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Original Article

Effects of an 8-week after-school resistance program in secondary school students

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Abstract:
The decline in physical fitness levels and the rise in childhood obesity are global concerns with long-term health implications. The global concern over the prevalence of childhood obesity and declining physical fitness levels in children and adolescents necessitates effective intervention strategies. After-school programs (ASPs) offer opportunities to deliver physical activity interventions. ASPs have been shown to be successful in improving health outcomes and providing a supportive and safe environment for children to engage in physical activities. Resistance training has gained importance in recent years for children and adolescents as it offers benefits such as improved muscle function, body composition, and sport performance. This study aimed to examine the effects of an 8-week resistance training program on secondary school adolescents in Germany. A total of 80 secondary school students participated, with 40 assigned to the intervention group and 40 to the control group. The intervention group underwent the resistance training program, which took place after school at a local boys-and-girls club. Pre- and post-tests were conducted to assess motor abilities (such as sit-ups, push-ups, standing broad jump, 6-minute run, 20-meter run, balance backwards, rapid alternation, sideways jumps, sit and reach, and countermovement jump) and physical attributes (body mass index, skinfold thickness). Statistical analyses revealed significant positive effects of the resistance training program on strength-related tests in the intervention group. This study provides valuable insights into the effects of an 8-week resistance training program on secondary school adolescents in Germany. The positive outcomes observed in the intervention group highlight the potential of resistance training interventions in improving strength-related measures in this population. Further research and implementation of similar programs are warranted to address the ongoing challenges of childhood obesity and declining physical fitness levels.
Key Words: **Resistance Training, Strength Training, Weight training, After-School Programs, Physical Education, Secondary School**

Introduction

Over the past 30-40 years, general declines in physical fitness levels in children and adolescents have been reported globally (Matton et al., 2007; Moliner-Urdiales et al., 2010; Tomkinson & Olds, 2007). Moreover, associated correlates such as obesity have increased. For instance, United States (U.S.) youth obesity has reached epidemic proportions, with almost one third of the U.S. youth being overweight or obese (Ogden et al., 2012).

This is concerning because children who are overweight and obese during childhood are more likely to be overweight and obese through adolescence and adulthood, placing them at higher risk of developing chronic diseases including diabetes and heart disease (Shaya et al., 2008; G. K. Singh et al., 2009). Childhood and adolescent obesity is linked to poor general health, and one or more functional limitations (Swallen et al., 2005). Increased risk of cardiovascular disease, non-insulin dependent diabetes mellitus, and some forms of cancer are also linked to childhood and adolescent obesity (Goran et al., 1999). In addition, perceived poor health is strongly related to depression; therefore, children with poor physical health are also likely to express emotional decrements. In relation to heart disease, a recent study reported that obese adolescents showed an increase in arterial stiffness and diastolic blood pressure after five years of being closely monitored (Dangardt et al., 2013).

A primary contributor to the current obesity epidemic is a decline in energy expenditure due to a reduction of regular physical activity (Bar-Or, 2003; Coleman et al., 2004; Crespo & Arbesman, 2003). In fact, multiple research studies have indicated a direct correlation between higher rates of obesity and reduced amount of regular physical activity (Crespo & Arbesman, 2003). Researchers suggest that an active lifestyle during childhood and adolescence can play an important role in optimizing growth and development, and improve body composition (Andersen et al., 1998). Statistics indicate that only 22 % of adults report regular and vigorous physical activity in the U.S. population (Coleman et al., 2004).

Out-of-school time opportunities such as after-school programs (ASPs) provide means through which physical activity interventions can be delivered. ASPs have been shown to be successful outlets for physical activity programs, which in turn can improve health outcomes (e.g., physical fitness, weight reduction) of children attending such programs (Beets, 2012; Beets et al., 2009; Beighle et al., 2010). ASPs can contribute to

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the improved health and physical activity of children (U.S. Department of Health and Human Services (HHS), 2006):

- Serve many groups of children most at risk for being overweight - specifically minorities and those in low socioeconomic status.
- Occur during a time of day when children are likely to be sedentary if not given any physical activity options.
- Reach children at the developmental stage when they are forming health patterns to be carried into adulthood.
- Have experience in making learning fun and modifying lessons for the needs of their students and clients.
- Offer a supportive, safe environment in which children can feel comfortable trying new activities and building new skills.
- Are led by caring adults who can act as role models with positive influence on children's health and nutrition choices.

Traditional youth activity barriers of transportation, cost, and time are reduced by ASPs (Orlowski et al., 2010). The potential for ASP physical activity lies not only in barrier removal, but also in the presence of established activity facilitators including peers, adult supervision, equipment, and facilities (El'Azar & McKay, 2020; Sallis et al., 2001; Sallis et al., 2000).

Although ASPs in general provide mixed results about improvement on academic achievement, and personal and social skill development (Durlak et al., 2010; Shernoff, 2010), ASPs involving physical activity show benefits in psychosocial measures (Beets et al., 2009). Furthermore, participation in physical activity is positively related to academic performance in children (Centers for Disease Control and Prevention (CDC), 2010; A. Singh et al., 2012).

To promote the engagement in life-long physical activity, activity-based programs must be enjoyable to all children, but at the same time must be vigorous enough to address the obesity issue (Watson et al., 2000). A reduced strength to body-weight ratio (relative strength) and level of cardiovascular fitness contributes to obese children often having greater difficulty performing various exercises and fatiguing more rapidly than more fit children. The difficulty that obese children experience when playing games or performing exercises further discourages them from engaging in physical activity (Centers for Disease Control and Prevention (CDC), 2012). Therefore, physical activities that are physically demanding and enjoyable for all children must be implemented in physical activity ASPs.

Recently, the importance of resistance training for children and adolescents has been increasingly emphasized (Dorgo et al., 2009; Faigenbaum, 2002, 2003; Hunter et al., 2000; Katsanis et al., 2021; Watts et al., 2004). To confront childhood obesity, several studies that used resistance training to treat youth obesity reported not only a decrease in fatness, but enjoyment and positive attitude toward training among participants (LaFontaine, 2002; Sothern et al., 1999). It appears that resistance training is particularly enjoyable for obese youth, mainly because it is less aerobically taxing and gives participants a chance to experience success and feel good about their performance (Faigenbaum, 2002, 2003).

For a given movement, the absolute strength of overweight children and adolescents tends to be greater than their normal-weight peers, which is perceived as a better performance (Faigenbaum, 2002). Unlike aerobic exercises, in which most overweight children perform poorly and fatigue quickly, resistance training may be an appropriate means to instill confidence and earn respect. Overweight children often receive positive feedback from their peers who are impressed with their performance (Faigenbaum, 2002). The motivational benefits of such feedback are enormous.

The term "resistance training" refers to a specific method of physical conditioning that involves the use of a wide range of resistive loads and a variety of training modalities (e.g., free weights, weight machines, elastic cords, medicine balls, and body weight) (Faigenbaum, 2003). Previously, youth resistance training was believed to be ineffective and unsafe, exposing children and adolescents to injury and possibly interfering with normal growth (Faigenbaum et al., 2009; Falk & Tenenbaum, 1996). Considering the growing body of evidence, it is now recognized that youth resistance training can be a safe, effective, and beneficial method of conditioning and should be an important component of youth fitness programs, health promotion objectives, and injury prevention (Dorgo et al., 2009; Faigenbaum, 2002; Faigenbaum et al., 2009; Katsanis et al., 2021).

The acceptance of youth strength training has become almost universal. The American Academy of Pediatrics (American Academy of Pediatrics, 2001), the American College of Sports Medicine (American College of Sports Medicine, 2009), and the National Strength and Conditioning Association (Faigenbaum et al., 2009) support youth participation in resistance training activities provided that the program is properly designed and competently supervised. Resistance training has multiple benefits for youth, including enhanced muscle function, increased muscle size, improved body composition and sport performance, and reduced risk of injuries (Faigenbaum et al., 2009). In addition, youth resistance training may help strengthen bones, promote healthy posture, facilitate weight control, improve cardiovascular risk profile, raise HDL cholesterol, regulate blood pressure, enhance mental health and well-being, and develop self-satisfaction and self-esteem (Faigenbaum, 2003; Sothern et al., 1999). The benefits of resistance training for diabetic youth are also enormous. Moreover, resistance training may stimulate a more positive attitude towards lifetime physical activity and may promote adherence to regular exercise by offering socialization, mental discipline and other related psychological benefits that are comparable to those gained from participation in team sports (Faigenbaum, 2002; Faigenbaum et al., 2009).

Resistance training is a form of higher-intensity physical activity and has several advantages over lower-intensity activities in preventing and treating youth obesity. First, instantaneous energy expenditure is greater during high-intensity activities than during low-intensity activities, due to the higher workload in the given time period (Hunter et al., 2000). A second advantage is an elevation in resting-energy expenditure (Goran et al., 1999; Hunter et al., 2000). Following high-intensity training, resting-energy expenditure remains elevated for up to 24-48 hours (Hunter et al., 2000).

The increased muscle mass associated with long-term resistance training also lends to an increased resting-energy expenditure on non-training days. A third advantage is that relatively high-intensity exercise is more successful in improving fitness levels than is low-intensity exercise (Goran et al., 1999; Hunter et al., 2000). Therefore, children with improved fitness are able to sustain exercise for longer durations or perform greater intensity exercise without developing fatigue, and consequently can expend more energy. A fourth advantage is that performing resistance training may reduce the risk of musculoskeletal-overuse injuries (Sothern et al., 1999). A fifth advantage of resistance training and probably most important for obese children is the motivational effect to engage in physical activity. Some studies investigating the benefits of resistance training for youth reported as much as 74 % strength gains (Faigenbaum et al., 2009), while most studies demonstrated strength gains of 30 to 50 % following short-term (8-20 weeks) resistance training programs (Faigenbaum et al., 2009; Falk & Tenenbaum, 1996), which exceeds the expected normal growth and maturation of youth (Faigenbaum et al., 2009). Such a significant and rapid increase in physical performance provides an immediate gratification and incentive for becoming more active, which may improve children's attitude toward physical activity (Bar-Or, 2003; Katsanis et al., 2021).

Material & methods

The purpose of the study was to establish and evaluate an after-school resistance-training program in secondary school adolescents, as there is only limited evidence available for this field in Germany (Höner & Demetriou, 2014).

A total of 80 students were recruited for the study. 40 students were assigned to the intervention group that was exposed to the after-school resistance-training program. The other 40 students were assigned to the control group that did not receive any treatment. All students were recruited from the same 10th grade cohort of a secondary school in the German federal state Rhineland-Palatinate. Body mass index (BMI), age, and gender were assessed at baseline. The descriptive statistics of the study group are shown in Table 1.

Table 1. *Characteristics of the study participants*

Variable	Intervention Group (*n* = 40)	Control Group (*n* = 40)
Age (years)	16.13 ± 0.42	16.01 ± 0.96
BMI (kg / m^2)	21.79 ± 2.81	21.64 ± 3.01
Gender (f / m)	10 / 10	12 / 8

Note. Data for age and BMI are mean ± SD. Data for gender are *n*.

The 40 intervention group students were divided into two groups of 20 participants, as the weight room facility could only be occupied and used by 20 individuals at the same time. Room size and federal law restrictions limited weight room activities the maximum of 20 individuals working out at the same time as well. However, a greater number of concurrently exercising participants would not have been enforced either, as the number of weight room supervisors and weight training equipment was limited, too. Each 20-participant intervention in-groups was exposed to the resistance-training program two times a week, right after regular school and under the same conditions.

The resistance-training program took place at a boys-and-girls club right across the street of the secondary school. For each exercising group, two supervisors were assigned who supported and monitored the students according to the training protocol. The supervisors were recruited among physical education teacher education (PETE) internship students who had also a background in strength and condition training and/or weight training, as they had either passed a strength and conditioning and/or weight training college level course and/or worked as a part-time weight training instructor at recreational centers or private gyms.

The resistance-training program was based on youth resistance-training guidelines by Faigenbaum (2003), which are consistent with current international resistance training guidelines (Lloyd et al., 2013; Miller et al., 2010) as well as with German national recommendations (Fröhlich et al., 2009; Granacher et al., 2011). Essentially, the training protocol by Granacher et al. (2011) was adapted. The after-school resistance-training program lasted eight consecutive weeks. The training protocol is described in Table 2.

Table 2. *Training protocol for the secondary school students resistance-training program (based on Granacher et al. (2011))*

Variable	Description
Exercises	Leg press. Knee extension/flexion. Seated calf-raise. Hip abduction/adduction (weight machine). Core exercises.
Volume	8-week training period with a total of 16 sessions. Exercises included 3 sets of 10-12 repetitions. 2 - 3 min rest between sets. Each session lasted 90 to 100 min (10 min warm up, 70 to 80 min resistance training, 10 min cool down).
Frequency	2 training sessions a week separated by at least 48 hours.
Intensity	70 - 80 % of the 1RM. Training intensity was examined for each participant on a fortnightly basis by means of 1RM tests. If necessary, the training load was adjusted.
Contraction	Participants were instructed to perform the exercises at moderate contraction velocity.

Note. An additional 2 training sessions were added before the start of the training period to become students accustomed with the training machines and training intensity. 1RM = One-repetition maximum.

The participating students exercised in pairs, so that one participant was exercising while the other one provided support regarding spotting and motivation. The students exercised on standard weight machines for the lower extremities (brand: Hammer Strength). Training intensity was controlled and adjusted if necessary. Adjustments were made according to one-repetition maximum (1RM) sets. Both intervention and control group students participated in regular school classes, including physical education (PE), wherein they were predominantly taught team games.

Each student's (both intervention and control group) physical attributes in regard to motor ability were assessed using tests from the DMT-6-18 (Bös et al., 2009), which is a German validated instrument for assessing motor abilities in children and adolescents from the age of 6 to 18 years multi-dimensionally. Included test items were sit-ups, push-ups, standing broad jump (all power), 6-minute run (endurance), 20-meter run (speed), balance backwards, rapid alternation, jumps sideways (all coordination), and sit and reach (flexibility) (Naul et al., 2012).

Additionally, countermovement jump (CMJ) height was included, as a previous studies by Granacher et al. (2011), and Weltman et al. (1986) have shown a significant effect of strength training on jumping height in adolescents. CMJ height was measured using a belt mat (Buckthorpe et al., 2012). Participants performed three CMJs with a resting period of 1 min between jumps. For each of these trials, participants were instructed to jump as high as possible. The best trial in regard to maximal jumping height was taken for data analysis.

In addition to measurement of the students' physical attributes, skinfold thickness was measured to assess percentage of body fat (Rodriguez et al., 2005). Skinfold thickness was calculated as the sum of triceps, abdominal, and calf skinfold measures (Dorgo et al., 2009). As more valid measurement methods such as dual X-ray absorptiometry or portable ultrasound were not available for this study according to cost efficiency, caliper measurement turned out to be the most adequate way to assess skinfold thickness.

Data was assessed at baseline (pre-test) before the start of the intervention and after the 8-week intervention period was completed (post-test). Data are presented as group mean (M) values and standard deviations (SDs). A multivariate analysis of variance (MANOVA) was performed to test for differences between study groups at baseline.

Repeated measures 2 × 2 (group: intervention group, control group × time: pre-test, post-test) MANOVA followed by subsequent univariate analyses of variance (ANOVAs) were conducted to test for changes of study variables for pre-study and post-study measurement points in both intervention and control group. The ANOVA model was corrected for gender. Effect sizes were determined by calculating partial η^2. Paired sample t-tests were performed to analyze independent changes for both the intervention and control group from pre- to post-test. The significance level was set to $p < 0.05$ for all statistical analyses. All data analyses were performed using the statistical software package IBM SPSS Statistics (Version 21) for Mac OS.

Values of the two 20-participant in-groups within the 40-participant intervention group were combined and treated as one single intervention group in further statistical analysis, as there were no statistical differences between the two 20-participant in-groups for both pre- and post-test measurement points (Wilks' $\lambda = 0.91\text{-}0.93$, $F(3, 32) = 4.23 - 7.75$, $p > 0.05$, $\eta^2 = 0.02 - 0.08$).

Results

Scores for study variables and groups are shown in Table 1. Despite subtle differences in the groups' mean descriptive values at baseline, there were no statistically significant differences for all study variables (Wilks' $\lambda = 0.87 - 0.92$, $F(3, 48) = 3.82\text{-}132.54$, $p > 0.05$, $\eta^2 = 0.01 - 0.12$) between the intervention and control group.

There were no statistically significant differences (Wilks' $\lambda = 0.74$, $F(3, 48) = 9.21$, $p > 0.05$, $\eta^2 = 0.03$) between intervention and control group for BMI and skinfold thickness according to MANOVA. Paired sample t-tests also showed no significant changes in BMI ($t(2) = -1.09$, $p > 0.05$) and skinfold thickness ($t(2) = 5.82$, $p > 0.05$) in both intervention and control group.

MANOVA revealed statistically significant effects for time (Wilks' $\lambda = 0.59$, $F(3, 48) = 8.79$, $p < 0.05$, $\eta^2 = 0.10$) and group × time interaction (Wilks' $\lambda = 0.51$, $F(3, 48) = 17.14$, $p < 0.05$, $\eta^2 = 0.09$) in the DMT-6-18 tests and CMJ height (Wilks' $\lambda = 0.67$, $F(3, 48) = 10.02$, $p < 0.05$, $\eta^2 = 0.06$). However, no statistically significant multivariate effect for group (Wilks' $\lambda = 0.85$, $F(3, 48) = 14.45$, $p > 0.05$, $\eta^2 = 0.03$) was found.

Subsequent univariate ANOVA results showed statistically significant time effects for sit-ups ($F(3, 48) = 12.31$, $p < 0.05$, $\eta^2 = 0.15$), push-ups ($F(3, 48) = 8.91$, $p < 0.05$, $\eta^2 = 0.21$), sit and reach ($F(3, 48) = 5.31$, $p < 0.05$, $\eta^2 = 0.04$), standings broad jump ($F(3, 48) = 86.11$, $p < 0.05$, $\eta^2 = 0.13$), and CMJ height ($F(3, 48) = 7.79$, $p < 0.05$, $\eta^2 = 0.08$), whereas no statistically significant time effect was found in 20-m sprint ($F(3, 48) = 3.64$, $p > 0.05$, $\eta^2 = 0.02$), rapid alternation ($F(3, 48) = 7.13$, $p > 0.05$, $\eta^2 = 0.06$), jumps sideways ($F(3, 48) = 5.66$, $p > 0.05$, $\eta^2 = 0.02$), balance backwards ($F(3, 48) = 7.09$, $p > 0.05$, $\eta^2 = 0.09$), and 6-min run ($F(3, 48) = 34.90$, $p > 0.05$, $\eta^2 = 0.10$).

The intervention group increased in sit-ups by 17.73 %, push-ups by 23.97 %, sit and reach by 8.01 %, standings broad jump by 4.31 %, and CMJ height by 2.79 %. Accordingly, group × time interactions revealed statistically significant results for sit-ups ($F(3, 48) = 9.41$, $p < 0.05$, $\eta^2 = 0.08$), push-ups ($F(3, 48) = 7.37$, $p < 0.05$, $\eta^2 = 0.11$), sit and reach ($F(3, 48) = 3.35$, $p < 0.05$, $\eta^2 = 0.08$), standings broad jump ($F(3, 48) = 66.13$, $p < 0.05$, $\eta^2 = 0.12$), and CMJ height ($F(3, 48) = 8.02$, $p < 0.05$, $\eta^2 = 0.12$), whereas no statistically significant time effect was found in 20-m sprint ($F(3, 48) = 4.19$, $p > 0.05$, $\eta^2 = 0.04$), rapid alternation ($F(3, 48) = 5.89$, $p > 0.05$, $\eta^2 = 0.04$), jumps sideways ($F(3, 48) = 5.54$, $p > 0.05$, $\eta^2 = 0.06$), balance backwards ($F(3, 48) = 8.12$, $p > 0.05$, $\eta^2 = 0.11$), and 6-min run ($F(3, 48) = 92.24$, $p > 0.05$, $\eta^2 = 0.13$). Paired sample t-tests also showed no significant changes for 20-m sprint, rapid alternation, balance backwards, and 6-min run ($t(2) = -2.45$, $p > 0.05$) in both intervention and control group.

Table 3. *Study variables before and after the resistance-training program intervention*

Test	Intervention Group (*n* = 40)		Control Group (*n* = 40)	
	Pre-Test	Post-Test	Pre-Test	Post-Test
BMI (kg / m^2)	21.79 ±2.81	21.33 ± 2.72	21.64 ± 3.01	21.54 ± 2.98
Sit-ups (*n*)	28.32 ± 5.12	33.34 ± 4.08*	27.29 ± 6.10	29.93 ± 6.11
Push-ups (*n*)	11.43 ± 2.09	14.17 ± 2.41*	12.00 ± 2.19	11.89 ± 2.37
Sit and reach (cm)	4.71 ± 4.94	5.09 ± 5.12*	4.62 ± 5.22	4.82 ± 6.01
20-m sprint (s)	3.77 ± 0.21	3.65 ± 0.39	3.81 ± 0.24	3.91 ± 0.21
Standing broad jump (cm)	201.43 ± 17.90	210.11 ± 20.68*	202.83 ± 18.78	201.12 ± 16.23
Rapid alternation (*n*)	35.85 ± 4.39	37.23 ± 4.98	37.10 ± 3.01	36.23 ± 4.53
Jumps sideways (*n*)	36.32 ± 4.83	37.12 ± 5.02	36.43 ± 4.21	35.87 ± 4.56
Balance backwards (*n*)	36.75 ± 5.09	37.93 ± 4.60	36.23 ± 3.24	37.76 ± 4.09
6-min run (m)	1087.80 ± 109.24	1063.32 ± 122.48	1101.49 ± 133.76	1089.62 ± 124.32
CMJ height (cm)	45.87 ± 4.87	47.15 ± 6.12*	46.12 ± 4.23	45.92 ± 4.39
Skinfold (mm)	45.55 ± 2.54	44.17 ± 3.46	46.83 ± 4.21	46.23 ± 4.40

Note. * = significant difference between pre- and post-test ($p < 0.05$). Values are mean ± SD. CMJ = countermovement jump.

Discussion

The most meaningful findings of this study were that a general 8-week after-school resistance-training program intervention statistically significantly improved DMT-6-18 test scores for sit-ups, push-ups, sit and reach, standing broad jump, as well as CMJ height scores in secondary school students. Compared to DMT-6-18 standard values reported by Bös et al. (2009) and diagnostic standard values (Ministerium für Familie, Kinder, Jugend, Kultur und Sport des Landes Nordrhein-Westfalen, 2010) for PE teachers, this study's sample was on an average fitness level.

The majority of the test results were expected, as the training protocol of the resistance-training program clearly enhanced motor abilities that were needed to accomplish decent test results for sit-ups, push-ups, standing broad jump, and CMJ. However, the statistically significant positive changes for sit and reach scores in the intervention group were unexpected, as flexibility and stretching were not specifically addressed throughout the program. Accordingly, recent studies (Azeem & Al Ameer, 2010; Morton et al., 2011) have shown that weight training may also have a positive effect on flexibility, which may also explains this study's findings.

The statistically non-significant results for a change of test scores for 20-m sprint, rapid alternation, jumps sideways, balance backwards, and 6-min run in the intervention group were expected, as the respective associated motor abilities in regard to these tests were not specifically addressed within the resistance-program intervention. The 6-min run is a test for aerobic training and endurance that were also not part of the training protocol. Although sprinting performance for the 20-m sprint improved in the intervention group by 3.28 %, this change did not turn out to be statistically significant. Nonetheless, previous studies (Azeem & Al Ameer, 2010; Young, 2006) showed a positive effect of weight training on sprinting performance. Although there was a small portion of core stability exercises included in the training protocol, test scores for rapid alteration, jumps sideways, and balance backwards. This result is not surprising, as the DMT-6-18 tests for rapid alteration, jumps sideways, and balance backward feature a large (intramuscular) coordination and motor control portion, which was not specifically addresses by this study's resistance-training program. The results are consistent with the majority of the empirical evidence that indicates that strength training does not have a significant effect on improved (intramuscular) coordination (Young, 2006). Although the test scores for balance backwards descriptively increased in the intervention group by 3.21 %, there was no statistically significant difference found. However, research on the comparison on resistance training and conventional training for improving balance indicates that resistance training may as well be equally effective as traditional balance training (Blackburn et al., 2000), or even more effective (Bruhn et al., 2004). For adolescents, this is also suggested by Granacher (2012).

The fact that BMI and skinfold thickness did not show major descriptive and statistically significant changes in the intervention group is most likely caused by the fact that this study's resistance-training program intervention may be simply too short in duration to achieve such a change. The relatively short duration of after-school programs is a commonly known problem (Granacher et al., 2011), as school holidays and national labor days frequently cut into a longer period than 8 to 10 weeks. Moreover, this study's participants appeared to be in good physical condition according to BMI mean scores and did not show any signs of obesity at all.

This study covered a relatively general and simple type of training protocol and methods. Upcoming studies may focus on different target groups, such as elementary school students, as training effects are most likely to be different (Granacher, 2012; Granacher et al., 2011). PE may also be a good shot at placing resistance training in a school setting, even without having a weight room and weight machines available (Langford & McCurdy, 2005). It can be assumed that a German school possessing its own weight room is quite rare to find, as only 10.4 % of German schools have access to a weight room (Deutscher Sportbund, 2005).

Including innovative treatments such as technology (e.g., apps, physical activity measurement devices, etc.), outdoor activities, mentor programs with (school and college) students and/or parents, nutrition, emphasizing psychosocial variables as well, and with greater sample sizes may also be considered for future iterations of (after-school) resistance-training programs in schools.

Conclusions

A general 8-week after-school resistance training program intervention in secondary school students proved to be effective in improving DMT-6-18 test scores for sit-ups, push-ups, sit and reach, standing broad jump, as well as CMJ height scores at a statistically significant level.

However, BMI and skinfold thickness did not show significant positive changes, which may be due to the short duration of the program.

Future research should aim to replicate this study's approach and findings in a larger-scale study that targets different groups. This will allow for the expansion of intervention/program duration and the inclusion of diverse treatment conditions, such as technology-enhanced learning and innovative training scenarios.

Conflicts of interest - If the authors have any conflicts of interest to declare.

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