9-12-2017

Elastic Resistance Effectiveness on Increasing Strength of Shoulders and Hips

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Notes/Citation Information
To be published in *Journal of Strength and Conditioning Research*.

This is a non-final version of an article published in final form in Picha, K.J., Almaddah, M.R., Barker, J., Ciochetty, T., Black, W.S.,& Uhl, T.L. (2017). Elastic resistance effectiveness on increasing strength of shoulders and hip. *Journal of Strength and Conditioning Research.* https://doi.org/10.1519/JSC.0000000000002216

Digital Object Identifier (DOI)
https://doi.org/10.1519/JSC.0000000000002216

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ABSTRACT

Elastic resistance is a common training method used to gain strength. Currently, progression with elastic resistance is based on the perceived exertion of the exercise or completion of targeted repetitions; exact resistance is typically unknown. This study's objective is to determine if knowledge of load during elastic resistance exercise will increase strength gains during exercises. Participants were randomized into two strength training groups, elastic resistance only and elastic resistance using a load cell (LC) that displays force during exercise. The LC group used a Smart Handle (Patterson Medical Supply, Chicago, IL) to complete all exercises. Each participant completed the same exercises three times weekly for 8 weeks. The LC group was provided with a set load for exercises whereas the elastic resistance only group was not. Participant's strength was tested at baseline and program completion, measuring isometric strength for shoulder abduction (SAb), shoulder external rotation (SER), hip abduction (HAb), and hip extension (HEx). Independent t-tests were used to compare the normalized torques between groups. No significant differences were found between groups. Shoulder strength gains did not differ between groups (SAb $p>0.05$; SER $p>0.05$). Hip strength gains did not differ between groups (HAb $p>0.05$; HEx $p>0.05$). Both groups increased strength due to individual supervision, constantly evaluating degree of difficulty associated with exercise and providing feedback while using elastic resistance. Using a LC is as effective as supervised training and could provide value in a clinic setting when patients are working unsupervised.

Word Count: 240/250

Key Words: Load cell, strength training, supervision

INTRODUCTION

Resistance training is the preeminent way to gain strength and muscle mass. [1-3] The work of Delorme[3] demonstrated the need for progressive resistive loads to be constantly adjusted in order to gain strength. Progressive overload refers to the increasing stress placed on the muscle via resistive exercise.[4,5] Resistance training can be modified by altering load, repetitions, type or intensity.[4]

Elastic resistance is a common resistive training mode that is used by fitness and health care professionals to gain strength. Elastic resistive bands have a unique advantage in that resistance can be developed in any direction the band is elongated. Conversely, when utilizing free weights as the chosen mode of resistance, the weights have to be lifted against gravity to produce desired resistance. Elastic resistance is generated linearly by lengthening the elastic band and is directly dependent on the band stiffness and length of the band.[6] The current method of progression with elastic resistance is typically based on the individual's rating of perceived exertion of the exercise difficulty or completion of target number of repetitions that has been found to be effective to increase strength.[1,7] Specific resistance during exercise is typically unknown. The load information is available to fitness and health care professionals to indicate loads based on length and stiffness level, yet is not readily used in practice. Recently, a load cell device (Roylan Smart Handle®, Patterson Medical Supply, Chicago, IL, USA) has become available that interfaces with the elastic resistance to provide specific loads being generated when tension is applied. Further, this device produces a tone when a specified target load is reached during an exercise. This provides feedback to the individual indicating the specific resistive level obtained during the exercises. Many studies indicate favorable results with the use of feedback in therapy and exercise.[8-10] An increase in muscle activation and reduction in pain with the use of feedback has been found,[9,10] indicating possible benefit of this technique.

Research has demonstrated that elastic resistance using level of perceived exertion can increase strength during exercises such as rowing, squats, and back extension.[7] Unfortunately, that does not give an objective load for an incremented progression. It is unknown if the knowledge of elastic resistance being achieved during exercise will provide benefit to gaining strength at increased rates. The purpose of this study is to determine if knowledge of load during elastic resistance exercise prescription will increase the rate of strength gains during exercises. We hypothesize greater strength change and a quicker rate of strength gains will occur in individuals using a load cell compared to using a perceived exertion to progress exercise resistance that over time.

METHODS

Participants

A total of 107 volunteers inquired about this study through email or phone from September 2015-May 2016. The study was approved by an Institutional Review Board (IRB). Potential participants were excluded for the following criteria: 1) they were outside the age range of 18-70 years of age, 2) answered "yes" to any question on the Physical Activity Readiness Questionnaire Scale indicating they have a medical limitation to exercise, 3) had shoulder, knee, or hip surgery within the last three months, or 4) have a history of heart or lung illness. Eligible participants had to be willing to exercise three times a week with supervision, subjects were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document. All data collection took place in a clinical laboratory from September 2015-July 2016.

Eighty-one participants age 18-67, agreed to participate in an 8 week resistive training study. Five patients did not meet inclusion criterion and 21 subjects were not interested in participation due to time demands (Figure 1). Independent t-tests were used to compare demographic and activity levels of the two groups. There were no differences observed between the two groups indicating randomization process was adequate. (Table 1) Subjects training levels in this study ranged from sedentary to moderately active at baseline according to Marx Shoulder Activity Scale, averaging 9±4[11] and Marx Activity Scale,[12] averaging 5±5 points. The Marx Shoulder Activity Scale is a 20-point upper extremity scale, and Marx Activity Scale is a 16-point lower extremity activity scale, a higher score indicating a more active individual.

*Figure 1. and Table 1. about here

Design

Power Analysis

A priori power analysis was conducted using NQuery (NQuery + nTerim 2.0, Statistical Solutions, Saugues, MA) to determine sample size prior to starting this project. The number of subjects was based on previous data with the assumption of .80 power.[7] An 8 ± 5% strength change in the load cell group compared to 5 ± 4% strength change in the elastic resistance only group. This would generate a moderate effect size of (0.66). Based on (0.66) effect size and 80% power with significant difference set a (p =.05). Thirty subjects in each group (60 total participants) needed to be enrolled in this study.

Randomization and Treatment Allocation

This study was a two-group, pre-test/post-test randomized clinical trial. The design is appropriate to find the difference in strength gains between groups after eight weeks of supervised training. On initial visit subjects completed baseline assessments and then were given an opaque envelop to open. The group membership was identified on a piece of paper in an envelope. Block randomization was performed prior to study commencing using the web site Randomization.com (http://www.randomization.com) using 10 groups of 8 subjects. The results of this procedure were blinded to all investigators until the participant opened the envelope. Participants were divided into two groups, the elastic resistance only (ERO) group or the load cell group. Neither participants nor investigators were blinded to group membership from this point forward. All participants had to work within the same space, therefore researchers performing strength testing and participants were not blinded to exercise group assignment. This is an obvious study limitation, but since all participants were using the same elastic resistive bands (Thera-band® CLX Consecutive Loops, Hygenic Corporation, Akron, OH USA) no participants requested to be changed into the other group. These elastic resistive bands come in seven different levels or colors (yellow, red, green, blue, black, silver, and gold). When stretched 100%, these bands range in load from approximately three pounds (yellow band) to 14.2 pounds (gold band).

Procedures

Baseline Testing

Upon arrival participants read and signed an IRB approved consent form, completed demographic information of age, height, weight, sex, and race, and completed both the upper extremity and lower extremity activity scales.[11,12]

Measurement of limb lengths were taken with a standard cloth tape measure in order to calculate torques to prescribe exercise loads. Arm length from the acromion process to the distal end of the third metacarpal was recorded in meters. The distance from the lateral epicondyle to the third metacarpal was recorded in meters. The distance from the greater trochanter to lateral malleolus was recorded in meters. These human lever arms measured were used to compute resistive training loads used for the exercises once subjects were randomized into the load cell group.

Maximal Isometric Strength

Maximal isometric strength measures were obtained bilaterally with the use of a dynamometer (BTE Primus, Hanover, MD). Two upper extremity motions, shoulder abduction and ER, and two lower extremity, hip abduction and extension, These testing exercises and positions were chosen based off previously literature, indicating their reliability.[13-17] Strength measurements were taken at baseline and weeks 2, 4, 6, and at the completion of week 8 by the same tester. Twenty-four hours prior to testing participants were asked to refrain from exercise to prevent the effects of fatigue during the testing sessions.

Prior to initiating the study testing, between day reliability was established using intraclass correlation coefficients (ICC), standard error of measurement (SEM), and minimal detectable change (MDC). The ICC for isometric testing of, shoulder abduction, shoulder external rotation, hip abduction, and hip extension were found to be very reliable based on ICC values (0.87-0.96) with SEM between 1-3% of body weight for all tests (Table 2).

*Table 2. about here

Shoulder abduction and ER were tested in a seated position with the participants arm at the side in a neutral position.[15-17] Shoulder abduction was tested with arm at side and elbow extended and the pad positioned superior to the lateral epicondyle of the elbow (Figure 2). Participants were instructed and encouraged to push outward into the lever arm pad maximally to determine the amount of force they could generate. Instructions given were consistent each test period for every participant. Shoulder ER was performed in the same manner; however, the elbow was flexed and supported at 90°, while the lever arm pad was placed proximal to the wrist (Figure 3).

*Figure 2. and Figure 3. about here

Hip abduction was tested in a side-lying position as previously described in the literature,[13,14] with the lever arm pad placed proximal to the knee joint (Figure 4). Hip extension was tested prone with knee flexed to 90° (Figure 5). [13,14] Participants were instructed to pushing their leg towards the pad maximally.

*Figure 4. and Figure 5. about here

When performing each movement for the testing process, first the distance was measured from the center of the BTE Primus (BTE Technologies, Hanover, MD) to the middle of the pad attached to the lever arm, and the measured distance was entered into the BTE software to obtain the force in Newtons (Figure 6). After measures were taken each participant was given an opportunity to practice the tested movement one to three repetitions before strength measurements were taken. This was performed in order to allow the subject to familiarize themselves with the movement, thus reducing any potential learning effect. During testing, consistent verbal encouragement was provided for an initial 5 second maximal effort.[19, 20] Following the initial five second maximal effort, the participant was allowed to rest for thirty seconds before a subsequent five second maximal effort was performed. All testing was performed bilaterally regardless of dominance. Following testing the average of the two maximal efforts were recorded for later data analysis. The same procedures were repeated at subsequent two week intervals until the strengthening program was completed.

*Figure 6. about here

Intervention

Exercise Description

Both groups performed exercises 3 times a week, at least twice a week they were under the supervision of a certified athletic trainer or licensed physical therapist, once a week the exercises were performed at home unsupervised. The time of day that these sessions took placed varied based on the subject's schedule. This intervention strategy would simulate a typical outpatient physical therapy intervention regimen. Exercises chosen were based on commonly prescribed exercises in a clinic setting and to target the intended musculature. Three exercises were performed for the upper extremity by both groups. Shoulder abduction was performed by having participant elevate arms against elastic resistance from side to 90° abduction in the scapular plane (Figure 7). Shoulder external rotation was performed at the side from full internal rotation to 50° of external rotation with elbow at the side (Figure 8). Shoulder extension was performed with elbow in full extension starting with both arms just above head level and pulled the elastic resistance down to their sides while retracting their shoulder blades simultaneously (Figure 9). Elastic resistance was held in the hand for all exercises, handles were provided to participants if they preferred.

*Figure 7. and Figure 8. and Figure 9. about here

Lower extremity exercises consisted of hip abduction, hip extension, and hip ER. Hip abduction was completed while standing (Figure 10). Participants would move their leg out to the side (abduct) to approximately 45°, while keeping their core tight to prevent trunk lean. Hip extension was also performed while standing upright (Figure 11). Participants moved into approximately 15° of hip extension. Hip ER was performed seated, moving until end range was reached (Figure 12).

*Figure 10. and Figure 11. and Figure 12. about here

Home exercises were performed in the same manner. Participants were provided the same bands they most recently were using along with cuff straps for their leg exercise and handles for their upper extremity if they requested. Participants were provided a home exercise log to record the same information as in the supervised training including load, repetitions, and perceived exertion using the Thera-band® Resistance Intensity Scale for Exercise (RISE) scale. The home exercise logs were returned to evaluate home exercise adherence at the end of the study.

Determination of Initial Exercise load

The load cell group performed all exercises with a predetermined target load for each exercise. The literature suggests in order to increase strength, a percentage ranging from 60-80% of 1RM or 10RM should be used.[18-20] The participants were instructed to perform the exercise with correct technique with a moderate to heavy level of resistance. An attempt was to start at 50% of maximum load but this was not obtainable by any subject in this group as the resistance load was too heavy. Primarily due to the fact that the lever arm during testing was shorter than the lever arm during exercise. Additionally, isometric testing was completed, whereas the exercises themselves were completed isotonically. If a participant was unable to keep correct form during the exercise the resistance was lowered to prevent compensation and to minimize the chance of injury. Resistive loads for the load cell group was reduced until the participant was able to demonstrate exercise appropriately.

The first day of exercise, the ERO group was given three different colors of resistance and asked to perform 3-5 repetitions with each band. The participant was asked which band they felt they could perform three sets of 10 repetitions keeping correct form as previously described.[7,21]

The participants chose the resistive band for each exercise. This procedure was repeated for each exercise and the color and length of band was recorded.

Exercise Progression

The load cell group was progressed by 1-2 pounds when the participant demonstrated correct form over all repetitions without difficulty. Resistance was also increased based on bi-weekly re-test measurements to keep resistive loads at or above 25% of average maximal force produced. The load cell provided feedback in the form of a tone. A tone emitted constantly from the load cell when the predetermined load was reached or exceeded. The load used for each exercise on each day of training was recorded for the duration of the study. After each exercise, participants were also asked to rate the difficulty of the exercise using the RISE. This is a 5 point Likert-type scale ranging from 1-5, 1= easy effort and 5 = maximal effort. This scale has been found to be highly correlated with OMNI-Resistance Exercise Scale of perceived exertion, showing similar construct and concurrent validity.[22] The RISE scale was recorded for each exercise throughout the training program.

The ERO group was progressed based on their perceived exertion using the RISE scale alone. This group was progressed as the exercises became a rating of equal to or below a 2 on the RISE.[23-25] The resistance was progressed by shortening the length of the band or changing the color of the band which is directly proportional to the stiffness of the resistance.[6] The color of elastic resistance, the length of the elastic band and the perceived exertion using the RISE scale was recorded for each exercise performed by a participant throughout the training program. Both groups received the same supervision and feedback from the therapist.

Data Reduction

Average torque was recorded from two isometric contractions performed for each test. The data from the dynamometer was entered into an excel spreadsheet and was normalized to body weight. A change score was used to measure changes in strength across the 8 weeks.

To measure the rate of strength change or slopes were calculated. The strength values recorded as percent of bodyweight captured across the five testing sessions (baseline, 2, 4, 6, and 8 weeks) for each of the 8 dependent measures were used to create the rate of strength change or slope. The slope function in excel (Microsoft, Redwood, WA) returns the slope of the linear regression line of best fit through the five data points provided. Slope for each subject was calculated and were averaged to compare rate of strength change between the two groups.

Statistical Analysis

For the purposes of gender differences, males and females were analyzed separately. In order to test our hypothesis that the load cell group will have greater strength gains than the ERO group, the strength change score was evaluated using an independent t-test. This measure was repeated for the eight measures of strength; bilateral shoulder abduction, shoulder external rotation, hip abduction, and hip extension, therefore to adjust for multiple comparisons significance level was set at $p=0.0063$.

In order to test our hypothesis that the load cell group will have a greater rate of change than the ERO group, the slopes was evaluated using an independent t-test. This measure was repeated for 8 measures of strength, therefore to adjust for multiple comparisons significance level was set at $p=0.0063$.

RESULTS

Data were analyzed for normality using the Shapiro-Wilk test and found to be normally distributed ($p>0.095$) allowing for parametric analysis. In general, all strength measurements increased over time in both groups and between males and females, descriptive strength data analysis is presented as a percentage of bodyweight (Table 3 and Table 4).

*Table 3 and Table 4 about here

Overall, there were no statistical differences in strength gains between groups for either upper (Table 5) or lower extremities (Table 6). Shoulder strength increased at a rate of approximately 0.5% BW per week but did not significantly differ between groups (Table 7). Hip strength increased at a rate of approximately 1.5% BW per week but no significant differences were observed between groups (Table 8).

*Table 5. and Table 6. and Table 7. and Table 8 about here

DISCUSSION

Previous studies have encountered difficulties modulating the force of the resistance band due to fluctuating elongation resulting in variable resistance.[26,27] This leaves the clinician dependent on patient perception of difficulty with no objective measure of progressing through exercise. This study examines the use of a load cell to resolve this issue. The load cell was designed to allow clinicians to set target loads in order to provide individual auditory and visual feedback when the pre-set load is achieved. Previous research has demonstrated benefit to increasing strength when EMG biofeedback is provided[28] but limited research exists regarding the use of force biofeedback to increase strength.[29] Our hypothesis that greater strength change and a quicker rate of strength gains would occur in individuals using a load cell compared to using a perceived exertion to progress exercise resistance was not supported.

The lack of strength difference between the groups may be explained from two perspectives; first from the exercise parameters used and second from the level of supervision provided. Exercise parameters during training are identified by four factors; frequency, intensity, time, and type. These parameters are often varied in order to prevent staleness in training and enhance improvements.[4,30] The protocols in this study were purposely designed to be similar in frequency, time and type with intensity as the single factor being compared between groups. Both groups exercised three days per week (frequency), the same number of repetitions was performed in both groups (time) and both groups used elastic resistance (type). This leaves intensity as the variable being tested. In the ERO group the individual participant chose the level of intensity to train with and progressed as they perceived the exercise became easy. The load cell group was increased based on their strength performance measures tested every other week and the effort of the known load. The results of this study support both methods produce increased strength gains overtime at the same rate. The clinical application of these results, are that clinicians need to supervise and progress elastic resistance exercise based on daily perceived exertion scale or when supervision is limited use a load cell that can provide constant and objective feedback of resistance. The effect size calculated in tables 4-7 suggest that the load cell feedback provides small to moderate beneficial effects at improving strength over the perceived exertion scale but these differences did not reach statistical significance.

The environment of this study was in a controlled clinical laboratory with one-on-one supervision of each participant. This is the ideal setting for a controlled experiment, but may not truly represent a clinical environment. Evidence suggests that greater improvements in stability, strength, and motivation are gained with supervised exercise compared to exercising alone.[31,32]In this study, both groups were equally supervised while exercising. Further, the level of perceived exertion for each exercise performed was recorded for each participant in both groups using the RISE scale. This is not typically done in the clinical setting. In order to minimize bias in this study the researchers thought it would be important to track exercise effort in both groups. The constant request to ask the participant their perceived level of difficulty for each exercise in both groups may have inadvertently biased the participant to report an erroneous effort in order to meet expectation of the researcher.[33] These combined factors of rating exercise intensity constantly and high level of supervision likely explain the similar results in both groups.

One unique component of this study was to investigate rate of strength gains using elastic resistance. Individuals participating in strength training activities or rehabilitation often inquire about when they will see improvement. Rate of strength loss in an immobilized limb has been found to occur at 1% per day over the course of the first 6 weeks.[34] This study demonstrated a rate of strength improvement of approximately 1.2% body weight per week for hip strengthening. Based on our average weight of participants this equals .88kg/ week improvement or nearly 2 lb improvement per week in hip strength. The rate of strength gains is not commonly reported however one study in men over the age of 60 following 12 weeks of knee extension and flexion exercises were found to have a rate of 5% strength improvement per week.[35] Frontera et al.[35] trained healthy volunteers at 80% of one-repetition maximum with 3 sets of 8 repetitions. The 80% load was adjusted weekly to assure a constant stimulus. Although the current study strengthening at different intensities, used elastic resistance, and targeted different muscle we found that both shoulder and hip strength increased at a rate ranging from 5-7% per week. This adds new information regarding the rate of strength gains that should be expected using elastic resistance. Access to an identified rate of progression will allow clinicians to better determine if rate of strength gains is on the correct trajectory with adequate training stimulus and formulate a prognosis for recovery.

This study is not the first to use resistance bands to increase strength in a healthy population.[1,2,7,36,37] This study contributes to the limited literature currently available that the use of elastic resistance is beneficial for increasing strength although differences were not observed between the two groups.[1,6,36] The current study is similar to others with an eight week duration using elastic resistance in lieu of conventional means such as free weights or pneumatic devices.[1,2,7,36] Ramos et al.[1], Hibberd et al.[38] and Jensen et al.[37] observed a comparable increase in strength while using an elastic resistance band training program. In this study, shoulder abduction and external rotation resulted in approximately 4% and 2% BW increase in strength, respectively. A shoulder strengthening program for swimmers detected similar percent body mass gains of approximately 2% for both shoulder abduction and external rotation.[38] Jensen et al.[37] reported isometric strength gains in hip abduction from 1.67 Nm/kg at baseline to 1.94 Nm/kg at eight weeks, a 17% percent strength increase from baseline in soccer players. We observed a 7-12% BW increase but when compared to baseline represents a 27% increase in hip abduction strength in the same time period in a generally healthy population. These results, support that elastic resistance training is beneficial to gaining strength when the appropriate exercise dose for response is performed.[19]

There appears to be some additional benefit when using a load cell for hip abduction in particular. Both training groups increased hip strength, although no difference were observed statistically between groups there were small to moderate beneficial effects using the load cell for training hip abduction. The load cell group was moderately more effective than the elastic resistance group for hip abduction for both males and females based on effect size (Cohen's d =

0.67, 0.65). Participants were able to hear the tone during all exercises in the load cell group indicating they met their pre-set load. We asked all participants to hold the contraction for 3 seconds; however, the hip abduction exercise in particular was challenging as the participant could easily lose their balance and often had to start the exercise holding on to a stable surface. All participants were encouraged to attempt to do the exercise without holding on but not able to be accomplished by all. The combination of maintaining balance and achieving the goal of hearing the tone for 3 seconds may have challenged the load cell group to focus more during the hip exercises which likely accounts for the greater effects.

There are three primary limitations of this study. Blinding of the participants and assessors was not feasible. Many of our participants completed their exercises at the same time, exposing them to the other group. This could have led to ascertainment bias of the participant and observer bias of the assessors. This type of bias could lead to favor of one intervention over another from being exposed to the other group. However, no subjects requested to use the load cell or switch groups, therefore we believe ascertainment bias minimally affected the outcome. Secondly, because one exercise session per week was completed at home we had to rely on subjective information indicating exercises were completed and done correctly. As our subjects were considered to be compliant if they missed 3 or fewer sessions out of 24 total, 65% (47/72) of our subjects fell into this category and we detected no difference between groups. Of those 47 compliant subjects, it was an even split between the groups, 24 subjects in the ERO and 23 subjects in the load cell group. Lastly, supervision may have been greater in our laboratory setting than in a typical exercise or physical therapy setting. This could be an additional reason for lack of differences between the two groups.

Future research should implement the use of feedback with a load cell in participant's homes. Throughout this study, participants stated their concerns with not working as intensely at home without the use of a load cell or our verbal ques. A previous study comparing a conventional home exercise program was compared to the use of augmented feedback, found that those in the augmented feedback group had longer at home exercise times similar to a clinic setting.[39] Applying the use of a load cell in participant's home with preset loads, may allow the appropriate feedback to participants that they have reached the desired work load also increasing exercise times.

PRACTICAL APPLICATIONS

Overall, supervision and providing feedback during exercise is beneficial in producing strength gains. Using a load cell is as effective as supervised training and could provide value in a clinic setting when patients are working unsupervised. If in a busy setting where a clinician may need to step away from an athlete or patient, having a load cell may assist in reaching strength gains without supervision. Even with supervised elastic resistance training, progression decisions are primarily dependent on the clinician's subjective decision. Using the load cell combined with perceived fatigue exertion provides a more objective method when reporting the patient exercise performance. Providing targeted loads during training increases strength similarly to using perceived exertion alone.

References

1. Ramos EMC, de Toledo-Arruda AC, Fosco LC, et al. The effects of elastic tubing-based resistance training compared with conventional resistance training in patients with moderate chronic obstructive pulmonary disease: a randomized clinical trial. *Clinical Rehabilitation.* 2014;28(11):1096-1106.
2. Colado JC, Garcia-Masso X, Pellicer M, Alakhdar Y, Benavent J, Cabeza-Ruiz R. A comparison of elastic tubing and isotonic resistance exercises. *Int J Sports Med.* 2010;31(11):810-817.
3. DeLorme TL. Restoration of muscle power by heavy resistance excercises. *Journal of Bone and Joint Surgery, American Volume.* 1945;27:645-667.
4. Kraemer WJ, Adams K, Cafarelli E, et al. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc.* 2002;34(2):364-380.
5. Kraemer WJ, Ratamess NA. Fundamentals of resistance training: progression and exercise prescription. *Med Sci Sports Exerc.* 2004;36(4):674-688.
6. Hughes CJ, Hurd K, Jones A, Sprigle S. Resistance properties of Thera-Band tubing during shoulder abduction exercise. *J Orthop Sports Phys Ther.* 1999;29(7):413-420.
7. Colado JC, Triplett NT. Effects of a short-term resistance program using elastic bands versus weight machines for sedentary middle-aged women. *Journal of strength and conditioning research / National Strength & Conditioning Association.* 2008;22(5):1441-1448.
8. Shaykevich A, Grove JR, Jackson B, Landers GJ, Dimmock J. Auditory feedback improves heart rate moderation during moderate-intensity exercise. *Med Sci Sports Exerc.* 2015;47(5):1046-1051.
9. Hwangbo PN. The effects of squatting with visual feedback on the muscle activation of the vastus medialis oblique and the vastus lateralis in young adults with an increased quadriceps angle. *J Phys Ther Sci.* 2015;27(5):1507-1510.
10. Ma C, Szeto GP, Yan T, Wu S, Lin C, Li L. Comparing biofeedback with active exercise and passive treatment for the management of work-related neck and shoulder pain: a randomized controlled trial. *Arch Phys Med Rehabil.* 2011;92(6):849-858.
11. Brophy RH, Beauvais RL, Jones EC, Cordasco FA, Marx RG. Measurement of shoulder activity level. *Clinical orthopaedics and related research.* 2005;439:101-108.
12. Marx RG, Stump TJ, Jones EC, Wickiewicz TL, Warren RF. Development and evaluation of an activity rating scale for disorders of the knee. *Am J Sports Med.* 2001;29(2):213-218.
13. Scott DA, Bond EQ, Sisto SA, Nadler SF. The intra- and interrater reliability of hip muscle strength assessments using a handheld versus a portable dynamometer anchoring station. *Arch Phys Med Rehabil.* 2004;85(4):598-603.
14. Nadler SF, DePrince ML, Hauesien N, Malanga GA, Stitik TP, Price E. Portable dynamometer anchoring station for measuring strength of the hip extensors and abductors. *Arch Phys Med Rehabil.* 2000;81(8):1072-1076.
15. Leggin BG, Neuman RM, Iannotti JP, Williams GR, Thompson EC. Intrarater and interrater reliability of three isometric dynamometers in assessing shoulder strength. *J Shoulder Elbow Surg.* 1996;5(1):18-24.
16. Cadogan A, Laslett M, Hing W, McNair P, Williams M. Reliability of a new hand-held dynamometer in measuring shoulder range of motion and strength. *Man Ther.* 2011;16(1):97-101.
17. Andersen KS, Christensen BH, Samani A, Madeleine P. Between-day reliability of a hand-held dynamometer and surface electromyography recordings during isometric submaximal contractions in different shoulder positions. *J Electromyogr Kinesiol.* 2014;24(5):579-587.
18. Fish DE, Krabak BJ, Johnson-Greene D, DeLateur BJ. Optimal resistance training: comparison of DeLorme with Oxford techniques. *Am J Phys Med Rehabil.* 2003;82(12):903-909.
19. Rhea MR, Alvar BA, Burkett LN, Ball SD. A meta-analysis to determine the dose response for strength development. *Med Sci Sports Exerc.* 2003;35(3):456-464.

20. Peterson MD, Rhea MR, Alvar BA. Maximizing strength development in athletes: a meta-analysis to determine the dose-response relationship. *Journal of strength and conditioning research / National Strength & Conditioning Association.* 2004;18(2):377-382.
21. Kraemer WJ, Keuning M, Ratamess NA, et al. Resistance training combined with bench-step aerobics enhances women's health profile. *Med Sci Sports Exerc.* 2001;33(2):259-269.
22. Colado JC, Garcia-Masso X, Triplett NT, et al. Construct and concurrent validation of a new resistance intensity scale for exercise with thera-band(R) elastic bands. *J Sports Sci Med.* 2014;13(4):758-766.
23. Fernandez-Fernandez J, Ellenbecker T, Sanz-Rivas D, Ulbricht A, Ferrauti A. Effects of a 6-Week Junior Tennis Conditioning Program on Service Velocity. *Journal of Sports Science & Medicine.* 2013;12(2):232-239.
24. Ferber R, Kendall KD, Farr L. Changes in knee biomechanics after a hip-abductor strengthening protocol for runners with patellofemoral pain syndrome. *J Athl Train.* 2011;46(2):142-149.
25. Escamilla RF, Fleisig GS, Yamashiro K, et al. Effects of a 4-week youth baseball conditioning program on throwing velocity. *Journal of strength and conditioning research / National Strength & Conditioning Association.* 2010;24(12):3247-3254.
26. Patterson MJ, Jansen CWS, Hogan HA, Navarro RA. Material properties of the Thera-band tubing. *Physical Therapy.* 2001;81(8):1437-1445.
27. Thomas M, Muller T, Busse MW. Quantification of tension in Thera-Band and Cando tubing at different strains and starting lengths. *J Sports Med Phys Fitness.* 2005;45(2):188-198.
28. Lepley AS, Gribble PA, Pietrosimone BG. EFFECTS OF ELECTROMYOGRAPHIC BIOFEEDBACK ON QUADRICEPS STRENGTH: A SYSTEMATIC REVIEW. *Journal of Strength & Conditioning Research (Lippincott Williams & Wilkins).* 2012;26(3):873-882.
29. Goldman RJ, Reinbold KA, Iglarsh ZA, Neustadter LM, Oatis CA, Schumacher HR. Phase I design and evaluation of an isometric muscle reeducation device for knee osteoarthritis rehabilitation. *J Rehabil Res Dev.* 2003;40(2):95-107.
30. Bird SP, Tarpenning KM, Marino FE. Designing resistance training programmes to enhance muscular fitness: a review of the acute programme variables. *Sports Med.* 2005;35(10):841-851.
31. Chuter VH, de Jonge XA, Thompson BM, Callister R. The efficacy of a supervised and a home-based core strengthening programme in adults with poor core stability: a three-arm randomised controlled trial. *Br J Sports Med.* 2015;49(6):395-399.
32. Courneya KS, Stevinson C, McNeely ML, et al. Effects of supervised exercise on motivational outcomes and longer-term behavior. *Med Sci Sports Exerc.* 2012;44(3):542-549.
33. Parsons HM. What happened at Hawthorne? *Science.* 1974;183(4128):922-932.
34. Bloomfield SA. Changes in musculoskeletal structure and function with prolonged bed rest. *Med Sci Sports Exerc.* 1997;29(2):197-206.
35. Frontera WR, Meredith CN, O'Reilly KP, Knuttgen HG, Evans WJ. Strength conditioning in older men: skeletal muscle hypertrophy and improved function. *J Appl Physiol (1985).* 1988;64(3):1038-1044.
36. Ghigiarelli JJ, Nagle EF, Gross FL, Robertson RJ, Irrgang JJ, Myslinski T. The effects of a 7-week heavy elastic band and weight chain program on upper-body strength and upper-body power in a sample of division 1-AA football players. *Journal of strength and conditioning research / National Strength & Conditioning Association.* 2009;23(3):756-764.
37. Jensen J, Holmich P, Bandholm T, Zebis MK, Andersen LL, Thorborg K. Eccentric strengthening effect of hip-adductor training with elastic bands in soccer players: a randomised controlled trial. *Br J Sports Med.* 2014;48(4):332-338.
38. Hibberd EE, Oyama S, Spang JT, Prentice W, Myers JB. Effect of a 6-Week Strengthening Program on Shoulder and Scapular-Stabilizer Strength and Scapular Kinematics in Division I Collegiate Swimmers. *Journal of Sport Rehabilitation.* 2012;21(3):253-265.

39. Hügli AS, Ernst MJ, Kool J, et al. Adherence to home exercises in non-specific low back pain. A randomised controlled pilot trial. *Journal of Bodywork & Movement Therapies*. 2015;19(1):177-185.