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Elastic Resistance Effectiveness on Increasing Strength of Shoulders and Hips

Kelsey J. Picha

University of Kentucky, kelsey.picha@uky.edu

Muataz R. Almaddah

University of Kentucky, m.almaddah@uky.edu

Jordan Barker

University of Kentucky, jordan.barker@uky.edu

Tavis Ciochetty

University of Kentucky, tavis.ciochetty@uky.edu

W. Scott Black

University of Kentucky, wsblac0@uky.edu

See next page for additional authors

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Authors

Kelsey J. Picha, Muataz R. Almaddah, Jordan Barker, Tavis Ciochetty, W. Scott Black, and Timothy L. Uhl

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1 Elastic Resistance Effectiveness on Increasing Strength of Shoulders and Hips

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48 ABSTRACT

49 Elastic resistance is a common training method used to gain strength. Currently, progression with
50 elastic resistance is based on the perceived exertion of the exercise or completion of targeted
51 repetitions; exact resistance is typically unknown. This study's objective is to determine if
52 knowledge of load during elastic resistance exercise will increase strength gains during exercises.
53 Participants were randomized into two strength training groups, elastic resistance only and elastic
54 resistance using a load cell (LC) that displays force during exercise. The LC group used a Smart
55 Handle (Patterson Medical Supply, Chicago, IL) to complete all exercises. Each participant
56 completed the same exercises three times weekly for 8 weeks. The LC group was provided with a
57 set load for exercises whereas the elastic resistance only group was not. Participant's strength was
58 tested at baseline and program completion, measuring isometric strength for shoulder abduction
59 (SAb), shoulder external rotation (SER), hip abduction (HAb), and hip extension (HEX).
60 Independent t-tests were used to compare the normalized torques between groups. No significant
61 differences were found between groups. Shoulder strength gains did not differ between groups
62 (SAb $p>0.05$; SER $p>0.05$). Hip strength gains did not differ between groups (HAb $p>0.05$; HEX
63 $p>0.05$). Both groups increased strength due to individual supervision, constantly evaluating
64 degree of difficulty associated with exercise and providing feedback while using elastic resistance.
65 Using a LC is as effective as supervised training and could provide value in a clinic setting when
66 patients are working unsupervised.

67 **Word Count:** 240/250

68 **Key Words:** Load cell, strength training, supervision

69

70 INTRODUCTION

71 Resistance training is the preeminent way to gain strength and muscle mass.¹⁻³ The work
72 of Delorme³ demonstrated the need for progressive resistive loads to be constantly adjusted in
73 order to gain strength. Progressive overload refers to the increasing stress placed on the muscle via
74 resistive exercise.^{4,5} Resistance training can be modified by altering load, repetitions, type or
75 intensity.⁴

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

92 exercise.⁸⁻¹⁰ An increase in muscle activation and reduction in pain with the use of feedback has
93 been found,^{9,10} indicating possible benefit of this technique.

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

103 METHODS

104 **Participants**

105 A total of 107 volunteers inquired about this study through email or phone from September
106 2015-May 2016. The study was approved by an Institutional Review Board (IRB). Potential
107 participants were excluded for the following criteria: 1) they were outside the age range of 18-70
108 years of age, 2) answered “yes” to any question on the Physical Activity Readiness Questionnaire
109 Scale indicating they have a medical limitation to exercise, 3) had shoulder, knee, or hip surgery
110 within the last three months, or 4) have a history of heart or lung illness. Eligible participants had
111 to be willing to exercise three times a week with supervision, subjects were informed of the
112 benefits and risks of the investigation prior to signing an institutionally approved informed consent
113 document. All data collection took place in a clinical laboratory from September 2015-July 2016.

114 Eighty-one participants age 18-67, agreed to participate in an 8 week resistive training study. Five
115 patients did not meet inclusion criterion and 21 subjects were not interested in participation due to
116 time demands (Figure 1). Independent t-tests were used to compare demographic and activity
117 levels of the two groups. There were no differences observed between the two groups indicating
118 randomization process was adequate. (Table 1) Subjects training levels in this study ranged from
119 sedentary to moderately active at baseline according to Marx Shoulder Activity Scale, averaging
120 9 ± 4 ¹¹ and Marx Activity Scale,¹² averaging 5 ± 5 points. The Marx Shoulder Activity Scale is a
121 20-point upper extremity scale, and Marx Activity Scale is a 16-point lower extremity activity
122 scale, a higher score indicating a more active individual.

123 *Figure 1. and Table 1. about here

124 **Design**

125 **Power Analysis**

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

133 **Randomization and Treatment Allocation**

134 This study was a two-group, pre-test/post-test randomized clinical trial. The design is
135 appropriate to find the difference in strength gains between groups after eight weeks of supervised
136 training. On initial visit subjects completed baseline assessments and then were given an opaque

137 envelop to open. The group membership was identified on a piece of paper in an envelope. Block
138 randomization was performed prior to study commencing using the web site Randomization.com
139 (<http://www.randomization.com>) using 10 groups of 8 subjects. The results of this procedure were
140 blinded to all investigators until the participant opened the envelope. Participants were divided
141 into two groups, the elastic resistance only (ERO) group or the load cell group. Neither participants
142 nor investigators were blinded to group membership from this point forward. All participants had
143 to work within the same space, therefore researchers performing strength testing and participants
144 were not blinded to exercise group assignment. This is an obvious study limitation, but since all
145 participants were using the same elastic resistive bands (Thera-band® CLX Consecutive Loops,
146 Hygenic Corporation, Akron, OH USA) no participants requested to be changed into the other
147 group. These elastic resistive bands come in seven different levels or colors (yellow, red, green,
148 blue, black, silver, and gold). When stretched 100%, these bands range in load from approximately
149 three pounds (yellow band) to 14.2 pounds (gold band).

150 **Procedures**

151 **Baseline Testing**

152 Upon arrival participants read and signed an IRB approved consent form, completed
153 demographic information of age, height, weight, sex, and race, and completed both the upper
154 extremity and lower extremity activity scales.^{11,12}

155 Measurement of limb lengths were taken with a standard cloth tape measure in order to
156 calculate torques to prescribe exercise loads. Arm length from the acromion process to the distal
157 end of the third metacarpal was recorded in meters. The distance from the lateral epicondyle to the
158 third metacarpal was recorded in meters. The distance from the greater trochanter to lateral
159 malleolus was recorded in meters. These human lever arms measured were used to compute

160 resistive training loads used for the exercises once subjects were randomized into the load cell
161 group.

162 Maximal Isometric Strength

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

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

175 *Table 2. about here

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

183 *Figure 2. and Figure 3. about here

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

188 *Figure 4. and Figure 5. about here

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

202 *Figure 6. about here

203 **Intervention**

204 Exercise Description

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

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

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

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

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

232 Determination of Initial Exercise load

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

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

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

249 Exercise Progression

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

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

268 **Data Reduction**

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

272 To measure the rate of strength change or slopes were calculated. The strength values
273 recorded as percent of bodyweight captured across the five testing sessions (baseline, 2, 4, 6, and
274 8 weeks) for each of the 8 dependent measures were used to create the rate of strength change or
275 slope. The slope function in excel (Microsoft, Redwood, WA) returns the slope of the linear
276 regression line of best fit through the five data points provided. Slope for each subject was
277 calculated and were averaged to compare rate of strength change between the two groups.

278 **Statistical Analysis**

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

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

289 **RESULTS**

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

294 *Table 3 and Table 4 about here

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

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

301 DISCUSSION

302 Previous studies have encountered difficulties modulating the force of the resistance band
303 due to fluctuating elongation resulting in variable resistance.^{26,27} This leaves the clinician
304 dependent on patient perception of difficulty with no objective measure of progressing through
305 exercise. This study examines the use of a load cell to resolve this issue. The load cell was designed
306 to allow clinicians to set target loads in order to provide individual auditory and visual feedback
307 when the pre-set load is achieved. Previous research has demonstrated benefit to increasing
308 strength when EMG biofeedback is provided²⁸ but limited research exists regarding the use of force
309 biofeedback to increase strength.²⁹ Our hypothesis that greater strength change and a quicker rate
310 of strength gains would occur in individuals using a load cell compared to using a perceived
311 exertion to progress exercise resistance was not supported.

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

330 The environment of this study was in a controlled clinical laboratory with one-on-one
331 supervision of each participant. This is the ideal setting for a controlled experiment, but may not
332 truly represent a clinical environment. Evidence suggests that greater improvements in stability,
333 strength, and motivation are gained with supervised exercise compared to exercising alone.^{31,32} In
334 this study, both groups were equally supervised while exercising. Further, the level of perceived

335 exertion for each exercise performed was recorded for each participant in both groups using the
336 RISE scale. This is not typically done in the clinical setting. In order to minimize bias in this study
337 the researchers thought it would be important to track exercise effort in both groups. The constant
338 request to ask the participant their perceived level of difficulty for each exercise in both groups
339 may have inadvertently biased the participant to report an erroneous effort in order to meet
340 expectation of the researcher.³³ These combined factors of rating exercise intensity constantly and
341 high level of supervision likely explain the similar results in both groups.

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

357 strength gains is on the correct trajectory with adequate training stimulus and formulate a prognosis
358 for recovery.

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

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

380 0.67, 0.65). Participants were able to hear the tone during all exercises in the load cell group
381 indicating they met their pre-set load. We asked all participants to hold the contraction for 3
382 seconds; however, the hip abduction exercise in particular was challenging as the participant could
383 easily lose their balance and often had to start the exercise holding on to a stable surface. All
384 participants were encouraged to attempt to do the exercise without holding on but not able to be
385 accomplished by all. The combination of maintaining balance and achieving the goal of hearing
386 the tone for 3 seconds may have challenged the load cell group to focus more during the hip
387 exercises which likely accounts for the greater effects.

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

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

409 PRACTICAL APPLICATIONS

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

419

420

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