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Impact of Resistance Training on Untrained Adolescence and children Upper body Strength: A Meta-Analysis

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Abstract

The purpose of this meta-analysis is to indicate the effect of resistance training protocols regarding duration and frequency on specific upper body strength, on children and adolescents. Studies investigating the effects of resistance training programs and used the bench press test as an assessment of upper body strength were analyzed. Twenty-three effect sizes were calculated in sub-groups by gender, age group (adolescents 11 to 15, childhood 8 to 10 years old), and training protocol (duration, frequency). A total of 691 participants were included in the analysis. This meta-analysis showed that females' upper body strength is significantly affected more than males by the resistance training program. Also, the results demonstrate that two training sessions per week are the most efficient method of strength gaining in the tested population. Indicative of the importance of resistance training earlier in the lifespan to assess motor development and enhance injury prevention especially in females.

Keywords: Adolescents, Childhood, Bench press test, Upper body, Resistance training

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التحليل التلوي لتأثير تدريبات المقاومة لدى المرحلة العمرية للمراهقين والأطفال غير المدربين على القوة العضلة للأطراف العلوية "التحليل التلوي"

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ملخص

هدفت هذه الدراسة التحليلية إلى تحديد تأثير تدريبات المقاومة من حيث المده والتكرار على تنمية القوة العضلية للجزء العلوي من الجسم لدى الأطفال والمراهقين من كلا الجنسين. تضمنت هذه الدراسة تحليل نتائج الدراسات التي اجريت على تدريبات المقاومة واستخدمت اختبار الضغط للصدر لتقيم القوة العضلية للأطراف العليا، تم استخراج ثلاث وعشرين معامل تأثير وتقسيمه الى مجموعات فرعية – للجنس (ذكور واناث) وللمرحلة العمرية (15–11سنة مراهقين و 8–10 سنة أطفال) إضافة إلى طبيعة التدريبات المقاومة من حيث (المدة و التكرار). تضمنت عينة الدراسة 691 شخص. أظهرت نتائج هذه الدراسة التحليلية أن التدريبات المقاومة أثرت في القوة العضلية للأطراف العليا من الجسم لدى الاناث أكثر من الذكور. كما أظهرت النتائج أن وحدتتين تدريبيتين في الاسبوع من تدريبات المقاومة كانت أكثر تأثيراً على تنمية القوة العضلية للأطراف العليا من الجسم. وخلصت الدراسة إلى إبراز أهمية تدريبات المقاومة لحياة افضل ولدعم التطور الحركي والوقاية من الإصابات وبالأخص لدى الإناث.

الكلمات الدالة: المراهقين، أطفال، اختبار الضغط على البنش، للأطراف العليا للجسم، تمارين المقاومة

Introduction

Physical activity levels in the youth population are integral in supporting normal growth, motor-development, and reduces the risk of chronic diseases .e.g., diabetes and high blood pressure and prevent injuries. The World Health Organization recommended that the school-aged youth should participate daily in 60 minutes or more of moderate to vigorous physical activity, including aerobic activities such as running and bicycling, muscle strengthening and bone strengthening.

As exercise programs are scheduled, they should be designed with specific aims and protocol, regarding the condition of participants' growth phases. Children between the ages of six to 12 years old are exposed to various sports for a short amount of time utilizing different skills, mechanics, and rules. Between the ages of 13 to 15 years old the youth specializes in a chosen sport and within one year usually they begin to play the game. (Micheli et al., 2012) addresses that an estimated 15% to 50% of all injuries sustained by youth while playing sports could be prevented if more emphasis were placed on developing fundamental fitness abilities prior to sports participation.

Resistance Training (RT) (also called strength training) is a specialized method of physical conditioning that involves the progressive use of a wide range of resistive loads and a variety of training modalities designed to enhance or maintain muscular fitness (Faigenbaum et al., 2009). The National Strength and Conditioning Association (NSCA, USA Colorado), summarized the benefits of youth prescribed and supervised resistance training programs as: enhancing muscular strength and local muscular endurance, regular participation in a youth resistance training program has the potential to positively influence aerobic fitness, body composition, blood lipids, bone mineral density, and motor performance skills (e.g., jumping and sprinting). Studies have supported the impact of resistance training programs in improving muscular endurance and strength in youth, although the methods of testing and strength have varied (Payne et al., 1997) Faigenbaum et al., 2005) and (Attarzadeh, 2012). Among upper body, multi-joint training exercises, the bench press is one of the most commonly used exercises (Wong et al., 2013). Bench press has been a fundamental exercise, for both testing and training the upper body strength. For example, (Christou et al., 2006) used bench press as an evaluation for his suggested resistance training program on the physical capabilities of adolescent soccer

players. Aside from the athlete population, numerous studies in the non-athletic population have also used bench press as strength measurement and training exercise. For example, (Abbasian et al., 2011) used to bench press increasing loads test to measure upper body strength of healthy, youth participants, whereas (Lillegard et al.,1997) used to bench press as a significant upper body training exercise for prepubescent and early prepubescent males and females (Nichols et al., 2001).

Upper extremity injuries are common in children and adolescents. Injury patterns are unique to the growing musculoskeletal system and specific to the demands of the involved sport and daily activates (Ingle et al., 2006) and (Kocher et al., 2002). For example, Bicycling is a favorite recreational and sporting activity among children and adolescents. 60% of all bicycle injuries occurred in children and adolescents between the ages of five and 14 years, and 85% of injuries involve the upper extremity (Faigenbaum et al., 1996) and(Kocher. 2000).

Resistance training is a well-established training technique for increasing the musculoskeletal strength of the upper extremity. Furthermore, debates have addressed some concurrence related to safety and effectiveness of resistance training protocols for children and youths in regards to the potential harm of the growth plates, overuse single joint injuries in addition to their impact on the immature cardiovascular system (Faigenbaum et al., 2002). Optimal physical conditioning requires consideration of four factors: initial level of fitness, exercise intensity, exercise frequency, and exercise duration (Ingle et al., 2006).

Following the concern of the effectiveness of RT protocols in terms of intensity, frequency, and duration, through the maturation process in youth. A meta-analysis was conducted to compare the result of previous literature that examined the effect of different RT protocols, such as strength outcomes from training one day per week or more, in strengthening the upper body in children and adolescents. The intensity of the RT has been well investigated by researchers and surmised by meta-analysis studies (Peny et al., 1997), (Rehea et al., 2003) and (Faigenbaum et al., 2009). The focus of this study was placed on the effectiveness of RT programs' durations and frequency. It was hypothesized that TR program in terms of

frequency, duration of the exercise and the program have no significant differences among two age groups (childhood, adolescents) and gender in upper body strength gains. In order to be included in a meta-analysis for a given field, each study needs to have a common metric. For this meta-analysis, the studies have the bench press test results as a measure of upper body strength gained as an outcome of resistance training protocols.

Each of the included studies contributes to an effect size to the meta-analysis. An effect size is a standard, statistical measure to represent the degree or amount of ‘outcomes’ or ‘effects,' and is quantified as the mean difference divided by the standard deviation. An effect size of 0.00 to .32 is considered “small” effect size of 0.33 to .55 is considered ‘ medium,’ and effect size of .56 to 1.2 is considered ‘large’; the larger the effect size is, the better.

Methods:

Definitions:

In this article, term “Resistance training” is defined an exercise that requires the musculature to contract against an opposing force generated by some resistance (e.g., body weight(barbell's dumbbells, elastic tubing). If free weight or specific machines were applied to generate resistance, the term “weight training” is used synonymously.

By contrast, the term “strength training” is used in a broader sense (i.e., to describe any conditioning that is used to increase physical strength). The term adolescents refer to the age group from 11 to 15. The term “childhood” is an acronym for the phrase of middle childhood that starts around eight years of age and ends at 10. Muscular strength was considered to be a force or tension that a muscle or group of muscles can exert against resistance on one maximal effort or very few repetitions.

Bench press test: the most widely accepted technique for strength gain evaluation is probably the one repetition maximum (1-RM) in which the most weight that can be lifted once through a full range of motion is determined (YMCA of the USA 2000) (Lawrence & Coldin, 2000). Upper body refers to the shoulder chest area, more specifically, muscle groups of the pectoralis major, anterior deltoid, and triceps brachii.

Literature search:

Systematic computerized search of the following database 2014: from Medline (1994), PudMed (1990) Web of science (1990), Google Scholar, and Sport Discuses 1990. The searches provided 180 studies that spanned the period of 1993-2013. This time period was chosen due the wieldy used of the bench press as an upper body assessment in the chosen population in this research.

Meta-analysis Procedure and data collection:

The following key words were used for the search: Resistance training, strength training, youth, children, adolescents, bench press, chest press, and upper body.

Inclusion criteria:

- The study design had included a resistance training intervention.
- The study had used bench press/ chest press as testing method for measuring the effect of resistance training program for upper body.
- The effect of resistance training on the upper body muscular strength must have been examined and reported in means and stander divisions SDs for the training and the control groups for pretests and posttests.
- The age of participants had to be 18 years or younger.
- The participants had to be healthy non obese and enrolled in any sport/specific team training.
- Published or translated into English, full text available.

Studies that met the criteria were 11 and they were coded by the primary investigator in Microsoft Excel and be transferred to the CMA software.

All meta-analysis were performed using Comprehensive Meta-Analysis (CMA) software program (Version 2; Borenstein, Hedges, Higgins, & Rothstein, 2005). Effect size estimates of continuous measures: The first step involved calculating for each study the effect sizes for the difference between control group and resistance trained group. For continuous

measures, Hedges' g effect size and its 95% confidence interval was calculated. This effect size is a variation on Cohen's d that corrects for biases due to small sample sizes. Each effect size was then weighted by the inverse of its variance. A random effect model used to allow for generalizability beyond the sample of studies included and to decrease the likelihood of a type I error, which may exaggerate the accuracy of meta-analytic results. Statistical heterogeneity among the study was assessed using Cochran Q test, with a $p > 0.05$ and an inconsistency I^2 statistic in which the value >50% considered indicative of high heterogeneity. The independent variables were the age group of participants, study duration, session per week, and exercise duration. Statistical Significance was set to $p \leq 0.05$ for all analysis.

Publication bias:

It has been argued that meta-analyses may overestimate the overall effect size because studies with non-significant findings are often not published. A conservative method often employed to address this issue involves calculating the fail-safe N which reflects the number of un-retrieved studies required to reduce the overall effect size to a non-significant level (Cooper et al., 2009). For the present study, we computed the fail-safe N for the major analyses. All effect size calculations and publication bias analyses were completed using the program Comprehensive Meta-Analysis, version 2.

Results:

Twenty-three effect sizes were included from 11 studies as some studies examined the effect of resistance training program protocols in different sub-groups. A total of 691 participants (trained: 387 and 256 control) were included in the analysis. A distinct gender imbalance was found: there was a total of (trained group: 138 control group: 115) of males and (trained group: 79 control group: 58) of females. Some studies did not report any specific gender, and there was no way to clarify the differences; it was combined with the overall effect of the TR program. Effect sizes and analysis are presented in table (1) and table (2).

Table (1) Subgroup Analysis for the Effect of Resistance Training on Gender Using Random- Effect Model

PROGRAM DURATION		EXERSIS DURATION		SESSION PER WEEK				Gender
2	1	2	1	3	2	1		
2.101	-.2	.247	1.996	1.451	-.391	-	H'g	Males
0.000	.695	.691	.023	.025	.667	-	P	
3.725	-.393	.397	2.279	2.244	-.430	-	Z	
4	5	6	3	6	3	-	#of effect sizes	
1.243	2.915	1.997	1.243	1.365	2.286	-	H'g	Females
.025	0.00	.016	.025	.008	.004	-	P	
2.241	3.16	2.4	2.241	1.646	2.909	-	Z	
4	2	4	2	3	3	-	#of effect sizes	

H'g :Effect size estimates (Hedges'g)

Table (2) Subgroup Analysis of the Effect of Resistance Training on Age Group Using Random-Effect Model

program duration		exersis duration		session per week				Gender
2	1	2	1	3	2	1		
3.22	1.270	-	1.496	3.22	1.412	.979	H'g	Males
0.00	.002	-	0.00	.019	.005	.394	P	
3.925	3.113	-	3.634	2.355	2.863	.852	Z	
1 F	7	-	8	1	6	1	#of effect sizes	
1.54	1.016	.903	1.682	1.244	1.29	-	H'g	Females
.008	0.064	.105	0.005	.032	.037	-	P	
2.654	1.855	1.62	2.805	2.148	2.082	-	Z	
7	8	8	7	8	7	-	#of effect sizes	

H'g :Effect size estimates (Hedges'g)

Overall the results on the figure (1) showed a significant effect of the RT programs in increasing the upper body strength measured by bench/chest press test (Hedges's g = 1.391, z= 4.668. p < 0.01). For both age groups the results showed a significant effect of the RT (Hedges's g= 1.260, z= 3.369 p < 0.05) for adolescents and (Hedges's g= 1.67, z= 3.160 p < 0.05) for childhood. For females results showed a significant effect of RT program as the (Hedges's g= 1.856, z=3.315 p < 0.01) and for males the results were non-significant as the (Hedges's g= .831 z= 1.486 p > 0.05). The RT session durations were coded as 1 for < 45 minutes and 2 for > 45 minutes, the results showed the longer exercise durations > 45 minutes were non-significant as (Hedges's g = .898z = 1.789 p > 0.05) and shorter sessions < 45 minutes were more effective as (Hedges's g= 1.669 z= 4.44 p < 0.01). For session per week of the RT programs the results showed a non-significant effect of one training session per week as (Hedges's g= .970 z = .657 p > 0.05) and higher significant effect of 2 session training per week (Hedges's g= 1.418 z= 3.14 p < 0.01) and significant effect for 3 session per week (Hedges's g= 1.429 z= 2.87 p < 0.01). For the RT program duration it was coded by 1 for ≤ eight weeks and 2 for > 8 weeks results showed a significant effect of overall duration on RT with longer programs to be more effective.

Moreover, the comparison between resistance training parameters (protocols) and age groups: showed that in the childhood age group, 2 and three resistance training sessions per week were statistically significant in increasing the upper body strength as the significant effect sizes were (Hedges' g = 1.412 , 95% CI, z = 2.863, P = . 05) for the two sessions per week and (Hedges' g = 3.22, 95% CI, z = 2.355, P < . 05) for the three sessions per week, as for the one sessions per week there was just one study for this age group, and the results were non-significant. The observed result indicated that both training programs duration measured by weeks had a significant impact on the upper body strength. Programs that last less than 8 weeks (Hedges' g = 1.27, 95% CI, z = 3.113, P < .05) and for programs that duration exceeded the 8 weeks the results were (Hedges' g = 3.22, 95% CI, z = 3.905, P < .01). Moreover, the examined studies indicated that childhood age group was significantly affected by the 45 minutes exercise duration (Hedges' g = 1.498, 95% CI, z = 3.634, P < .01), there was no effect sizes examined for the impact of the second exercise duration time > 45 minutes.

Adolescent age group upper body strength has been significantly affected by the number of RT sessions per week. As for two sessions per week the results were (Hedges' g = 1.29, 95% CI, z = 2.082, P <.05) and for the three session per week the results were (Hedges' g = 1.244, 95% CI, z = 2.148, P <.05), non-effect sizes were indicated from the examiner studies for one session of RT per week. For the exercise duration, significant effects were observed for the 45 min duration (Hedges' g = 1.683, 95% CI, z = 2.805, P =.05), non-significant result for the > 45 minutes exercise duration (Hedges' g = .903, 95% CI, z = 1.62, P >.05). Furthermore, the results were non-significant for the RT programs that lasted for 8 weeks (Hedges' g = 1.016, 95% CI, z = 1.855, P >.05) while RT for a longer period of time > 8 weeks were statistically significant in increasing upper body strength (Hedges' g = 1.54, 95% CI, z = 2.654, P <.05).When comparing the effect of RT protocols among gender, the results showed that males didn't gain any upper body strength form the 2 sessions per week (Hedges' g = -.391, 95% CI, z = -.430, P >.05) in the other hand the results were significant for the 3 sessions per week (Hedges' g = 1.451, 95% CI, z = 2.244, P >.05). Although, shorter exercise durations were significant. In addition to the significant RT parameter that affected upper body was longer program duration > 8 weeks as (Hedges' g = 2.101, 95% CI, z = 3.725, P <. 05). As for females' upper body strength, all the studied exercise parameters were significant, sessions per week and program durations and exercise duration. Table (1) and table (2) summarize the obtained results.

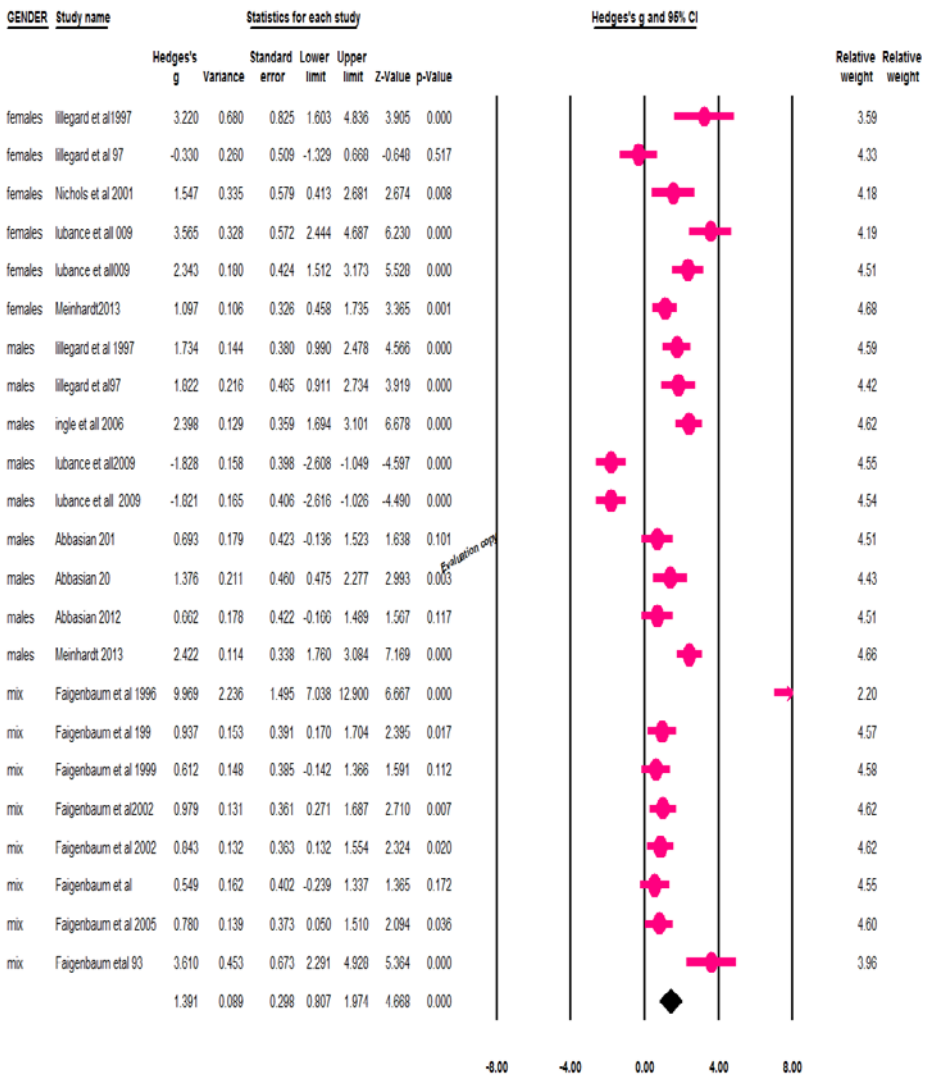

Figure 1. Effect size estimtes (Hedger'g) and the statisitcl tests of the effect of resistance training programs on the upper extermity strength masured by bench press test.

Discussion:

This study aimed to address the effectiveness of resistance training programs in improving upper body strengthen and the differences between gender and two age groups (childhood and adolescents).In addition to clarifying the impact of resistance training program protocols in terms of frequency and duration on specific upper body strength of the assessed by an objective strength test "bench press." The results demonstrate that resistance training programs significantly increase upper body strength in children and youths. This finding generally supports the recommendations of the National Strength and Conditioning Association 2009 and American College of Sports Medicine recommendations for strength training 2005 and previous meta-analysis and review studies (Payne et al., 1997, and Rhae et al., 2002; Faigenbaum et al., 2002; Faigenbaum et al., 2009). Furthermore, this meta-analysis showed that females' upper body strength is significantly affected more than males by the resistance training, as similar results were founded by (Payne et al., 1997) and (Meinhardt et al., 2013). According to the trigger hypothesis by Katch's (1983), boys take longer to reach the trigger point than girls, which affect the muscle mass development, due to an earlier trigger point (closer to sexual maturation), girls may have demonstrated more significant effects. Also, these results can be explained by the natural differences in gender activities as males tend to be more active than females, any change in females daily activity can significantly affect their physical condition and strength. The short duration of RT sessions for untrained children and youths were more effective than longer durations > 45 minute, as they tended to fatigue due to lack of endurance. Additionally (Winett, 2004) in his review of resistance training concluded that simple, time efficient, single set, lower volume protocols appear to be just as effective as multiple-set, higher volume protocols for increasing muscular strength regardless of the goal or training status. The results demonstrate that two training sessions per week are the most efficient method of strength gaining in the tested population followed by 3 sessions per week, but the results were non-significant for the 1 session per week, these results aligned with the results of (Rhea et al., 2003) meta-analysis paper for a similar population (untrained). The tendency for children to improve strength founded to be rapidly during the early phase of training is

consistent with the results from other studies (Lillegard et al., 1997), (Lubance et al., 2009) (Abbasian et al., 2011) and (Meinhardt et al., 2013) it is possible that gains in the upper-body strength did not follow a similar pattern. It could be that the differences in muscle mass development in the examined age groups had a direct effect on the upper body muscle group strength gaining. (Faigenbaum et al., 1999).

The findings from this study are limited by the following. First, the limited number of studies included due to the criteria. Secondly, RT studies often examine the impact of the suggested training program, and the included parameters (study duration, RT duration, and session per week) as secondary outcomes and so relevant statistics were not available in the initial publication. Gender imbalance was prevalent as boys were more numerous than girls and some studies did not report any gender which could skew the results. Additionally, the impact of some parameters cannot be generalized due to the absence of related results from the initial studies and small effect sizes.

Conclusion:

The purpose of this meta-analysis was to indicate the effect of RT programs on specific upper body strength, tested by bench press for untrained youth participants, furthermore, to indicate the most efficient RT protocols in terms of training program duration, RT session duration and sessions per week. This study results aligned with previous meta-analyses that examined the overall strength gaining from the RT programs without considering the effect of mass muscle development through the age groups, as girls' bodies tend to slow upper body muscle mass development around 13 years old, due to early maturation and sexual hormones. This results may be indicative of the importance of targeting these muscle groups earlier in their life to assess their motor development and enhance injury prevention. Furthermore, the results of the RT tested protocols, met the training recommendations of the age group, 30 to 40-minute exercise duration for three times a week, with follow-up training.

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