# VALIDATION OF TWO MOBILE APPS TO PREDICT MAXIMAL STRENGTH

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Through recent advances in smartphone technology, two mobile applications (apps), *LizaPlus* and *PowerLift*, have been developed to monitor strength training and predict 1RM based on maximal concentric velocity during submaximal exercises. The aim of this study was to assess the validity of the two apps to predict 1RM using the bench press exercise. Strong correlations were found between actual 1RM and predicted 1RM values (r-values: 0.80 to 0.86, $p < 0.001$). Bland and Altman plots show a systematic bias such that predicted 1RMs tend to be higher than actual 1RM for both apps. Results indicate both apps are valid in predicting 1RM but there appears to be systematic bias to overestimate actual 1RM. Caution should be used when basing training loads on these predicted 1RM values as there is an increased risk of injury through prescription of excessive training load.

**KEYWORDS:** maximal strength, validation, mobile technology, LizaPlus, PowerLift.

**INTRODUCTION:** One repetition maximum (1RM) testing is a gold standard for measuring maximal strength, but is time-consuming and can cause significant fatigue in participants (Niewiadomski et al., 2008). For these reasons, a number of alternate submaximal approaches to quantify maximal strength have been developed (Brzycki, 1993; Jidovtseff, Harris, Crielaard, & Cronin, 2011; Macht, Abel, Mullineaux, & Yates, 2016). In multi-joint movements, the relationship between load and velocity is linear such that as load increases the maximal concentric movement velocity decreases (Garcia-Ramos, Jaric, Padial, & Feriche, 2016; Jaric, 2015; Sreckovic et al., 2015). 1RM prediction methods based on maximal concentric velocity at submaximal effort report high positive correlations with actual 1RM performance (Jidovtseff et al., 2011; Picerno et al., 2016). Recent advances in smartphone technology has seen the development of applications (apps) that capture data from embedded sensors such as accelerometers and high-speed cameras to monitor athletic performance. Two mobile apps, *LizaPlus* and *PowerLift*, have been developed to predict 1RM based on maximal concentric velocity during submaximal loads.

*LizaPlus* utilizes the smartphone's in-built accelerometer to measure barbell velocity based on the integration of acceleration data (Rey, Barcala-Furelos, & Padron-Cabo, 2017). An in-built protocol prescribes the four submaximal loads that the participant must lift with maximal velocity for three repetitions. On completion of testing, *LizaPlus* provides a report that includes a predicted 1RM value, which according to app developers is based on the known load-velocity relationship. In contrast to *LizaPlus*, *PowerLift* utilizes the smartphone video camera to record barbell movement during maximal velocity lifts at four submaximal loads (Balsalobre-Fernandez, Marchante, Munoz-Lopez, & Jimenez, 2018). *PowerLift* does not prescribe the loads and leaves it to the user to determine the submaximal loads. The user then analyses one repetition from each set performed to determine start and end frames of the movement. The user must also input values of video frame rate and barbell displacement, which allows the app to calculate barbell velocity from which a load-velocity curve is created along with a predicted 1RM.

These apps could be of benefit to coaches and athletes by reducing the time and fatigue associated with 1RM testing while still quantifying maximal strength. *PowerLift* has been previously validated by the app developer (Balsalobre-Fernandez et al., 2018); however, there are no published studies reporting validation of *LizaPlus*. The aim of this study was to assess the validity of the two apps to predict 1RM bench press strength in well-trained male athletes.

**METHODS:** 21 resistance-trained male participants (mean (SD) age: 32.2 (9.0) yr; height: 1.8 (0.1) m; mass: 95.5 (12.7) kg; training experience: 9.4 (8.5) yr) completed a single test session

during which they performed a series of bench press repetitions on a Smith machine. A single test session was chosen to reduce time burden on participants and ensure each participant was tested under similar conditions for the submaximal and maximal testing. The test session included 2 warm-up sets of 5 repetitions with an unloaded barbell (20 kg), followed by a submaximal test consisting of 4 sets of 3 repetitions, with 2 minutes of rest between sets. Initial loads ranged from 20 to 40 kg with the final set ranging from 65 to 110 kg. These loads were determined by the *LizaPlus* app using an unspecified algorithm that is based on participant demographics (i.e. age, sex, training status). Due to simultaneous data collection as outlined below, these loads were also used for *PowerLift*.

During the submaximal test protocol, barbell acceleration (100 Hz) was recorded via the *LizaPlus* (version no. 3.1, Exelio Srl, Tavagnacco, Italy) installed on an iPod Touch (iOS version 9.3.5, Apple Inc., Cupertino, USA) that was attached to the linear bearing case of the Smith machine. High-speed video (240 Hz) of each set was simultaneously recorded using *PowerLift* (Version 5.4.2, Carlos Balsolobre, Madrid, Spain) installed on an iPhone 6s (iOS version 9.3.3, Apple Inc., Cupertino, USA) mounted on a tripod positioned behind the head of each participant and aligned 3 m behind the center of the barbell.

Upon completion of the submaximal test protocol, participants rested for 5 minutes before completing a series of single repetitions at progressively increasing loads with 5 minutes of rest between each repetition, to establish actual 1RM (Haff and Triplett, 2015). Participants were instructed to perform each repetition with a controlled lowering of the bar to the chest then, without bouncing or heaving the barbell, to fully extend the arms at maximal velocity.

Following data collection, predicted 1RM values were determined from each app. The *LizaPlus*-predicted 1RM was automatically determined through the app based on the submaximal load and acceleration information. As per the *PowerLift* requirements, video files were analyzed by selecting the start and end of the concentric movement phase of the first repetition of each submaximal set. *PowerLift* subsequently determined the mean velocity of each repetition, based on the pre-determined barbell displacement and the duration of the concentric phase. The *PowerLift*-predicted 1RM was then automatically determined by the app based on the submaximal load and velocity data.

Normality of the data set was confirmed using a Shapiro-Wilk test. Pearson correlation coefficients (r) with 95% confidence intervals (CI) were used to examine the strength of relationship between actual 1RM and the predicted 1RM values from the apps. The agreement between actual and predicted 1RM values was further examined graphically using Bland and Altman plots in which the difference between the actual 1RM and the predicted 1RM was plotted against the mean of the two measures. A linear regression line was fitted to the Bland and Altman plots with the $R^2$ value of the regression line determined and a lower $R^2$ value indicating lower proportional bias. Furthermore, paired t-tests, and mean differences with 95% CI were used to examine differences in actual 1RM and predicted 1RM values and provided insight into any constant bias. All statistical analyses were performed using MedCalc Statistical Software (version 18.11.3, MedCalc Software bvba, Ostend, Belgium). Statistical significance was set at an alpha of 0.05.

**RESULTS:** Strong positive correlations were noted between actual 1RM and *PowerLift*-predicted 1RM ($r(19) = 0.80$ (95%CI: 0.57 to 0.92), $p < 0.001$; Figure 1A) as well as between actual 1RM and *LizaPlus*-predicted 1RM ($r(19) = 0.86$ (95%CI: 0.69 to 0.94), $p < 0.001$; Figure 1B).

Bland and Altman plots depicting limits of agreement between actual 1RM and predicted 1RMs show that the majority of data points are within the 95% confidence intervals (CI) with a constant bias such that predicted 1RMs tend to be higher than actual 1RM (Figure 2). This finding was supported with the paired t-tests revealing significant differences between *PowerLift*-predicted 1RM and actual 1RM ($t(20) = 4.76$, $p < 0.001$, mean difference (95% CI): 10.74 (6.30 to 15.45) kg) and *LizaPlus*-predicted 1RM ($t(20) = 2.22$, $p = 0.04$, mean difference (95% CI): 4.38 (0.27 to 8.48) kg). There was no proportional bias between the *PowerLift*-predicted 1RM and actual 1RM, nor the *LizaPlus*-predicted 1RM and actual 1RM (Bland and Altman plot $R^2 = 0.05$ and 0.01, respectively; $p > 0.5$).

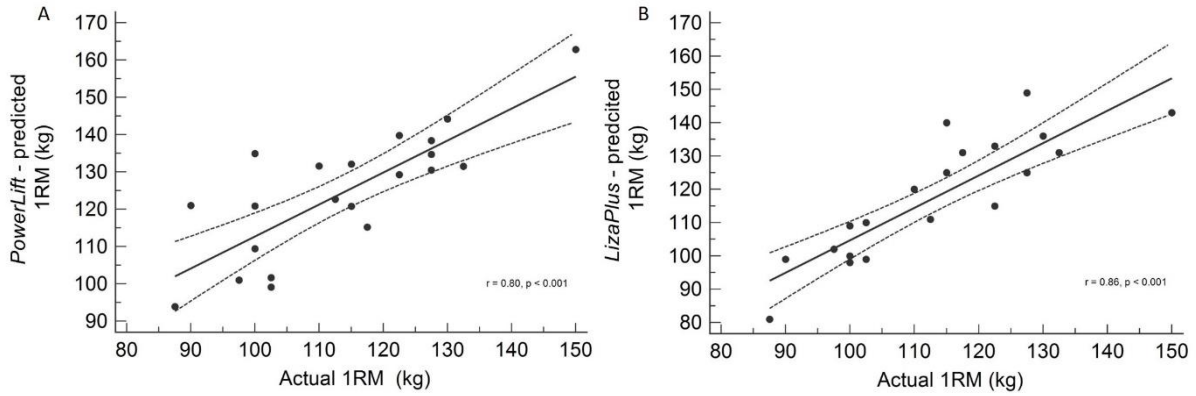


**Figure 1**: Scatterplots and regression lines with 95%CIs depicting relationships between (A) actual 1RM and *PowerLift*-predicted 1RM, and (B) actual 1RM and *LizaPlus*-predicted 1RM for the bench press exercise.

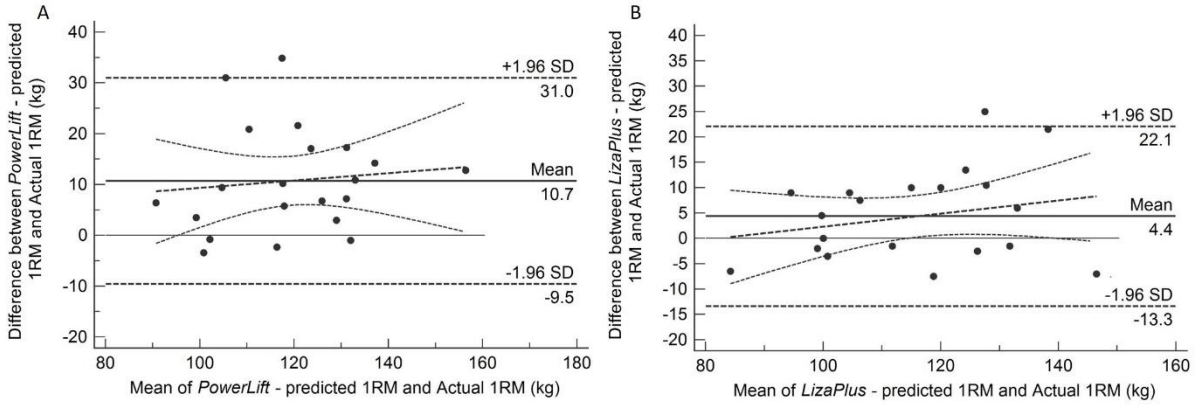


**Figure 2**: Bland-Altman plots with regression lines and 95%CI depicting the level of agreement between (A) *PowerLift*-predicted 1RM and actual 1RM, and (B) *LizaPlus*-predicted 1RM and actual 1RM.

**DISCUSSION:** *PowerLift* and *LizaPlus* predicted 1RMs had strong positive relationships with actual 1RM; however, both apps overestimated actual 1RM. As demonstrated by the t-test results, *PowerLift* significantly overestimated the actual 1RM by 10.7 kg with individual participant differences ranging from -3.4 kg (3% underestimation of actual 1RM) to 34.9 kg (35% overestimation of actual 1RM). On the other hand, the average overestimation of *LizaPlus* was 4.4 kg with individual differences ranging from -7.5 kg (6% underestimation of actual 1RM) to 25.0 kg (21% overestimation of actual 1RM). These large overestimations could be problematic, particularly if training loads are based on the predicted 1RM values as it could lead to overtraining. However, for most participants (18 (86%) for *LizaPlus* and 14 (67%) for *PowerLift)* the difference in predicted 1RM and actual 1RM was within ±10%.

The overestimation of the apps may be a result of the velocities calculated by the apps and used in the regression equations to predict 1RM. To calculate velocity, *PowerLift* requires a 'displacement' value be entered during the set-up of a participant's profile within the app and this value is subsequently used in the velocity calculations. To improve upon the velocity calculation, it would be beneficial to allow for measurement of the lift displacement within each video rather than relying on a pre-set value as displacement may be affected by changes in body position throughout the lift and could vary across repetitions. Unfortunately, there is limited information available on how *LizaPlus* processes the acceleration data to obtain velocity. Providing access to the algorithm may facilitate further development of *LizaPlus*. Further research to compare velocities calculated by each app, and the velocity of the barbell using a gold standard device, such as a linear transducer, is also warranted to determine if the error is in the measurement of velocity or in the prediction equations used to determine 1RM.

The strong positive correlation between *PowerLift*-predicted 1RM and actual 1RM is in agreement with Balsalobre-Fernández et al. (2018). However, results of the paired t-test are in contrast to Balsalobre-Fernández et al. (2018) who found that *PowerLift* tended to underestimate actual 1RM. These differences could potentially be due to variations in the testing protocols between studies as our submaximal testing included 4 sets of 3 repetitions at maximal velocity (set by the *LizaPlus* app). While 2 minutes of rest were given between sets and further rest provided during the 1RM protocol, there is potential that the submaximal testing led to fatigue and limited the subsequent 1RM result. It is also possible that participants' expectations of their 1RM may have limited their effort, particularly when attempting loads higher than their perceived 1RM, as Ness and Patton (1979) noted participants were able to lift ~9kg more when they believed the load was less than its actual value.
The present study is the first to assess the validity of the *LizaPlus* and has shown similar findings to the *PowerLift* app; however, a direct comparison between the apps has not been undertaken. Limitations of the study include the homogeneity of participants as the findings may not be generalizable to other populations and the use of a single exercise as the validity for prediction of 1RM during the bench press may differ to other exercises.

**CONCLUSION:** While results indicate the predicted values from both apps are strongly correlated to actual 1RM, both exhibit systematic bias towards overestimating actual 1RM, which for some participants was quite large. Based on the current app versions, it is recommended that caution be used when setting training loads on predicted 1RM values given they may potentially increase the risk of injury through an overestimation of ability and prescription of excessive training load.

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