Smith, Jordan J.; Diallo, Thierno M. O.; Bennie, Jason A.; Tomkinson, Grant R.; Lubans, David R. "Factors associated with adherence to the muscle-strengthening activity guideline among adolescents". *Psychology of Sport and Exercise* Vol. 51, Issue November 2020, no. 101747 (2020).

Available from: http://dx.doi.org/10.1016/j.psychsport.2020.101747

Factors associated with adherence to the muscle-strengthening activity guideline among adolescents

Jordan J. SMITH, PhD[a,§], Thierno M. O. DIALLO, PhD[b], Jason A. BENNIE, PhD[c], Grant R. TOMKINSON, PhD[d e] and David R. LUBANS, PhD[a]

[a]Priority Research Centre for Physical Activity and Nutrition, School of Education, University of Newcastle, Callaghan, NSW, Australia.
[b]School of Social Sciences and Psychology, Western Sydney University, Kingswood, NSW, Australia.
[c]Physically Active Lifestyles Research Group, Institute for Resilient Regions, University of Southern Queensland, Springfield, QLD, Australia.
[d]Department of Education, Health and Behavior Studies, University of North Dakota, Grand Forks, ND, United States of America.
[e]Alliance for Research in Exercise, Nutrition and Activity (ARENA), School of Health Sciences, University of South Australia, Adelaide, SA, Australia

Running title
Correlates of adolescents' muscle-strengthening activity

§**Corresponding author**
Jordan J. Smith, PhD
Priority Research Centre for Physical Activity and Nutrition
School of Education, University of Newcastle
Callaghan, NSW, Australia, 2308
Email: jordan.smith@newcastle.edu.au
Telephone: +61 2 4921 7704
Fax: +61 2 4921 2084

Trial registration number: ACTRN12615000360516

Disclosure of interest: The authors report no conflicts of interest.

Funding and acknowledgements: This research was funded by the Australian Research Council (Grant number: FT140100399) and the New South Wales Department of Education School Sport Unit. DRL is supported by a National Health and Medical Research Council Career Development Fellowship. JS has received travel support from Ms Jennie Thomas and the Hunter Medical Research Institute. The authors would like to thank Ms Tara Finn and Ms Emma Pollock for their assistance with data collection, and all schools, teachers and students for their involvement in this research.

ABSTRACT

Purpose. We aimed to explore associations between guideline-concordant muscle-strengthening activity (MSA) and demographic, biological, psychosocial, and behavioral factors among Australian adolescents.

Methods. We used baseline data from the 'Resistance Training for Teens' cluster randomized controlled trial (collected April–June, 2015). Adolescents (n = 602, mean age = 14.1±0.5 years, 50% female) from 16 schools in New South Wales, Australia self-reported their sex, primary language spoken at home, postal code (for socioeconomic status), resistance training (RT) self-efficacy, motivation for RT, perceived strength, moderate-to-vigorous physical activity (MVPA), screen-time, and sleep. Participants also completed tests of height, weight, cardiorespiratory and muscular fitness, flexibility, and RT skills. MSA was self-reported and participants were dichotomized as 'meeting' (3–7 days) or 'not meeting' (0–2 days) the MSA guideline. Binary logistic regression with odds ratios (OR) was used to determine associations with adolescents' MSA.

Results. Analyses for each variable group explained a small-to-moderate amount of variance in MSA. Sex, muscular fitness, RT self-efficacy, perceived strength, and total MVPA emerged as statistically significant factors. However, only RT self-efficacy (OR = 2.48 [1.37 to 4.50]) and total MVPA (OR = 1.48 [1.22 to 1.79]) were associated with guideline-concordant MSA in the full model, which explained 52% of the variance.

Conclusions. Our study adds to the limited understanding of adolescents' MSA behavior. RT self-efficacy and total MVPA were independently associated with guideline-concordant MSA among Australian adolescents. The findings have implications for the design and delivery of future interventions targeting adolescents' MSA behavior.

Key words: resistance training; youth; exercise; fitness; strength; correlates

HIGHLIGHTS

- One in three adolescents met the WHO muscle-strengthening activity (MSA) guideline
- One in four adolescents reported completing no MSA at all
- Males were more likely than females to meet the MSA guideline
- In the fully adjusted model, resistance training self-efficacy and overall PA were independently related to guideline-concordant MSA

INTRODUCTION

Muscle-strengthening physical activities (MSA), including formal resistance training (RT) and certain leisure-time activities (e.g., climbing on playground equipment), contribute to the health and well-being of school-aged youth. For example, clinical studies conducted with children and adolescents have demonstrated the efficacy of resistance training (RT) for improving various health-related outcomes, including body composition, insulin sensitivity, sports-injury risk, self-esteem, and sports performance (1). Moreover, muscular fitness is associated with skeletal health, total and central adiposity, cardiovascular/metabolic parameters, and self-perceptions (2). Such associations might explain why muscular fitness during adolescence predicts morbidity and mortality in adulthood (3), and highlights the need to support youths' MSA participation.

Of note, the World Health Organization (WHO) has, since 2010, explicitly recommended youth aged 5–17 years engage in activities to strengthen muscle and bone at least three times per week (4). First introduced in the 2008 'Physical Activity Guidelines for Americans', this recommendation has since been adopted by a number of countries, including the United Kingdom (U.K.), Canada, Australia, and 19 member states of the European Union. Despite its widespread endorsement there is surprisingly little global data describing youth participation in MSA. In particular, the proportion of youth engaging in sufficient (or 'guideline-concordant') MSA is largely unknown. Indeed, the most recent global matrix of report card grades on physical activity for children and adolescents did not mention MSA, focusing instead on participation rates for organized sports, active play, active transportation, recreational screen-time, and overall moderate-to-vigorous intensity physical activity (MVPA) (5).

To date, representative population estimates of youth MSA participation have been confined mostly to North America. According to the 2017 Youth Risk Behavior Surveillance

System (YRBSS), 51% of U.S. high school students (62% of boys and 41% of girls) engage in guideline-concordant MSA (6). Corresponding YRBSS data indicate this is higher than in 1991 (48%) but lower than in 2011 (56%) (6). Similar MSA prevalence has been reported in Canada, with COMPASS study data indicating 54% of adolescents (58% of boys and 50% of girls) met the MSA guideline in 2013–14 (7). By contrast, the 2017–18 National Health Survey found only 13% (22% of boys and 8% of girls) of Australian 15–17 year olds satisfy the MSA guideline (8). Yet, little is known about why some young people, in Australia or elsewhere, engage in sufficient MSA while others do not.

Identifying the correlates of youths' MSA behavior is an important first step towards designing and implementing effective interventions, but there is a distinct lack of research on MSA correlates. A recent systematic review identified a range of factors associated with adult participation in RT (e.g., education, self-efficacy, subjective norms etc.) (9), but no equivalent evidence synthesis has been conducted for children and adolescents. Of the work that has been done, associations have been found between adolescents' MSA and demographic variables, including sex/gender, race/ethnicity, and socioeconomic status (SES) (10, 11); biological variables, such as cardiorespiratory fitness (CRF), muscular fitness (12), and (albeit with mixed findings) body composition (10-12); and psychosocial variables, including perceptions/beliefs about PA, and peer/parent social support (11).

These studies provide insights into several factors that may be relevant for adolescents' MSA behavior, but as all were conducted with U.S. youth the findings may not be generalizable to those elsewhere. In addition, there might be other factors linked to MSA in this population, justifying the examination of novel variables that have not been evaluated previously (e.g. behavioral factors). For example, physical activity and sedentary behaviors seem to covary (in opposite directions) across the transition from primary to secondary school (13). In addition, meta-analytic evidence indicates a strong association between physical activity and sleep during mid-adolescence and early adulthood (*d* = 0.894 [0.484 to 1.305]) (14). Whether or not these associations extend to MSA remains an open question. Considering the paucity of evidence on MSA correlates within the published literature, the aim of the present study is to quantify associations between guideline-concordant MSA among a sample of Australian adolescents and a range of demographic, biological, psychosocial, and behavioral factors.

METHODS

Participants and procedure

Data were drawn from participants taking part in the 'Resistance Training for Teens' (hereafter: RT for Teens) cluster randomized controlled trial (RCT). The trial was prospectively registered with the Australian and New Zealand Clinical Trials Registry (ACTRN12615000360516), and a full description of the study protocols (15) and main findings (16) have been published previously. Participants (*n* = 607, 50% female, mean age = 14.1±0.5 years) attending 16 Government secondary schools in the Hunter, Central Coast and Sydney regions of New South Wales (NSW), Australia, were enrolled and assessed at the schools by trained research assistants (April–June, 2015). Eligible participants were apparently healthy Grade 9 students (third year of secondary school), without an illness or injury that would preclude them from participating in physical activity. Ethics approval for the study was obtained from the Human Research Ethics Committees of the University of Newcastle (H-2014–0312) and NSW Department of Education (SERAP: 2,012,121). All participants (and their parents/guardians) provided informed written assent/consent prior to enrolment.

Study measures

Detailed information on the administration, scoring, validity and reliability of study measures can be found elsewhere (15).

Muscle-strengthening activity

MSA was assessed using a single-item self-report measure previously used in the YRBSS (12). Participants were asked to report the number of days in the past week they had participated in "*exercises to strengthen or tone the muscles such as push-ups, sit-ups, or weight lifting*" (possible range = 0 to 7 days). Participants reporting 3–7 days were classified as meeting the WHO recommendation, whereas those reporting 0–2 days were classified as not meeting the recommendation (4).

Demographic factors

Participants completed an online survey using electronic tablets and reported their sex, cultural background, language spoken at home, and residential postal code. Postal code was used to determine area-level SES, using the Socio-Economic Indexes For Areas (SEIFA) Index of Relative Socio-economic Disadvantage (IRSD) (17). The IRSD is expressed in percentile units, with lower values indicating greater disadvantage.

Biological factors

Upper body muscular endurance was assessed using the 90° push-up test (18), and lower body strength/power was assessed using the standing broad jump (SBJ) test (19). Both tests have acceptable test-retest reliability in youth, and the SBJ demonstrates high criterion validity (20). Conversely, push-up performance is influenced substantially by body composition. Therefore, push-up test results were normalized for body mass using the allometric scaling parameter recommended by Jaric et al. (21). Results for both muscular fitness tests were then standardized by sex (value–mean/SD) and summed to create a composite muscular fitness score (MFS). CRF was assessed using a submaximal step-test protocol (22). Participants were fitted with a heart rate (HR) monitor and instructed to step up and down on a portable step for 3 minutes, after which their HR was recorded at 5 and 15 seconds. HR recovery between 5 and 15 seconds was used to estimate $\dot{V}O_2$ max in mL/kg/min (22). Flexibility was assessed by the sit and reach test (18), and calculated as the sum of reach distances on left and right sides. Height and body mass were assessed in light clothing without shoes. Body mass index (BMI) was calculated using mass [kg] divided by height $[m]^2$ and converted to age- and sex-specific *z*-scores. International Obesity Task Force cut-offs (23) were used to determine weight status, dichotomized as 'not overweight' (i.e., thin and healthy weight) or 'overweight/obese' (i.e., overweight, obese, and morbidly obese).

Psychosocial factors

RT self-efficacy was assessed using a brief scale designed for use with adolescents (24). Participants responded to 4-items (e.g., *I have the skill and technique to complete resistance training exercises safely*) using a 5-point Likert scale (1 = *strongly disagree* to 5 = *strongly agree*). The internal consistency of items among the study sample was acceptable (Cronbach's $\alpha = 0.79$). Motivation for RT was assessed using a modified version of the Behavioral Regulations in Exercise Questionnaire-2 (25), with items adapted to reflect RT participation (e.g., *I value the benefits of resistance training*). Participants responded to each item using a 5-point scale (1 = *not true for me* to 5 = *very true for me*), and a relative autonomy index (RAI) was calculated as the sum of weighted subscales: (−3 x amotivation) + (−2 x controlled) + (−1 x introjected) + (2 x identified) + (3 x intrinsic). Possible scores range from −24 to 20, with positive values indicating greater autonomous motivation for RT. The internal consistency of items for each subscale among the study sample was good

(Cronbach's α >0.80 for all). Perceived strength was assessed using a single item from the International Fitness Scale (IFIS), which has been shown to correctly rank adolescents according to objectively measured strength, and also has moderate reliability (kappa = 0.54) (26). Participants reported perceptions of their 'muscular strength' relative to their peers using a 5-point scale (1 = *very poor* to 5 = *very good*).

Behavioral factors

Total MVPA was self-reported using a single item measure previously validated with adolescents (27). In brief, participants were asked to reflect on the past week and responded to the question: "*on how many days have you done a total of 60 minutes or more of physical activity, which was enough to raise your breathing rate?"* (possible range = 0 to 7). Recreational screen-time was assessed using a modified version of the Adolescent Sedentary Activity Questionnaire (ASAQ) (28). Further detail on the modifications made to the ASAQ for this study can be found elsewhere (29). Briefly, participants were asked to reflect on a normal week, and reported (for each day) the total time spent sitting using screens for the purposes of entertainment. Sleep duration was assessed using items from the School Sleep Habits survey (30), which has been previously validated against diary-reported and actigraphically-estimated sleep among high school aged youth (31). Participants reflected on the past two weeks and reported their usual bedtime, wake time, and time taken to get to sleep (i.e., sleep onset latency). Sleep duration was calculated as the time between bedtime and wake time minus sleep onset latency, and classified as 'sufficient' if above minimum thresholds of recommended sleep for age (32). Sleep duration below these thresholds was classified as 'insufficient'. RT skill competency was assessed using video analysis of the Resistance Training Skills Battery (RTSB), which has previously shown acceptable construct validity and test-retest reliability (ICC = 0.88) (33), as well as inter-rater reliability (CV =

4.9%) with adolescents (34). After watching a standardized video demonstration, participants were video recorded completing two sets of four repetitions of six foundational RT skills (i.e., squat, lunge, overhead press, suspended row, push-up, front support with chest touch). A trained research assistant with a postgraduate degree in strength and conditioning and substantial prior experience with this tool scored the video recordings, with scores for individual skills summed to create an overall RT skill score (possible range = 0 to 56).

Statistical analysis

The analytical sample comprised those who provided data for MSA participation ($n = 602$, 99% of full sample). Analyses were performed using the Mplus 8.3 program (Muthén & Muthén, Los Angeles, CA), with statistical significance set at $p < 0.05$. First, Pearson correlation coefficients were calculated to determine bivariate associations between study variables. Binary logistic regression models with odds ratios and their 95% confidence intervals (OR; 95% CI) were then estimated: (i) separately for each group of factors (i.e., demographic, biological, psychosocial, and behavioral), and (ii) in a full model with all variables included together. The preliminary models were tested to identify the most important predictive variables within a variable group, and to evaluate and compare the explanatory power of groups of related variables, whereas the full model was tested to evaluate the total variance explained by all study variables. For interpretation, OR's for categorical variables represent the odds of guideline-concordant MSA relative to the reference category, whereas OR's for continuous variables represent the odds of guideline-concordant MSA per unit increase in the independent variable.

The robust maximum likelihood estimation procedure was used to account for missing data and the non-independence of students nested within schools by adjusting the standard errors using a sandwich estimator. Symmetric confidence intervals were estimated by this procedure using the adjusted standard errors. However, the *p*-value was inconsistent with symmetric confidence intervals. Therefore, non-symmetric confidence intervals and standard errors were estimated. All standard errors and confidence intervals were estimated using bootstrap estimates. Finally, intra-class correlation coefficients (ICC) were calculated for all variables to quantify clustering at the school-level.

Thresholds for interpreting the magnitude of effect sizes are as follows (35): correlation coefficients of 0.20, 0.50, and 0.80; *R*-square values of 4%, 25%, and 64%; and OR's of 2.0 (or 0.50), 3.0 (or 0.33) and 4.0 (or 0.25) each represent 'small', 'moderate' and 'strong' effects, respectively.

RESULTS

Characteristics of the study sample are provided in Table 1. The vast majority spoke English as their primary language at home, and two-thirds identified their cultural background as 'Australian'. Two-thirds were a healthy weight, while one-fifth were overweight and 8.2% were obese. One in four participants reported zero days of MSA per week, followed by one (21%) and two (19%) days. In total, 35% met the MSA recommendation. Bivariate correlations between study variables are provided in Table 2. MSA was significantly correlated (r's $\geq \pm 0.2$) with muscular fitness, RT self-efficacy, motivation for RT, perceived strength, and total MVPA. The ICC's for study variables ranged from 0.00 to 0.70 (Table 3).

Logistic regression results by variable groups

Separate logistic regression models were estimated to determine the total variance in guideline-concordant MSA explained by each variable group, and to identify initially significant factors (Table 3). The total variance explained ranged from 3.1% for demographic variables to 23.3% for psychosocial variables. Female sex was associated with lower odds of guideline-concordant MSA (OR [95%CI] = 0.55 [0.34 to 0.91], effect size [ES] = small). Greater muscular fitness (OR = 1.27 [1.08 to 1.50], ES = negligible), RT self-efficacy (OR = 1.94 [1.33 to 2.82], ES = small), perceived strength (OR = 2.14 [1.59 to 2.89], ES = small), and total MVPA (OR = 1.58 [1.39 to 1.79], ES = negligible) were associated with higher odds.

Logistic regression results including all variables

The full model including all variables simultaneously explained 52% of the variance in guideline-concordant MSA (Table 4). In this model, the association for RT self-efficacy became stronger (OR = 2.48 [1.37 to 4.50], ES = small), while the association for total MVPA weakened but remained statistically significant (OR = 1.48 [1.22 to 1.79], ES = negligible). While not statistically significant, there was a trend ($p < 0.10$) towards significance for SES ($p = 0.06$) and recreational screen-time ($p = 0.08$), but the corresponding effect sizes were negligible. The associations for sex, muscular fitness, and perceived strength were no longer significant in the full model.

DISCUSSION

To our knowledge, this is the first study to comprehensively examine factors associated with adolescents' adherence to the MSA guideline. Initially, sex, muscular fitness, RT self-efficacy, perceived strength, and total MVPA were significantly associated with guideline-concordant MSA. However, only RT self-efficacy and total MVPA were independent correlates in the full model. These findings provide a novel contribution to the literature, given the lack of research focused on MSA behavior among adolescents. Moreover, our study is timely in light of recent evidence showing secular declines in muscular fitness among Australian youth (36).

A key finding from the present study was the independent association between MSA and RT self-efficacy. To our knowledge, this is the first time RT self-efficacy has been identified as a correlate of guideline-concordant MSA in adolescents. Specifically, there was 2.5-fold greater odds of meeting the MSA guideline per unit increase in RT self-efficacy. For interpretation, a one-unit difference in RT self-efficacy in the study sample equated to approximately 1.5 standard deviations. Notably, RT self-efficacy was a significant correlate in both models, but the association strengthened in the full model with all variables included. Conversely, the associations for most other variables weakened, and several were attenuated to non-significance (i.e., sex, muscular fitness, and perceived strength). Some of these variables were correlated with RT self-efficacy, suggesting their association with MSA is actually explained by this construct. Overall, this finding reinforces the importance of self-efficacy for MSA behavior in adolescents, which is consistent with systematic review findings for adults (9).

It is generally accepted that self-efficacy is both a determinant and an outcome of physical activity (37). For example, past trials have shown RT programs can improve RT self-efficacy among apparently healthy (16) and overweight/obese (38) adolescents. Further, a moderate effect for RT self-efficacy was reported in a recent meta-analysis of youth RT trials (39). Alternatively, popular health behavior theories including Social Cognitive Theory (40) identify self-efficacy (or analogous constructs) as important predictors of future behavior. Given most adolescents will have had little prior experience with formal RT, it is perhaps more likely that RT self-efficacy is influencing intentions to engage in MSA in the present study population (rather than MSA participation improving RT self-efficacy). It is worth noting that our RT self-efficacy measure evaluated 'task' self-efficacy, but 'barrier' self-efficacy (i.e., one's belief in their ability to overcome barriers to participation) might also be relevant for adolescents' MSA. Consequently, barrier self-efficacy should be examined as a determinant of MSA in future research.

A second key finding was the small but significant independent association between total MVPA and guideline-concordant MSA, which in the full model translated to 48% greater odds for each additional day/week of sufficient MVPA. It must be noted that MVPA and MSA were assessed using very similar measures (i.e., self-reported as days/week). In addition, the MVPA item did not require participants to distinguish between aerobic physical activity and MSA. Hence, our MVPA measure may be capturing participation in MSA to some extent. Nonetheless, MSA and MVPA were only weakly-to-moderately correlated (r = 0.39, $p < 0.01$), suggesting they are not measuring the same thing. Although the magnitude of the OR for total MVPA was negligible, this could be in part due to the sensitivity of the measure, which does not provide an estimate of overall MVPA 'volume' (i.e., minutes/week). Future research using objective/device-based measures of MVPA (e.g., accelerometry) might provide a clearer indication of the association between MVPA and MSA. For example, the present finding could simply be the result of common method bias due to the similarity in measures used. Alternatively, our crude MVPA measure might be underestimating the positive association between MVPA and MSA.

Measurement issues aside, the persistent association for total MVPA is plausible. For example, the individual characteristics, interpersonal facilitators, and supportive environments that enable some adolescents to participate in high amounts of MVPA are probably transferrable to MSA. Alternatively, youth reporting greater MVPA may be more likely to engage in certain activities within which MSA is encouraged or explicitly taught. Prior work has identified sports participation as a consistent correlate of overall physical activity among adolescents (41), emphasizing the contribution of sport to an active lifestyle. Similarly, organized sport might provide an opportunity for regular MSA, whereas certain other PA contexts may not to the same extent (e.g., active transportation). Specifically, coaches might utilize MSA during the conditioning component of sports practice. Moreover, the desire to improve sports performance might lead athletic youth to pursue formal RT as a supplement to regular sports practice.

Regarding demographic factors, our data showed a clear difference in the proportion of boys and girls meeting the MSA guideline (i.e., 41.8% versus 28.7%), which is consistent with findings for MVPA (42). Notably, the magnitude of this difference was very similar to that found among a large representative sample of Australian youth (8). Sex was the only significant demographic predictor, with females demonstrating 45% lower odds of guideline-concordant MSA compared with males. Sex differences in MSA (favoring males) have previously been reported among U.S. (6, 10, 11) and Canadian (7) youth, but to our knowledge there are no comparative data from other countries. Interestingly, our findings contrast with the adult literature, which find no sex differences in MSA in Australia (43).

Considering the above, future research exploring why adolescent girls participate in less MSA would be valuable. Participant sex was not a significant factor in the full model suggesting that other factors (related to sex) are driving the observed sex-differences in MSA. Of note, perceived strength was significantly correlated (albeit weakly) with sex, and this variable was associated with MSA in the psychosocial factors model. It could be that differences in physical self-perceptions in part explain the differential participation in MSA between boys and girls. However, it is also possible that other unmeasured factors (e.g., perceived social norms, peer/parent social support etc) underpin this finding. Future intervention studies targeting this group should also consider maturational timing, as early maturation has been linked with less physical activity among adolescent girls (mediated through negative self-concept) (44). This may or may not also extend to girls' MSA behavior.

SES and language spoken at home were not related to adolescents' MSA, which is somewhat surprising given 'low SES' and 'non-English speaking background' have been linked with poor muscular fitness in Australian youth (45). Biological factors were also unrelated to MSA in the full model, despite an initially significant association for muscular fitness. This was also unexpected, as participation in regular MSA should theoretically result in improved muscular fitness. However, we did not assess students' maturational stage, and variation in muscular fitness attributable to differences in maturation at this age (14-15 years) might be difficult to distinguish from variation due to MSA. Indeed, age at peak height velocity (PHV), a common marker of biological maturation, can vary from 10−15 years in girls and from 11−16 years in boys (mean age at PHV is 12 and 14 for girls and boys, respectively) (46). Finally, RT skill competency was also non-significant in both models. This was again surprising as actual competence should theoretically be related to MSA behavior. However, it might be that perceived rather than actual competence is the more important contributor to behavior. Indeed, prior research evaluating other movement skills has shown adolescents' perceptions of their physical abilities is a better predictor of physical activity behavior than their actual abilities when assessed objectively (47).

Strengths of the present study include the assessment of a range of novel factors that would not be feasible for larger population-based surveys, adjustment for school-level clustering in the analysis, and use of validated measures with acceptable measurement properties. However, there are several limitations that must be recognized. First, the study sample was smaller than some other studies of physical activity correlates. In addition, the study schools were not randomly sampled, participants were from a single school grade, and all had agreed to enroll in a school-based physical activity intervention. While the sample appears similar to the general population, we cannot discount the possibility of sampling or selection bias, and care should be taken in generalizing the findings to other groups. Second, given the cross-sectional design we cannot determine causality. Third, our findings for MVPA should be treated with caution, given the recognized limitations of self-report and potential for double counting of MSA using this specific item. Finally, MSA was self-reported in days/week precluding a robust analysis of associations with overall MSA volume, and it is possible participants' responses were influenced by social desirability or recall bias. Also, the validity and reliability of our MSA item is currently unclear, although in adults a similar single-item self-report measure of MSA demonstrated excellent test-retest reliability (Kappa = 0.85-0.92)(48). Nevertheless, there is presently no viable alternative, given device-based measures are poor at detecting non-ambulatory physical activity, and to the authors' knowledge there are no validated instruments for evaluating youths' MSA behavior with greater resolution (i.e., providing detail on frequency, intensity, time, or type of MSA performed)

Practical implications

The present study contributes to our understanding of MSA, but further research is required to gain a more complete picture of this behavior during adolescence. Nonetheless, there are some potential implications of our findings for practice. First, as previously noted there is a clear rationale for MSA interventions designed specifically for adolescent girls. Although beliefs about 'gendered' physical activities appear to be slowly changing in many countries, young girls may still perceive MSA to be a predominantly male activity. This could be tied to self-perceptions of physical strength (49), which might contribute to girls' beliefs regarding 'appropriate' physical activity choices.

Second, the robust association with RT self-efficacy highlights the need for future interventions to consider strategies to support self-efficacy. Pedagogical principles for maximizing youths' engagement in, motivation for, and satisfaction with organized physical activity opportunities generally (50), and RT specifically (51), have appeared recently in the published literature. These frameworks provide useful advice for practitioners on how to support youths' self-efficacy, including: i) thoughtful exercise prescription that provides an optimal level of challenge and is matched to the participant's current abilities and experience, and ii) promotion of a mastery climate that fosters self- rather than peer-comparison of performance.

Finally, school PE might be a suitable context for adolescents to be introduced to RT, as teachers can provide proper instruction on technique, correct performance errors through the provision of appropriate feedback, educate students on the benefits of MSA for health and well-being, and provide support for students to complete MSA outside of school (e.g., by identifying suitable places for MSA in the local area, or by helping youth to develop their own tailored exercise plans and goals). All of these strategies might help to support students' self-efficacy, which could plausibly lead to greater adoption and maintenance of MSA. High-quality teacher training/professional development might support this objective (52).

CONCLUSIONS

The present study contributes to our understanding of MSA behavior in adolescents, which has thus far received little attention from the public health research community. Overall, RT self-efficacy and total MVPA were significantly and independently associated with guideline-concordant MSA. Future research should examine whether these findings are reproducible in other population groups (e.g., children, older adolescents, and youth from low- and middle-income countries). In addition, the causal direction of associations should be evaluated using prospective and experimental research designs. Finally, exploration of other novel MSA correlates is warranted, given our full model explained just over half the variance in MSA guideline attainment.

REFERENCES

1. Lloyd RS, Faigenbaum AD, Stone MH. Position statement on youth resistance training: the 2014 international consensus. Br J Sports Med. 2014;48(7):498-505.

2. Smith JJ, Eather N, Morgan PJ, Plotnikoff RC, Faigenbaum A, Lubans DR. The health benefits of muscular fitness for children and adolescents: A systematic review and meta-analysis. Sports Med. 2014;44(9):1209-23.

3. Ortega FB, Silventoinen K, Tynelius P, Rasmussen F. Muscular strength in male adolescents and premature death: cohort study of one million participants. Br Med J. 2012;345:e7279.

4. World Health Organization. Global recommendations on physical activity for health. Geneva: WHO; 2010.

5. Aubert S, Barnes JD, Abdeta C, Abi Nader P, Adeniyi AF, Aguilar-Farias N, et al. Global matrix 3.0 physical activity report card grades for children and youth: results and analysis from 49 countries. Journal of Physical Activity and Health. 2018;15(Supplement 2):S251-S73.

6. Centers for Disease Control and Prevention. 2017 High School Youth Risk Behavior Surveillance System. Atlanta, GA: U.S. Department of Health & Human Services; 2017.

7. Harvey A, Faulkner G, Giangregorio L, Leatherdale ST. An examination of school-and student-level characteristics associated with the likelihood of students' meeting the Canadian physical activity guidelines in the COMPASS study. Can J Public Health. 2017;108(4):348-54.

8. Australian Bureau of Statistics. National Health Survey: First Results, 2017–18. Catelogue No. 4364.0.55.001. Canberra: Australian Bureau of Statistics; 2018.

9. Rhodes RE, Lubans DR, Karunamuni N, Kennedy S, Plotnikoff R. Factors associated with participation in resistance training: a systematic review. Br J Sports Med. 2017.

10. Song M, Carroll DD, Fulton JE. Meeting the 2008 physical activity guidelines for Americans among US youth. Am J Prev Med. 2013;44(3):216-22.

11. Roth SE, Gill M, Chan-Golston AM, Rice LN, Crespi CM, Koniak-Griffin D, et al. Physical activity correlates in middle school adolescents: perceived benefits and barriers and their determinants. J Sch Nurs. 2019;35(5):348-58.

12. Morrow Jr JR, Tucker JS, Jackson AW, Martin SB, Greenleaf CA, Petrie TA. Meeting physical activity guidelines and health-related fitness in youth. Am J Prev Med. 2013;44(5):439-44.

13. Chong KH, Parrish A-M, Cliff DP, Kemp BJ, Zhang Z, Okely AD. Changes in physical activity, sedentary behaviour and sleep across the transition from primary to secondary school: A systematic review. J Sci Med Sport. 2019.

14. Lang C, Kalak N, Brand S, Holsboer-Trachsler E, Pühse U, Gerber M. The relationship between physical activity and sleep from mid adolescence to early adulthood. A systematic review of methodological approaches and meta-analysis. Sleep Med Rev. 2016;28:32-45.

15. Lubans DR, Smith JJ, Peralta LR, Plotnikoff RC, Okely AD, Salmon J, et al. A school-based intervention incorporating smartphone technology to improve health-related fitness among adolescents: rationale and study protocol for the NEAT and ATLAS 2.0 cluster randomised controlled trial and dissemination study. BMJ Open. 2016;6(6):e010448.

16. Kennedy SG, Smith JJ, Morgan PJ, Peralta LR, Hilland TA, Eather N, et al. Implementing resistance training in secondary schools: A cluster RCT. Med Sci Sports Exerc. 2017;50(1):62-72.

17. Australian Bureau of Statistics. 2039.0 - Information paper: An introduction to Socio-Economic Indexes for Areas (SEIFA) 2006. Canberra (AUST): ABS; 2008.

18. Cooper Institute for Aerobics Research. Fitnessgram: Test administration manual. Champaign, IL: Human Kinetics; 1999.

19. Castro-Piñero J, Ortega FB, Artero EG, Girela-Rejón MJ, Mora J, Sjöström M, et al. Assessing muscular strength in youth: usefulness of standing long jump as a general index of muscular fitness. J Strength Cond Res. 2010;24(7):1810-7.

20. Castro-Piñero J, Artero EG, España-Romero V, Ortega FB, Sjöström M, Suni J, et al. Criterion-related validity of field-based fitness tests in youth: a systematic review. Br J Sports Med. 2010;44(13):934-43.

21. Jaric S, Mirkov D, Markovic G. Normalizing physical performance tests for body size: a proposal for standardization. J Strength Cond Res. 2005;19(2):467-74.

22. Francis K, Feinstein R. A simple height-specific and rate-specific step test for children. South Med J. 1991;84(2):169-74.

23. Cole T, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes. 2012;7(4):284-94.

24. Lubans DR, Morgan P, Callister R, Plotnikoff RC, Eather N, Riley N, et al. Test–retest reliability of a battery of field-based health-related fitness measures for adolescents. J Sports Sci. 2011;29(7):685-93.

25. Markland D, Tobin V. A modification to the behavioural regulation in exercise questionnaire to include an assessment of amotivation. J Sport Exerc Psychol. 2004;26(2):191-6.

26. Ortega FB, Ruiz JR, Espana-Romero V, Vicente-Rodriguez G, Martinez-Gomez D, Manios Y, et al. The International Fitness Scale (IFIS): usefulness of self-reported fitness in youth. Int J Epidemiol. 2011;40(3):701-11.

27. Scott JJ, Morgan PJ, Plotnikoff RC, Lubans DR. Reliability and validity of a single-item physical activity measure for adolescents. J Paediatr Child Health. 2015;51(8):787-93.

28. Hardy LL, Booth ML, Okely AD. The reliability of the adolescent sedentary activity questionnaire (ASAQ). Prev Med. 2007;45(1):71-4.

29. Smith JJ, Morgan PJ, Plotnikoff RC, Dally KA, Salmon J, Okely A, D.,, et al. Rationale and study protocol for the 'Active Teen Leaders Avoiding Screen-time' (ATLAS) group randomized controlled trial: An obesity prevention intervention for adolescent boys from schools in low-income communities. Contemp Clin Trials. 2014;37(1):106-19.

30. Wolfson AR, Carskadon MA. Sleep schedules and daytime functioning in adolescents. Child Dev. 1998:875-87.

31. Wolfson AR, Carskadon MA, Acebo C, Seifer R, Fallone G, Labyak SE, et al. Evidence for the validity of a sleep habits survey for adolescents. Sleep. 2003;26(2):213-7.

32. Australian Government. Australian 24-hour movement guidelines for children and young people (5 to 17 years): An integration of physical activity, sedentary behaviour, and sleep. 2019.

33. Lubans DR, Smith JJ, Harries SK, Barnett LM, Faigenbaum AD. Development, test-retest reliability and construct validity of the resistance training skills battery. J Strength Cond Res. 2014;28(5):1373-80.

34. Barnett L, Reynolds J, Faigenbaum AD, Smith JJ, Harries S, Lubans DR. Rater agreement of a test battery designed to assess adolescents' resistance training skill competency. J Sci Med Sport. 2015;18(1):72-6.

35. Ferguson CJ. An effect size primer: A guide for clinicians and researchers. Prof Psychol Res Pr. 2009;40(5):532.

36. Fraser BJ, Blizzard L, Tomkinson GR, Lycett K, Wake M, Burgner D, et al. The great leap backward: changes in the jumping performance of Australian children aged 11− 12-years between 1985 and 2015. J Sports Sci. 2019;37(7):748-54.

37. McAuley E, Blissmer B. Self-efficacy determinants and consequences of physical activity. Exerc Sport Sci Rev. 2000;28(2):85-8.

38. Schranz N, Tomkinson G, Parletta N, Petkov J, Olds T. Can resistance training change the strength, body composition and self-concept of overweight and obese adolescent males? A randomised controlled trial. Br J Sports Med. 2014;48(20):1482-8.

39. Collins H, Booth JN, Duncan A, Fawkner S, Niven A. The effect of resistance training interventions on 'the self' in youth: a systematic review and meta-analysis. Sports Med Open. 2019;5(1):29.

40. Bandura A. Social foundations of thought and action: A social cognitive theory. Englewood Cliffs, NJ: Prentice-Hall; 1986.

41. Van der Horst K, Paw MJCA, Twisk JW, Van Mechelen W. A brief review on correlates of physical activity and sedentariness in youth. Med Sci Sports Exerc. 2007;39(8):1241-50.

42. Biddle SJ, Atkin AJ, Cavill N, Foster C. Correlates of physical activity in youth: a review of quantitative systematic reviews. Int Rev Sport Exerc Psych. 2011;4(1):25-49.

43. Bennie JA, Pedisic Z, van Uffelen JG, Charity MJ, Harvey JT, Banting LK, et al. Pumping Iron in Australia: Prevalence, Trends and Sociodemographic Correlates of Muscle Strengthening Activity Participation from a National Sample of 195,926 Adults. PLoS One. 2016;11(4):e0153225.

44. Jackson L, Cumming SP, Drenowatz C, Standage M, Sherar LB, Malina RM. Biological maturation and physical activity in adolescent British females: The roles of physical self-concept and perceived parental support. Psychol Sport Exerc. 2013;14(4):447-54.

45. Hardy LL, Mihrshahi S, Drayton BA, Bauman A. NSW Schools Physical Activity and Nutrition Survey (SPANS) 2015: Full Report. Sydney: NSW Department of Health; 2016.

46. Stratton G, Oliver JL. Chapter 1: The impact of growth and matuartion on physical performance. In: Lloyd RS, Oliver JL, editors. Strength and conditioning for young athletes: science and application. New York and London: Routledge; 2020.

47. De Meester A, Maes J, Stodden D, Cardon G, Goodway J, Lenoir M, et al. Identifying profiles of actual and perceived motor competence among adolescents: associations with motivation, physical activity, and sports participation. J Sports Sci. 2016;34(21):2027-37.

48. Yore MM, Ham SA, Ainsworth BE, Kruger J, Reis JP, Kohl III HW, et al. Reliability and validity of the instrument used in BRFSS to assess physical activity. Med Sci Sports Exerc. 2007;39(8):1267-74.

49. Lubans DR, Cliff DP. Muscular fitness, body composition and physical self-perception in adolescents. J Sci Med Sport. 2011;14(3):216-21.

50. Lubans DR, Lonsdale C, Cohen K, Eather N, Beauchamp MR, Morgan PJ, et al. Framework for the design and delivery of organized physical activity sessions for children and adolescents: rationale and description of the 'SAAFE' teaching principles. International journal of behavioral nutrition and physical activity. 2017;14(1):24.

51. Faigenbaum AD, McFarland JE. Resistance training for kids: right from the start. ACSM's Health & Fitness Journal. 2016;20(5):16-22.

52. Kennedy SG, Peralta LR, Lubans DR, Foweather L, Smith JJ. Implementing a school-based physical activity program: process evaluation and impact on teachers' confidence, perceived barriers and self-perceptions. Physical Education and Sport Pedagogy. 2019;24(3):233-48.

Table 1. Characteristics of the study sample

Characteristics[a]	**All (*n* = 602)**	**Boys (*n* = 299)**	**Girls (*n* = 303)**
Age, years	14.1 (0.5)	14.2 (0.5)	14.1 (0.4)
English language spoken at home, n (%)	547 (90.9)	270 (90.3)	277 (91.4)
Cultural background, n (%)			
Australian	396 (65.8)	194 (64.9)	202 (66.7)
European	51 (8.5)	26 (8.7)	25 (8.3)
African	5 (0.8)	1 (0.3)	4 (1.3)
Asian	74 (12.3)	41 (13.7)	33 (10.9)
Middle Eastern	9 (1.5)	5 (1.7)	4 (1.3)
Other	67 (11.1)	32 (10.7)	35 (11.6)
ATSI, n (%)	44 (7.3)	19 (6.4)	25 (8.3)
Socio-economic status, decile, n (%)			
1–2	66 (11.0)	36 (12.1)	30 (10)
3–4	136 (22.7)	68 (22.8)	68 (22.6)
5–6	233 (38.9)	98 (32.9)	135 (44.9)
7–8	27 (4.5)	17 (5.7)	10 (3.3)
9–10	137 (22.9)	79 (26.5)	58 (19.3)
Weight status, n (%)			
Thinness	24 (4.0)	12 (4.0)	12 (4.0)
Healthy Weight	410 (68.6)	202 (67.8)	208 (69.3)
Overweight	115 (19.2)	55 (18.5)	60 (20.0)
Obese	49 (8.2)	29 (9.7)	20 (6.6)
Push-ups, repetitions	11.9 (7.8)	11.7 (6.9)	12.1 (8.6)
Standing broad jump, cm	158.3 (34.7)	179.0 (29.3)	137.6 (26.4)
Cardio-respiratory fitness, mL/kg/min	48.3 (8.7)	51.4 (7.7)	45.1 (8.5)
Flexibility, cm	24.6 (7.6)	22.5 (7.0)	26.7 (7.7)
RT self-efficacy, units	3.7 (0.7)	3.7 (0.6)	3.7 (0.7)
Motivation for RT, units	3.8 (6.0)	3.1 (5.9)	4.5 (6.0)
Perceived strength, units	3.3 (0.8)	3.4 (0.8)	3.1 (0.8)
Total MVPA, days/week	3.5 (1.8)	3.8 (1.8)	3.2 (1.8)
Screen-time, minutes/day	175 (122)	162 (104)	188 (136)
RT skill competency, units	34.9 (7.3)	34.8 (7.0)	35.0 (7.6)
Sleep duration, hours/day	8.3 (1.3)	8.2 (1.3)	8.3 (1.3)
Days per week of MSA, n (%)			
0	149 (24.8)	68 (22.7)	81 (26.7)
1	129 (21.4)	47 (15.7)	82 (27.1)
2	112 (18.6)	59 (19.7)	53 (17.5)
3	97 (16.1)	56 (18.7)	41 (13.5)
4	41 (6.8)	21 (7.0)	20 (6.6)
5	32 (5.3)	21 (7.0)	11 (3.6)
6	10 (1.7)	6 (2.0)	4 (1.3)
7	32 (5.3)	21 (7.0)	11 (3.6)
Meets MSA recommendation, n (%)[b]	212 (35.2)	125 (41.8)	87 (28.7)

Note. ATSI = Aboriginal or Torres Strait Islander, MSA = muscle-strengthening activity, MVPA = moderate-to-vigorous physical activity, RT = resistance training, SD = standard deviation.

[a] Data are presented as mean (SD) unless otherwise specified

[b] ≥ 3 days per week

Table 2. Bivariate correlations between study variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. MSA	**-**														
2. Sex	0.14**	-													
3. Language	−0.01	-0.02	-												
4. SES	−0.07	0.04	**0.31****	-											
5. MFS	**0.23****	0.01	−0.01	0.14**	-										
6. CRF	0.15**	**0.36****	−0.03	0.17**	**0.35****	-									
7. Flexibility	0.07	**−0.27****	-0.06	0.02	**0.31****	−0.00	-								
8. BMI *z*-score	-0.05	0.03	0.08	−0.13**	**-0.32****	**-0.30****	−0.02	-							
9. RT self-efficacy	**0.33****	0.03	0.03	0.02	**0.37****	**0.23****	0.14**	−0.12**	-						
10. Motivation for RT	**0.21****	−0.11**	−0.00	0.04	**0.27****	0.14**	**0.20****	-0.08	**0.45****	-					
11. Perceived strength	**0.36****	0.15**	0.04	0.01	**0.36****	**0.22****	0.14**	0.11**	**0.53****	**0.25****	-				
12. Total MVPA	**0.39****	0.16**	0.01	0.09*	**0.29****	**0.32****	0.12**	−0.08*	**0.36****	0.17**	**0.33****	-			
13. Screen-time	−0.15**	−0.11**	−0.04	−0.06	−0.13**	−0.19**	−0.04	0.06	−0.17**	-0.06	−0.10*	**−0.25****	-		
14. RT skills	0.10	−0.01	−0.01	0.19**	**0.45****	**0.30****	**0.23****	**-0.23****	**0.31****	0.19**	**0.20****	**0.20****	−0.19**	-	
15. Sleep duration	0.02	−0.01	0.04	0.09*	−0.01	0.03	−0.05	−0.09*	0.08	0.07	0.04	0.07	−0.18**	0.07	-

Note. MSA expressed in days/week; Sex coded as 0 = female, 1 = male. BMI = body mass index; CRF = cardiorespiratory fitness; MFS = muscular fitness score; MSA = muscle-strengthening activity; MVPA = moderate-to-vigorous physical activity; RT = resistance training; SES = socio-economic status. Statistically significant correlations ≥ ±0.20 appear in bold type.

* $p < 0.05$; ** $p < 0.01$

Table 3. Logistic regression results by groups of predictors

Predictors	ICC	Coefficient		Odds Ratio	
		Estimate	SE	Estimate	95% CI
Demographic					
Sex (ref. male)	0.05	−0.59*	0.24	0.55	0.34 to 0.91
Language at home (ref. English)	0.44	−0.13	0.33	0.88	0.46 to 1.66
SES, percentile	0.70	−0.01	0.00	0.99	0.99 to 1.00
					R-square = 3.1%
Biological					
Muscular fitness score, units	0.13	0.24*	0.08	1.27	1.08 to 1.50
CRF, mL/kg/min	0.12	0.02	0.01	1.02	1.00 to 1.05
Flexibility, cm	0.08	0.00	0.01	1.00	0.98 to 1.02
Weight status (ref. not overweight)	0.03	−0.05	0.14	0.95	0.72 to 1.26
					R-square = 7.9%
Psychosocial					
RT self-efficacy, units[a]	0.06	0.66**	0.19	1.94	1.33 to 2.82
Motivation for RT, units[b]	0.00	0.03	0.02	1.03	0.98 to 1.07
Perceived strength, units[a]	0.00	0.76***	0.15	2.14	1.59 to 2.89
					R-square = 23.3%
Behavioral					
Total MVPA, days/week[c]	0.05	0.46***	0.06	1.58	1.39 to 1.79
Screen-time, hours/day	0.07	−0.11	0.06	0.89	0.79 to 1.01
RT skill competency, units[d]	0.25	−0.01	0.02	0.99	0.94 to 1.03
Sleep duration (ref. insufficient)	0.05	0.25	0.36	1.28	0.63 to 2.60
					R-square = 20.4%

Note. CI = confidence intervals; CRF = cardiorespiratory fitness; ICC = intra-class correlation coefficient; MVPA = moderate-to-vigorous physical activity; RT = resistance training; SE = standard error. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

[a] possible range = 1 to 5

[b] possible range = −24 to 20

[c] possible range = 0 to 7

[d] possible range = 0 to 56

Table 4. Logistic regression results with all predictors

Predictors	Coefficient		Odds Ratio	
	Estimate	SE	Estimate	95% CI
Sex (ref. male)	−0.40	0.29	0.67	0.38 to 1.18
Language at home (ref. English)	0.06	0.64	1.06	0.30 to 3.73
SES, percentile	−0.01	0.01	0.99	0.98 to 1.00
Muscular fitness score, units	0.17	0.12	1.18	0.93 to 1.50
CRF, mL/kg/min	−0.01	0.02	0.99	0.96 to 1.03
Flexibility, cm	0.00	0.01	1.00	0.97 to 1.02
Weight status (ref. not overweight)	0.17	0.42	1.19	0.52 to 2.70
RT self-efficacy, units[a]	0.91**	0.30	2.48	1.37 to 4.50
Motivation for RT, units[b]	0.02	0.03	1.02	0.97 to 1.08
Perceived strength, units[a]	0.02	0.33	1.02	0.53 to 1.96
Total MVPA, days/week[c]	0.39***	0.10	1.48	1.22 to 1.79
Recreational screen-time, hours/day	−0.10	0.06	0.90	0.81 to 1.01
RT skill competency, units[d]	−0.03	0.02	0.98	0.93 to 1.02
Sleep duration (ref. insufficient)	0.13	0.31	1.14	0.62 to 2.10
				R-square = 52.4%

Note. CI = confidence intervals; CRF = cardiorespiratory fitness; MVPA = moderate-to-vigorous physical activity; RT = resistance training; SE = standard error. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

[a] possible range = 1 to 5

[b] possible range = −24 to 20

[c] possible range = 0 to 7

[d] possible range = 0 to 56