | 23         |                      |
| **Number of friends**          |           |            |            |                      |
| **None**                       |           | 29         | 19         | 0.052                |
| **1–2**                        |           | 590        | 381        |                      |
| **3–5**                        |           | 936        | 609        |                      |
| **6 or more**                  |           | 238        | 131        |                      |
| **PA (mean ± SD) [min/week]**  |           | 126.98 ± 120.98 | 152.82 ± 132.17 | 0.000               |
| **ST (mean ± SD) [min/day]**   |           | 384.53 ± 222.20 | 360.13 ± 224.47 | 0.000               |
| **SLP (mean ± SD) [min/day]**  |           | 443.57 ± 91.52 | 436.39 ± 98.25 | 0.012               |

BMI: body mass index;  
MSE: muscle-strengthening exercise;  
MSE guidelines: reporting at least 2 days was regarded as meeting the guidelines;  
PA: physical activity;  
ST: sedentary behavior;  
SLP: sleep duration;  
SD: standard deviation.
|                      | Total | Male | Female | \( p \) for sex difference |
|----------------------|-------|------|--------|----------------------------|
|                      | N     | %    | n      | %   |
| MSE days             |       |      |        |     |
| 0 days               | 1292  | 72.06| 379    | 58.04| 0.000|
| 1 day                | 55    | 3.07 | 31     | 4.75 | 2.11 |
| 2 days               | 104   | 5.80 | 54     | 8.27 | 4.39 |
| 3 days               | 142   | 7.92 | 73     | 11.18| 6.05 |
| 4 days               | 77    | 4.29 | 39     | 5.97 | 3.33 |
| 5 days               | 63    | 3.51 | 39     | 5.97 | 2.11 |
| 6 days               | 25    | 1.39 | 18     | 2.76 | 0.61 |
| 7 days               | 35    | 1.95 | 20     | 3.06 | 1.32 |
| MSE guidelines       |       |      |        |     |
| Not met              | 1347  | 75.13| 410    | 62.79| 0.000|
| Met                  | 446   | 24.87| 243    | 37.21| 17.81|
| Depression (mean ± SD)| 6.80 ± 5.19 | 6.04 ± 5.13 | 7.24 ± 5.17 | 0.000 |

BMI: body mass index;
MSE: muscle-strengthening exercise;
MSE guidelines: reporting at least 2 days was regarded as meeting the guidelines;
PA: physical activity;
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SLP: sleep duration;
SD: standard deviation.
Table 2
Correlation matrix among the variables included in this study (for MSE days)

|     | 1   | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   | 13   | 14   |
|-----|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 1   | 1   |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 2   | -0.04 | 1   |      |      |      |      |      |      |      |      |      |      |      |      |
| 3   | -0.31** | 0.09*** | 1   |      |      |      |      |      |      |      |      |      |      |      |
| 4   | 0.13*** | 0.003 | -0.15*** | 1   |      |      |      |      |      |      |      |      |      |      |
| 5   | -0.06* | 0.10*** | 0.02 | 0.21*** | 1   |      |      |      |      |      |      |      |      |      |
| 6   | 0.12*** | -0.10*** | -0.04 | -0.04 | -0.19*** | 1   |      |      |      |      |      |      |      |      |
| 7   | 0.01 | 0.02 | 0.03 | -0.09*** | -0.04 | -0.11*** | 1   |      |      |      |      |      |      |      |
| 8   | 0.03 | -0.13*** | 0.03 | -0.26*** | -0.33*** | 0.20*** | 0.01 | 1   |      |      |      |      |      |      |
| 9   | 0.03 | -0.18*** | 0.03 | -0.31*** | -0.33*** | 0.20*** | 0.03 | 0.61*** | 1   |      |      |      |      |      |
| 10  | -0.05 | 0.004 | -0.001 | -0.05* | -0.03 | 0.09*** | -0.002 | 0.02 | 0.07** | 1   |      |      |      |      |
| 11  | -0.16*** | -0.05 | 0.11*** | -0.06* | -0.05* | 0.09*** | -0.01 | 0.04 | 0.06** | 0.06* | 1   |      |      |      |
| 12  | 0.08*** | 0.005 | -0.06* | -0.02 | -0.06** | -0.02 | -0.05 | 0.05* | 0.04 | -0.004 | -0.18*** | 1   |      |      |
| 13  | 0.06* | -0.08*** | -0.07** | -0.002 | -0.02 | 0.06** | 0.02 | -0.01 | 0.02 | 0.04 | 0.02 | 0.06* | 1   |      |
| 14  | -0.22*** | -0.10*** | 0.11*** | -0.12*** | -0.06** | 0.05* | -0.01 | 0.08** | 0.12*** | 0.05* | 0.27*** | -0.11*** | -0.04 | 1   |
| 15  | 0.11*** | 0.000 | -0.05* | 0.07** | -0.01 | -0.14*** | 0.06* | 0.01 | -0.02 | -0.22*** | -0.12*** | 0.14*** | -0.13*** | -0.11* |

* *p < 0.05
** p < 0.01
*** p < 0.001

1: Sex
2: Age
3: BMI
4: Siblings
5: Residence
6: Family structure
7: Perceived family affluence
8: Father education level
9: Mother education level
10: Number of friends
11: PA
12: ST
13: SLP
14: MSE days
15: Depression

PA: physical activity
ST: sedentary time
SLP: sleep duration
MSE: muscle-strengthening exercise
|     | 1 | 2   | 3 | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    | 13    | 14    |
|-----|---|-----|---|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1   | 1 |     |   |       |       |       |       |       |       |       |       |       |       |       |
| 2   | -0.04 | 1  |   |       |       |       |       |       |       |       |       |       |       |       |
| 3   | -0.31*** | 0.09*** | 1 |       |       |       |       |       |       |       |       |       |       |       |
| 4   | 0.13*** | 0.003 | -0.15*** | 1 |       |       |       |       |       |       |       |       |       |       |
| 5   | -0.06* | 0.09*** | 0.02 | 0.27*** | 1     |       |       |       |       |       |       |       |       |       |
| 6   | 0.12*** | -0.10*** | -0.04 | -0.04 | -0.19*** | 1     |       |       |       |       |       |       |       |       |
| 7   | 0.01 | 0.02 | 0.03 | -0.09*** | -0.04 | -0.11*** | 1     |       |       |       |       |       |       |       |
| 8   | 0.03 | -0.13** | 0.03 | -0.26*** | -0.33*** | 0.20*** | 0.01 | 1     |       |       |       |       |       |       |
| 9   | 0.03 | -0.18*** | 0.03 | -0.31*** | -0.33*** | 0.20*** | 0.03 | 0.61*** | 1     |       |       |       |       |       |
| 10  | -0.05 | 0.004 | -0.001 | -0.05* | -0.03 | 0.09*** | -0.002 | 0.02 | 0.07* | 1     |       |       |       |       |
| 11  | -0.16*** | -0.05 | 0.11*** | -0.06* | -0.05* | 0.09*** | -0.01 | 0.04 | 0.06** | 0.06* | 1     |       |       |       |
| 12  | 0.09*** | 0.01 | -0.06* | -0.02 | -0.06** | -0.02 | -0.05 | 0.05* | 0.04 | -0.004 | -0.18*** | 1     |       |       |
| 13  | 0.06* | -0.08*** | -0.07** | -0.002 | -0.02 | 0.06** | 0.02 | -0.01 | 0.02 | 0.04 | 0.02 | 0.06* | 1     |       |
| 14  | -0.22*** | -0.08** | 0.10*** | -0.11*** | -0.06* | 0.03 | 0.002 | 0.06* | 0.10*** | 0.05* | 0.28*** | 0.12*** | -0.01 | 1     |
| 15  | 0.11*** | 0.0004 | -0.05* | 0.07** | -0.01 | -0.14*** | 0.06* | 0.01 | -0.02 | -0.22*** | -0.12*** | 0.14*** | 0.13*** | -0.11** |}

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

1: Sex
2: Age
3: BMI
4: Siblings
5: Residence
6: Family structure
7: Perceived family affluence
8: Father education level
9: Mother education level
10: Number of friends
11: PA
12: ST
13: SLP
14: MSE days
15: Depression

PA: physical activity;
ST: sedentary time;
SLP: sleep duration;

MSE: muscle-strengthening exercise (MSE guidelines: reporting at least 2 days was regarded as meeting the guidelines).
Table 4
Multilevel regression model results between MSE days and depression

|                        | Beta  | 95% CI   | p value |
|------------------------|-------|----------|---------|
| Intercept              | 13.55 | 9.32     | 17.78   | 0.000   |
| Sex                    |       |          |         |         |
| Male                   | -0.86 | -1.38    | -0.35   | 0.001   |
| Female                 | Ref   |          |         |         |
| Siblings               |       |          |         |         |
| Single                 | -0.45 | -0.97    | 0.08    | 0.099   |
| Two or more            | Ref   |          |         |         |
| Residence              |       |          |         |         |
| Urban                  | 0.26  | -2.92    | 0.81    | 0.356   |
| Rural                  | Ref   |          |         |         |
| Family structure       |       |          |         |         |
| Full                   | -2.18 | -3.42    | -0.94   | 0.001   |
| Divorced               | -2.56 | -4.08    | -1.03   | 0.001   |
| Other                  | Ref   |          |         |         |
| Father education level |       |          |         |         |
| Middle school or below | -0.15 | -1.63    | 1.34    | 0.847   |
| High school            | 0.09  | -1.36    | 1.55    | 0.903   |
| College or university  | 0.28  | -1.21    | 1.77    | 0.714   |
| Master or above        | Ref   |          |         |         |
| Mother education level |       |          |         |         |
| Middle school or below | 0.18  | -1.63    | 1.98    | 0.848   |
| High school            | 0.21  | -1.56    | 1.98    | 0.815   |
| College or university  | 0.30  | -1.56    | 2.16    | 0.749   |
| Master or above        | Ref   |          |         |         |
| Number of friends      |       |          |         |         |
| None                   | 6.66  | 4.77     | 8.55    | 0.000   |
| 1–2                    | 2.52  | 1.78     | 3.26    | 0.000   |
| 3–5                    | 1.20  | 0.50     | 1.90    | 0.001   |
| 6 or more              | Ref   |          |         |         |
| Age                    | -0.06 | -0.20    | 0.09    | 0.427   |
| Perceived family       | -0.35 | -0.50    | -0.21   | 0.000   |

BMI: body mass index;
PA: physical activity;
ST: sedentary time;
SLP: sleep time;
MSE: muscle-strengthening exercise.
|                | Beta  | 95% CI  | P value |
|----------------|-------|---------|---------|
| BMI            | -0.01 | -0.10   | 0.07    | 0.805  |
| PA             | -0.001| -0.004  | 0.0002  | 0.085  |
| ST             | 0.002 | 0.002   | 0.003   | 0.000  |
| SLP            | -0.01 | -0.01   | -0.005  | 0.000  |
| **MSE days (0–7 days)** | **-0.17** | **-0.31** | **-0.03** | **0.015** |

BMI: body mass index;  
PA: physical activity;  
ST: sedentary time;  
SLP: sleep time;  
MSE: muscle-strengthening exercise.
Table 5
The association between MSE guidelines and depression by multilevel regression model.

|                  | Beta  | 95% CI    | p value |
|------------------|-------|-----------|---------|
| Intercept        | 12.75 | 8.52      | 16.97   | 0.000   |
| Sex              |       |           |         |         |
| Male             | -0.88 | -1.39     | -0.36   | 0.001   |
| Female           | Ref   |           |         |         |
| Siblings         |       |           |         |         |
| Single           | -0.46 | -0.99     | 0.07    | 0.089   |
| Two or more      | Ref   |           |         |         |
| Residence        |       |           |         |         |
| Urban            | 0.26  | -0.29     | 0.82    | 0.353   |
| Rural            | Ref   |           |         |         |
| Family structure |       |           |         |         |
| Full             | -2.18 | -3.42     | -0.94   | 0.001   |
| Divorced         | -2.53 | -4.06     | -1.01   | 0.001   |
| Other            | Ref   |           |         |         |
| Father education level |       |           |         |         |
| Middle school or below | -0.17 | -1.65     | 1.32    | 0.825   |
| High school      | 0.07  | -1.39     | 1.53    | 0.924   |
| College or university | 0.24  | -1.25     | 1.73    | 0.756   |
| Master or above  | Ref   |           |         |         |
| Mother education level |       |           |         |         |
| Middle school or below | 0.26  | -1.54     | 2.06    | 0.777   |
| High school      | 0.31  | -1.46     | 2.07    | 0.734   |
| College or university | 0.41  | -1.45     | 2.26    | 0.666   |
| Master or above  | Ref   |           |         |         |
| Number of friends |       |           |         |         |
| None             | 6.59  | 4.70      | 8.48    | 0.000   |
| 1–2              | 2.53  | 1.79      | 3.27    | 0.000   |
| 3–5              | 1.20  | 0.50      | 1.90    | 0.001   |
| 6 or more        | Ref   |           |         |         |
| Age              | -0.05 | -0.20     | 0.09    | 0.467   |
| Perceived family affluence | -0.36 | -0.50     | -0.21   | 0.000   |
| BMI              | -0.01 | -0.02     | 0.00    | 0.875   |
| PA               | -0.002| 0.00      | 0.00    | 0.884   |
| ST               | 0.002 | 0.00      | 0.00    | 0.000   |
| SLP              | -0.01 | -0.01     | 0.00    | 0.000   |

MSE: muscle-strengthening exercise (MSE guidelines: reporting at least 2 days was regarded as meeting the guidelines).

BMI: body mass index;
PA: physical activity;
ST: sedentary time;
SLP: sleep time;
|                  | Beta | 95% CI | p value |
|------------------|------|--------|---------|
| Not meeting      | 0.63 | 0.07   | 1.19    | 0.027   |
| Meeting          | Ref  |        |         |         |

BMI: body mass index;  
PA: physical activity;  
ST: sedentary time;  
SLP: sleep time;  
MSE: muscle-strengthening exercise (MSE guidelines: reporting at least 2 days was regarded as meeting the guidelines).