ARTICLE

Muscle-Strengthening Exercise Links with Lower Odds for Depression in Adolescents

Weijun Yu[1,2], Jiangang Sun[3], Ying Wu[1,*] and Si-Tong Chen[4]

[1]School of Physical Education and Sport Training, Shanghai University of Sport, Shanghai, 200438, China

[2]Faculty of Sport, College of Teacher Education, Taizhou University, Taizhou, 317000, China

[3]School of Physical Education, West Anhui University, Luan, 237012, China

[4]Institute for Health and Sport, Victoria University, Melbourne, 8001, Australia

[*]Corresponding Author: Ying Wu. Email: wuying135790@163.com

ABSTRACT

Purpose: Physical activity is a well-recognized protective factor against depression in adolescents. As a component of physical activity, muscle strengthening exercise (MSE) is also viewed as a correlate associated with lower risks of depression in adults. However, little is known about the association in adolescents. This study aimed to explore the association between MSE and depression in a sample of Chinese adolescents. **Method:** A self-reported questionnaire was used for data collection including variables of MSE, depression (assessed by Children's Depression Inventory) and selected sociodemographic factors (e.g., sex, grade, height and weight [for body mass index]). Generalized Linear Models was utilized to estimate the association between MSE and depression. **Results:** Results showed a negative association between MSE and depression (Beta = –0.66; both MSE and depression were treated as continuous variables). When treating MSE (meeting or not meeting the recommendations) and depression as binary variables, odds ratio for depression in adolescents not meeting the MSE recommendation was significant higher (odd ratio = 1.50, 95%CI: 1.15–1.96) than those meeting the MSE recommendations. **Conclusions:** This study found that MSE may be a protective factor against MSE in adolescents. Future studies are encouraged to confirm or negate our study finding using improved study design.

KEYWORDS

Physical activity; muscle strengthening activities; depression; middle and high school students

1 Introduction

Depression is a common mental disorder which not only affects individuals' physical and mental health, but also causes serious social problems [1]. According to the Diagnostic and Statistical Manual for Mental Disorders 5th Edition (DSM-V), low mood and anhedonia is the core symptoms of depression, with abnormal weight gain and loss, insomnia or drowsiness as additional symptoms a mood dysregulation [2]. The World Health Organization declares that depression has become the world's second largest health risk factor by 2020 [3]. It is also predicted that by 2030, depression will become the first global burden of disease factors [4]. Therefore, effective preventions against depression has been listed as an important public health issue in many countries.

Furthermore, adolescence is a transitional period from immaturity to maturity, undergoing tremendous changes in physical and mental indicators, which leads to an increased likelihood of adolescent' depression. In the United States, approximately 15% of children and adolescents were diagnosed as with severe depression [5]. China based research also showed that 20% to 44% of adolescents had depressive symptoms [6]. Recently, a number of cross-sectional studies found that adolescent depression can result in school dropout [7], and a higher risk for unhealthy lifestyle behaviors such as smoking and alcohol abuse, as well as severe social and cognitive impairment [8]. Therefore, adolescent depression is an urgent public health issue to be addressed and prevented from multiple effective approaches.

Early studies have found that adequate physical activity (PA) can reduce the incidence of depression in adolescents [9–11]. Recent methodological developments have led to the establishment of a new framework, called time-use epidemiology, where periods of time spent in PA, SB and sleep are no longer considered as independent risk factors, but instead are treated as mutually exclusive and exhaustive parts of the 24-h day [12–14]. Therefore, it should be considered as a whole, when it affects health. In this line, it is worthwhile to examine the association between specific components of PA and health outcomes in various population groups.

To reduce the burden of depression, it is necessary to understand factors influencing depression in adolescents. From a perspective from behavioural epidemiology, increasing PA is a protective factor against depression in adolescents. As a component of PA, muscle strengthening exercise (MSE) has been recognized as promotion factor of individuals' health [15–17]. Hence, the World Health Organization (WHO) recommends that children and adolescents should engage in MSE for three times per week [16]. Recently, in addition to examining the association between overall PA and depression in different groups populations, researchers have explored the association between MSE and depression in adults. For example, using nationally representative samples in Germany adults, Bennie et al. [18] found that more days engaged in MSE was negatively associated with severity of depression in adults. Another study also by Bennie et al. [19] suggested that more days for MSE may reduce the odds for depression regardless of levels of PA in the US adults. The evidence based on cross-sectional research could also be supported by randomized controlled trials [20,21]. In general, evidence from the observational and experimental studies suggested that any increases in MSE at the population-level may be beneficial for prevention and treatment of depression. It can be therefore hypothesized that MSE will be associated with depression in young people.

However, some research gaps remain across the literature. As mentioned above, most studies were based on adults rather than young people, such as adolescents. It is thus, to examine the association between MSE and depression in adolescents, which can help and inform more approaches to promote mental health in adolescents. The other reason for examining the association between MSE and depression in adolescents is that this can provide more research evidence to support the health benefits of MSE, which in turn offers evidence-base for relevant public health strategies and guidelines. Moreover, previous studies have failed to control sufficient sociodemographic factors to assess the association between MSE and depression, which may elicit bias. The final gap relates with studied population, where previous studies selected western populations. little is known about that in Chinese population groups, like adolescents. Hence, to fill the gaps in the literature, this study aimed to explore the association between MSE and depression while controlling for some selected sociodemographic factors in Chinese adolescents.

2 Method

2.1 Study Design and Participant

This study was a cross-sectional survey which was designed to explore the different kinds of physical activity and associated multiple health outcomes (e.g., behavioural, physical and mental health), conducted from October to December 2018 in Taizhou, Zhejiang Province of China. The research staff contacted

10 schools (5 middle schools and 5 high schools), of which three middle schools and 4 high schools consented to participate in this study. In middle school, we randomly selected 5 classes and all students from the classes were voluntarily invited as study participants. The same procedure was replicated in high schools. In total, 2970 students were invited to participate in the survey. Data were collected and analysed anonymously. In response, 2432 students (response rate = 81.9%) completed the self-reported questionnaire. The questionnaire consisted of 30 questions, such as participants' sociodemographic information (e.g., sex, grade and residence), physical activity and sedentary time, beliefs towards their children's exercise and MSE. The study protocol and procedure were approved by the Institutional Review Board (IRB) of Taizhou University in June 2018. Participants and their legal guardians provided written consent. To improve the reliability and validity of the survey, the research staff promised that participants' information will be strictly protected and treated anonymously.

2.2 Measures

2.2.1 Muscle-Strengthening Exercise (MSE)

The study participants were required to answer the following question "how many days did you do muscle-strengthening exercise (MSE) over the past week?" In this context, MSE was defined as "activities involving major muscle groups like push-ups, weightlifting, curl-ups or pull-ups". Responses for study participants ranged from 0 to 7 days (continuous variable). There is evidence to support the reliability and validity of this question in the previous studies [22,23]. According to the WHO guidelines, it is recommended that children and adolescents should accumulate 3 days for MSE a week for health promotion [16,17]. Thus, the variable of MSE can be categorised into a binary variable (meeting or not meeting).

2.2.2 Depression

Depression was assessed by Children's Depression Inventory (CDI), which has been validated in Chinese children and adolescents [24]. CDI was a scale to screen children's depression. Its Cronbach alpha coefficient was 0.82, test-retest reliability coefficient was 0.89 [24]. The CDI has 27 questions to assess children and adolescents' depressive symptoms, of which each item is rated 0–2 scores. In sum, the overall scores of CDI ranges 0 to 54 [24]. The study participants rated with a score of 19 or above are screened as having depression positively based on previous studies [25].

2.2.3 Covariates

Based on previous studies [18,19,26–28], covariates in the current study included sex (boy or girl), grade (7, 8,…11), ethnicity (Han or minority), residence (urban or rural), self-reported height (cm) and weight (kg), siblings (none or at least having one), perceived family affluence (very rich, rich, average, poor, very poor), father and mother's education level (middle school or below, high school or primary occupation school, senior occupation school, college or university, master and above).

2.3 Data Analysis

Statistical analyses were performed using STATA 16.1 (Stata Corp, College Station, Texas). First, descriptive statistics were used to report frequency (percentage) and mean (standard deviation) of categorical and continuous variables, respectively. Continues variables was confirmed as normal distribution using Shapiro-Wilk test. Differences in categorical and continuous variables across different groups were examined by *chi* square test and student *t* tests, respectively. To explore the association between MSE and depression, two models were established using Generalized Linear models with maximum likelihood estimate. The first model was based on treatment that the variables of MSE and depression were continuous variables, which explored the days of engagements in MSE and depression scores. Beta with 95% confidence interval (CI) was reported. The second model treated the variables of

MSE and depression as binary variable based on the well-acceptable cutoffs [16,24,25]. In this model, a binary logistic regression was used to explore the associations between MSE and depression after controlling for all the covariates in this study. Not meeting the MSE recommendation (at least 3 days a week) [16] was set as reference group and we compared the likelihood of meeting the MSE recommendations for not having depression with those not meeting the MSE recommendation. Odds ratio (OR) and its 95% confidence interval (CI) was reported as estimated values. Statistical significance was set up as $p < 0.05$ (two sided).

3 Results

Tab. 1 shows general characteristics of study participants of this study. Of 2432 participants, boys accounted for 47.7% (n = 1159). The proportion of study participants in each grade (7–11) ranged from 17.3% to 24.2%, while there was no sex difference in the grades ($p > 0.05$). Over 50% of study participants had siblings in their family. As for the residence and race, the majority of study participants lived in urban areas and were Han race people. The mean of BMI was 20.2 with as standard deviation of 3.1. The prevalence of meeting the MSE recommendation was 21.3%, with a sex difference that more boys met the recommendation ($p < 0.001$). Similarly, 21.5% of study participants were determined as depression. More details can be found in Tab. 1.

Table 1: General characteristics of study participants of this study

		Total		Boy		Girl		p value for sex difference
		n	%	n	%	n	%	
Total		2432	100.0	1159	47.7	1273	52.3	/
Grades								
	7	588	24.2	290	25.0	298	23.4	0.351
	8	536	22.0	239	20.6	297	23.3	
	9	421	17.3	199	17.2	222	17.4	
	10	436	17.9	203	17.5	233	18.3	
	11	451	18.5	228	19.7	223	17.5	
Siblings								
	None	1143	47.0	598	51.6	545	42.8	0.000
	Having at least one	1289	53.0	561	48.4	728	57.2	
Residence								
	Urban	1877	77.2	875	75.5	1002	78.7	0.059
	Rural	555	22.8	284	24.5	271	21.3	
Race								
	Han	2357	96.9	1120	96.6	1237	97.2	0.444
	Minority	75	3.1	39	3.4	36	2.8	
Body mass index (mean ± sd)		20.2	3.1	20.9	3.5	19.6	2.6	0.000

(Continued)

Table 1 (continued).

		Total		Boy		Girl		*p* value for sex difference
		n	%	n	%	n	%	
Perceived family affluence								
	Very rich	98	4.0	48	4.1	50	3.9	0.062
	Rich	661	27.2	302	26.1	359	28.2	
	Average	1214	49.9	565	48.7	649	51.0	
	Poor	384	15.8	199	17.2	185	14.5	
	Very poor	75	3.1	45	3.9	30	2.4	
Father education level								
	Middle school or below	900	37.0	428	36.9	472	37.1	0.000
	High school or primary occupation school	776	31.9	375	32.4	401	31.5	
	Senior occupation school	278	11.4	82	7.1	196	15.4	
	College or university	372	15.3	206	17.8	166	13.0	
	Master or above	106	4.4	68	5.9	38	3.0	
Mother education level								
	Middle school or below	1105	45.4	529	45.6	576	45.2	0.000
	High school or primary occupation school	685	28.2	313	27.0	372	29.2	
	Senior occupation school	216	8.9	71	6.1	145	11.4	
	College or university	351	14.4	190	16.4	161	12.6	
	Master or above	75	3.1	56	4.8	19	1.5	

Table 1 (continued).

		Total		Boy		Girl		*p* value for sex difference
		n	%	n	%	n	%	
Days for muscle strengthening exercise								
	0	1463	60.2	618	53.3	845	66.4	0.000
	1	188	7.7	82	7.1	106	8.3	
	2	264	10.9	128	11.0	136	10.7	
	3	221	9.1	139	12.0	82	6.4	
	4	104	4.3	65	5.6	39	3.1	
	5	96	3.9	57	4.9	39	3.1	
	6	55	2.3	43	3.7	12	0.9	
	7	41	1.7	27	2.3	14	1.1	
Meeting the muscle strengthening exercise recommendations								
	Not meeting	1915	78.7	828	71.4	1087	85.4	0.000
	Meeting	517	21.3	331	28.6	186	14.6	
Depression (mean ± sd)		12.8	10.1	11.6	10.1	13.9	9.9	
Depression categorization								0.000
	Depression	522	21.5	215	18.6	307	24.1	0.001
	Non-depression	1910	78.5	944	81.4	966	75.9	

Note: Sd: standard deviation.

Tab. 2 displays the results for the associations between days for MSE and depression scores. In the full model, days for MSE was negatively associated with depression (beta = −0.66, 95%CI: −0.88 − −0.44, $p < 0.01$). The associations of other factors with depression can found in Tab. 2. In Tab. 3, the results from logistic regression are presented. Adolescents meeting the MSE recommendations were more likely to be determined as non-depression (OR = 1.50, 95%CI: 1.15–1.96). More information can be seen in Tab. 3 as well.

4 Discussion

This study aimed to explore the association between MSE and depression in a sample of Chinese adolescents (grades of 7–11). Based on the results of the current study, we mainly found that more days for MSE was negatively associated with depression in adolescents. Specifically, one more day for engagement in MSE was negatively associated with lower odds for depression (beta = −0.66), and also, meeting the MSE recommendations was positively associated with screening as non-depression (OR = 1.50, 95%CI: 1.15–1.96). There is a minor research finding that is only 21.1% of adolescents in this study met the MSE recommendations.

Table 2: The association between muscle strengthening exercise and depression (continuous variables)

		Beta	95%CI		p value
Grades					
	11	−1.57	−2.78	−0.36	0.01
	10	−2.37	−3.59	−1.16	0.00
	9	−0.53	−1.76	0.70	0.40
	8	−0.50	−1.66	0.66	0.40
	7	Ref			
Sex					
	Boy	−2.29	−3.09	−1.49	0.00
	Girl	Ref			
Siblings					
	Having one or more	1.38	0.49	2.27	0.00
	None	Ref			
Residence					
	Rural	−0.81	−1.87	0.25	0.13
	Urban	Ref			
Perceived family affluence					
	Very poor	6.85	3.92	9.78	0.00
	Poor	5.06	2.87	7.24	0.00
	Average	1.28	−0.73	3.29	0.21
	Rich	0.59	−1.48	2.66	0.58
	Very rich	Ref			
Father education level					
	Master and above	0.22	−2.35	2.79	0.87
	College or university	0.41	−1.22	2.03	0.62
	Senior occupation school	0.92	−0.75	2.59	0.28
	High school or primary occupation school	0.68	−0.39	1.75	0.21
	Middle school or below	Ref			
Mother education level					
	Master and above	−2.12	−5.07	0.83	0.16
	College or university	−1.82	−3.49	−0.14	0.03
	Senior occupation school	−0.04	−1.84	1.76	0.96
	High school or primary occupation school	−0.29	−1.39	0.80	0.60
	Middle school or below	Ref			
Body mass index		−0.03	−0.16	0.09	0.62
Muscle–strengthening exercise days		−0.66	−0.88	−0.44	0.00

Note: CI: confidence interval.

Table 3: The association between muscle strengthening exercise and depression (Binary variable)

		OR	95%CI	
Grades				
	11	4.54	1.85	11.13
	10	1.31	0.95	1.80
	9	1.35	0.98	1.87
	8	0.98	0.73	1.34
	7	1.08	0.81	1.44
	6	Ref		
Sex				
	Boy	1.40	1.15	1.70
	Girl	Ref		
Siblings				
	Having one or more	0.75	0.60	0.95
	None	Ref		
Residence				
	Rural	1.19	0.91	1.55
	Urban	Ref		
Perceived family affluence				
	Very poor	0.28	0.14	0.57
	Poor	0.43	0.24	0.76
	Average	0.88	0.51	1.52
	Rich	1.11	0.63	1.96
	Very rich	Ref		
Father education level				
	Master and above	0.62	0.31	1.24
	College or university	0.84	0.55	1.28
	Senior occupation school	0.59	0.39	0.90
	High school or primary occupation school	0.74	0.57	0.96
	Middle school or below	Ref		
Mother education level				
	Master and above	2.08	0.85	5.07
	College or university	1.52	0.97	2.39
	Senior occupation school	0.92	0.59	1.42
	High school or primary occupation school	1.03	0.79	1.36
	Middle school or below	Ref		

(Continued)

Table 3 (continued).

		OR	95%CI	
Body mass index		1.00	0.97	1.04
Muscle strengthening exercise days				
	Meeting the recommendations	1.50	1.15	1.96
	Not meeting the recommendations	Ref		

Note: OR: odd ratio; CI: confidence interval; Ref: reference group; The reference group was screened for depression.

To our knowledge and date, very few studies based on Chinese children and adolescents reported the prevalence of meeting the MSE recommendations. The current study adds to the current literature, and we found that only about one in fifth of adolescents met the recommended MSE recommended by the World Health Organization (3 days a week). The prevalence of meeting the MSE recommendation (21.2%) was lower than the previous studies based on Australia children [23] and American children [22]. This difference, to some extent, suggests that Chinese adolescents may have weak awareness of engagements in MSE and know little about its associated health benefits, which may be a barrier to their health promotion and overall development. In addition to this, to date, epidemiological surveys on MSE in China remains scant. It is required to conduct more surveys to capture the levels and trends in MSE in Chinese children and adolescents, which would add more meaningful significance and clinical relevance for better understanding of populational physical activity [15].

This is the first epidemiological survey to assess the association between MSE and depression in Chinese adolescents. However, owing to paucity of evidence based on young people, we cannot compare our result with other research focusing on children and adolescents. Consistent with research focusing on adults [18,19], the current study found that more participations in MSE were associated with lower odds for depression. Based on evidence from studies using adult samples, our study finding can be supported. Besides, our research finding on the association between MSE and depression can also be corroborated by evidence from randomized controlled trials [20,29]. There are some possible underlying mechanisms to explain the associations, including psychosocial (e.g., enhanced self-efficacy, self-esteem and, social connectedness), and neurobiological (e.g., changes in neuroplastic mechanisms, increasing cerebral blood flow, reducing oxidative stress and inflammation). Although, given the complexity of mental health problems such as depression, it is likely the mechanisms are multifactorial. Furthermore, contrasted to the decades of mechanistic research on the anti-depressive effects of aerobic exercise, comparative research on MSE is limited [20,29], and hence warrants further study to clearly explore the underlying mechanism.

4.1 Practical Implications

It has been recognized that engagements in MSE is an incentive to young people's health [16,17]. Since the importance of MSE to health promotion, it is needed to improve the prevalence of MSE in adolescents. Put another, adolescents are encouraged to engage in more MSE for health promotion. Finding effective ways to promote adolescents' MSE would be a next research issue. With this reference, exploring the correlates of adolescents' MSE is a necessary step. However, the relevant research is scant. Therefore, it is recommended to determine the correlates and determinants of adolescents' MSE and studying an efficient way to making adolescents participate in more MSE.

As this study found positive roles of MSE and associated benefits in reducing depression, future studies could incorporate MSE into depression preventions and interventions. However, when doing this, more research is strongly recommended to examine the effectiveness and generalisation of an intervention including MSE that aims at reducing depression in adolescents. Although we provide the preliminary

evidence, other researchers should also consider feasibility of MSE as mental health promotion approach at the population level. Therefore, a series of studies are strongly encouraged to conduct.

4.2 Study Limitations

Our study findings should be interpreted in light of some inherent limitations. First of all, it must be mentioned that our study design was cross-sectional design. Owing to the nature of cross-sectional design, it is impossible to draw a cause-and-effect relationship between MSE and depression in adolescents. Second, the measure of MSE was self-reported, which could result in measurement error and recall bias because of study participants' social desirability and relatively low accuracy. This would be a disadvantage or bias to assess the association between MSE and depression. We should also admit a limitation that may result from sampling. Because our study participants were recruited using a convenient sampling method, it is thus possible that generalisation of our research findings may be limited. The final study limitation is covariates. It is well-recognized that depressive is influenced by a large number of factors. However, we failed to include covariates as many as possible, which may negatively affect the estimation of association between MSE and depression in adolescents. Hence, future studies are encouraged to address the limitations of our study to generate robust evidence.

5 Conclusion

This study found that only about 20% of Chinese children and adolescents met the recommended days for MSE and also demonstrated a negative association between MSE and depression. This study stresses of importance of MSE for health promotion, especially mental health problems prevention, in children and adolescents. However, improved studies with well-constructed designs are encouraged to confirm the casual association between MSE and depression in adolescents, which can inform efficient depression interventions.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

References

1. Li, J. Y., Li, J., Liang, J. H., Qian, S., Jia, R. X. et al. (2019). Depressive symptoms among children and adolescents in China: A systematic review and meta-analysis. *Medical Ence Monitor International Medical Journal of Experimental & Clinical Research, 25(22),* 283–303.

2. American Psychiatric Association (1994). *Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR).* American Psychiatric Association, Washington DC, USA.

3. Tengilimoğlu, D., Zekioğlu, A., Tosun, N., Işık, O., Tengilimoğlu, O. (2021). Impacts of COVID-19 pandemic period on depression, anxiety and stress levels of the healthcare employees in Turkey. *Legal Medicine, 48(32),* 423–439.

4. Reddy, M. S. (2010). Depression: The disorder and the burden. *Indian Journal of Psychological Medicine, 32(1),* 1–2. DOI 10.4103/0253-7176.70510.

5. Birmaher, B., Ryan, N. D., Williamson, D. E., Brent, D. A., Kaufman, J. et al. (1996). Childhood and adolescent depression: A review of the past 10 years. Part I. *Journal of the American Academy of Child and Adolescent Psychiatry, 35(12),* 1575–1583. DOI 10.1097/00004583-199612000-00008.

6. Sheng, F. L., Dan, S., Ming, S. Z. (2009). Characteristics of anxiety and depression in adolecents. *Chinese Journal of Clinical Psychology, 17(4),* 468–470.

7. Karadag, M. (2020). Evaluation of depression and anxiety levels in school dropout adolescents. *Journal of Clinical Psychiatry, 23(3),* 274–279.

8. Goldstein, A. L., Faulkner, B., Wekerle, C. (2013). The relationship among internal resilience, smoking, alcohol use, and depression symptoms in emerging adults transitioning out of child welfare. *Child Abuse & Neglect, 37(1),* 22–32. DOI 10.1016/j.chiabu.2012.08.007.

9. Sanchez-Villegas, A., Ara, I., Guillen-Grima, F., Bes-Rastrollo, M., Varo-Cenarruzabeitia et al. (2008). Physical activity, sedentary index, and mental disorders in the SUN cohort study. *Medicine & Science in Sports & Exercise, 40(5),* 827–834. DOI 10.1249/MSS.0b013e31816348b9.

10. Rebar, A. L., Vandelanotte, C., van Uffelen, J., Short, C., Duncan, M. J. (2014). Associations of overall sitting time and sitting time in different contexts with depression, anxiety, and stress symptoms. *Mental Health & Physical Activity, 7(2),* 105–110. DOI 10.1016/j.mhpa.2014.02.004.

11. Bao, X. B., Yan, H. S., Kai, X., Wen, H. W. (2019). A meta-analysis of the relationship between sleep quality and depression in Chinese college students. *Chinese Journal of Health Statistics, 36(3),* 420–422.

12. Dumuid, D., Stanford, T. E., Martin-Fernández, J. A., Pedišić, Ž., Maher, C. A. et al. (2018). Compositional data analysis for physical activity, sedentary time and sleep research. *Statistical Methods in Medical Research, 27(12),* 3726–3738. DOI 10.1177/0962280217710835.

13. Liangruenrom, N., Suttikasem, K., Craike, M., Bennie, J. A., Biddle, S. J. et al. (2018). Physical activity and sedentary behaviour research in Thailand: a systematic scoping review. *BMC Public Health, 18(1),* 314. DOI 10.1186/s12889-018-5643-y.

14. Pedišić, Ž. (2014). Measurement issues and poor adjustments for physical activity and sleep undermine sedentary behaviour research-The focus should shift to the balance between sleep, sedentary behaviour, standing and activity [Problemi u mjerenju i neadekvatna parcijalizac]. *Kinesiology International Scientific Journal of Kinesiology & Sport, 46(1),* 135–146.

15. Bennie, J. A., Shakespear-Druery, J., De Cocker, K. (2020). Muscle-strengthening Exercise Epidemiology: A New Frontier in Chronic Disease Prevention. *Sports Medicine-Open, 6(1),* 1102. DOI 10.1186/s40798-020-00271-w.

16. World Health Organization (2020). WHO guidelines on physical activity and sedentary behaviour. https://www.who.int/publications/i/item/9789240015128.

17. World Health Organization (2020). WHO guidelines on physical activity and sedentary behaviour: web annex: evidence profiles. https://apps.who.int/iris/handle/10665/336657.

18. Bennie, J. A., Teychenne, M., Tittlbach, S. (2020). Muscle-strengthening exercise and depressive symptom severity among a nationally representative sample of 23,635 german adults. *Journal of Affective Disorders, 266(7),* 282–287. DOI 10.1016/j.jad.2020.01.172.

19. Bennie, J. A., De Cocker, K., Biddle, S. J., Teychenne, M. J. (2020). Joint and dose-dependent associations between aerobic and muscle-strengthening activity with depression: A cross-sectional study of 1.48 million adults between 2011 and 2017. *Depresssion and Anxiety, 37(2),* 166–178. DOI 10.1002/da.22986.

20. Gordon, B. R., McDowell, C. P., Hallgren, M., Meyer, J. D., Lyons, M. et al. (2018). Association of efficacy of resistance exercise training with depressive symptoms: meta-analysis and meta-regression analysis of randomized clinical trials. *JAMA Psychiatry, 75(6),* 566–576. DOI 10.1001/jamapsychiatry.2018.0572.

21. Brignardello-Petersen, R., Izcovich, A., Rochwerg, B., Florez, I. D., Hazlewood, G. et al. (2020). *GRADE approach to drawing conclusions from a network meta-analysis using a partially contextualised framework,* pp. 371–379. Washington DC, USA, BMJ.

22. Morrow, J. R. Jr, Tucker, J. S., Jackson, A. W., Martin, S. B., Greenleaf, C. A. et al. (2013). Meeting physical activity guidelines and health-related fitness in youth. *American Journal of Preventive Medicine, 44(5),* 439–444. DOI 10.1016/j.amepre.2013.01.008.

23. Smith, J. J., Diallo, T. M., Bennie, J. A., Tomkinson, G. R., Lubans, D. R. (2020). Factors associated with adherence to the muscle-strengthening activity guideline among adolescents. *Psychology of Sport and Exercise, 51(Supplement 2),* 101747. DOI 10.1016/j.psychsport.2020.101747.

24. Wu, W. F., Lu, Y. B., Tan, F. R., Yao, S. Q. (2010). Reliability and validity of the Chinese version of Children's Depression Inventory. *Chinese Mental Health Journal, 24(10),* 775–779.

25. Wu, W., Lu, Y., Tan, F., Yao, S., Steca, P. et al. (2012). Assessing measurement invariance of the children's depression inventory in Chinese and Italian primary school student samples. *Assessment, 19(4),* 506–516. DOI 10.1177/1073191111421286.

26. Gu, J., Chen, S. T. (2020). Association between active travel to school and depressive symptoms among early adolescents. *Children, 7(5),* 41–54. DOI 10.3390/children7050041.

27. Lin, J., Guo, T., Becker, B., Yu, Q., Chen, S. T. et al. (2020). Depression is associated with moderate-intensity physical activity among college students during the COVID-19 pandemic: Differs by activity level, gender and gender-role. *Psychology Research and Behavior Management, 13,* 1123.

28. Lu, C., Chi, X., Liang, K., Chen, S. T., Huang, L. et al. (2020). Moving more and sitting less as healthy lifestyle behaviors are protective factors for insomnia, depression, and anxiety among adolescents during the COVID-19 pandemic. *Psychology Research and Behavior Management, 13,* 1223–1233.

29. Gordon, B. R., McDowell, C. P., Lyons, M., Herring, M. P. (2017). The effects of resistance exercise training on anxiety: A meta-analysis and meta-regression analysis of randomized controlled trials. *Sports Medicine, 47(12),* 2521–2532. DOI 10.1007/s40279-017-0769-0.