A SIMPLE METHOD FOR ASSESSMENT OF MUSCLE MECHANICAL CAPACITIES FROM FUNCTIONAL MOVEMENT TASKS

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The aim of the present study was to evaluate the level of agreement between the routinely used "multiple-load method" and a simple "two-load method" based on direct assessment of the F-V relationship from only 2 external loads applied. Twelve participants were tested on the maximum performance vertical jumps, cycling, bench press throws, and bench pull performed against a variety of different loads. All four tested tasks revealed both exceptionally strong relationships between the parameters of the 2 methods (median R = 0.98) and a lack of meaningful differences between their magnitudes (fixed bias below 3.4%). Therefore, addition of another load to the standard tests of various functional tasks typically conducted under a single set of mechanical conditions could allow for the assessment of the muscle mechanical properties, such as the muscle F, V, and P producing capacities.

KEY WORDS: regression; mechanics; parameter; output; load

INTRODUCTION Routine procedures for testing muscle function have been usually conducted under a single mechanical condition and, consequently, the muscle capacities for producing high F, V and P outputs were not distinguished from single outcomes of such tests (Jaric, 2015). A solution of that problem could be based on a number of recent studies that have been focused upon the force-velocity (F-V) relationship of muscular systems performing various functional movement tasks, such as jumping, cycling or lifting (Jaric, 2015). Specifically, a manipulation of external loads provided a range of F and V data that allowed for applying various regression models revealing V associated decrease in F. The applied regressions typically revealed exceptionally strong and linear F-V relationship (i.e., $F = F_{max} - aV$) from functional tasks such as lifting, jumping and leg push offs, cycling, and running. The regressions inevitably revealed the maximum F (i.e., the F-intercept; F_{max}), maximum V (V-intercept; $V_{max} = F_{max}/a$), and maximum power [$P_{max} = (F_{max}\ V_{max}\ /4)$; (Driss, Vandewalle, Le Chevalier, & Monod, 2002; Jaric, 2015; Samozino, Rejc, Di Prampero, Belli, & Morin, 2012)]. Therefore, the F-V relationship could provide a comprehensive and valuable set of information regarding different mechanical capacities of the tested muscles (Bobbert, 2012; Jaric, 2015; Rabita et al., 2015; Samozino et al., 2012; Samozino, Rejc, di Prampero, Belli, & Morin, 2014).

The method of obtaining the linear F-V relationship from loaded functional movements procedure could be developed into a routine procedure for testing the muscle mechanical capacities (Cuk et al., 2014; Garcia-Ramos, Jaric, Padial, & Feriche, in press; Jaric, 2015; Meylan et al., 2015; Nikolaidis, 2012; Sreckovic et al., 2015). A plausible simplification of the standard procedure of obtaining F-V relationship referred to as the *multiple-load method* could be based on drawing a line through just 2 pairs of F and V data obtained from two distinctive loads (i.e., the *two-load method*). Namely, if the multiple-load method is based on a strong linear F-V relationship, a plausible assumption would be that the two-load method could accurately replicate it.

To explore to what extent the outcome of the two-load method replicates the actual F-V relationship obtained from the multiple-load method, we conducted four functional movement tests under various external loads. We specifically hypothesized that there would be a high level of agreement between the parameters depicting the F, V, and P producing capacity of the tested muscles (i.e., F_{max}, V_{max}, and P_{max}, respectively) obtained from the two-load method and the standard multiple-load methods.

METHODS Twelve healthy male participants (age 22.1 ± 3.4 years; body height 184.1 ± 7.1 cm; body mass 80.8 ± 8.2 kg, body mass index 24.5 ± 1.5 cm/kg^2, and percent body fat 11.2 ± 2.8 %; data shown as mean ± SD) were tested on maximum counter-movement jumps (JUMP) performed on a force plate (AMTI; Watertown, USA) wearing a weighted vest and belt (load ranging from 0 to 32 kg). Six seconds maximal cycling sprint test (CYCLING) performed against different external resistances (2-10 kg) on a Monark 834E leg cycle ergometer provided the maximum power output and cadence. Maximum bench-press throws test (BPRESS) was performed on a Smith machine against different loads with the instruction "to throw the bar as high as possible". During the maximum bench press pull test (BPULL) the participants pulled up the bar with different sets of load plates with the maximum effort until the bar struck the cushioned underside of the bench. The individual maximum load lifted in BPRESS and BPULL was between 62 and 90 kg.

The analyses were performed on the parameters F_{max}, V_{max}, and P_{max} and correlation coefficients obtained separately from the multiple-load and two-load method. The level of statistical significance was set to $p<0.05$.

RESULTS Figure 1A shows the averaged across the participants F and V data obtained from individual loads applied on 4 functional performance tests. The multiple-load method revealed exceptionally strong and approximately linear relationships. When applied on individual sets of data, the same method revealed the correlation coefficients 0.951 (0.877-0.992) in JUMP, 0.995 (0.978-0.999) in CYCLING, 0.984 (0.963-0.991) in BPRESS, and 0.990 (0.940-0.997) in BPULL [all data shown as median (range)]. Figure 1B illustrates the similarity of the multiple-load and two-load method outcomes observed from a representative set of individual data since the two lines almost overlap.

Figure 2 presents the differences between the magnitudes the same parameters observed from the multiple-load and two-load method applied separately on different functional performance tasks. Although 4 out of 12 comparisons revealed significant differences ($p < 0.05$; paired t-test), note that the magnitudes of the differences were exceptionally small.

All correlation coefficients between the same parameters proved to be strong (all $r > 0.952$; $p < 0.01$). Although the correlation coefficients obtained from BPRESS appear to be somewhat lower than in the remaining three tests, none of the 12 correlation coefficients was either above or below the 95% confidence intervals of others.

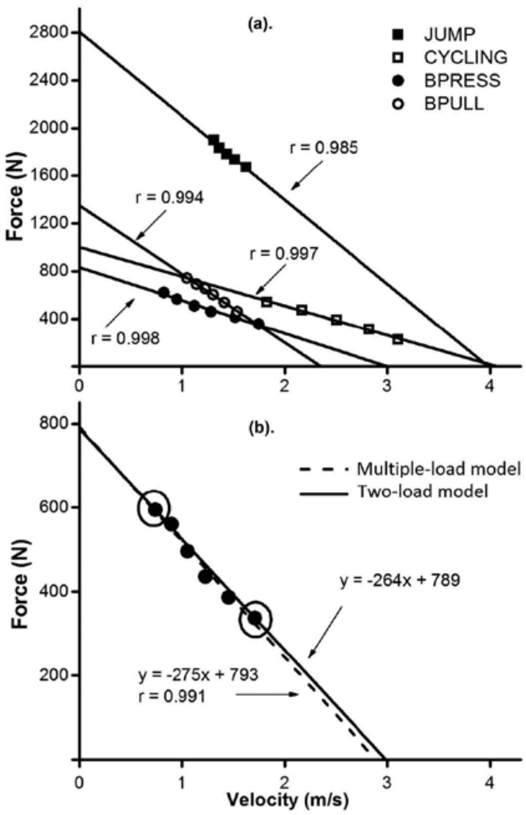

Figure 1. (A) The linear regressions obtained from the averaged across the participant data recorded from 4 functional movement tests. (B) Comparison of the two methods applied on a representative set of individual data obtained from BPRESS.

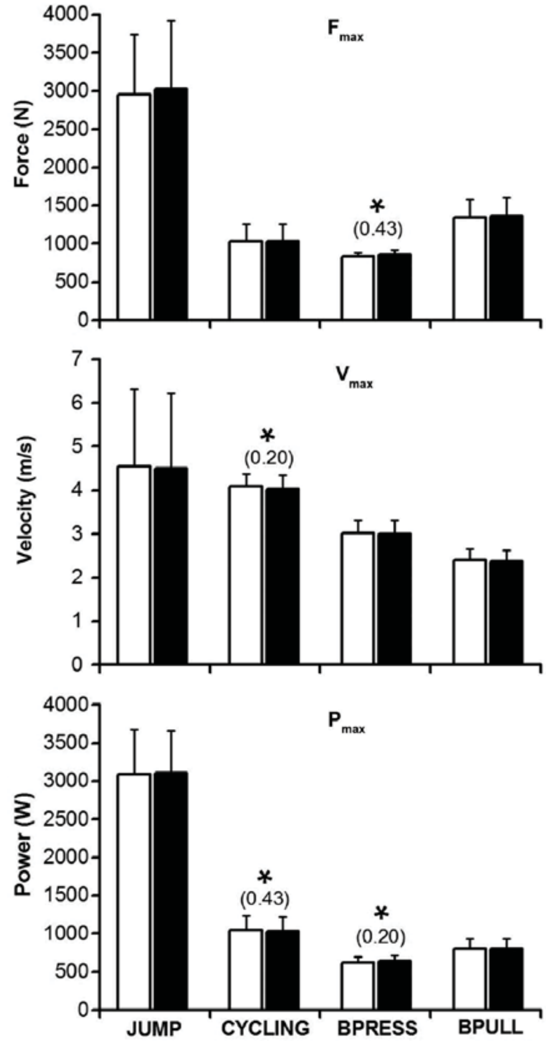

Figure 2. The averaged across the participant values of the parameters F_{max} (top panel), V_{max} (middle panel) and P_{max} (bottom panel) obtained from the multiple-load (open bars) and two-load method (filled bars) for different tests. * p<0.05 between the 2 methods are also presented.

DISCUSSION The obtained results strongly suggest that the two-load method that requires neither the regression modelliing nor more than 2 different loads applied provides virtually identical outcomes regarding the magnitudes of the F-V parameters. This could be considered as an outcome that supports the concurrent validity of the two-load method with respect to the multiple-load method already extensively used in literature [(Jaric, 2015); see also Introduction]. Note that the finding could be at least partly explained by the fact that the 2 methods are based on the same assumption that the F-V relationship is a strong and linear.

Not that over last several decades various populations have been typically tested under a single set of mechanical conditions including a single external load. However, a single experimental point does not allow for the assessment of the F-V relationship and, therefore, for discerning between the muscle F, V, and P producing capacities.

The present data, however, suggest that adding of just another external load could allow for using the two-load method that distinguishes among the discussed muscle capacities. Although

there are no data in the literature yet, it is plausible to assume the two selected loads should be more, rather than less distinctive loads [as shown in Figure 1b; (Jaric, 2016)]. Namely, the error of the obtained F-V relationship (and, therefore, of F_{max}, V_{max}, and P_{max}) would be smaller if calculated from more distant experimental points.
Regarding the limitations and directions for further research, note that the two-load method could be applied only on multi-joint functional movement tasks, since the F-V relationship observed from in vitro muscles and single-joint movements is generally considered to be curvilinear (Kaneko, Fuchimoto, Toji, & Suei, 1983; McMahon, 1984). However, the functional movement tasks are not only extensively used in routine testing, but also more ecologically valid and typically more familiar for participants (Jaric, 2015). Note also that despite their apparent physiological meaning, two out of three parameters (i.e., F_{max}, V_{max}, and P_{max}) obtained from either of the methods allow for calculation of the third parameter. Furthermore, it remains underexplored how different types of loads affect both the F-V relationship in general and the concurrent validity of the two-load method (Leontijevic et al., 2012; Leontijevic, Pazin, Kukolj, Ugarkovic, & Jaric, 2013). Finally, despite a high level of agreement of the two-load method with the multiple-load method that already revealed highly reliable parameters [(Jaric, 2015); see also Introduction], the reliability of the two-load method apparently needs further evaluation.

CONCLUSIONS The use of the two-load method could both improve routine testing methods and resolve a number of debated issues in literature regarding the interpretation of the outcomes of various functional movement tests. With respect to the multiple-load method routinely applied in the literature, the two-load method also provides a simpler and quicker testing procedure that is also less prone to fatigue. Nevertheless, further research is needed to standardize the testing procedures regarding the magnitudes of external loads applied, their type (Leontijevic et al., 2013), and additionally explore the reliability, validity and sensitivity of the observed parameters.

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