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Lubans, David R.; Smith, Jordan J.; Harries, Simon K.; Barnett, Lisa M.; Faigenbaum, Avery D.; 'Development, test-retest reliability, and construct validity of the resistance training skills battery'. Published in Journal of Strength and Conditioning Research Vol. 28, Issue 5, p. 1373-1380 (2014)

Available from: <http://dx.doi.org/10.1519/JSC.0b013e31829b5527>

This is a non-final version of an article published in final form in Journal of Strength and Conditioning Research Vol. 28, Issue 5, p. 1373-1380 (2014)

Accessed from: <http://hdl.handle.net/1959.13/1303616>

Development, Test-Retest Reliability and Construct Validity of the Resistance Training Skills

Battery

JSCR-08-3414R1

ABSTRACT

The aim of this study was to describe the development and assess test-retest reliability and construct validity of the Resistance Training Skills Battery (RTSB) for adolescents. The RTSB provides an assessment of resistance training skill competency and includes six exercises (i.e., body weight squat, push-up, lunge, suspended row, standing overhead press and front support with chest touches). Scoring for each skill is based on the number of performance criteria successfully demonstrated. An overall resistance training skill quotient (RTSQ) is created by adding participants' scores for the six skills. Participants (44 males and 19 females, mean age = 14.5 ± 1.2 years) completed the RTSB on two occasions separated by seven days. Participants also completed the following fitness tests, which were used to create a muscular fitness score (MFS): handgrip strength, timed push-up and standing long jump tests. Intraclass correlation (ICC), paired samples t-tests and typical error were used to assess test-retest reliability. To assess construct validity, gender and RTSQ were entered into a regression model predicting MFS. The rank order repeatability of the RTSQ was high (ICC = 0.88). The model explained 39% of the variance in MFS ($p < .001$) and RTSQ ($r = .40, p < .001$) was a significant predictor. This study has demonstrated the construct validity and test-retest reliability of the RTSB in a sample of adolescents. The RTSB can reliably rank participants in regards to their resistance training competency and has the necessary sensitivity to detect small changes in resistance training skill proficiency.

Key words: Physical fitness; exercise; strength training; muscular fitness; motor skills, movement skills

INTRODUCTION

Despite the extensive benefits of physical activity, a large proportion of the world's population remain inactive (18). Approximately 80% of adolescents are not accumulating at least 60 minutes of moderate-to-vigorous physical daily, of which 2-3 days per week should involve muscle strengthening activities (18). Resistance training is activity designed specifically to enhance muscular fitness (i.e., muscular strength, power and endurance) by progressively increasing the workload placed on the muscles (17). Resistance training with qualified instruction and supervision is now recognized as a safe, effective and worthwhile activity for adolescents (8, 16, 21), and numerous studies have demonstrated the health- and fitness-related benefits of resistance training for children and adolescents, which include: increased muscular fitness (9, 15, 25, 39), decreased body fat (9, 39), improved blood lipid profiles (9) and positive changes in physical self-concept (29, 39).

Resistance training programs are typically evaluated using product type fitness tests that assess muscular strength and local muscular endurance. There have been concerns regarding the use of fitness testing with children and adolescents, such as their lack of validity and reliability and the potential stigmatization of children (10, 40). However, if used appropriately, fitness testing can help: i) support students' understanding of the effects of activity on fitness, ii) facilitate the learning of physical fitness concepts, iii) provide useful information to parents on their children's health status and iv) help children link health-related fitness to present and future health status (40). Despite these potential contributions, existing fitness tests are product measures that do not provide feedback on actual movement skill technique. Alternatively, process oriented assessment involves assessing the presence or absence of the criteria you need to successfully complete an exercise or skill (i.e., your technique).

Although there are existing process measures for identifying injury risk factors in athletes (37), to our knowledge, there are no validated movement skill batteries for evaluating resistance training skill

competency. Therefore, the aim of our study was to develop and assess the test-retest reliability and construct validity of the Resistance Training Skills Battery (RTSB) for adolescents. The RTSB was designed to serve the following purposes: (i) evaluate the efficacy of school- and community-based resistance training programs, (ii) assess individual progress and provide feedback in resistance training programs, and (iii) use as a measurement instrument in research focusing on movement skill competency.

METHODS

Experimental Approach to the Problem

Fourteen experts in youth resistance training were contacted to determine their willingness and availability to assess the content validity of the RTSB. Each of the experts had a doctorate degree in a relevant field (e.g., kinesiology, exercise physiology, physical education), had published in international refereed journals and was currently employed at an Australian, American, British or Canadian university or college. Eight experts responded and provided feedback on the instrument within eight weeks of the original mailing. Experts were provided with a copy of the RTSB and asked to comment on the following: (i) the importance of developing a resistance training skill battery, (ii) the selected resistance training exercises and (iii) the skill performance criteria for each skill identified by the research team. Feedback from experts was then collated and the necessary modifications were made to the original measure. Examples of modifications include: consistency in the number of repetitions for each exercise, changes to the exercises, addition/removal of performance criteria and the inclusion of pictures depicting the different exercises.

The six exercises included in the final RTSB (i.e., body weight squat, push-up, lunge, suspended row, standing overhead press and front support with chest touches) were chosen because: (i) they were considered safe and developmentally appropriate for adolescents, (ii) they require minimal equipment

and/or access to facilities and (iii) they represent the movements commonly used in adolescent resistance training programs (8, 17, 21). Competency in these movements will provide the foundation for developing physical strength in a range of bodily movements, notably: i) trunk stability (front support and chest touches), upper body pushing strength (push-up), upper body pulling strength (suspended row), lower body bilateral strength (squat), and lower body unilateral strength (lunge). Furthermore, exercises such as the body weight squat, standing overhead press and push-up provide the foundation for more advanced lifts, including the clean and jerk and bench press. The six exercises included in the RTSB target the major muscle groups: lower body (squat/lunge), chest, back and arms (push-up and suspended row), shoulders (standing overhead press) and core (front support with chest touches). Finally, the RTSB was designed to be administered in a school setting and does not require access to a gymnasium or weight room, but does require bar (e.g., wooden bar or PVC pipe) and a suspended bar or suspension straps and anchor point for administration.

Subjects

Study approval was sought and obtained from the University of Newcastle Research Ethics Committee, the Newcastle and Maitland Catholic Schools Diocese and the school principal from one secondary school in Newcastle, New South Wales (NSW), Australia. Information letters, parental permission forms and participant assent forms were sent home with students and those who returned signed forms were permitted to participate in the study. Eligible participants were school students in year 7 to 10 (aged 12 to 16 years) from the study school (Table 1). The final sample included 44 males and 19 females (mean age = 14.5 ± 1.1 years). Participants were ineligible if they had a medical condition or physical injury preventing testing or training, as self-reported by parents and participants prior to start of study.

Procedures

Assessments were conducted by trained research assistants at the study school on two occasions seven days apart (Trial 1 and Trial 2, hereafter called T1 and T2). On muscular fitness tests, a 7-day separation period is commonly used (30). A period of one week was considered sufficient time to reduce the learning effect of the testing procedures without introducing additional error due to maturation. All research assistants participated in a full-day training workshop in preparation for the assessments.

Participants completed the assessments at school during the same time of day (i.e., between 9am and 3pm) for T1 and T2 in gender-matched groups (i.e., all males or all females) of three or four.

Participants completed the exercises individually under the supervision of the research assistant.

Standardized warm-up activities were not performed before participants completed the RTSB because all of the exercises included body weight resistance or a bar with no weight. Prior to performing each skill, participants observed demonstrations by a research assistant and only questions pertaining to the exercise protocol (e.g., number of repetitions) were permitted. General encouragement was provided by the research assistants, but no skill specific feedback was provided at T1 or T2. Participants completed two sets of four repetitions for each skill in the following order: (i) body weight squat (ii) push-up (iii) lunge (iv) suspended row (v) standing overhead press and (vi) front support with chest touches.

Participants were given 20-30 seconds to recover between sets and also between exercise skills (total time taken to complete the RTSB was 8-10 minutes per participant). All skills were recorded using a digital video camera positioned at a 45 degree angle to the participant to enable front- and side-on views. This was considered the best viewing position to enable the assessor to properly evaluate each skill during video analysis.

The structure and scoring format of the RTSB was based on the Test of Gross Motor Development 2 (38). Each of the exercises in the RTSB includes four (push-up and suspended row) or five (body

weight squat, lunge, standing overhead press and front support with chest touches) performance criteria. A full description of the exercises and their corresponding performance criteria are included as Supplemental Digital Content 1. An experienced research assistant, who held a Bachelor's degree in physical education and had over five years of resistance training experience, assessed all of the skills in the current study. Before assessing the skills, the research assistant and the lead investigator viewed a sample of videos to establish what was considered "acceptable" for each of the performance criteria for the six skills. For example, this involved identifying what was considered to be an acceptable level of lateral movement (approx. 10cm) in the front support with chest touches exercise. This information was then used to identify participants (three for each skill level) with high (i.e., all criteria performed correctly), moderate (i.e., most criteria performed correctly) and low (i.e. few criteria performed correctly) resistance training skill competency. These examples were then used as a reference and the research assistant was encouraged to review these examples before scoring the videos.

As participants may require several repetitions before they demonstrate a skill to their best ability, scoring of the RTSB was based on their "best repetition technique". This was defined as the repetition during which the participant satisfied the highest number of performance criteria. For example, if the participant satisfied two of the criteria on their first repetition and then three criteria on their second repetition, they were awarded a score of three for the set. Participants were awarded a 1 for each performance criterion that was correctly demonstrated and a 0 if the criterion was not performed appropriately. Scores of 0.5 were not awarded. Totals for the two sets were added to obtain a raw score for each skill (i.e., a total of eight for skills involving four criteria and 10 for those involving five criteria). To ensure that there was not a learning effect between set 1 and set 2, the difference in group (i.e., males and females) means were calculated. For females, the difference between sets ranged from 0.1 for the push-up to -0.1 for the suspended row. For males, the difference between sets ranged from -0.2 for the lunge to 0.1 for the push-up. Overall these findings do not support the existence of a

learning effect. The skill scores were then added to create a resistance training skill quotient (RTSQ) (possible range 0 to 56).

As there are no existing measures for assessing youth resistance training skill competency, it was not possible to assess the criterion validity of the RTSB. However, we tested the construct validity of the RTSB by examining the relationship between overall resistance training skill competency (i.e., RTSQ) and a muscular fitness score (MFS), which combined participants' results for the handgrip strength, timed push-up and standing long jump tests (2). It would be expected that resistance training skill competency would be associated positively with muscular fitness thereby providing a rationale for the assessment of resistance training technique. Relative values (i.e., participant result divided by their body weight) for the handgrip test were first computed to account for differences in body size. Values were then standardized using the following formula: $\text{standardized value} = (\text{value} - \text{group mean}) / \text{standard deviation}$. The MFS was then computed by summing the standardized values of the grip strength, timed push-up and standing long jump tests. These tests were selected because they have good test-retest reliability (23, 32) and validity when assessed against upper- and lower-body criterion muscle strength measures in adolescents (20).

Body mass was measured in light clothing without shoes using a portable digital scale (Seca 770, Wedderburn) to the nearest 0.1kg and stature was measured to the nearest 0.1 cm using a portable stadiometer (Design No. 1013522, Surgical and Medical Products, Seven Hills, Australia). Body mass index (BMI) was calculated using the standard equation ($\text{body mass}[\text{kg}] / \text{stature}[\text{m}]^2$) and the International Obesity Task Force (IOTF) cut-points were used to classify participants as healthy weight, overweight or obese (11).

Strength of the hand and forearm muscles was assessed using a grip dynamometer (Smedley's TTM Tokyo). The grip-span was adjusted to suit the hand size of the participant prior to performance. Subjects were asked to squeeze the dynamometer continuously as hard as possible for two to three seconds with the elbow in full extension down by the side of the body. The test was performed three times each for the left and right hands, alternating hands after each trial. The score in kilograms was recorded. The average of the scores for the right and left hands was used in the analysis.

The 90-degree timed push-up test was used as a measure of upper body muscular endurance. Testing procedures were explained to the participants prior to the test. The test began with participants in the push-up position with hands and toes touching the floor, arms approximately shoulder width apart and back straight. Participants lowered themselves to the floor in a controlled manner until a 90-degree angle was formed at the elbow then pushed back up. Push-ups were performed in time with a metronome, which was set at 40 beats per minute, allowing for one push up every three seconds. The test concluded when participants either failed to lower themselves to the required depth on three non-consecutive repetitions (warnings verbalised by assessor), failed to maintain the movement in time with the metronome, or upon volitional failure. Assessors did not provide verbal encouragement during the conduct of the test.

Muscular power was assessed using the Standing long jump test. Testing procedures were explained to participants prior to performance. Subjects began with their toes behind a line marked at zero centimetres and performed a maximal long jump, taking off and landing with two feet. The distance reached (in cm), in line with the heel of the rearmost foot was recorded. The test was performed twice separated by a rest period of approximately ten seconds. The average of the two scores was used in the analysis.

Statistical analyses

Statistical analyses were completed using PASW Statistics 17 (SPSS Inc. Chicago, IL) software and alpha levels were set at $p < 0.05$. Inter-trial differences were calculated by subtracting T1 from T2 and independent samples t-tests were used to explore gender differences for inter-trial differences. Three types of reliability were assessed: rank order repeatability, change in mean and typical error. Intraclass correlation (ICC) was used to provide an estimate of rank order repeatability. ICC provides an indication of how well the ranking (i.e., from lowest value to highest value) of participants in one trial is replicated in subsequent trials. For the current study, an ICC > 0.70 was considered to be acceptable. Change in mean was assessed using paired samples t-tests to identify systematic (e.g., learning or maturation effects) and random change in trial results. Bivariate correlations between the inter-trial difference (T2-T1) and the mean of the trials $[(T2-T1)/2]$ were used to explore proportional bias. Finally, typical error (i.e., standard error of measurement) was used to explore within-subject variation. Atkinson and Nevill (3) have argued that researchers should consider the purpose of their measures before determining the appropriate degree of error. The RTSB was primarily developed to evaluate the efficacy of school- and community-based resistance training programs. Therefore, it requires the sensitivity to detect small improvements in both individual skills and overall skill competency. As each resistance training skill is performed twice and the performance criteria is summed for each skill (i.e., a score of 8 or 10), an increase of two units represents an improvement in one key performance criteria for one skill. Similarly, an increase in six units on the RTSQ indicates an improvement in three performance criteria (e.g., 3 from 1 skill or 1 from 3 skills). Therefore, we suggest that the RTSB requires the sensitivity to detect a difference of two for the individual skills and six for the RTSQ. The construct validity of the RTSB was tested using multiple regression modeling. Age, gender and RTSQ scores were included as independent variables in the regression model, while MFS was the dependent variable. Age was not significantly associated with MFS and was subsequently removed from the final model.

RESULTS

No injuries or adverse events occurred during assessments. Based on the IOTF cut-points, 36 (81.8%) of the males and 14 (73.7%) of the females were classified as healthy weight (Table 1). Eight males and five females were considered to be overweight. Mean values, standard deviations and inter-trial differences for the individual skills and the RTSQ are reported in Table 2. The inter-trial difference for the RTSQ was significantly higher in females (-1.7) than in males (0.3). Females' scores ranged from 4 to 10 (out of 10) for the squat to 33 to 52 (out of 56) for the RTSQ. Males' scores ranged from 3 to 10 (out of 10) for the chest touches 36 to 53 (out of 56) for the RTSQ.

The ICC estimates, changes in mean and typical error are reported in Table 3. The ICC values for individual exercises ranged from 0.67 (95% CI = 0.54, 0.80) for the standing overhead press to 0.87 (95% CI = 0.78, 0.92) for the suspended row. The ICC for the RTSQ was (0.88, 95% CI = 0.80, 0.93). The change in mean was small (range = -0.4 to 0.3), but statistically significant for the lunge and suspended row. There was some evidence of proportional bias for the front support with chest touches, indicating that the inter-trial difference was inversely related to the mean of trials ($r = -0.26$, $p < 0.05$). The typical error of the individual skills ranged from 0.6 for lunge and suspended row to 1.2 for the body weight squat and front support with chest touches. Typical error for the RTSQ was small (RTSQ = 2.5, 95% CIs = 2.1, 3.0).

The final regression model explained 39% of the variance in MFS ($p < .001$). Both gender ($r = .52$, $p < .001$) and RTSQ ($r = .40$, $p < .001$) were significantly associated with MFS, suggesting that participants with higher levels of resistance training skill competency scored higher on the tests of muscular fitness.

DISCUSSION

The aim of this study was to develop and assess the validity and reliability of the Resistance Training Skills Battery for adolescents. Based on feedback from eight experts in pediatric resistance training and movement skill development, the final measure included six skills representing the basic movements commonly used in youth resistance training programs. Our findings indicate that the RTSB has acceptable construct validity based on the significant association between skill competency and muscular. Furthermore, our findings suggest that the RTSB can be used to reliably rank adolescents on their overall resistance training competency and has the necessary sensitivity to detect improvements in resistance training skill proficiency in adolescents.

The importance of developing correct resistance training technique is emphasized in position statements from the American Academy of Pediatrics (1), the Australian Strength and Conditioning Association (4), the Canadian Society for Exercise Physiology (8), the National Strength and Conditioning Association (17) and the United Kingdom Strength and Conditioning Association (21). To our knowledge, this is the first resistance training skills test for adolescents. Although injury rates from supervised youth resistance training are relatively low, using incorrect technique with unsafe behavior may increase the risk of both minor and serious injuries (1, 16, 27). It seems prudent for adolescents to develop proficiency in basic resistance training skills such as those included in the RTSB before progressing to more advanced exercises. Moreover, progression in a resistance training program should be based on technical proficiency and an understanding of fundamental resistance training principles. For example, physical education lessons taught by qualified teachers could address the importance of developing proper exercise technique and the RTSB could be used to assess students' resistance training skill competency over a semester.

The RTSB was primarily conceived as a tool for assessing the efficacy of school- and community-based resistance training programs. Based on the changes in mean and typical error results, the RTSB can be used reliably to detect small changes in individual skills and overall resistance training competency. There was some evidence of systematic bias for the lunge and suspended row, as observed by a significant increase between trials for the lunge and a significant group decrease for the suspended row. While statistically significant, these differences are not considered to be clinically meaningful (diff. = 0.3 for the lunge and diff. = -0.3 for the suspended row). The importance of discussing reliability findings in terms of practical and or clinical significance has been noted in the sports science literature (19). The change in mean and typical error was small for the individual skills (typical error ≤ 1.2) and the RTSQ (typical error ≤ 2.5). In recent years, there has been an increase in the number of studies evaluating the effects of school- and community-based resistance training programs for both healthy weight (14, 22, 25, 39) and overweight/obese youth (28). These studies typically report their effect on muscular fitness, body composition, metabolic health and sometimes psychological well-being. Assessment of resistance training competency may provide additional evidence for program efficacy and learned behaviors. We also suggest that pediatric researchers, health care providers and physical education teachers use the RTSB to provide constructive feedback to participants, which will likely enhance performance, motivation and self-concept.

The RTSB was designed to be used in pediatric research focusing on the importance of resistance training skill competency. The construct validity of the RTSB and its capacity to reliably rank participants (i.e., from least to most skillful), has implications for researchers and practitioners interested in the psychological and physiological benefits of resistance training competency. In the current study, resistance training skill competency (i.e., RTSQ) was significantly associated with muscular fitness, suggesting that more skilled children performed better on the tests of muscular fitness. This is an important finding and provides evidence for the construct validity of the measure.

Importantly, resistance training skill competency was significantly associated with fitness after controlling for gender. Competency in a range of fundamental movement skills (FMS; e.g., running, leaping, throwing, kicking) is considered to provide the foundation for a physically active lifestyle (5, 24) and as children progress from participating in traditional team sport activities to lifetime physical activities, studies examining the relationship between skill competency and health outcomes may provide additional evidence for the benefits of regular participation in resistance training activities during childhood and adolescence. Furthermore, longitudinal studies may assess the relationship between changes in RT skill competency and rates of physical activity-related injury in young people.

Self-Determination Theory (SDT)(12) and the Exercise and Self-esteem Model (EXEM) (34) describe the importance of competence and how it influences motivation and self-concept. According to SDT, perceived competence is one of three basic psychological needs that drive intrinsic motivation (12), which has been found to influence physical self-concept in young people (35). Similarly, the EXEM (34) proposes that beliefs about one's ability to perform specific exercises or training activities generalize to a broader perceived physical competence. Providing participants with quantifiable feedback regarding their resistance training competency may help satisfy their basic psychological needs and increase their intrinsic motivation for exercise. This information may complement feedback from fitness test results and provide additional information for self-monitoring (including goal setting), which has been identified as an important strategy for promoting physical activity in young people (13, 36). For example, Dishman and colleagues (13) demonstrated that physical activity self-management strategies (e.g., thoughts, goals, plans, and acts) mediate the relationship between self-efficacy and behavior in adolescent girls. This finding suggests that adolescent girls with high levels of self-efficacy are more likely to self-monitor their physical activity behavior, which in turn, is associated with more physical activity. Providing adolescents with feedback on their resistance skill competency and encouraging them to set performance goals (i.e., competency goals) may improve their exercise self-

efficacy and their exercise adherence, indirectly via self-monitoring. Studies examining the role of resistance training skill competency on physical activity self-efficacy and behavior in experimental studies are needed to further explore these hypotheses.

Interestingly, popular fitness test batteries such as FITNESSGRAM®, which was designed to promote lifelong physical activity and fitness, do not include process measures of FMS competency or more specific measures of resistance training competency. This is disappointing because both perceived (6) and actual movement skill competency (7) are important determinants of physical activity behavior in young people. Based on anecdotal evidence from the research assistants, the adolescents enjoyed completing the process-oriented RTSB. Because the performance criteria were not revealed publicly, the testing environment was more consistent with a mastery climate. Evidence suggests that adolescents who perceive their PE lessons as having a mastery climate are more intrinsically motivated to participate (33). Alternatively, a performance climate in PE is associated with less self-determined forms of motivation (31). In traditional fitness testing lessons, effort and ability are on public display, which can be a source of anxiety for some students (10). It may not be feasible for teachers to assess students' skills using video cameras in class; however, it is possible that qualified PE teachers and/or research assistants may be trained to reliably assess skills live in the school setting as is commonly done in the motor assessment literature. As new technologies emerge, real-time assessment and feedback of students' movement skills may become possible using portable digital devices (e.g., smartphones and tablets).

It should be emphasized that our findings may not be generalizable to youth with pathologies or physical injury. Also, our study sample was relatively small and not representative of all adolescents. All of the skills in the current study were assessed by the same research assistant in a relatively

homogenous group of adolescents. Further work is needed to determine to test the validity and reliability of the RTSB with different adolescent populations and researchers.

PRACTICAL APPLICATIONS

Considering the importance of muscular fitness for young people (26) and the popularity of youth resistance training programs, the development of a RTSB that was purposely designed to assess exercise movement competency is a valuable tool for researchers and practitioners. Based on our findings, the RTSB can be used researchers and practitioners in school- and community-based resistance training programs to evaluate intervention effects and provide additional information for participants to enhance their exercise adherence. This study has demonstrated the construct validity and test-retest reliability of the RTSB in a sample of adolescents. The RTSB can reliably rank participants in regards to their resistance training competency and has the necessary sensitivity to detect small changes in resistance training skill proficiency.

Acknowledgements

The authors would like to thank the following content experts for providing feedback on the Resistance Training Skills Battery: Dr Baraket Falk, Dr David Behm, Dr Amanda Benson, Dr Tim Gabbett, Dr Gerry Naughton, Dr Rhodri Lloyd, Dr Sophia Nimphius, Dr Grant Tomkinson and Natasha Shranz. The authors would like to thank Ben Mulligan, Tara Finn, Kathryn Riley and Sarah Costigan for their assistance in data collection and entry. The authors would also like to thank St Mary's High School, the school students, and parents for supporting this study.

REFERENCES

1. American Academy of Pediatrics. Strength training by children and adolescents: Council on Sports Medicine and Fitness. *Pediatrics*: 121: 835-840, 2008.
2. Artero EG, Ruiz JR, Ortega FB et al. Muscular and cardiorespiratory fitness are independently associated with metabolic risk in adolescents: The HELENA study. *Pediatr Diab*: 12: 704-712, 2011.
3. Atkinson G, Nevill AM. Statistical methods for addressing measurement error (reliability) in variables relevant to sports medicine. *Sports Med*: 26: 217-238, 1998.
4. Australian Strength and Conditioning Association. *Resistance Training for Children and Youth: A Position Stand from the Australian Strength and Conditioning Association*. Australian Strength and Conditioning Association; 2007. p.
5. Barnett LM, Morgan PJ, Ball M, Van Beurden E, Lubans DR. An examination of the directional relationships between motor skill proficiency and physical activity in adolescents. *Med Sci Sports Exerc*: 43: 898-904, 2011.
6. Barnett LM, Morgan PJ, van Beurden E, Beard JR. Perceived sports competence mediates the relationship between childhood motor skill proficiency and adolescent physical activity and fitness: a longitudinal assessment. *Int J Behav Nutr Phys Act*: 5: doi:10.1186/1479-5868-1185-1140, 2008.
7. Barnett LM, van Beurden E, Morgan PJ, Brooks LO, Beard JR. Childhood motor skill proficiency as a predictor of adolescent physical activity. *J Adolesc Health*: 44: 252-259, 2009.
8. Behm DG, Faigenbaum AD, Falk B, Klentrou P. Canadian Society for Exercise Physiology position paper: resistance training in children and adolescents. *Appl Physiol Nutr Metab*: 33: 547-561, 2008.
9. Benson AC, Torode ME, Fiatarone Singh MA. The effect of high-intensity progressive resistance training on adiposity in children: a randomized controlled trial. *Int J Obes*: 1016–1027, 2008.
10. Cale L, Harris J, 14 (1): . Fitness testing in physical education - a misdirected effort in promoting healthy lifestyles and physical activity? *Phys Educ Sport Pedagogy*: 14: 89-108, 2009.

11. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*: 320: 1240-1243, 2000.
12. Deci EL, Ryan RM. The “what” and “why” of goal pursuits: Human needs and the self-determination of behavior. *Psychol Inq*: 11: 227-268, 2000.
13. Dishman RK, Motl RW, Sallis JF et al. Self-management strategies mediate self-efficacy and physical activity. *Am J Prev Med*: 29: 10-18, 2005.
14. Faigenbaum A, Farrell A, Fabiano M et al. Effects of integrative neuromuscular training on fitness performance in children. *Pediatr Exerc Sci*: 23: 573-584, 2011.
15. Faigenbaum A, Milliken L, Moulton L, Westcott W. Muscular fitness adaptations in children in response to two different resistance training regimens. *Pediatr Exerc Sci*: 17: 237-248., 2005.
16. Faigenbaum A, Myer G. Resistance training among young athletes: Safety, efficacy and injury prevention effects. *Brit J Sports Med*: 44: 56-63, 2010.
17. Faigenbaum AD, Kraemer WJ, Blimkie CJ et al. Youth resistance training: updated position statement paper from the national strength and conditioning association. *J Strength Cond Res*: 23: S60-79, 2009.
18. Hallal PC, Bo Andersen L, Bull FC et al. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet*: 380: 247-257, 2012.
19. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*: 41: 3-12, 2009.
20. Institute of Medicine. *Fitness Measures and Health Outcomes in Youth*. National Academies Press; 2012. p.
21. Lloyd R, Faigenbaum A, Myer G et al. United Kingdom Strength and Conditioning Association (UKSCA) Position Statement on youth resistance training. *Prof Strength Cond*: 26: 26-39, 2012.

22. Lubans DR, Morgan PJ, Aguiar E, Callister R. Randomized controlled trial of the Physical Activity Leaders (PALs) program for low-active adolescent boys from disadvantaged secondary schools. *Prev Med*: 52: 239-246, 2011.
23. Lubans DR, Morgan PJ, Callister R et al. Test-retest reliability of a battery of field-based health-related fitness measures for adolescents. *J Sports Sci*: 29: 685-693, 2011.
24. Lubans DR, Morgan PJ, Cliff DP, Barnett LM, Okely AD. Fundamental movement skills in children and adolescents: Review of associated health benefits. *Sports Med*: 40: 1019-1035, 2010.
25. Lubans DR, Sheaman C, Callister R. Exercise adherence and intervention effects of two school-based resistance training programs for adolescents. *Prev Med*: 50: 56–62, 2010.
26. Magnussen CG, Schmidt MD, Dwyer T, Venn A. Muscular fitness and clustered cardiovascular disease risk in Australian youth. *Eur J Appl Physiol*: 112: 3167-3171, 2012.
27. Malina RM. Weight training in youth-growth, maturation, and safety: an evidence-based review. *Clin J Sport Med*: 16: 478-487, 2006.
28. McGuigan M, Tatasciore M, Newton R, Pettigrew S. Eight weeks of resistance training can significantly alter body composition in children who are overweight or obese. *J Strength Cond Res*: 23: 80-85, 2009.
29. Morgan PJ, Lubans DR, Saunders KL. Improving physical self-perception in adolescent boys from disadvantaged schools: Psychological outcomes from the Physical Activity Leaders randomised controlled trial. *Pediatr Obes*: 7: e27–e32, 2012.
30. Mota J, Vale S, Martins C et al. Influence of muscle fitness test performance on metabolic risk factors among adolescent girls. *Diabetol Metab Syndr*: 23: 42, 2010.
31. Ntoumanis N, Biddle SJ. A review of motivational climate in physical activity. *J Sport Sci*: 17: 643-665, 1999.
32. Ortega FB, Artero EG, Ruiz JR et al. Reliability of health-related physical fitness tests in European adolescents. The HELANA study. *Int J Obes*: 32: S49-S57, 2008.

33. Parish LE, Treasure DC. Physical activity and situational motivation in physical education: influence of the motivational climate and perceived ability. *Res Q Exerc Sport*: 74: 173-182, 2003.
34. Sonstroem RJ, Harlow LL, Josephs L. Exercise and self-esteem: Validity of model expansion and exercise associations. *J Sport Exerc Psych*: 16: 29-42, 1994.
35. Standage M, Gillison FB, Ntoumanis N, Treasure DC. Predicting students' physical activity and health-related well-being: A prospective cross-domain investigation of motivation across school physical education and exercise settings. *J Sport Exerc Psych*: 34: 37-60, 2012.
36. Taymoori P, Lubans DR. Mediators of behavior change in two tailored physical activity interventions for adolescent girls *Psychol Sport Exerc*: 9: 605-619, 2008.
37. Teyhen DS, Shaffer SW, Lorensen CL et al. The Functional Movement Screen: a reliability study. *J Orthop Sports Phys Ther*: 42: 530-540, 2012.
38. Ulrich DA. Test of Gross Motor Development Examiner's Manual. Austin, Texas: Pro.Ed, 2000.
39. Velez A, Golem DL, Arent SM. The impact of a 12-week resistance training program on strength, body composition, and self-concept of Hispanic adolescents. *J Strength Cond Res*: 24: 1065-1073, 2010.
40. Wiersma LD, Sherman CP. The responsible use of youth fitness testing to enhance student motivation, enjoyment, and performance. *Measure Phys Educ Exerc Sci*: 12: 167-183, 2008.

Supplemental Digital Content 1. Resistance Training Skills Battery instructions and scoring sheet