Guidelines and Resources for Prescribing Load using Velocity Based Training

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Abstract

Different relative loads during resistance training movements are considered to result in varying physiological adaptions. The challenge facing coaches and athletes is how to determine what absolute load relates to the prescribed relative load and how to account for changes in strength. Velocity based training may offer a solution to this problem. Currently there are limited guidelines for coaches to follow and the proposed methods are associated with increased burden. Therefore, this article provides simple evidence based guidelines and an online application to support the use of velocity based training as a method of auto-regulation during resistance training.

1.0 Introduction

1.1 The "problem"

The use of resistance training to boost athletic performance is widespread within sporting and recreational populations. Regardless of the goals or experience of the participants, the configuration of training variables is a key consideration to maximising the effectiveness of exercise (8, 16). Specifically, the number of sets and repetitions, and the prescribed relative load have been shown to be key determinants of the adaptations resulting from resistance training (21, 26). The challenge facing strength and conditioning (S&C) practitioners is how to prescribe and regulate these training variables over training cycles where fluctuations in strength and fatigue mean prescribing a load to elicit certain adaptations is difficult.

Traditionally, loads have been prescribed based on pre-training one repetition maximum (1RM) testing and relative loads aimed at eliciting specific adaptations (e.g. maximal strength ≥ 85% 1RM) (22, 24). To account for changes in strength due to muscular adaptations, standardized increases in prescribed loads (e.g. week 1: 80% 1RM; week 2: 82% 1RM) are often programmed. Other approaches include auto-regulatory methods where load is manipulated using ratings of perceived exertion (RPE) or repetitions in reserve (RIR) (9, 14, 27). Such methods allow practitioners to progress or regress resistance programmes to maximise their effectiveness. Despite their widespread use, and identified effectiveness (13), the use of programmed systematic increases in load and subjective measures of athlete perception have associated limitations (4, 15, 25).

Prescription of load based on 1RMs is susceptible to errors due to the day-to-day variation in absolute strength that can be as high as 18% (15), and gains in strength that will cause the pre training assessments to no longer represent the true strength of an athlete (15). These limitations may result in sub-optimal load prescription, potentially compromising the intended training stimulus and subsequent physiological adaptations. Auto-regulation methods, such as using RPE to manipulate load, may address these issues but are associated with their own limitations. Altering load based on subjective athlete feedback may lead to between session and athlete inconsistencies due to training experience, daily motivation, and current perceived fatigue (11, 12). Additionally, the accuracy of an athlete's perceived and actual RIR has been shown to reduce the further from failure they are, limiting the efficacy of such approaches when lifting sub-maximal loads (11, 27). The limitations to the currently employed methods of achieving optimal load prescription mean that despite their widespread use, they may fail account for fluctuations in athlete strength and fatigue that occur on a set by set and session by session basis. One area that may provide a more effective approach is velocity based training (VBT).

1.2 Velocity Based Training

The use of lift velocity within S&C practices has grown since the ability to accurately measure such variables has become more accessible with tools ranging from linear positional transducers (6) to mobile applications (2). The velocity that the concentric section of a lift is performed has been shown to be related to its relative load (10, 19). This relationship between concentric lift velocity and relative load is referred to as a load-velocity profile (LVP;

Figure 1). LVPs have been shown to remain unchanged despite significant increases in absolute strength (1, 10), and have therefore been theorised as a potential auto-regulatory approach for prescribing training load. Early explorations into LVPs focussed on developing group equations that could be implemented into other samples of a similar training demographic (2, 19), these data provided practitioners with average profiles. Recent research has begun to highlight that LVPs are individual to each athlete and therefore that group profiles although being accurate for some athletes (1), may not be for others (Figure 1). The positives and negatives of using group and individual profiles are discussed later in the article however, both can be used as a method of auto-regulation (5, 7).

The theorised benefit of the use of an LVP to inform training prescription is based on the assumption that despite changes in absolute strength, due to training stimuli or fatigue, the profile will enable a practitioner to estimate the relative load being lifted by measuring the velocity of the lift (15). By estimating the percentage of 1RM a load represents, the athlete's acute 1RM (15) and subsequently the load relating to a certain percentage (7) can be calculated. This approach provides practitioners with a method by which set-by-set changes can be accounted for, ensuring athletes are lifting at a set percentage of their acute 1RM. In comparison to other auto regulation methods, VBT may therefore offer an objective approach that is able to adjust load to ensure that athletes are lifting the correct load that has been programmed to elicit specific physiological adaptations. One cautionary note on the use of LVPs to predict an athlete's 1RM, is that current evidence suggests it is associated with small errors (3, 18), and therefore the

proposed method is not fully supported as an approach for athlete testing. Instead the errors of using an LVP to predict an athlete's current strength may still allow a more accurate dictation of training load than other auto-regulatory methods.
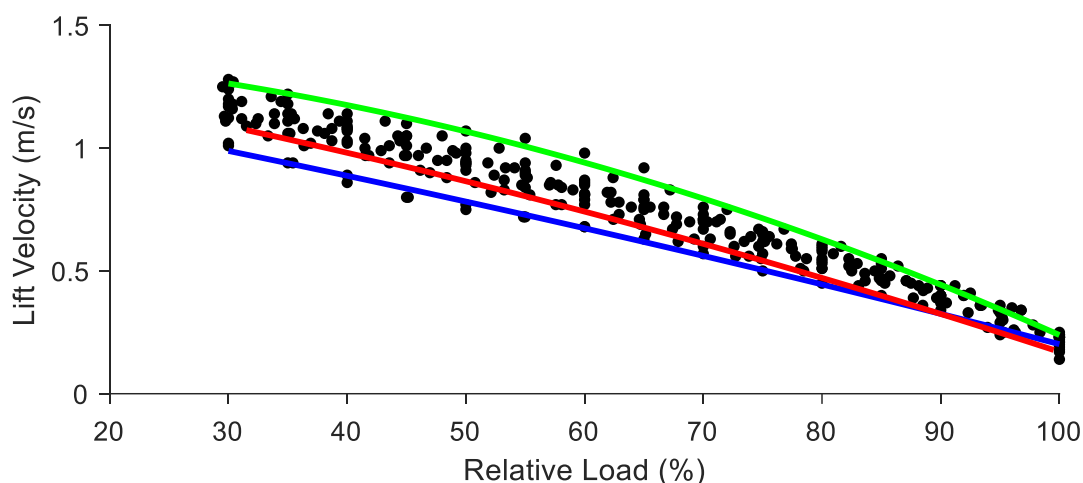
Figure 1. Velocity data from a group of resistance trained males (n=19) and the load-velocity profiles of three individuals within the sample highlighting the differences in profiles of different athletes. Data used with permission from Dorrell, Moore and Gee (5).

Few studies have explored the validity of a VBT approach to auto-regulation within training cycles however, those that have appear to support its benefits (4, 5, 7). Dorrell, Smith and Gee (7) compared traditional load prescription based on pre-training 1RMs to a VBT approach using group LVPs to dictate load on a set-by-set basis in 16 resistance-trained men (Table 1). Over a six-week strength and power programme, significant increases ($p < 0.05$) in maximal strength for back squat (VBT 9%, PBT 8%), bench press (VBT 8%, PBT 4%), strict overhead press (VBT 6%, percentage based training 6%), and deadlift (VBT 6%) were identified. In addition to the data supporting similar or favourable adaptations when using VBT, these improvements were achieved despite a significantly lower total volume lifted in the back squat (9%), bench press (6%), and strict overhead press (6%). Similar or greater adaptations despite less total volume supports using group LVPs to dictate load. The use of group profiles within this study supports that despite their associated errors they still provide a usable and effective tool for manipulating training load. Despite this, individual profiles may provide a more effective and accurate approach to auto-regulation than group profiles.

Dorrell, Moore and Gee (5) compared the adaptations to a six-week strength and power resistance program in 19 trained males (Table 1) when regulating load using either a group or individual LVP. Both interventions were shown to significantly ($p < 0.05$) increase squat 1RM with individual LVPs resulting in greater gains (individual: 9.7%; group: 7.2%). The data provides further support for the use of LVPs in resistance-training regulation, and supports that errors associated with group profiles make them less effective compared to an individual approach when applied in this manner. Individual profiles although appearing to be more effective are associated with increased testing and athlete burden, and therefore may not be viable in certain situations.

The discussed use of VBT for regulating and prescribing training load offers S&C practitioners a potential solution for how to maximise programmed resistance training activities whilst avoiding some of the limitations related to currently employed auto-regulation methods. However, VBT is associated with its own limitations, specifically in relation to its application to professional and applied settings. Firstly, the collection of individual LVPs requires athletes to work to their 1RM, something that is not viable within some populations; and secondly, once an LVP is obtained a number of computational steps are required each time it is used to calculate the required load. Therefore, the aim of this article is to provide guidelines for the use of VBT to dictate training load, and provide a free online application to enable this to be implemented into applied S&C practice.

2.0 Proposed Methods for using VBT to Dictate Load

There are two steps to implementing VBT as a method of dictating load, obtaining, and using the LVP. Both of these steps are described in detail below, including background information and practical guidelines. A flow diagram is presented in Figure 2 to provide a systematic guide to using VBT to dictate load, and highlight certain sections of the article that are useful depending on the intended use.

2.1 Athlete Profiling

2.1.1 Background

The foundation of using VBT to dictate load is the LVP (15, 19). Recent evidence has supported that each athlete has a unique LVP (4, 5) and that despite changes in absolute strength the profile acts as a passport of sorts that describes an athlete's ability to lift a percentage of their maximum at a set velocity. More research is required to explore whether periods of training and detraining (e.g. injury layoffs) result in changes in this profile and for how long this profile remains accurate. What evidence is currently available supports that periods (~6 weeks) of strength training, despite increases in absolute strength (mean±SD; 9.3±6.7%), do not result in changes in the LVP (10). As described, group velocity profiles from published literature or squad testing offer a general LVP that can be used as a mode of auto regulation when prescribing training variables, however to maximise the effectiveness and where the environment permits, individual athlete profiling should be conducted. It should be noted that each movement has its own LVP, and therefore requires separate profiling for each athlete or group (20).

The method by which the LVP of a given movement is obtained has yet to be explored within the literature, resulting in a variety of approaches being employed. Although attempts have been made to obtain an LVP through submaximal testing the associated errors relating to prediction of a 1RM and the velocity at which that maximal lift would be completed mean it is not a suitable approach (17). The generally accepted method creates the LVP retrospectively from a selection of maximal effort lifts at varying loads. Participants complete a given number of repetitions (inversely related to mean velocity or relative intensity) at a range of increasing loads, working to a 1RM. Once all data has been collected, relative load and the respective velocity output (generally mean concentric or mean propulsive) are plotted, before a line of best fit is fitted. Two considerations should be accounted for 1) the accuracy of an LVP increases as more relative loads are tested,

and 2) the measured velocities should be of unfatigued lifts and therefore sets should be separate by adequate rest and consist of only 1-3 repetitions.
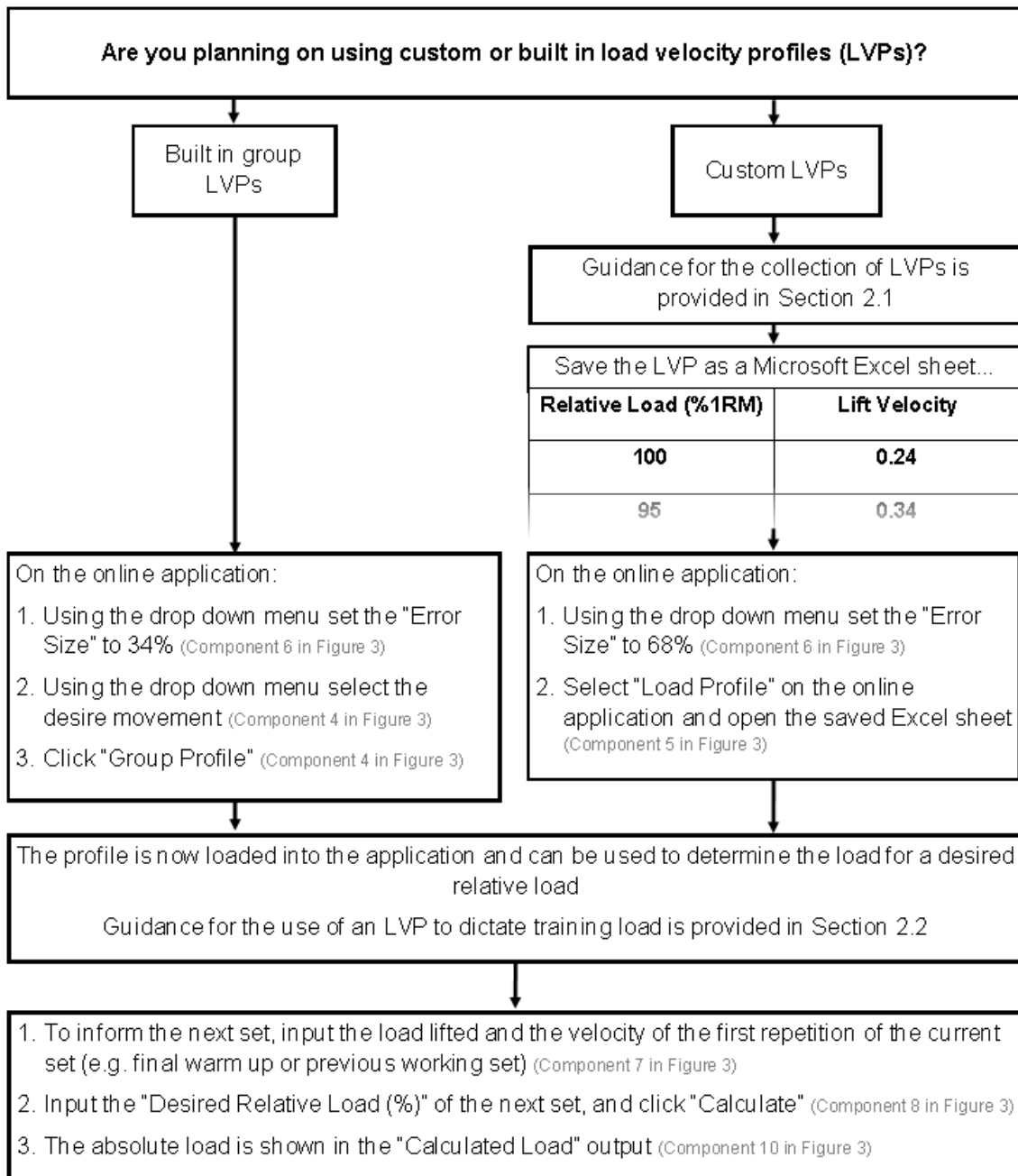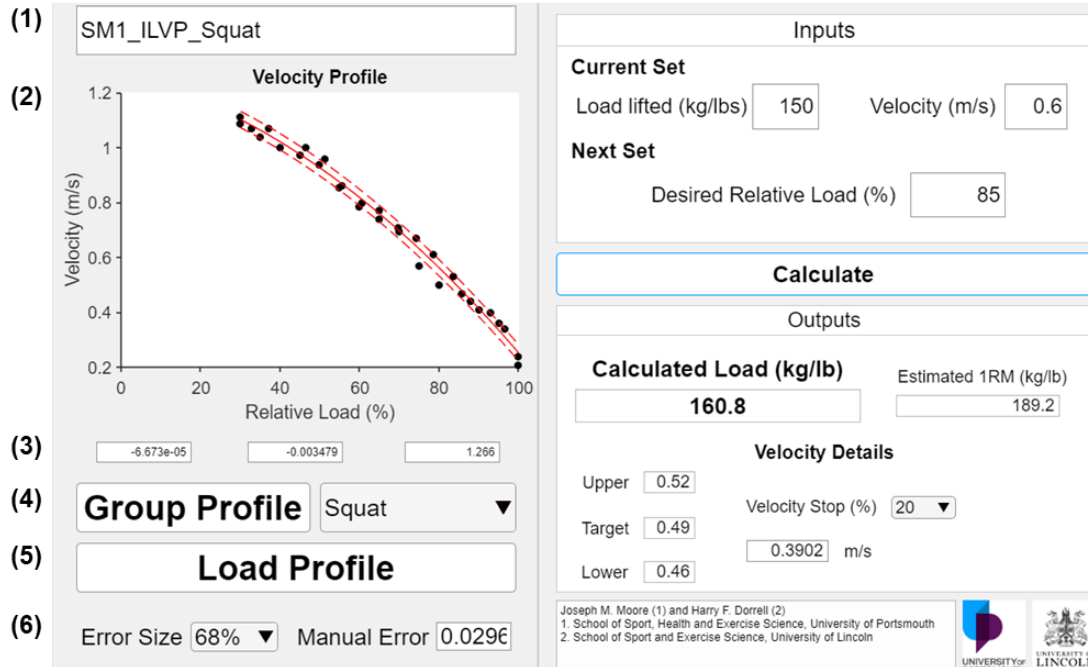

Figure 2. A flow diagram of the steps to using a load velocity profile, lift velocity, and the online application to dictate load during resistance training exercises.

A link to a free online application (MATLAB WebApps, The MathWorks Inc., Natick, MA, US) is included in this article (Figure 3). The application is capable of calculating an LVP from velocity data, and using this LVP to provide estimates of an athlete's 1RM. Group LVPs for resistance-trained males are included for squat, deadlift, and strict overhead press taken from the authors (HD) research (5, 7). This application is

compatible with laptop browsers and tablets, and can be accessed through the following URL (https://matlab-webapps.port.ac.uk/webapps/home/).

The application intends to increase the accessibility of the method of dictating load described in this article for practitioners and researchers. The application intends to increase the accessibility of the method of dictating load described in this article for practitioners and researchers. Due to limitations with the host server, the application has a maximum number of concurrent users and therefore a Microsoft Excel Document is provided (Supplemental Data File 1) that can be used with the included group LVPs. Please cite this article when using the application or spreadsheet for research purposes.

Figure 3. Components of a MATLAB WebApp to create and use load velocity profiles (LVP) to dictate training load. Available at https://matlab-webapps.port.ac.uk/webapps/home/

2.1.2 Guidelines

A number of approaches to establishing an LVP are available and each may offer certain advantages. The authors present one approach used by Dorrell, Moore and Gee (5). During all lifts, the load and mean concentric velocity should be measured for all repetitions. To obtain a more robust measure of velocity, the average of the repetitions completed at each load should be used to create the profile. The profiling procedure presented here (Figure 4) is an adaptation of the 1RM guidelines established by the National Strength and Conditioning Association (23).

- Initial load should be set to approximately 30% estimated 1RM, or as close as equipment allows - *starting at such a low load creates a more complete LVP even if the profile is not intended to be used at such low loads.*
- Lifts should be completed at incremental loads of 5% estimated 1RM following completion of successful repetitions – *having velocity data at this many relative*

loads allows the LVP to be modelled more accurately.
- For light loads (≤50% estimated 1RM) participants should complete three repetitions, decreasing to two repetitions for medium loads (55-80% estimated 1RM), and a single repetition for high loads (≥85% estimated 1RM) – *by only completing a low number of repetitions for each load the risk of fatiguing the athlete is reduced.*
- Once an athlete has completed a repetition at approximately 95% of their estimated 1RM the load increments should be adjusted to ensure the athlete's true 1RM is reached and recorded.
- Finally, relative load (%1RM) of each lift should be calculated and plotted against velocity before a linear line of best fit or a second order polynomial is fit to the data – *this is achievable in a variety of software (e.g. Microsoft Excel) however, the provided online application can perform these tasks.*
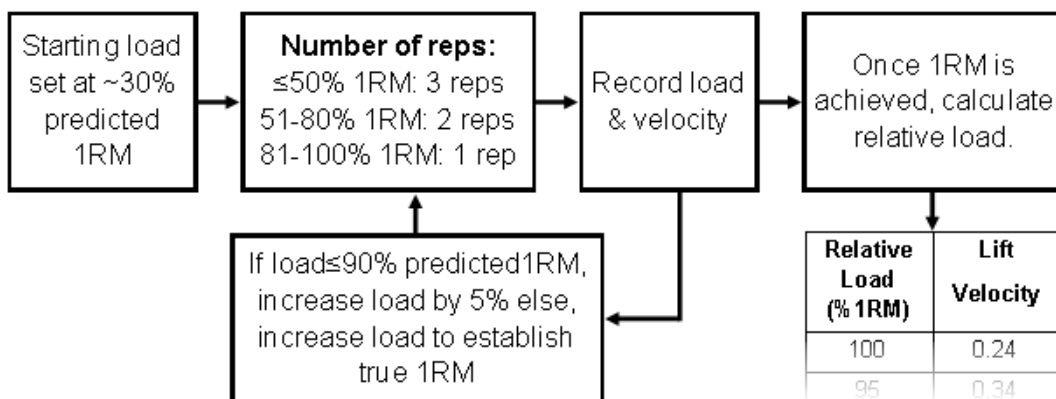

Figure 4. Flow diagram of a method of profiling an athlete to establish a load-velocity profile

The online application is capable of creating an LVP from included group velocity data or by importing a Microsoft Excel document. Preprogramed group data is available by selecting the desired movement from the drop down menu and clicking the "Group Profile" button (Component 4 in Figure 3). The athlete details of the group data is provided in Table 1. To load external data the "Load Profile" should be clicked (Component 5 in Figure 3) and a Microsoft Excel document opened. The spreadsheet is required to be in a certain configuration with relative load in the first column and the corresponding velocity in the second column. An example profile is provided as part of this article (Supplementary Material 2). An additional step that is required when creating the LVP is to set the level of error that is to be accounted for in subsequent calculations. The advice of the authors is to use 68% for individual profiles and 34% for group profiles (Component 6 in Figure 3).

Table 1. Mean ± SD of athlete information for the group load velocity profiles for the deadlift and strict overhead press (7), and squat (5) included in the online application.

|	Deadlift and Strict Press	Squat
Number of Participants	16	19
Age (years)	22.8 ± 4.5	23.6 ± 3.7
Height (m)	1.80 ± 0.06	1.83 ± 0.05
Mass (kg)	89.3 ± 13.3	92.2 ± 8.7
Squat 1RM (kg)	147.8 ± 25.0	150.7 ± 23.7
Deadlift 1RM (kg)	176.4 ± 31.4	NA
Strict Press 1RM (kg)	64.6 ± 8.5	NA

2.2 Use of the Profile

2.2.1 Background

There are many uses of the LVP however, the method used by Dorrell, Moore and Gee (5) by which prescribed load can be regulated is described here. Regardless of whether a group or individual LVP is used, a mathematical equation is created that describes the relationship between the mean concentric velocity of a lift and the relative load that it represents. Additionally, by calculating the confidence limits (the boundaries of the data) of the LVP, the variation of an athlete's velocity at a set relative load can also be taken into account. If the assumption that regardless of changes in absolute strength the LVP remains constant, the relative load an athlete has lifted and therefore their current 1RM can be calculated. The authors of this article recommend a number of steps to conduct this process. A worked example is presented in Figure 5.

1. To account for the variation and minimise the risk of overestimating an athletes 1RM, the equation of the upper boundary of the LVP is solved for the measured lift velocity to provide an estimate of the relative load.
2. Using the estimated relative load, the athletes 1RM can be calculated by dividing the load by the relative load as a decimal (e.g. 80% = 0.80).
3. Using this estimated 1RM, the load of the next set can be calculated taking into account the current strength of the athlete.

a)

b)

c)
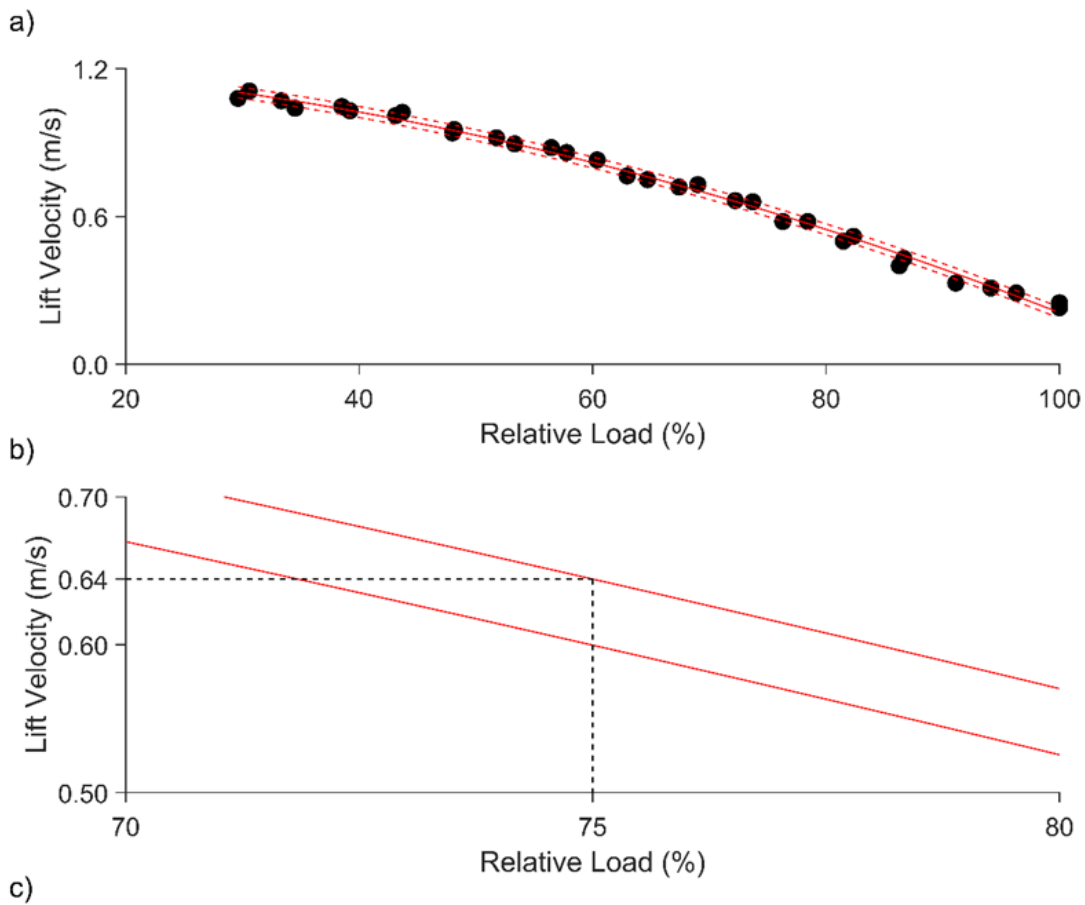
1. An athlete performs a **100 kg** back squat with a mean concentric velocity of **0.64 m/s**.

2. Using the athlete's load velocity profile and velocity of the lift, **100 kg** is shown to be **75%** of the athlete's **1RM** (b).

3. We can then predict that athlete's acute 1RM: 75% = 100 kg; **100% = 133 kg**.

4. The next programmed relative load is **80%** so the athlete should lift **106 kg**.

Figure 5. a) A load velocity profile calculated from one-repetition maximum testing, b) how the relative load of a lift can be determined using its velocity, and c) a worked example of determining the correct load for a pre-programmed relative load.

The use of the described method to predict an athlete's 1RM would allow a practitioner to manipulate the load of each set to ensure that an athlete is lifting the correct absolute load relating to the prescribed relative load. Despite this attractive prospect, and the evidence to support such approaches (5, 7), a number of barriers limit its potential use in applied settings. Some of these barriers are the need to conduct a number of computational steps including creating the LVP by fitting a polynomial, solving the equation of the line using the measured velocity, and finally calculating the athlete's acute 1RM. To address these limitations, simple guidelines are provided on how to use an LVP to manipulate load, including how the provided online application can be used within applied practice.

2.2.2 Guidelines

Once an LVP has been established the process for estimating an athlete's acute 1RM and therefore allowing adjustment of absolute load is the same, irrespective of the LVP used. To allow for the estimation of an athlete's acute 1RM, the load and velocity of a repetition is required. In practice, this would most likely be the final warm up set or the previous working set. This information in combination with the desired relative load can be inputted into the online application (Components 7 & 8 in Figure 3) to calculate the absolute load of the next set (Figure 6). This process can be repeated after each working set meaning set-by-set auto-regulation can be achieved. It should be noted that the inputted data could be of any relative load that is within the assessed LVP boundaries (i.e. greater than 30% 1RM). An example of how the described approach to auto-regulation could be included into practice is by regulating the load of the main compound lift. For example, by loading the group squat LVP on a tablet or laptop running the application, athletes could input their load and velocity of a previous set, and the programmed relative load of the next set to inform them what absolute load should be on the bar. The use of a group profile would allow multiple athletes to use the application together automating the decisions about what load should be lifted, therefore reducing the practitioner burden, and maximising the effectiveness of the designed programme.
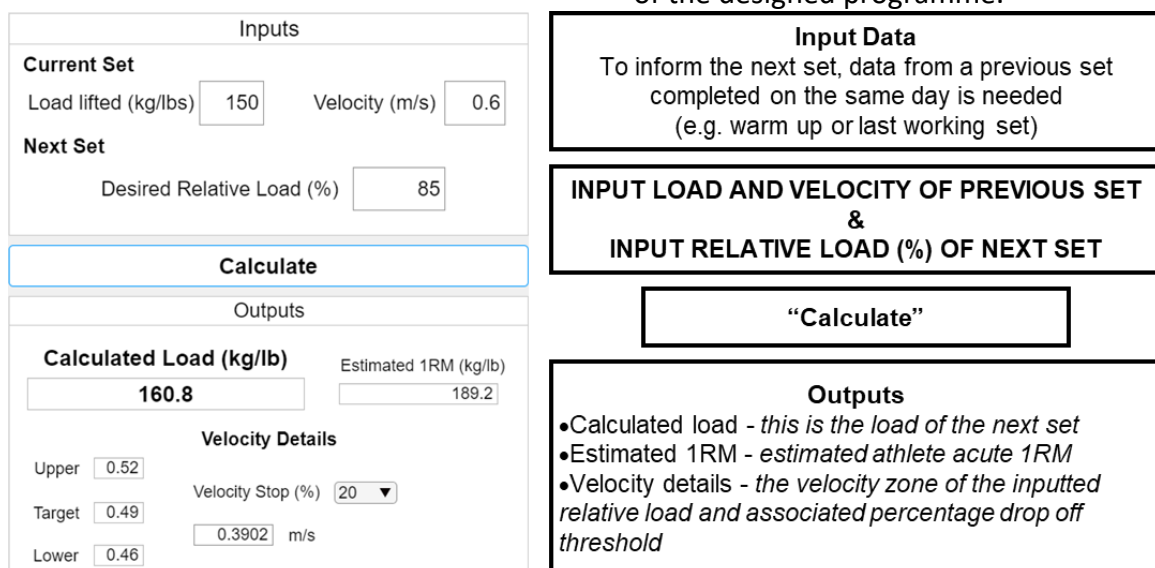
Figure 6. Process of calculating absolute load based on a load velocity profile, lift velocity, and desired relative load

3.0 Considerations for Application to Practice

The need for more sophisticated auto-regulation methods is driven by the need for S&C practitioners to maximise the effectiveness of their prescribed programs by optimising training variables. This article has described how VBT and the use of LVPs can provide an approach that allows for set-by-set regulation based on previously established LVPs. An online application and guidelines for profiling are provided.

The worth of the described approach is how it is able to progress or regress prescribed load based on the athlete's acute strength. As previously discussed, the LVP appears to be consistent for an athlete despite changes in absolute strength. Meaning that even if an athlete increases (or decreases) their 1RM by 5 kg, they will still lift 80% of their 1RM at the same velocity. This apparent trait of an LVP means that the presented method of auto-regulation is able to manipulate the load lifted to ensure the athlete is always lifting the prescribed relative load. Such an approach has been found to be more effective than traditional percentage based approaches (7), with individual LVPs offering even more benefit (5). If an LVP can be established, such as those provided in the online application, the described approach may be a solution to the problem of how to regulate load. However, any new approaches will be associated with additional athlete and practitioner burden.

The online application included in this article was designed to minimise the negative effects the computational steps of VBT would have on a typical resistance training session. Once the LVP has been loaded into the online application, the process of calculating the next load only requires the input of three numbers. The calculations described in Section 2.2.1 are then completed instantly on clicking "Calculate". Additionally, as only the first repetition of a set is required, the process could be completed before the athlete has finished their set. These characteristics of the described VBT method may still make it unsuitable in certain S&C environments, however it is hoped that this article has made the approach more accessible to practitioners.

To conclude VBT and the use of LVPs may offer an objective approach to auto-regulation that is able to progress and regress absolute load based on an estimation of an athlete's acute strength. Factors such physiological adaptations, readiness to train, and fatigue would all theoretically result in changes in the athlete's 1RM on that day however, as the LVP states that the relationship between relative load and velocity is consistent the described approach may be able to account for these factors. It is accepted that there are barriers to the implementation of VBT as method of auto-regulation but the provided guidelines and online application is intended to minimise these.

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