Ability to predict repetitions to momentary failure is not perfectly accurate, though improves with resistance training experience

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‘Repetitions in Reserve’ (RIR) scales in resistance training (RT) are used to control effort but assume people accurately predict performance a priori (i.e. the number of possible repetitions to momentary failure [MF]). This study examined the ability of trainees with different experience levels to predict number of repetitions to MF. One hundred and forty one participants underwent a full body RT session involving single sets to MF and were asked to predict the number of repetitions they could complete before reaching MF on each exercise. Participants under predicted the number of repetitions they could perform to MF (Standard error of measurements [95% confidence intervals] for combined sample ranged between 2.64 [2.36 to 2.99] and 3.38 [3.02 to 3.83]). There was a tendency towards improved accuracy with greater experience. Ability to predict repetitions to MF is not perfectly accurate among most trainees though may improve with experience. Thus, RIR should be used cautiously in prescription of RT. Trainers and trainees should be aware of this as it may have implications for the attainment of training goals, particularly muscular hypertrophy.
Title: Ability to predict repetitions to momentary failure is not perfectly accurate, though it improves with resistance training experience.

Running title: Predicted vs actual reps to failure

Original Research Article

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Abstract

‘Repetitions in Reserve’ (RIR) scales in resistance training (RT) are used to control effort but assume people accurately predict performance \textit{a priori} (i.e. the number of possible repetitions to momentary failure [MF]). This study examined the ability of trainees with different experience levels to predict number of repetitions to MF. One hundred and forty one participants underwent a full body RT session involving single sets to MF and were asked to predict the number of repetitions they could complete before reaching MF on each exercise. Participants under predicted the number of repetitions they could perform to MF (Standard error of measurements [95\% confidence intervals] for combined sample ranged between 2.64 [2.36 to 2.99] and 3.38 [3.02 to 3.83]). There was a tendency towards improved accuracy with greater experience. Ability to predict repetitions to MF is not perfectly accurate among most trainees though may improve with experience. Thus, RIR should be used cautiously in prescription of RT. Trainers and trainees should be aware of this as it may have implications for the attainment of training goals, particularly muscular hypertrophy.
1. Introduction

Resistance training (RT) is an exercise mode evidenced to provide a wide range of health benefits (Steele et al., 2017). As such, understanding prescription of RT to maximise these outcomes is of considerable interest. One variable which may be of primary importance is the intensity of effort employed i.e. whether or not RT is performed to momentary failure (MF; Steele, 2014; Steele, Fisher, Giessing, and Gentil, 2017). A plethora of recent work shows that when effort is matched by having RT performed to MF, manipulations of other RT variables have a lesser impact upon the magnitude of outcomes. These secondary variables include; load (Morton et al., 2016; Schoenfeld, Peterson, Ogborn, Contreras, and Sonmez, 2015; Schoenfeld, Wilson, Lowery, and Krieger, 2016; Fisher, Ironside, and Steele, 2016), repetition duration (Schoenfeld, Ogborn, and Krieger, 2015), and the use of advanced or complicated training methods such as pre-exhaustion (Fisher, Carlson, Steele, and Smith, 2014), breakdown sets (Fisher, Carlson, and Steele, 2015) or occlusion training (Barcelos et al., 2015; Farup, de Paoli, Bjerg, Riis, Ringgard, and Vissing, 2015).

A number of recent reviews have also concluded that training to MF may confer greater adaptations in strength (Fisher, Steele, Smith, and Bruce-Low, 2011), hypertrophy (Fisher, Steele, and Smith, 2013) and possibly cardiorespiratory fitness (Steele, Fisher, McGuff, Bruce-Low, and Smith et al., 2012) than training not to MF. Conversely, more recent empirical work has shown contrasting results regarding the efficacy of training to MF (Fisher, Blossom, and Steele, 2016; Giessing, Eichmann, Steele, and Fisher, 2016; Giessing, Fisher, Steele, Rothe,
Proximity to MF has been considered a determinant of the effort employed during RT, and MF (as a set end-point) has been suggested as the only way to objectively match inter- and intra-individual effort due to the variations in number of repetitions possible prior to MF at the same relative loads i.e. % one repetition maximum (%1RM; Steele, 2014; Steele, Fisher, Giessing, and Gentil, 2017). In fact, it has been argued that training to MF is the most appropriate way to control the application of a RT stimulus (Dankel et al., 2016).

However, the current body of research has typically considered this variable dichotomously (i.e. people training ‘to MF’ or ‘not to MF’). As a result, the dose-response nature of sub maximal intensities of effort resulting from set end-points occurring at different proximities to MF is unclear. Furthermore, it is unclear whether there is a threshold of relative effort which optimises adaptations. As such, to understand sub maximal effort some have developed scales to assess effort during RT relative to MF (Hackett, Johnson, Halaki, and Chow 2012; Hackett, Cobley, Davies, Michael, and Halaki, 2016; Zourdos et al., 2016; Helms, Cronin, Storey, and Zourdos, 2016). These ‘Repetitions in Reserve’ (RIR) scales are designed as a way of assessing/controlling relative effort by participants estimating how many repetitions they can perform before reaching MF.

In comparison with traditional rating of perceived effort (RPE) scales, RIR scales appear more likely to offer valid representations of effort when training to, or close to, MF (Helms et al., 2016) whereas traditional RPE often yields far less accurate ratings under such conditions (Hackett et al., 2012). Indeed, even when training to MF, traditional RPE is often less than maximal (Steele, Fisher, McKinnon, and McKinnon, 2017). This in combination with the
considerable inter- and intra-individual variations in number of repetitions possible prior to MF at the same relative loads suggests that RIR scales may offer an improvement in control of effort during RT compared with either use of %1RM or traditional RPE.

However, the use of these scales assumes that trainees are able to accurately predict the number of repetitions they could perform to MF with a particular load. Studies which have shown differences between groups training to MF compared with those not training to MF (where the participants were instructed to stop at the point they predicted MF on the next repetition), might be explained by the participants’ inability to accurately predict MF (i.e. they actually stopped >1 repetitions away from MF; Giessing, Eichmann, Steele, and Fisher, 2016; Giessing et al., 2016). A study by Hackett et al (2012) supports this, and revealed that trained participants were not perfectly accurate at predicting the number of repetitions they could perform to MF using a RIR scale, although their accuracy improved with subsequent sets. This would question the value of using ‘intuitive’ approaches to RT such as the RIR scales. Ability to predict proximity to MF may improve with training experience and thus it has been noted that the use of RIR scales may present greater value in experienced trainees (Helms et al., 2016). However, a follow-up study from Hackett et al. (2016) study suggested that previous RT experience did not affect ability to predict proximity to MF.

In light of the potential value of training to MF, as well as the introduction of recent RIR scales to control RT effort, it is of interest to examine trainees with differing levels of RT experience in their ability to predict the number of repetitions they can perform to MF. Further, examination of this in controlled yet ecologically valid conditions such as their usual gym environment offers considerable practical information. As such the aim of this study was to compare predicted with actual repetitions to MF in participants with a range of RT experience.
2. **Methods**

2.1. **Experimental approach to the Problem**

Participants in this study underwent a single RT trial in order to examine whether they were able to accurately predict the number of repetitions they could perform when training to MF. All participants, grouped according to their RT experience, were asked to provide a prediction of repetitions to MF and then undergo a test of actual repetitions to MF for comparison.

2.2. **Participants**

One hundred and forty-one participants (males \( n = 72 \), age 29±10 years; females \( n = 69 \), age 25±8 years) were recruited from the existing membership pool of a private exercise facility in Germany. Participants were required to have no medical condition for which RT would be contraindicated, and were grouped based upon duration of previous RT experience; <1.5 months (orientation, \( n = 15 \)), 1.5 to 6 months (beginner, \( n = 21 \)), 6 to 12 months (experienced, \( n = 21 \)), 12 to 36 months (advanced, \( n = 42 \)), and >36 months (expert, \( n = 42 \)). Written informed consent was provided by all participants and the study was ethically approved by the author’s institution.

2.3. **Procedures**

Participants underwent a single RT session involving the following exercises: seated row, chest press, leg press, elbow flexion, and pulldown, all using selectorised resistance machines, and sit-ups using additional free weight loading. All participants were required to have been performing these exercises in their pre-existing training programs and to have the current
training load they were using recorded in their training logs. Participants performed a single set of each exercise to concentric MF according to recent definitions of this concept i.e. the set ending when the trainee reached the point where, despite attempting to do so, they could not complete the concentric portion of their current repetition without deviation from the prescribed form of the exercise (Steele, Fisher, Giessing, and Gentil, 2017). Participants were informed to use the repetition duration they normally used during training for each exercise, to retain familiarity. Exercises were performed in the order that the participants typically performed them in their current training based upon their recorded training logs and participants were permitted to rest between each exercise for as long they typically would or felt necessary to ensure maximal performance on the subsequent exercise. This was also to ensure that participant’s predictions were based upon the RT conditions that they had previously experienced. All exercises were supervised by one of the investigators who observed the participants whilst they performed the exercise without verbal encouragement so as to ensure consistency across participants. The investigator counted repetitions in their head and then noted these without the participant’s knowledge. Prior to beginning each exercise participants were asked to consider the current load they were training with and to provide a prediction of the number of repetitions they could complete before reaching MF. Participants were informed that this was defined as the number of repetitions performed with the current load whilst continuing to the point where, despite the greatest effort and attempting to do so, they could not complete the current repetition (i.e. what repetition number they thought they would reach MF on). Participants were also asked to report their current training goals.

2.4. **Statistical Analysis**
Agreement between predicted and actual repetitions to MF was examined using standard error of measurement (SEM) and 95% confidence intervals (CI) in order to provide an absolute indication of the agreement between the variables. This was performed for each exercise. Calculations were performed using Microsoft Office Excel 2013 (Microsoft Corporation, Redmond, WA, USA) and spreadsheets for analysis of validity by Hopkins (2015) were used. Actual repetitions were considered the ‘criterion’ and predicted repetitions where considered the ‘practical’.

3. Results

Descriptive statistics suggested that on average participants under predicted the number of repetitions they could perform to MF (table 1). For the combined sample SEMs (95%CIs) were 2.91 (2.61 to 3.30) for the chest press, 2.64 (2.36 to 2.99) for the elbow flexion, 3.38 (3.02 to 3.83) for the leg press, 2.95 (2.64 to 3.35) for the pulldown, 2.71 (2.43 to 3.08) for the seated row, and 3.36 (3.00 to 3.80) for the sit-up. SEMs and 95%CIs are reported in table 2 for each exercise and group. There was a tendency towards improved accuracy in predicting actual repetitions to MF with greater experience across most exercises evidenced by reduced SEMs and narrower ranges between upper and lower 95%CIs. The training goal of muscular hypertrophy was reported with the highest frequency in the combined participant sample and all groups. Table 3 shows the training goals for each group by frequency.

4. Discussion

The current study examined the ability of participants to predict the number of repetitions they could perform to MF, with a given load, across a number of exercises and range of levels of
experience. It was anticipated that participants would not be perfectly accurate in predicting actual repetitions to MF, in spite of performing exercises and using loads with which they were familiar. It was also hypothesised that there would be increased accuracy with greater RT experience. Descriptive data suggested participants on average under predicted the number of repetitions they could perform to MF, though the average difference was reduced with greater experience. The SEMs indicated that participants indeed were not perfectly accurate at predicting repetitions to MF with SEMs for the combined sample ranging from 2.64 to 3.38 repetitions. In contrast with the descriptive data, SEMs suggested this was the case even for groups with greater experience, although there did still appear to be an improvement in accuracy with greater experience across most exercises. Considering the predominant training goal reported by the participants in this study (muscular hypertrophy), a less than perfectly accurate ability to predict repetitions to MF may have implications for achieving this goal.

Training to MF involves giving a maximal effort and is also anecdotally associated with higher discomfort. The less than perfectly accurate predictive ability reported herein may be a result of participants anchoring their prediction based upon discomfort. As we have recently noted in several papers (Steele, 2014; Steele, Fisher, McKinnon, and McKinnon, 2017; Steele, Fisher, Giessing, and Gentil, 2017), and as have others, differentiation between perceptions of effort and discomfort are important (Abbiss, Peiffer, Meeusen, and Skorski, 2015; Marcora, 2009; Smirnau, 2012) particularly within RT (Steele, 2014; Steele, Fisher, McKinnon, and McKinnon, 2017). In studies using traditional rating of perceived exertion scales higher ratings are given, despite conditions being controlled by supposedly training to MF, with lower loads for lower body exercise (Shimano et al., 2006), as set volume increases (Silva et al., 2014), with increased volume-load (Pritchett, Green, Wickwire, Pritchett and Kovacs et al., 2009), and with
increased work rate (Hiscock, Dawson, Donnelly, and Peeling, 2016; Hiscock, Dawson and Peeling, 2015) supporting that participants may have expressed their feelings of increasing discomfort (Steele, 2014; Steele, Fisher, McKinnon, and McKinnon, 2017; Steele, Fisher, Giessing, and Gentil, 2017).

In some studies there have been attempts to differentiate between effort and discomfort during RT. Though participants appear able to report different values for each, there is a similar pattern for both responses. Hollander et al (2003, 2008) found that, though effort is typically reported as being higher than discomfort (the authors used the term pain) under a range of RT conditions (different loads and muscle actions), both respond in a similar pattern. Such a relationship may be inherent; however, perception of effort is independent from afferent feedback mechanisms (Marcora, 2009). This would seem to disagree with observations of higher perceived efforts under conditions known anecdotally to induce higher feelings of discomfort (e.g. fatiguing low load lower body exercise). It is possible that participants were either consciously or unconsciously anchoring their effort and discomfort responses upon one another.

When instructed to differentiate the two, participants are able to do so during RT (Steele Fisher, McKinnon, and McKinnon, 2017; Fisher, Ironside, and Steele, 2016; Fisher, Farrow, and Steele, 2017). But there appears to be a tendency to anchor one upon the other without such instruction.

Anchoring of perception of effort upon discomfort thus may have implications for whether a person is truly training to, or close to enough to, MF. Another point to consider is that participants in this study likely based their prediction upon prior experience of training whilst unsupervised as most persons train in this manner. Thus, the not perfectly accurate predictive ability of participants in this study might reflect that under unsupervised conditions participants are not reaching MF during training despite thinking that they may be, possibly due to the
discomfort associated with such training. As such, persons training alone may find difficulty in
training to MF unless highly self-motivated. Numerous studies report that strength and body
composition changes are poorer when participants train unsupervised versus training under
supervision (Coutts, Murphy, and Dascombe, 2004; Gentil and Bottaro, 2010; Mazzetti et al.,
2000). When participants self-select RT load they often choose to train with lower loads than
those recommended (Elsangedy, Krause, Krinski, Alves, Hsin Nery Chao, and da Silva, 2013;
Glass and Stanton, 2004) and, considering the typical ranges of repetitions performed to MF by
trainees at these loads (Shimano et al., 2006), are likely not training anywhere close to MF.
Indeed, the RPE reported when participant’s self-select load and repetition range, in addition to
trainer observation, support this (Glass and Stanton, 2004). Instead, under supervision
participants are more likely to train with heavier loads but also to report higher RPE (Ratamess,
Faigenbaum, Hoffman, and Kang, 2008). In fact it has been suggested that the poorer adaptations
as a result of unsupervised training may be due to participants not training with sufficient
proximity to MF and thus with lower effort (Gentil and Bottaro, 2010).

Evidently there may be implications for whether a person is able to achieve their training
goals if they are unable to accurately perceive whether they are training to true MF or not.
However, as noted there is disagreement within the literature as to whether performing RT to MF
is indeed desirable and further that the consideration of MF in a dichotomous fashion (i.e. people
training ‘to MF’ or ‘not to MF’) renders difficulty in understanding the nature of sub-maximal
efforts during RT (Steele, Fisher, Giessing and Gentil, 2017). As a result, RIR scales have been
developed to be used in controlling sub maximal effort in RT as an improvement upon the
typical %1RM and traditional RPE based approaches (Hackett et al., 2012, 2016; Zourdos et al.,
2016). The results reported here are in agreement with other research (Hackett et al., 2012, 2016)
that participants are likely not perfectly accurate at predicting the number of repetitions they can
perform to MF and thus suggest there may be reason to question the value of RIR scales. The use
of RIR scales assumes a trainee is able to accurately predict the number of repetitions they could
perform to MF. However, if a trainee is not perfectly accurate at making such a prediction then it
is likely that they will be systematically training with a lower than desired effort level which may
impact upon their adaptation to RT.

For untrained persons this may not be of considerable practical concern. In this case, even
when using a lower than intended effort during RT on an individual set, cumulative fatigue can
be induced by increased volume resulting in an increased effort, and thus closer proximity to
MF, in later sets (Fisher, Blossom and Steele, 2016; Giessing, Fisher, Steele, Rothe et al., 2016).

However, experience may a play role in a trainee’s ability to predict proximity to MF and
indeed the results reported here support this notion. There was a relationship between the level of
experience of participants and the SEMs and width of 95%CIs found, with the most experienced
group under predicting by ~1-2 repetitions compared with the least experienced under predicting
by ~4-5 repetitions. Hackett et al (2012) found experienced trainees (8±3 years RT experience)
were initially not perfectly accurate at predicting repetitions to MF using the RIR scale over the
first 1-2 sets (mean difference ranging 0.8 to 1.9 repetitions). However, on average accuracy
improved in later sets. This suggests that, similar to our findings, even experienced trainees are
still not perfectly accurate at predicting repetitions to MF, yet acute practice/experience appears
to improve predictive ability. Further supporting the effect of experience, Zourdos et al (2016)
found that their RIR scale reflected more experienced lifters giving a more accurate estimation of
their effort, particularly when using heavier loads, based upon average repetition velocities. Thus
the novice trainees in their study likely overestimated their effort and therefore were likely under predicting how many repetitions away from MF they were.

Though increased experience would appear to increase predictive ability experienced trainees still under estimate by ~1-2 repetitions. Thus using sub-maximal effort based RT prescriptions based upon RIR scales will result in most training at a lower than intended effort. For trained persons this may have a bigger impact upon adaptations. When attempting to stop a set of repetitions at a set end-point corresponding to a ‘self determined repetition maximum’ (where the participants were instructed to stop at the point they predicted MF on the next repetition) strength and hypertrophic outcomes may be sub-optimal (Giessing, Eichmann, Steele, and Fisher, 2016). Thus, the use of ‘intuitive’ approaches that involve a person’s ability to accurately predict the number of repetitions they could perform to MF may be questionable as an approach to prescribing and controlling effort in RT. However, the use of self determined repetition maximum based training compared with training to MF in experienced participants has only been examined with use of single set approaches (Giessing, Fisher, Steele, Rothe et al., 2016). As accuracy of predictive ability improves with multiple sets of an exercise (Hackett et al., 2012) then RIR scales may have more utility in multiple set RT programs. Indeed, similarly to in untrained populations (Fisher, Blossom and Steele, 2016; Giessing, Fisher, Steele, Rothe et al., 2016), even if training with a systematically lower than intended effort, the use of multiple sets, and thus the accumulation of fatigue, combined with improved predictive ability, makes it likely that in later sets trainees would be closer to achieving desired intensities of effort. As such, though even ‘expert’ participants in this study under predicted by ~1-2 repetitions, it is likely that this represents an acceptable degree of error if RIR scale based approaches to training are being utilised in multiple set routines. However, it seems as though even this degree of error has
implications when using single set routines and as such predictive ability appears unacceptable for this approach.

It is worth considering the strengths and limitations of the present study. Firstly the present study was able to recruit a large sample size sufficient for examining validity/agreement between different measures (Hopkins, 2000). Due to this we were also able to sub group into a range of different experience levels. However, in order to achieve this large sample, participants were recruited from a private facility and testing conducted at this facility. This meant participants performed the testing using their current training equipment and load and, based upon the average repetitions, relative loads typically increased with experience. As such, the effects of experience level on the SEMs reported may be confounded as a result of differing ability to predict repetitions to MF when training using heavier or lighter loads. Greater predictive ability may therefore occur with heavier loads (Zourdos et al., 2016; Helms, Brown, Cross, Storey, Cronin and Zourdos, 2017). This may be reflective of the conflation between effort and discomfort described above as greater perceived discomfort occurs with lower load RT (Fisher, Ironside et al., 2016; Fisher, Farrow, and Steele, 2017). Future research should examine the impact that manipulation of other RT variables such as load, and its interaction with perceived discomfort, has upon ability to accurately predict repetitions to MF. A final limitation could be that we asked participants to predict the number of repetitions they could perform to MF prior to the execution of the exercise. Prior studies have asked participants during the execution of the set (Hackett et al., 2012; 2016) and thus participants may be able to make better predictions during the gestalt experience of actually performing the exercise. However, it should be noted that in studies where participants have attempted to stop one repetition prior to MF sub optimal adaptations have still been reported (Giessing, Eichmann, Steele, and Fisher, 2016;
Giessing, Fisher, Steele, Rothe, Raubold, and Eichmann, 2016). Also, we did not control when the participant’s penultimate training session prior to the testing sessions were, nor did we control and match other factors such as time of day, diet, sleep, etc. As such, there is still scope for further work to identify what factors may positively or negatively impact upon a person’s predictive ability in performing repetitions to MF.

5. Conclusion

Management of effort within RT by manipulation of whether a trainee reaches MF or not is a common approach by trainees and practitioners. Effort, and thus proximity to MF, may have implications for the optimisation of adaptations, in particular hypertrophy which for most commercial gym attendees is the most common training goal. Recently, RIR scales have been promoted as a means of controlling this and represent an improvement on %1RM and traditional RPE scales. However, they assume the trainee can make accurate predictions regarding their ability to perform repetitions to MF. The findings of the present study reveal that ability to predict repetitions to MF is not perfectly accurate amongst most trainees. However, there may be some increase in predictive ability with greater RT experience.

These results have implications regarding training adaptations from RT as most persons train unsupervised and thus are likely not training to actual MF in their current training programs. Further, for those not employing MF in their training but instead using sub-maximal efforts based upon proximity to MF, it is likely that they are systematically training with a lower than intended effort. These results suggest that RIR scales should be used with caution in most trainees. It appears that experience may improve a trainee’s ability to predict repetitions to MF and therefore RIR scales may be more appropriate for experienced trainees. Lastly, these results
apply to single set applications of RT. Prior research suggests with multiple sets predictive
ability increases. As such, RIR scales may have the greatest utility in experienced trainees using
multiple set RT programs.
References

1. Abbiss, C. R., Peiffer, J. J., Meeusen, R., & Skorski, S. (2015). Role of ratings of perceived exertion during self-paced exercise: What are we actually measuring? *Sports Medicine, 45*, 1235–1243. doi: 10.1007/s40279-015-0344-5

2. Barcelos, L. C., Nunes, P. R., de Souza, L. R., de Oliviera, A. A., Furlanetto, R., Marocolo, M., & Orsatti, F. L. (2015). Low-load resistance training promotes muscular adaptation regardless of vascular occlusion, load, or volume. *European Journal of Applied Physiology, 115*, 1559-1568. doi: 10.1007/s00421-015-3141-9

3. Coutts, A. J., Murphy, A. J., & Dascombe, B. J. (2004). Effect of direct supervision of a strength coach on measures of muscular strength and power in young rugby league players. *Journal of Strength and Conditioning Research, 18*, 316-323.

4. Dankel, S. J., Jessee, M. B., Mattocks, K. T., Mouser, J. G., Counts, B. R., Buckner, S. L., & Loenneke, J. P. (2016). Training to fatigue: The answer for standardization when assessing muscle hypertrophy? *Sports Medicine*, Epub ahead of print.

5. Elsangedy, H. M., Krause, M. P., Krinski, K., Alves, R. C., Hsin Nery Chao, C., & da Silva, S. G. (2013). Is the self-selected resistance exercise intensity by older women consistent with the American College of Sports Medicine guidelines to improve muscular fitness? *Journal of Strength and Conditioning Research, 27*, 1877-84. doi: 10.1519/JSC.0b013e3182736cfa

6. Farup, J., de Paoli, F., Bjerg, K., Riis, S., Ringgard, S., & Vissing, K. (2015). Blood flow restricted and traditional resistance training performed to fatigue produce equal muscle
hypertrophy. *Scandinavian Journal of Medicine and Science in Sports*, 25, 754–63. doi: 10.1111/sms.12396

7. Fisher, J. P., Blossom, D., & Steele, J. (2016). A comparison of volume equated knee extensions to failure, or not to failure, upon rating of perceived exertion and strength adaptations. *Applied, Physiology, Nutrition, and Metabolism*, 41, 168-174. doi: 10.1139/apnm-2015-0421

8. Fisher, J. P., Carlson, L., & Steele, J. (2015). The effects of breakdown set resistance training on muscular performance and body composition in young males and females. *Journal of Strength and Conditioning Research*, 30, 1425-1432. doi: 10.1519/JSC.0000000000001222

9. Fisher, J. P., Carlson, L., Steele, J., & Smith, D. (2014). The effects of pre-exhaustion, exercise order, and rest intervals in a full-body resistance training intervention. *Applied, Physiology, Nutrition, and Metabolism*, 39, 1-6. doi: 10.1139/apnm-2014-0162

10. Fisher, J., Farrow, J., & Steele, J. (2017). Acute fatigue, and perceptual responses to resistance exercise. *Muscle and Nerve*, Epub ahead of print. doi: 10.1002/mus.25645

11. Fisher, J., Ironside, M., & Steele, J. (2016). Heavier- and lighter- load resistance training to momentary failure produce similar increases in strength with differing degrees of discomfort. *Muscle and Nerve*, Epub ahead of print. doi: 10.1002/mus.25537

12. Fisher, J., Steele, J., & Smith, D. (2013). Evidence-based resistance training recommendations for muscular hypertrophy. *Medicina Sportiva*, 17, 217–235. doi: 10.5604/17342260.1081302
13. Fisher, J., Steele, J., Smith, J., & Bruce-Low, S. (2011). Evidence based resistance training recommendations. *Medicina Sportiva, 15,* 147-162. doi: 10.2478/v10036-011-0025-x

14. Gentil, P., & Bottaro, M. (2010). Influence of supervision ratio on muscle adaptations to resistance training in nontrained subjects. *Journal of Strength and Conditioning Research, 24,* 639-643. doi: 10.1519/JSC.0b013e3181ad3373

15. Giessing, J., Eichmann, B., Steele, J., & Fisher, J. (2016). A comparison of low volume ‘high-intensity-training’ and high volume traditional resistance training methods on muscular performance, body composition, and subjective assessments of training. *Biology of Sport, 33,* 241-249. doi: 10.5604/20831862.1201813

16. Giessing, J., Fisher, J., Steele, J., Rothe, F., Raubold, K., & Eichmann, B. (2016). The effects of low volume resistance training with and without advanced techniques in trained participants. *Journal of Sports Medicine and Physical Fitness, 56,* 249-258.

17. Glass, S. C., & Stanton, D. R. (2004). Self-selected resistance training intensity in novice weightlifters. *Journal of Strength and Conditioning Research, 18,* 324-327.

18. Hackett, D. A., Cobley, S., Favies, T., Michael, S., & Halaki, M. (2016). Accuracy in estimating repetitions to failure during resistance exercise. *Journal of Strength and Conditioning Research,* Epub ahead of print

19. Hackett, D. A., Johnson, N. A., Halaki, M., & Chow, C. (2012). A novel scale to assess resistance-exercise effort. *Journal of Sports Sciences, 30,* 1405-1413. doi: 10.1080/02640414.2012.710757
20. Helms, E. R., Cronin, J., Storey, A., & Zourdos, M. (2016). Application of the repetitions in reserve-based rating of perceived exertion scale for resistance training. *Strength and Conditioning Journal, 38*, 42-49.

21. Helms, E. R., Brown, S. R., Cross, M. R., Storey, A., Cronin, J., & Zourdos, M. (2017). Self-rated accuracy of rating of perceived exertion-based load prescription in powerlifters. *Journal of Strength and Conditioning Research*, Epub ahead of print. doi: 10.1519/JSC.0000000000002097

22. Hiscock, D. J., Dawson, B., & Peeling, P. (2015). Perceived exertion responses to changing resistance training programming variables. *Journal of Strength and Conditioning Research, 29*, 1564-1569. doi: 10.1519/JSC.0000000000000775

23. Hiscock, D. J., Dawson, B., Donnelly, C. J., & Peeling, P. (2016). Muscle activation, blood lactate, and perceived exertion responses to changing resistance training programming variables. *European Journal of Sport Science, 16*, 536-544. doi: 10.1080/17461391.2015.1071880

24. Hollander, D. B., Duran, R. J., Trynicki, J. L., Larock, D., Castracane, V. D., Hebert, E. P., & Kraemer, R. R. (2003). RPE, pain, and physiological adjustment to concentric and eccentric contractions. *Medicine and Science in Sports and Exercise, 35*, 1017-1025.

25. Hollander, D. B., Kilpatrick, M. W., Ramadan, Z. G., Reeves, G. V., Francois, M., Blakeney, A., Castracane, V. D., & Kraemer, R. R. (2008). Load rather than contraction type influences rate of perceived exertion and pain. *Journal of Strength and Conditioning Research, 22*, 1184-1193. doi: 10.1519/JSC.0b013e31816a8bc2

26. Hopkins, W. G. (2000). Measures of Reliability in Sports Medicine and Science. *Sports Medicine, 30*, 1-15.
27. Hopkins, W. G. (2015). Spreadsheets for analysis of validity and reliability. *Sportscience, 19*, 36-42. Retrieved from [http://sportsci.org/2015/ValidRely.htm](http://sportsci.org/2015/ValidRely.htm). Accessed 12th May 2016.

28. Izquierdo-Gabarren, M., Gonzalez De Txbarri Exposito, R., Garcia-pallares, J., Sanchez-Medina, J., De Villarreal, E. S., & Izquierdo, M. (2010). Concurrent endurance and strength training not to failure optimises performance gains. *Medicine and Science in Sports and Exercise, 42*, 1191 – 1199. doi: 10.1249/MSS.0b013e3181c67e6c

29. Marcora, S. (2009). Perception of effort during exercise is independent of afferent feedback from skeletal muscles, heart, and lungs. *Journal of Applied Physiology, 106*, 2060–2062. doi: 10.1152/japplphysiol.90378.2008

30. Mazzetti, S. A., Kraemer, W. J., Volek, J. S., Dunca, N. D., Ratamess, N. A., Gomez, A. L., … Fleck, S. J. (2000). The influence of direct supervision of resistance training on strength performance. *Medicine and Science in Sports and Exercise, 32*, 1175-1184.

31. Morton, R. W., Oikawa, S. Y., Wavell, C. G., Mazara, N., McGlory, C., Quadrilatero, J., … Phillips, S. M. (2016). Neither load nor systemic hormones determine resistance training-mediated hypertrophy or strength gains in resistance-trained young men. *Journal of Applied Physiology, 121*, 129-138. doi: 10.1152/japplphysiol.00154.2016

32. Pritchett, R. C., Green, J. M., Wickwire, P. J., Pritchett, K. L., & Kovacs, M. S. (2009). Acute and session RPE responses during resistance training: Bouts to failure at 60% and 90% of 1RM. *South African Journal of Sports Medicine, 21*, 23–26

33. Ratamess, N. A., Faigenabum, A. D., Hoffman, J. R., & Kang, J. (2008). Self-selected resistance training intensity in healthy women: The influence of a personal trainer.
34. Sampson, J. A., & Groeller, H. (2016). Is repetition failure critical for the development of muscle hypertrophy and strength? *Scandinavian Journal of Medicine and Science in Sports, 26*, 375-383. doi: 10.1111/sms.12445

35. Schoenfeld, B. J., Ogborn, D. I., & Krieger, J. W. (2015). Effect of repetition duration during resistance training on muscle hypertrophy: a systematic review and meta-analysis. *Sports Medicine, 45*, 577-585. doi: 10.1007/s40279-015-0304-0

36. Schoenfeld, B. J., Peterson, M. D., Ogborn, D., Contreras, B., & Sonmez, G. T. (2015). Effects of low- versus high-load resistance training on muscle strength and hypertrophy in well-trained men. *Journal of Strength and Conditioning Research, 29*, 2954-2963. doi: 10.1519/JSC.0000000000000958

37. Schoenfeld, B. J., Wilson, J. M., Lowery, R. P., & Krieger, J. W. (2016). Muscular adaptations in low-versus high-load resistance training: A meta-analysis. *European Journal of Sport Science, 16*, 1-10. doi:10.1080/17461391.2014.989922.

38. Shimano, T., Kraemer, W. J., Spiering, B. A., Volek, J. S., Hatfield, D. L., Silvestre, R., … Häkkinen, K. (2006). Relationship between the number of repetitions and selected percentages of one repetition maximum in free weight exercises in trained and untrained men. *Journal of Strength and Conditioning Research, 20* 819–823

39. Silva, V. L., Azevedo, A. P., Cordeiro, J. P., Duncan, M. J., Cholewa, J. M., Siqueira-Filho, M. A., … Guimaraes-Ferreira, L. (2014). Effects of exercise intensity on perceived exertion during multiple sets of bench press to volitional failure. *Journal of Trainology, 3*, 41–46. doi:org/10.17338/trainology.3.2_41
40. Smiraul, B. D. P. C. (2012). Sense of effort and other unpleasant sensations during exercise: clarifying concepts and mechanisms. *British Journal of Sports Medicine, 46*, 308-311. doi: 10.1136/bsjsm.2010.071407

41. Steele, J. (2014). Intensity; in-ten-si-ty; noun. 1. Often used ambiguously within resistance training. 2. Is it time to drop the term altogether? *British Journal of Sports Medicine, 48*, 586-1588. doi: 10.1136/bjsports-2012-092127

42. Steele, J., Fisher, J., Giessing, J., & Gentil, P. (2017). Clarity in reporting terminology and definitions of set end points in resistance training. *Muscle and Nerve*, Epub ahead of print. doi: 10.1002/mus.25557

43. Steele, J., Fisher, J., McGuff, D., Bruce-Low, S., & Smith, D. (2012). Resistance training to momentary muscular failure improves cardiovascular fitness in humans: a review of acute physiological responses and chronic physiological adaptations. *Journal of Exercise Physiology, 15*, 53-80

44. Steele, J., Fisher, J., McKinnon, S., & McKinnon, P. (2017). Differentiation between perceived effort and discomfort during resistance training in older adults: reliability of trainee ratings of effort and discomfort, and reliability and validity of trainer ratings of trainee effort. *Journal of Trainology, 6*, 1-8.

45. Steele, J., Fisher, J., Skivington, M., Dunn, C., Arnold, J., Tew, G., … Winett, R. (2017). A higher effort-based paradigm in physical activity and exercise for public health: making the case for a greater emphasis on resistance training. *BMC Public Health, 17*, 300

46. Zourdos, M. C., Klemp, A., Dolan, C., Quiles, J. M., Schau, K. A., Jo, E., Helms, E., Esgro, B., Duncan, S., & Garcia-Merino Blanco, R. (2016). Novel resistance training-
specific rating of perceived exertion scale measuring repetitions in reserve. *Journal of Strength and Conditioning Research, 30*, 267-275. doi: 10.1519/JSC.0000000000001049
Table 1 (on next page)

Descriptive data (mean±SD) for each exercise and group
## Table 1. Descriptive data (mean±SD) for each exercise and group

| Exercise         | Combined   | Orientation | Beginner | Experienced | Advanced | Expert |
|------------------|------------|-------------|----------|-------------|----------|--------|
| Chest Press      | 12.38±3.45 | 15.40±2.77  | 14.86±3.00 | 14.00±3.46  | 11.14±2.55 | 10.48±2.86 |
|                  | Actual     | 14.21±5.52  | 20.47±6.36 | 18.76±6.78  | 15.86±4.16 | 12.17±3.39 |
| Elbow Flexion    | Predicted  | 11.53±2.99  | 15.40±2.77 | 13.38±2.85  | 12.67±3.07 | 10.60±2.06 |
|                  | Actual     | 12.48±4.32  | 18.20±4.95 | 16.57±4.65  | 13.14±2.67 | 10.74±2.36 |
| Leg Press        | Predicted  | 12.50±3.41  | 15.40±2.77 | 14.95±3.14  | 13.67±3.65 | 11.45±2.62 |
|                  | Actual     | 16.40±6.29  | 23.87±7.04 | 22.19±5.75  | 17.62±4.50 | 14.52±4.13 |
| Pulldown         | Predicted  | 12.48±3.47  | 15.40±2.777| 15.27±3.13  | 13.29±3.36 | 11.55±2.93 |
|                  | Actual     | 13.81±5.19  | 20.27±6.92 | 17.86±5.76  | 14.57±4.04 | 11.95±2.81 |
| Seated Row       | Predicted  | 12.38±3.45  | 15.40±2.77 | 14.86±3.00  | 14.00±3.46 | 11.14±2.55 |
|                  | Actual     | 14.09±5.29  | 19.67±5.38 | 18.33±5.80  | 15.81±4.24 | 12.26±3.60 |
| Sit-up           | Predicted  | 14.62±3.05  | 15.93±2.40 | 16.43±2.62  | 15.71±2.99 | 13.88±2.92 |
|                  | Actual     | 16.99±3.65  | 18.73±5.19 | 17.71±3.99  | 17.76±2.02 | 17.31±3.23 |
Table 2 (on next page)

SEMs and 95% CIs for each exercise and group.
Table 2. SEMs and 95% CIs for each exercise and group.

| Exercise      | Orientation | Beginner | Experienced | Advanced | Expert |
|---------------|-------------|----------|-------------|----------|--------|
| Chest Press   |             | 4.33 (3.14 to 6.97) | 4.00 (3.04 to 5.84) | 2.58 (1.96 to 3.76) | 1.91 (1.57 to 2.45) | 1.57 (1.29 to 2.00) |
| Elbow Flexion |             | 4.30 (3.12 to 6.93) | 6.39 (4.86 to 9.33) | 1.51 (1.15 to 2.20) | 1.95 (1.60 to 2.50) | 1.27 (1.04 to 1.62) |
| Leg Press     |             | 4.98 (3.61 to 8.03) | 3.37 (2.56 to 4.92) | 3.07 (2.34 to 4.49) | 2.49 (2.05 to 3.19) | 1.73 (1.42 to 2.21) |
| Pulldown      |             | 4.15 (3.01 to 6.68) | 3.89 (2.96 to 4.92) | 2.49 (1.89 to 3.64) | 1.83 (1.50 to 2.34) | 1.35 (1.11 to 1.73) |
| Seated Row    |             | 4.51 (3.27 to 7.27) | 3.50 (2.66 to 5.11) | 2.28 (1.73 to 3.33) | 2.06 (1.69 to 2.63) | 1.71 (1.40 to 2.19) |
| Sit-up        |             | 5.13 (3.72 to 8.26) | 4.08 (3.10 to 5.96) | 2.06 (1.57 to 3.01) | 2.87 (2.36 to 3.68) | 2.29 (1.88 to 2.94) |
Table 3 (on next page)

Participants training goals by frequency.
Table 3. Participants training goals by frequency.

|                         | Combined $(n = 141)$ | Orientation $(n = 15)$ | Beginner $(n = 21)$ | Experienced $(n = 21)$ | Advanced $(n = 42)$ | Expert $(n = 42)$ |
|-------------------------|----------------------|------------------------|---------------------|------------------------|---------------------|------------------|
| Fitness                 | 6 (4.3%)             | 1 (6.6%)               | 2 (9.5%)            | 2 (9.5%)               | 0                   | 1 (2.4%)         |
| Maintenance             | 3 (2.1%)             | 0                      | 1 (4.8%)            | 0                      | 1 (2.4%)            | 1 (2.4%)         |
| Muscular definition     | 8 (5.7%)             | 0                      | 1 (4.8%)            | 1 (4.8%)               | 2 (4.8%)            | 3 (7.1%)         |
| Muscular hypertrophy    | 107 (75.9%)          | 10 (66.6%)             | 14 (66.6%)          | 14 (66.6%)             | 36 (85.7%)          | 33 (78.6%)       |
| Strength                | 4 (2.8%)             | 0                      | 1 (4.8%)            | 0                      | 1 (2.4%)            | 2 (4.8%)         |
| Weight loss             | 13 (9.2%)            | 4 (26.6%)              | 2 (9.5%)            | 4 (19.0%)              | 1 (2.4%)            | 2 (4.8%)         |