A Randomized Factorial Feasibility Study of High-Resistance Circuit Training and Strength Training Intervention in Untrained Adolescents: A Mixed Methods Approach

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Methods

Experimental design

This study used an explanatory sequential design by collecting quantitative data first, then qualitative data to expand understanding of participant experience. After receiving University of Utah IRB and Murray School District Board approval, a cohort of participants were recruited for a before-school trial. Due to low enrollment of the before-school trial, another cohort of participants were recruited for an after-school trial following the conclusion of the before-school trial. Before-school sessions were conducted October 23rd to November 17th at 6:30 AM to 7:50 AM. After-school sessions were conducted November 27th to December 14th at 2:40 PM to 4:00 PM. After obtaining parental consent and participant assent, participants completed a pre-intervention testing session. Using randomizing software from randomizer.org, participants were randomized and stratified by sex into the high-resistance circuit training group (HRC) or traditional strength training group (ST). A waitlist control group was part of the original experimental design, however due the small sample, it was removed. The training section below contains details on the training protocols for the different groups. Concluding the intervention, subjects completed post-intervention testing. Primary feasibility outcomes included: consent rate, fidelity, participant attendance, study retention, adverse events, and participant experience. Secondary outcomes included measures of strength, body composition and aerobic fitness. After the conclusion of the intervention and quantitative data analysis, participants were invited for a one month follow up interview assessing their motivation to join the study, barriers and experiences partaking in the study.

Participants

Seven healthy untrained adolescents (16.9 ± .7 years old, 4 males and 3 females) from a northern Utah high school participated. The high school had 1,500 students across 10th, 11th and 12th grades. For the purpose of this study, untrained participants were defined as participants who reported being physically inactive with no regular participation in physical activity for the past month prior to the intervention. Participants were recruited through posted flyers and table events during lunch periods. Exclusion criteria included recent injuries or medical conditions that may influence high-intensity performance, currently enrolled in another training program including resistance, cardiovascular, or sports-based program, uninsured participants, drastically altering diet and use of performance-enhancing substances (i.e., creatine, pre-workout, post-workout supplements). Prior to the start of the study, participants and respective guardians read and signed informed consent, parent permission and assent documents. The 2023 PAR-Q + form and modified Copper Institute Fitnessgram and Activitygram questionnaires were used to screen participants.

Table 1. Summary Table of Participants

Category	**Frequency**	**Percent**
Sex		
Male	4	57%
Female	3	43%
Ethnicity		
Non-Hispanic	7	100%
Race		
White	7	100%

Category	Mean	Standard Deviation
Age	16.9	0.7
BMI	24.4	5.8
Body Fat Percentage	25.3	8.9

Table 1 shows the baseline participant characteristics.

Protocol

Participants performed 1-1 ½ hour sessions three times a week for four weeks under the supervision of the primary researcher. Participants followed the weekly progression adapted from Alcarez [32]. Exercises were adapted to fit the facility's equipment by prioritizing free weight compound movements over single joint machine exercises. In addition, instead of prescribing 6RM (85% of 1RM) to untrained participants, an autoregulatory approach using rate of perceived exertion (RPE) was prescribed (Figure 2). To simplify RPE use, participants used whole numbers such as 8 RPE which lowers the intensity from HRC's traditional intensity of 85% of 1RM to 80% 1RM. Literature supports the use of RPE-based loading as an effective alternative to prescribing percentages of 1RM for improving strength [39]. Use of RPE-based loading negated a safety concern with untrained participants conducting 1RM testing.

Figure 2. Equivalent Intensity Prescriptions of Traditional Percentage Based and RPE

Targeted strength quality	Percent of 1RM	Rate of perceived exertion	Reps left in reserve
Maximal strength	85%	8.5	1-2
Strength-speed	80%	8	2

Figure 2 shows the equivalent values for percent of 1RM loading vs RPE-based loading adapted from Shattock & Tee [40].

The following four-week progression was developed to help participants become familiar with basic weightlifting movements in addition to appropriately increase intensity of sessions (Figure 3). In the first week of the intervention, ST and HRC groups completed 4 sets of each exercise at 6 RPE on the 1-10 modified Borg Scale. During this time, emphasis was given to proper weightlifting technique over the amount of weight being used. In the second week, participants completed 2 sets of 6 RPE, then 2 sets of 7 RPE. In the third week, participants increased intensity to 2 sets of 7 RPE and 2 sets of 8 RPE. In the fourth week, participants increased intensity to 4 sets of 8 RPE. Participants were expected to complete the workouts and appropriately increase the difficulty of resistance used if movements were performed correctly. Lifts were performed at a tempo with a 3 second eccentric phase, 2 second isometric pause, followed by a concentric phase at maximum velocity. Participants were able to adjust resistance by 2-5% each set based on RPE.

Figure 3. Periodization of Training Volume

Week 1	Week 2	Week 3	Week 4
4 sets at 6 RPE	2 sets at 6 RPE 2 sets of 7 RPE	2 sets at 7 RPE 2 sets of 8 RPE	4 sets at 8 RPE

Figure 3 shows the progression of prescribed sets across weeks.

Training

Warm Up. Participants in ST and HRC groups engaged in a 5 min warm-up specific to the first block followed by 5 min of dynamic stretching and mobility. Participants then performed 2 sets of the first three exercises using the following sequence; 10 reps at 5 RPE with 30 sec - 1 min rest, 8 reps at 6-7 RPE with 30 sec - 1 min rest, then participants started target sets of 6 reps at the prescribed RPE.

Strength Training. Once the warm-up was completed, ST participants performed the 6 reps of the first exercise at the prescribed RPE then rested 1 minute. Participants then completed another set of their first exercise with the required rest until the prescribed sets were completed. Participants performed the second and third exercise in the same fashion. Once the first block was completed, participants rested 5 min, then completed the second block with the same warm up sequence.

High-Resistance Circuit Training. An adapted version of Alcaraz's HRC was utilized in the intervention. Exercises and intensities used by ST was the same for HRC except HRC participants performed the first three exercises as a circuit with 35 seconds rest between exercises (Figure 4).

Figure 4. Protocols for the ST and HRC Training Groups

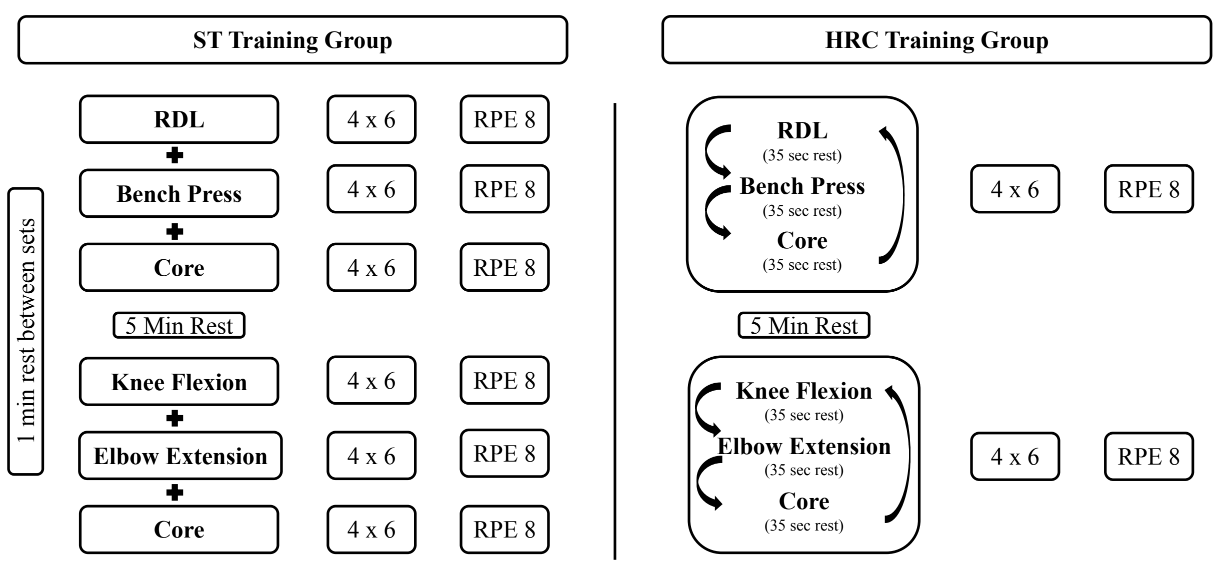

Figure 4 shows the Traditional Strength Training (ST) and High-Resistance Circuit Training (HRC) interventions at week 4 of the intervention. ST participants performed four sets of six reps of a single exercise with 1 minute rest between sets. HRC performed the same exercises in a circuit fashion rotating from one exercise to another with 35 sec rest between sets.

Feasibility outcomes

Primary feasibility outcomes included recruitment process, sample size, consent rate, retention rate, fidelity, attendance, participant experience, and adverse events.

Recruitment process. The recruitment process refers to the protocols used to find, select, and enroll participants into a study [41]. The recruitment process for this study was represented by reporting the total number of unique QR code scans from posted flyers and tabling events, the number of completed interest forms, the number of eligible participants and the number of consented participants. A recruitment period of 3 weeks was given for the before and after-school trials.

Sample size. Sample size was used as another key feasibility marker and refers to the total number of individuals used in the intervention. A sample size of 30 participants per trial with 15 participants in each treatment group was established based on previous literature examining the difference between resistance training groups [32], suggestions of 12 participants minimum per group in feasibility trials from Julious [42], and practicality how many participants could receive intervention treatment with proper supervision. While larger sample sizes would be ideal for secondary fitness outcomes, the primary purpose of this study was to assess feasibility outcomes and not report statically powered differences.

Consent rate. Consent rate is often referred to as the percentage of participants enrolled divided by the number of eligible participants [43]. For this study, consent rate was calculated by taking the total number of participants that consented and were randomized divided by the number of eligible students. An acceptable consent rate was set at 80% based on findings from Jacques [43].

Retention rate. Retention rate is defined as the percentage of the total number of randomized participants assessed for primary outcomes and used in the primary outcome analysis [43]. For the purpose of this study, researchers were interested in retention for both primary and secondary outcomes meaning researchers tracked retention from pre-intervention fitness testing, through treatments, and post-intervention fitness testing sessions. The follow up interview was not included in calculating the retention rate. Only participants that withdrew from the study or were not included in the primary and secondary outcome analysis influenced the retention rate. Thus, retention was calculated as the percentage of participants that completed pre and post-intervention fitness assessments and intervention treatment divided by the number of participants randomized into treatment groups. Participants that withdrew (i.e., stopped attending) from the study were tracked by the investigator. Based on prior literature, 80% retention rate was used as an acceptable threshold [44].

Fidelity. Fidelity is referred to how well an intervention was delivered as intended and is measured at the participant, deliverer or setting level [41]. For this study, fidelity was assessed at the instructor (deliverer) and participant level. Instructor fidelity was measured as a percentage by totaling the provided sessions divided by the total number of planned sessions. An acceptable percentage was set at 80% due to conflicts with events such as holiday breaks or parent teacher conferences. To assess participant fidelity, the primary researcher and participants recorded session durations, completed sets and intensity along with activity and diet audits at weeks 2, and 4 of the intervention. The activity and diet audit included a modified Copper Institute Fitnessgram and Activitygram questionnaire (Figure 5). If participants recorded additional days of aerobic, muscular strength and muscular endurance activities and/or a dramatic change in diet, resulting post-intervention data was excluded in the secondary performance outcomes data analysis.

Figure 5. Modified Fitnessgram Physical Activity and Diet Audit Questions

Aerobic	Outside of the intervention with the researcher, how many of the past 7 days did you participate in any physical activity for a total of 30 to 60 minutes or over the course of a day? This includes moderate to vigorous activities (walking, slow bicycling, or outdoor play) as well as vigorous activities (jogging, active games, or active sports such as basketball, tennis, or soccer). (0, 1, 2, 3, 4, 5, 6, 7 days)
Muscular strength and endurance	Outside of the intervention with the researcher. how many of the past days did you exercise to strengthen or tone your muscles? This includes exercises such as push-ups, sit-ups, or weightlifting. (0, 1, 2, 3 ,4 ,5 ,6 ,7 days)
Diet	Have you changed your diet in the past 7 days? If so, please describe.

Figure 5 is a modified physical activity and diet questionnaire from the Cooper Institute's Fitnessgram and Activitygram assessment manual to investigate additional activity and diet changes outside of the investigation [45].

Participant attendance. Participant attendance was observed by the researcher and measured as attended sessions divided by total sessions offered. Based on systematic reviews and meta-analyses [46, 47], 80% was selected as an acceptable attendance threshold.

Adverse events. Adverse events were recorded during the intervention by the participants on workout documents and by observations from the primary researcher. The primary researcher used no adverse events as an acceptable threshold.

Participant experience. Participant experience was assessed by utilizing the validated short form 4 item Physical Activity Enjoyment Scale (PACES-S) survey for adolescents [48]. Participants answered 4 items including: "I enjoyed it; I find it pleasurable; It is very pleasant; and It feels good" by responding with the five-point Likert scale ranging from 1= "strongly disagree" to 5 = "strongly agree". To further investigators' depth of understanding, participant experience was also assessed by a follow up interview concluding the intervention. Please see qualitative assumptions, interview process and qualitative data analysis section below for further details.

Progression criteria

Of the above feasibility measures, selected outcomes were used as key markers to assess if further investigations were warranted for the future. The following criteria for evaluating feasibility are below:

1. No adverse events related to the intervention treatment.
2. Sample size of 30 participants per trial.
3. Consent rate no less than 80%.
4. Retention rate no less than 80%.
5. Attendance rates no less than 80%.

If all five criteria were met, then further investigations can continue without modification. If three to four criteria were met, then further investigations can continue with modifications. If two or less criteria were met, the study is assessed as not feasible.

Secondary outcomes

All secondary outcome assessments were taken pre and post-intervention. Testing protocols required participants to avoid strenuous physical activity 48 hours prior to testing days.

Assessments took a single session to complete and all participants were tested within similar time periods.

Bioelectric Impedance Analyzer. In a separate private room, one participant at a time weighed themselves on a certified scale. Participants used the handheld Omron model HBF-306 to enter their weight, age, sex and activity level. Resulting BMI and body fat percentage data was recorded. Omron HBF-306 has been shown to be a reliable tool to track body composition over time [49].

Isometric lower body pull. Using the Baseline 12-0400 Back-Leg-Chest dynamometer participants stood up-right and feet hip width apart on the dynamometer platform with the chain adjusted so the handle was at the intra-articular space of the knee joint. Participants were instructed to grip the handle evenly at the center then produce a maximal 5 sec pull keeping the back from bending and arms straight. Participants were allowed to rest 30 sec between attempts. Participants had one practice attempt for familiarization purposes and then the best score of the three following attempts were recorded. Prior research has established reasonable test-retest reproducibility of the Baseline 12-0400 Back-Leg-Chest dynamometer in adolescent populations [50].

90° push-up. Participants were paired; participant 1 performed the test while participant 2 recorded the number of push-ups. Participants performed the assessment in accordance with the Cooper Institute's procedures [45]. Participant 1 assumed a prone plank position with hands slightly outside of shoulders, fingers stretched out and legs straight with a slight gap. While performing push-ups, the participants' back maintained a straight line from head to ankles. Participants started by lowering their body until the upper arms became parallel to the ground. The participant then extended their arms straight pushing their body up. This movement was performed every three seconds by metronome and repeated until failure. Participants were allowed one form correction and two form corrections resulted in test termination. Form corrections included participants stopping to rest, a failure to maintain a straight back, achieving proper depth or fully extending the arms. Prior research notes the acceptable reliability of the push-up assessment in males and females [51].

Modified Pull-up. Participants performed the modified pull-up test in accordance with Cooper Institute's procedure [45]. Participants placed a barbell in a squat rack so that the barbell was one to two inches away from participant's reach while supine on the ground. A band was then placed seven to eight inches below the barbell. Participants started the assessment by overhand gripping the barbell and creating a straight line from head to heels so that only the heels were in ground contact. Participants then pulled their body toward the barbell until the chin was above the band. This movement was performed every three seconds by metronome and repeated until failure. Participants were allowed one form of correction and two form corrections would result in test termination. Form corrections included participants stopping to rest, failure to maintain a straight line, achieve proper depth and fully extending the arms.

PACER. To assess cardiovascular fitness, the Progressive Aerobic Cardiovascular Endurance Run (PACER) assessment was used. Prior to the start of assessment, the primary investigator measured and marked a designated 20-meter distance in the gymnasium for testing. Participants were briefed on the assessment guidelines and participated in one practice opportunity prior to the official assessment. Once familiarized, participants ran the 20-meter distance in accordance to PACER cadences from the Cooper Institute for as long as possible. The test was terminated when the participant voluntarily stopped due to fatigue or when two laps were missed. The primary researcher recorded total number of successful levels. Once completed, the primary researcher computed predicted peak VO_2 by using VO_2peak = 0.353(Laps) – 1.121(Age) + 45.619. This equation has been shown to have moderately strong linear relationships compared to measured VO_2 peak of adolescents [52].

Quantitative data analysis

Non-parametric analyses of primary and secondary outcomes were used due to the small sample size. Wilcoxon signed rank tests were used to test significance of pre and post-intervention data within treatment groups. Reports of Wilcoxon signed rank included medians, inner quartile ranges, z scores and p-values. Two sample Wilcoxon rank sum (Mann-Whitney) tests were used to test significance between treatment group differences. Reports of Wilcoxon rank-sum (Mann-Whitney) tests included medians, inner quartile ranges, U statistic and p-values. Due to an underpowered sample, effect sizes were calculated for all secondary outcome statistical tests. Given the exploratory nature of this study and the small sample, effect sizes may be more useful in guiding future research. Effect sizes were interpreted as small if $r = 0.2 - 0.5$, medium if $r = 0.5 - 0.8$ medium and large if $r > 0.8$. Statistical package STATA (version; BE 18.0, StataCorp, College Station, Texas, USA) was used and Alpha level was set at $P< 0.05$.

Qualitative assumptions

Following quantitative data analysis, a constructivist paradigm was utilized for the qualitative phase. Hatch [53] depicts the ontological assumption (nature of reality) in a constructivist paradigm as “multiple realities are constructed”. In a constructivist paradigm the epistemological assumption (nature of data) is that data is collected in close, personal and interactive settings. Researchers in this paradigm let the participants drive the investigation to explain their perceived reality without the addition of the researcher’s influence. Thus, the axiological assumption (value of data) is subjective and relative to the participant. These realities are important to consider as perceptions may influence how the participant behaves.

Interview methods

Participants were invited to a recorded interview for 30 min on Zoom. The interview followed a piloted semi-structured interview guide (Figure 6) created by the primary researcher to further understand participant experiences of the training protocols. Participants were given pseudonyms to protect their identity.

Figure 6. Interview Guide

Background info

Do you enjoy being active, if so why?

What about weightlifting do you find appealing?

Explain to me why you wanted to sign up for this study.

Participant experience

Did the timing of the workout sessions work well for you? Why or why not?

Tell me about some of the factors, if any, that made it difficult to attend.

Were there aspects of the workout sessions that you enjoyed and if so why?

Were there aspects of the workout sessions that you disliked and if so why?

In what ways did participating in this study benefit you?

In what ways did participation in this study not benefit you?

Tell me about some parts of the program, if any, that made it challenging to complete as directed.

If anything, what would you change regarding the workout sessions?

In general, how would you describe your experience participating in this study?

Figure 6 shows the semi-structured follow up interview guide.

Qualitative data analysis

Once interviews were concluded, thematic analysis as described by Terry and colleagues [54] was conducted to analyze data. The primary researcher familiarized himself with the data by viewing recorded interviews and checking transcripts for correct transcription. Initial codes were then generated by highlighting test segments relevant to the study aims examining participant experiences. Codes were grouped into initial themes based on their underlying conceptual similarities. Themes were then reviewed and revised to generate three final themes: “It was a positive experience”, “workout difficulty and duration”, and “barriers”. Extracts of interviews were used to support reported themes.

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