Comparison of the bench press one-repetition maximum obtained by different procedures: Direct assessment vs. lifts-to-failure equations vs. two-point method

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Abstract
This study examined the differences in the bench press one-repetition maximum obtained by three different methods (direct method, lifts-to-failure method, and two-point method). Twenty young men were tested in four different sessions. A single grip width (close, medium, wide, or self-selected) was randomly used on each session. Each session consisted of an incremental loading test until reaching the one-repetition maximum, followed by a single set of lifts-to-failure against the 75% one-repetition maximum load. The last load lifted during the incremental loading test was considered the actual one-repetition maximum (direct method). The one-repetition maximum was also predicted using the Mayhew’s equation (lifts-to-failure method) and the individual load–velocity relationship modeled from two data points (two-point method). The actual one-repetition maximum was underestimated by the lifts-to-failure method (range: 1–2 kg) and overestimated by the two-point method (range: –3 to –1 kg), being these differences accentuated using closer grip widths. All predicted one-repetition maximums were practically perfectly correlated with the actual one-repetition maximum (r ≥ 0.95; standard error of the estimate ≤ 4 kg). The one-repetition maximum was higher using the medium grip width (83 ± 3 kg) compared to the close (80 ± 3 kg) and wide (79 ± 3 kg) grip widths (P ≤ 0.025), while no significant differences were observed between the medium and self-selected (81 ± 3 kg) grip widths (P = 1.000). In conclusion, although both the Mayhew’s equation and the two-point method are able to predict the actual one-repetition maximum with an acceptable precision, the differences between the actual and predicted one-repetition maximums seem to increase when using close grip widths.

Keywords
Load-velocity relationship, maximal dynamic strength, resistance training, strength testing

Introduction
Resistance training intensity is commonly quantified and prescribed as a percentage of an individual’s one-repetition maximum (1RM).1 The direct assessment of the 1RM consists of determining the maximum load that can be lifted just once for a given exercise (i.e. direct method).2 However, the limitations associated with the direct method (e.g. time consuming or physically and psychologically demanding) have promoted the proliferation of different strategies for predicting the 1RM.3–6 First studies proposed 1RM prediction...
equations based on the maximum number of repetitions completed to failure with a submaximal load (i.e. lifts-to-failure method).\textsuperscript{5,7,8} More recently, the assessment of the individual load–velocity relationship has been recommended for predicting the 1RM.\textsuperscript{3,4} It is possible to estimate the 1RM from the velocity collected under only two loading conditions (i.e. two-point method).\textsuperscript{9}

The bench press is probably the most used exercise for the development of upper-body strength and power during resistance training programs.\textsuperscript{10,11} Previous studies have confirmed the validity of different lifts-to-failure equations to estimate the bench press 1RM in various populations.\textsuperscript{8,12,13} Similarly, the individual load–velocity relationship modeled by the two-point method also seems to provide an accurate prediction of the bench press 1RM.\textsuperscript{14,15} The main advantage of the lifts-to-failure method over the two-point method is that no sophisticated equipment is needed to estimate the 1RM (e.g. linear position transducer), while the main advantage of the two-point method is that subject do not need to reach muscular failure to estimate the 1RM.\textsuperscript{16} However, to the best of our knowledge, only two studies have compared the accuracy between the lifts-to-failure and velocity-based methods for predicting the 1RM.\textsuperscript{16,17} García-Ramos et al.\textsuperscript{16} observed that the lifts-to-failure methods (Lombardi’s and O’Connor’s equations) overestimated the actual 1RM (range: 3–4 kg) during the free-weight prone bench pull exercise, while no significant differences were found when the 1RM was estimated through the individualized load–velocity relationship modeled either by the multiple- (\textsuperscript{49}50–60–70–80\% of 1RM) or 2- (\textsuperscript{49}50–80\% of 1RM) point methods (range: –1 to 0 kg). Pérez-Castilla et al.\textsuperscript{17} observed that the lifts-to-failure methods (Mayhew’s and Wathan’s equations) significantly underestimated the actual 1RM (range: –7 to –2 kg) during the lat pull-down and seated cable row exercises, while no systematic differences were reported for when the 1RM was estimated through the individualized load–velocity relationship modeled either by the multiple- (\textsuperscript{49}40–55–70–85\% of 1RM) or 2- (\textsuperscript{49}40–85\% of 1RM) point methods (range: –2 to 2 kg).

Therefore, there is a need for more research to elucidate which prediction method (lifts-to-failure or two-point method) is able to estimate the bench press 1RM with a higher precision.

One of the most important factors when assessing bench press performance is the grip width.\textsuperscript{18–20} In this regard, it is important to note that previous studies that have assessed the feasibility of lifts-to-failure and velocity-based methods to estimate the bench press 1RM have used a standardized grip width slightly higher than shoulder-width apart or a self-selected grip width.\textsuperscript{8,14,21} Therefore, it is unknown whether the precision in the estimation of the bench press 1RM could be affected by the grip width. Although slight variations in the grip width do not meaningfully affect the magnitude of the 1RM load,\textsuperscript{22} the decrease in the grip width has been associated with a lower number of repetitions completed to failure\textsuperscript{22} and higher bar velocities\textsuperscript{18,23} when lifting the same absolute load. Therefore, it is plausible that the prediction of the bench press 1RM using the lifts-to-failure and two-point methods could be affected by the grip width. Specifically, based on the results presented above, the decrease in the grip width could be associated with an underestimation of the 1RM using the lifts-to-failure method and an overestimation of the 1RM using the two-point method.

To address the existing gaps in the literature, the present study was designed to examine the accuracy of lifts-to-failure (i.e. Mayhew equation) and velocity-based (i.e. two-point method) methods for predicting the 1RM during the bench press exercise performed in a Smith machine using four different grip widths (close, medium, wide, and self-selected). Specifically, the aims of this study were (I) to compare the magnitude of the bench press 1RM between the direct, lifts-to-failure, and two-point methods, and (II) to explore the concurrent validity of the lifts-to-failure and two-point methods for predicting the bench press 1RM using different grip widths. We hypothesized that (I) a comparable 1RM load would be obtained for the three methods using wider grip widths (self-selected and wide grip widths), while the highest 1RM would be obtained for the two-point method (i.e. overestimate the actual 1RM) and the lowest 1RM for the lifts-to-failure method (i.e. underestimate the actual 1RM) using closer grip widths (close and medium grip widths), and (II) both prediction methods would report an acceptable and comparable level of precision for estimating the bench press 1RM.

**Methods**

**Experimental approach to the problem**

A randomized crossover design was used to examine the accuracy of the Mayhew’s lifts-to-failure equation and the two-point method for predicting the 1RM during the bench press exercise performed in a Smith machine using four grip widths. Following a familiarization session, the close, medium, wide, or self-selected grip widths were tested in a randomized order during four sessions separated by 48–72 h (Figure 1). All sessions consisted of an incremental loading test until reaching the 1RM, followed by a set of lifts-to-failure against the 75\% 1RM load. All sessions were performed at the same time of the day for each subject.