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Human Kinetics
BRIEF REVIEW

The 2-Point Method: Theoretical Basis, Methodological Considerations, Experimental Support, and Its Application Under Field Conditions

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The "2-point method," originally referred to as the "2-load method," was proposed in 2016 by Prof Slobodan Jaric to characterize the maximal mechanical capacities of the muscles to produce force, velocity, and power. Two years later, in 2018, Prof Jaric and I summarized in a review article the scientific evidence showing that the 2-point method, compared with the multiple-point method, is capable of providing the outcomes of the force–velocity (F–V) and load–velocity (L–V) relationships with similar reliability and high concurrent validity. However, a major gap of our review was that, until 2018, the feasibility of the 2-point method had only been explored through testing procedures based on multiple (more than 2) loads. This is problematic because (1) it has misled users into thinking that implementing the 2-point method inevitably requires testing more than 2 conditions and (2) obtaining the data from the same test could have artificially inflated the concurrent validity of the 2-point method. To overcome these limitations, subsequent studies have implemented in separate sessions the 2-point method under field conditions (only 2 different loads applied in the testing protocol) and the standard multiple-point method. These studies consistently demonstrate that while the outcomes of the 2-point method exhibit comparable reliability, they tend to have slightly higher magnitudes compared with the standard multiple-point method. This review article emphasizes the practical aspects that should be considered when applying the 2-point method under field conditions to obtain the main outcomes of the F–V and L–V relationships.

Keywords: force–velocity, load–velocity, power, testing

The 2-point method can be used to describe the relationship between any 2 variables that are directly or inversely related. The theoretical basis underlying the use of the 2-point method is that when 2 variables are linearly related, the line depicting their relationship can be obtained by recording both variables under only 2 different conditions (eg, 2 different loads used). The parameters of the regression line (ie, intercept and slope) and its derived outcomes (eg, maximal mechanical capacities) should not be meaningfully affected by the number of conditions tested because all experimental points are expected to be located over (or very close to) the regression line. In other words, the same regression line is expected to be obtained when 2 linearly related variables are measured under 2 (2-point method) or more than 2 (multiple-point method) testing conditions (Figure 1). Therefore, the 2-point method potentially simplifies the testing procedures required to determine the relationship between any 2 variables that behave linearly.

The "2-point method," originally referred to as the "2-load method," was proposed in 2016 by Prof Slobodan Jaric to distinguish among the maximal mechanical capacities of the muscles to produce force (F_0), velocity (v_0), and power (P_{max}) through the assessment of the force–velocity (F–V) relationship.[1] A few years later, Garcia-Ramos et al[2] extended the use of the 2-point method to the modeling of the load–velocity (L–V) relationship with the intention of elucidating whether it could also provide an accurate estimate of the 1-repetition maximum (1RM). More recently, the 2-point method has been used to determine through the L–V relationship analogue outcomes as the ones derived from the F–V relationship (theoretical maximal load [L_0; load at 0 m·s^{-1}], maximal velocity [v_0; velocity at 0 kg], and area under the L–V relationship line [$A_{line} = L_0 \times v_0/2$]).[3] It is beyond the scope of this review to delve into the different practical applications of the outcomes derived from the F–V (F_0, v_0, P_{max}, and F–V slope) and L–V (1RM, L_0, v_0, and A_{line}) relationships, but interested readers can consult the following related references.[4–9]

This review article delves into the theoretical bases and practical aspects that should be considered when applying the 2-point method to obtain the main outcomes of the F–V and L–V relationships. However, it is important to note that the 2-point method has been also shown effective to describe the relationship between other important variables related to muscle function.[10,11] Therefore, although in this study we have focused on the F–V and L–V relationships, researchers are encouraged to implement the 2-point method in their respective fields of research (provided that they study variables that behave linearly) to elucidate whether the 2-point method could also simplify their testing procedures.

Shape of the F–V and L–V Relationships

Early studies revealed that, in isolated animal muscles and individual human muscle groups, the F–V relationship follows a nonlinear upward concave shape and could therefore be expressed by a hyperbolic function.[12–14] Conversely, the F–V relationship has been reported to be approximately linear during multijoint maximum performance tasks.[15–17] Of note is that early studies examined

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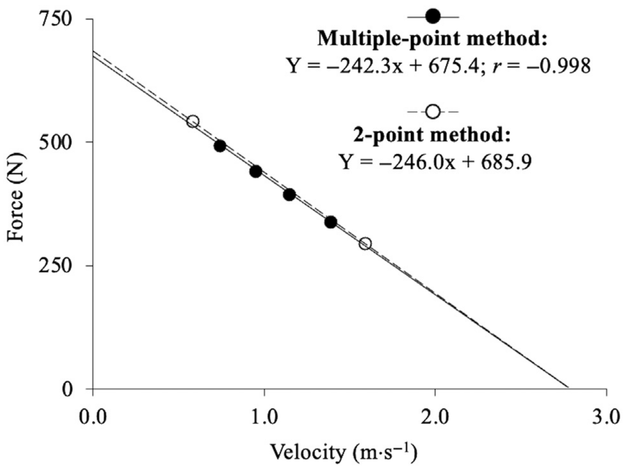

Figure 1 — Force–velocity relationships obtained from the averaged across subjects force and velocity data collected against 6 loading conditions (multiple-point; 20%–30%–40%–50%–60%–70% of the 1-repetition maximum) or only the 2 most distal loading conditions (2-point method; 20%–70% of 1RM) during the bench-press throw exercise. Note the great overlap between the regression lines representing the multiple- (straight line considering all dots) and 2-point (dashed line considering only the 2 empty dots) methods. The regression equations and the Pearson product–moment correlation coefficients (r) are depicted. Data were extracted from a previously published work of García-Ramos et al.[27]

the muscle's force production and its shortening velocity,[12,13] whereas the mechanical output of the whole muscular system, not the mechanical output of individual muscles, is measured during multijoint tasks. As pointed out by Jaric,[16] the different shape of the F–V relationship could indicate that the combined mechanical properties of muscular systems acting within a multijoint task do not follow the same pattern as the mechanical properties of individual muscles. However, it cannot be ruled out, as it has been suggested by some researchers,[18,19] that the high linearity of the F–V relationship during multijoint tasks is due to the fact that the recorded experimental points (ie, force and velocity values) only cover a limited portion of the F–V relationship.

What is clear is that within the range of loads that can be applied using a standard range of motion, the F–V and L–V relationships have proven to be highly linear (Pearson multivariate coefficient of determination [r^2] > .90) in a variety of acyclic and cyclic multijoint tasks such as the vertical jump,[20,21] squat,[20,22] deadlift,[23,24] leg press,[15,25] bench press,[26,27] bench pull,[28] cycling,[29] or running.[30] It is also worth noting that a number of studies have compared the goodness of fit (eg, r^2) between linear and curvilinear regression models in an attempt to determine the mathematical function which fits at best the experimental data.[19,21,31–33] All studies have revealed that the simple linear regression model provides a lower (or at most comparable) r^2 than the more complex curvilinear models, but this is not surprising since it is mathematically infeasible for a simpler model (ie, with less degrees of freedom) to reveal a greater r^2. Therefore, instead of focusing exclusively on the goodness of fit, researchers' attention should preferably be redirected to elucidating what type of regression model allows obtaining the main outcomes of the F–V and L–V relationships with greater reliability, sensitivity, accuracy, and practical and physiological relevance.

Most of the scientific literature agrees that the linear regression model provides the main outcomes of the F–V and L–V relationships with the highest simplicity, reliability, accuracy, and apparent physiological meaning.[26,31,33,34] For example, Pérez-Castilla et al[33] revealed during the bench press exercise (loads ranged from 17 kg to the 1RM) that linear regression models were able to provide the main outcomes of the F–V relationship (F_0, v_0, and P_{max}) with greater reliability than quadratic polynomial, hyperbolic, and exponential regression models, whereas all curvilinear regression models often yielded illogical F–V relationship parameters. Regarding the L–V relationship, it has been repeatedly shown that the linear regression model provides more accurate estimates of the 1RM and of the velocities associated with different %1RM than a more complex second-order polynomial regression model.[26,34] These findings do not rule out the possibility that the linearity of the F–V and L–V relationships could be distorted at their extremes,[18,19,35] but it does emphasize the uselessness of modeling these relationships with curvilinear models since (1) both relationships are highly linear within the portion of the F–V and L–V relationships that can be directly tested in field testing and (2) the application of curvilinear models to a range of linearly distributed data compromises the reliability and accuracy of the final outcomes derived from these relationships.

Influence of the Experimental Points on F–V and L–V Relationship Variables

The most standard testing procedure used for assessing the F–V and L–V relationships consists of recording external force or load and lifting velocity under multiple (more than 2) conditions. Regardless of the testing condition (isoinertial or isokinetic) and type of relationship (F–V or L–V), it has been repeatedly shown that movement velocity exhibits an inverse linear relationship with the external force applied (in newtons) and the load lifted (in kilograms).[6,7,16] Therefore, a linear regression model can be applied to the force (or load) and velocity data recorded against different loading/velocity conditions to determine the F–V (or L–V) relationship. However, it is important to note that the reliability and accuracy in the estimation of the main outcomes derived from the F–V and L–V relationships are far from perfect. The 4 basic characteristics of the experimental points with potential to affect the reliability and accuracy of the main outcomes derived from the F–V and L–V relationships are presented in this section: (1) distance between the 2 extreme experimental points, (2) distance from the variable of interest to the closest experimental point, (3) reliability of the experimental points, and (4) number of experimental points.

Distance Between the 2 Extreme Experimental Points

The slope of the F–V and L–V relationships is expected to be more stable, as the distances between the lowest and highest experimental points of these relationships increase. This assumption is demonstrated with the simulation detailed in Figure 2. We simulated a L–V relationship based on 6 experimental points (EP1: 20 kg and 1.30 m·s^{-1}; EP2: 30 kg and 1.10 m·s^{-1}; EP3: 40 kg and 0.90 m·s^{-1}; EP4: 50 kg and 0.70 m·s^{-1}; EP5: 60 kg and 0.50 m·s^{-1}; EP6: 70 kg and 0.30 m·s^{-1}) with a perfect goodness of fit ($r^2 = 1$) and a slope of −50.0 kg·s·m^{-1}. Thereafter, 3 different 2-point methods were constructed based on the combination of the 2 most

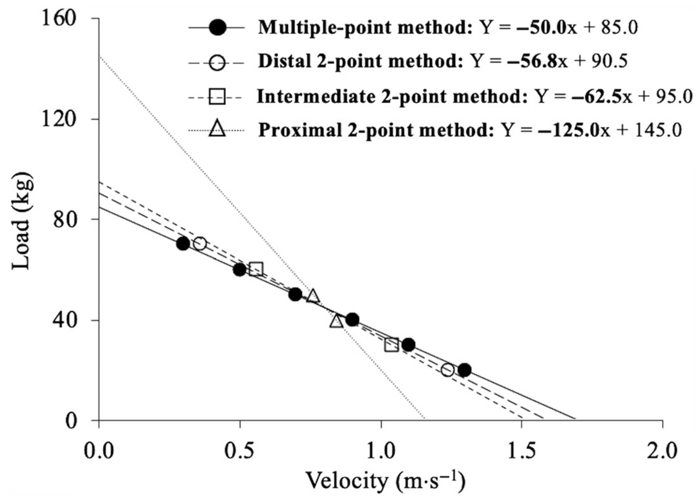

Figure 2 — Simulation of load–velocity relationships based on 6 experimental points (*multiple-point method*; solid line and filled dots) and 2-point methods based on the combination of the 2 most distal (*distal 2-point method*; long-dashed line and empty dots), 2 intermediate (*intermediate 2-point method*; short-dashed line and empty squares), and 2 most proximal (*proximal 2-point method*; dotted line and empty triangles) experimental points. Note that, in comparison with the multiple-point method, the velocity of the lightest and heaviest loads of each 2-point method was arbitrarily decreased and increased by 0.06 $m\cdot s^{-1}$, respectively. The differences with respect to the slope of the multiple-point method were accentuated with decreasing distances between the experimental points of the 2-point methods ($\Delta = 150.0\%$, 25%, and 13.6% for the proximal, intermediate, and distal 2-point methods, respectively).

distal (EP1 and EP6), intermediate (EP2 and EP5), and proximal (EP3 and EP4) experimental points. Obviously, the very same L–V relationship (ie, slope and its derived parameters) would be obtained if the velocity outputs of the 2-point methods were exactly the same as the velocity outputs of the multiple-point method. However, due to technological errors and inherent biological variability, the velocity achieved against the same absolute loads is rarely identical when the measurement is repeated. In the simulation, the velocity of the experimental points associated to the lightest and heaviest loads used for each 2-point method was arbitrarily decreased and increased by 0.06 $m\cdot s^{-1}$, respectively. Of note is that the same change in velocity presented a deeper impact in the proximal 2-point method (L–V slope = −125.0 $kg\cdot s\cdot m^{-1}$; $\Delta = 150.0\%$), followed by the intermediate 2-point method (L–V slope = −62.5 $kg\cdot s\cdot m^{-1}$; $\Delta = 25.0\%$), and finally in the distal 2-point method (L–V slope = −56.8 $kg\cdot s\cdot m^{-1}$; $\Delta = 13.6\%$).

The magnitude of the main outcomes of the F–V (F_0, v_0, and P_{max}) and L–V (1RM, L_0, v_0, and A_{line}) relationships depends on the slope of their relationship, so a greater stability of the slope due to increasing the distance between the lowest and highest experimental points is expected to also increase the reliability and accuracy of the relationship parameters. This factor becomes even more important when it is the slope of the F–V relationship itself that is used as a reference to prescribe individualized training programs. The best-known application of the F–V slope to guide training prescription was proposed by Samozino and colleagues, who argued that each individual has an optimal F–V slope that allows maximizing ballistic performance for a given value of P_{max}.[4,36,37] Therefore, knowing the differences between the optimal and actual (measured) F–V slopes, training can be prescribed to reduce the differences between both F–V slopes (eg, velocity-deficit athletes use light loads and force-deficit athletes use heavy loads).[5] However, it is important to note that the optimized F–V training approach is based on F–V profiles obtained through loaded vertical jumps in which the experimental points often cover a very small portion of the F–V relationship.[21,38,39] For these reasons, based on my own personal experience, the feasibility of the optimized F–V training approach seems to be reduced (1) in weak individuals who are not able to jump more than 10 cm against an external load of at least 60 kg and (2) in very heavy individuals (body mass > 100 kg) because the experimental point associated to the lightest possible load is very far from v_0. The development of new equipment that allows jumping by reducing the effect of gravity (assisted or horizontal jumps) might improve the accuracy and extend the optimized F–V profile to other populations.[40]

Distance From the Variable of Interest to the Closest Experimental Point

The larger the extrapolation from the closest experimental point to the variable of interest (eg, axis intercepts) the lower the reliability and accuracy of the final outcome (see Figure 3 for a simulation). Abundant scientific evidence supports the idea of locating the experimental points as close as possible to the variables of interest to maximize their reliability and accuracy. For example, regarding the F–V relationship, in cycling and running v_0 can be obtained with greater reliability than F_0,[30,41] while in jumping F_0 is more reliable than v_0.[21,38] The main cause of these results is that the inherent characteristics of the tasks promote that the experimental points are located closer to v_0 in cycling and running and closer to F_0 in jumping. Regarding the L–V relationship, it has been repeatedly shown that the accuracy of the L–V relationship to estimate the 1RM progressively decreases with increasing distances from the experimental point associated with the heaviest load used to the minimal velocity threshold represented by the 1RM.[42,43]

Reliability of the Experimental Points

Experimental points characterized by greater variability in force and velocity outputs upon repeated measurements are likely to undermine the reliability and accuracy of the main outcomes derived from the F–V and L–V relationships. It is not uncommon to observe that the experimental points of the distal portions (at least one of them) of the F–V and L–V relationships are obtained with a lower reliability than the experimental points of more proximal portions.[41,44] Therefore, a common concern of researchers has been to discriminate whether there is a specific point of the F–V (or L–V) relationship from which the reliability of the experimental points is markedly reduced and, consequently, to elucidate if the modeling of experimental points beyond this threshold could compromise the accuracy of the F–V (or L–V) relationship.

García-Ramos et al[41] reported in the leg cycle ergometer exercise a progressive decrease in the reliability (ie, greater coefficient of variation; CV%) of velocity outputs (cadence in revolutions per minute; rpm) when sprinting against increasing resistive forces (CV = 1.42% for R1 [≈172 rpm], 1.62% for R2 [≈154 rpm], 2.28% for R3 [≈134 rpm], 3.21% for R4 [≈110 rpm], and 6.25% for R5 [≈83 rpm]). Note that the reliability of R5 was at least twice lower than the one observed for the remaining resistances tested. Consequently, the 2-point method based on the combination of R1 and R4 provided the 4 F–V relationship parameters (F_0, v_0, F–V slope, and P_{max}) with greater reliability than the 2-point method based on the combination of R1 and R5 despite that in the latter (1) the distance

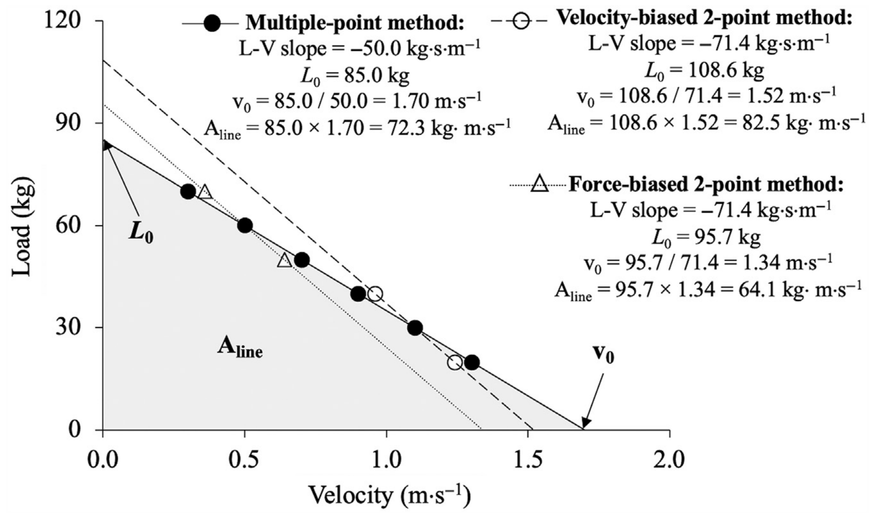

Figure 3 — Simulation of L–V relationships based on 6 experimental points (*multiple-point method*; solid line and filled dots) and 2-point methods based on the combination of 2 light (*velocity-biased 2-point method*; long-dashed line and empty dots) and 2 heavy (*force-biased 2-point method*; dotted line and empty triangles) experimental points. Note that, in comparison to the multiple-point method, the velocity of the lightest and heaviest loads of each 2-point method was arbitrarily decreased and increased by 0.06 $m \cdot s^{-1}$, respectively. Of note is that despite the same absolute changes in velocity and same L–V slope for both 2-point methods, the differences in L_0 with respect to the multiple-point method were greater using the *velocity-biased 2-point method* ($\Delta = 27.7\%$) than the *force-biased 2-point method* ($\Delta = 12.6\%$), whereas the differences in v_0 were greater using the *force-biased 2-point method* ($\Delta = -21.2\%$) than the *velocity-biased 2-point method* ($\Delta = -10.6\%$). The gray area represents the area under the L–V relationship line of the multiple-point method. A_{line} indicates area under the L–V relationship line; L_0, maximal theoretical load; L–V, load–velocity; v_0, maximal velocity.

between the lowest and highest experimental points is larger and (2) there is a lower distance from the heavier experimental point to F_0. Similar findings have been reported for vertical jumps for which the reliability of jump height is known to be markedly reduced when it is lower than 10 cm,[44] and this could explain why the reliability of the F–V relationship parameters is also reduced when experimental points associated with jump height values lower than 10 cm are considered for the modeling of the F–V relationship.[45]

Regarding the estimation of the maximal neuromuscular capacities, it seems reasonable to speculate that a greater reliability could be obtained through the L–V relationship compared to the F–V relationship because the former is only affected by the variability in velocity (not load) and the latter is affected by the variability in both force and velocity. Finally, the importance of the reliability of the experimental points to obtain accurate estimates of the 1RM was confirmed by Pérez-Castilla et al[46] who reported that the velocity monitoring devices that are capable of recording mean velocity outputs with greater reliability, are also the devices that allow for the most accurate estimations of the bench press 1RM through the L–V relationship.[47] The results presented in this section collectively suggest that experimental points with low reliability (CV > 10%) should be avoided because they are expected to reduce the reliability and precision of the parameters estimated from both the F–V and L–V relationships.

Number of Experimental Points

A factor that has shown to have only minor effects on the reliability and accuracy of the main outcomes derived from the F–V and L–V relationships is the number of experimental points considered for the modeling of the F–V and L–V relationships. This is because the 2 distal experimental points of the F–V and L–V relationships have a greater influence on the final outcomes derived from these relationships than the intermediate experimental points (see Figure 4 for a simulation).

García-Ramos and Jaric[48] carried out the most comprehensive study to answer the question of whether the number or distance between experimental points is more important to maximize the reliability of the F–V relationship parameters. Force and velocity outputs of 63 subjects were collected during the bench press throw exercise against 6 loads (20%–30%–40%–50%–60%–70% of 1RM). Thereafter, 3 different F–V relationships were constructed: (1) standard multiple-point method (20%–30%–40%–50%–60%–70% of 1RM), distal 2-point method (20 %–70% of 1RM), and proximal multiple-point method (30%–40%–50%–60% of 1RM). The main finding of the study is that the reliability of the F–V relationship parameters was generally greater for the distal 2-point method than for the proximal multiple-point method, confirming that the distance between experimental points is more important than the number of them. In addition, the reliability of the F–V relationship parameters was comparable for the distal 2-point method and the standard multiple-point method (CV differences ≤1.0%), suggesting that the number of experimental points presents trivial effects on the reliability of the F–V relationship parameters provided that the distance between the experimental points represented by the lightest and heaviest loads remains constant. Regarding the possibility of estimating the 1RM through the individualized L–V relationship, it has also been shown in multiple exercises that, provided that the heaviest load is the same for both methods, the 1RM can be estimated with comparable accuracy by the multiple- and 2-point methods.[28,34,49] These results collectively suggest that instead of focusing on testing many different loads/velocities, more attention should be paid to selecting the 2 most optimal distal experimental points.

Experimental Support to the 2-Point Method Applied Under Field Conditions

In 2018, Prof Slobodan Jaric and I summarized the scientific evidence showing that the 2-point method, compared with the

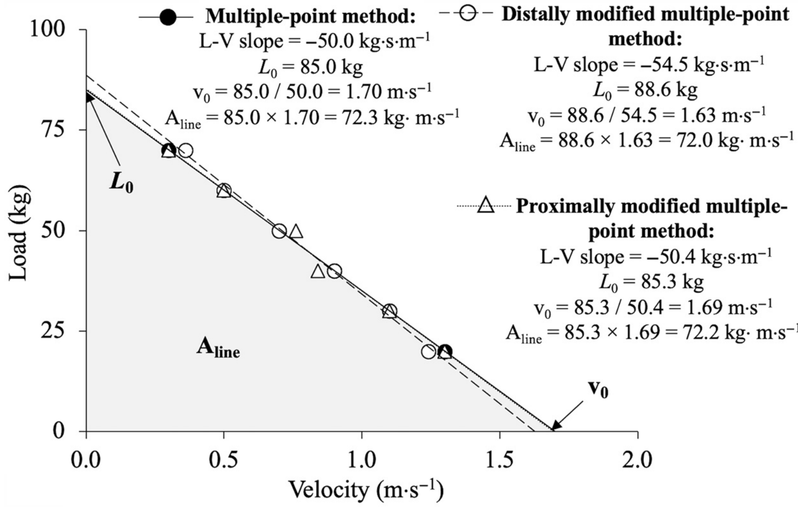

Figure 4 — Simulation of an L–V relationship based on 6 experimental points (*multiple-point method*; solid line and filled dots). The modifications of the L–V relationship consisted of decreasing (for the lightest load) and increasing (for the heaviest load) by 0.06 m·s^{-1} the 2 most distal (*distally modified multiple-point method*; dashed line and empty dots) or 2 most proximal (*proximally modified multiple-point method*; dotted line and empty triangles) experimental points. Note that the differences with respect to the *multiple-point method* were always greater for the *distally modified multiple-point method* (Δ = 4.2%, –4.4%, –0.3%, and 9.0% for F_0, v_0, A_{line}, and L–V slope, respectively) than for the *proximally modified multiple-point method* (Δ = 0.3%, –0.4%, 0.0%, and 0.7% for F_0, v_0, A_{line}, and L–V slope, respectively). The gray area represents the A_{line} of the multiple-point method. A_{line} indicates area under the L–V relationship line; F_0, maximal theoretical force; L_0, maximal theoretical load; L–V, load–velocity; v_0, maximal velocity.

multiple-point method, is capable of providing the outcomes of the F–V and L–V relationships with comparable reliability and high concurrent validity.[7] Later studies from different laboratories did not challenge those findings provided that the experimental points associated to the lightest and heaviest loads were the same for the multiple- and 2-point methods,[33,49–51] otherwise it makes no sense to compare the feasibility between methods because the results would be affected by the factors described in sections "Distance Between the 2 Extreme Experimental Points," "Distance From the Variable of Interest to the Closest Experimental Point," and "Reliability of the Experimental Points." However, a major gap in our latest review was that, until 2018, the feasibility of the 2-point method had only been explored through testing procedures based on multiple (more than 2) loads. This is problematic because (1) it has misled users into thinking that implementing the 2-point method inevitably requires testing more than 2 loading/velocity conditions and (2) obtaining the data from the same test could have artificially inflated the concurrent validity of the 2-point method. To solve these limitations, 4 subsequent studies have implemented in separate sessions the 2-point method under field conditions (only 2 different conditions applied in the testing protocol) and the standard multiple-point method.[39,52–54] These studies have shown that the outcomes derived from the 2-point method (1) present a comparable reliability, (2) are highly correlated, and (3) tend to be of greater magnitude compared to the same outcomes derived from the multiple-point method (Table 1).

The 2-point method was proposed as a quicker and less prone to fatigue procedure for assessing the F–V and L–V relationships.[1,2,7] While the quickness of the procedure is obvious (it takes less time to evaluate 2 than 6 loads), it was necessary to verify experimentally that the 2-point method applied under field conditions induces less fatigue than the multiple-point method. This assumption was verified several different studies that have shown that the main outcomes of the F–V and L–V relationships tend to be of greater magnitude when they are obtained by the 2-point method compared to the multiple-point method.[39,52–54] The greater magnitude of the outcomes derived from the F–V and L–V relationships obtained by the 2-point method is positive since (1) it could more faithfully represent the maximum mechanical capacities and (2) it could interference less with performance when a training session is scheduled immediately after completing the testing procedures. In addition, since the generalizability of the outcomes of the F–V relationship between different functional tasks is low,[18,32,55,56] researchers and practitioners could be interested in evaluating different tasks within the same session. Therefore, the problem of the duration of the tests and associated fatigue of the multiple-point method could be accentuated when several exercises are evaluated within the same testing session. This could be a direction for future research because, so far the advantages of the 2-point method applied under field condition with respect to the multiple-point method have only been demonstrated when 1 exercise was applied in the testing session, but the advantages are expected to be magnified when multiple exercises are tested within the same session.

Limitations of the 2-Point Method Applied Under Field Conditions

The most frequently heard limitation is: how is it possible to select the 2 optimal experimental points when subjects are tested for the first time? This is a recurring problem for researchers, but not so much for coaches who frequently work with the same athletes. The most feasible solution is the application of the 3-point method! Note that the most common concern is the selection of the heaviest load in order to be close enough to the variable of interest (eg, 80%–90%1RM), but avoiding, for safety reasons, to go beyond the variable of interest (eg, 115% of 1RM). In this situation, after completing a full warm-up, athletes are instructed to perform 3 repetitions against the lightest load and 2 repetitions against an

Table 1 Comparison of the Main Outcomes Derived From the F–V and L–V Relationships When Obtained by the Multiple-Point (More Than 2 Loads Applied in the Testing Procedure) and the 2-Point Method Applied in Field Conditions (Only 2 Loads Applied in the Testing Procedure)

Study	Protocol	Main findings
García-Ramos et al[52]	Ten men completed 4 sessions using the leg cycle ergometer exercise to determine the F–V relationship parameters: • Two sessions using the multiple-point method (6 loads applied in an incremental order) • Two sessions using the 2-point method (only the lightest and heaviest loads applied). Before and after each testing method, the participants performed a maximal sprint against the optimal load.	• The F–V relationship parameters were obtained with comparable reliability by the multiple- (CV range: 1.91%–3.94%; ICC range: .72–.99) and 2-point (CV range: 1.41%–4.62%; ICC range: .76–.95) methods. • The F–V relationship parameters were highly correlated between both methods ($r = .88$ for F_0, .86 for v_0, and .91 for P_{max}). • The magnitude of F_0 ($\Delta = 6.0\%$) and P_{max} (6.0%) was greater for the 2-point compared with the multiple-point method ($P < .05$) with no significant differences observed for v_0 ($\Delta = -0.5\%$; $P = .570$). • The testing procedure based on multiple loads (pretest: 1083 [162] W; posttest: 1029 [159] W; $P = .001$), but not the 2-point method (pretest: 1074 [152] W; posttest: 1058 [149] W; $P = .133$), elicited an acute decrease in the capacity to generate power against the optimal load.
Janicijevic et al[39]	Twelve men completed 2 sessions of the SJ exercise, one using a 90° knee angle and another using the self-preferred knee angle, and the F–V relationships were assessed by the force plate and Samozino approaches. In each session, subjects performed 2 blocks against 3 loads that were applied in the following order: 0.5 kg (L1), 61.4 (12.4) kg (L3; load that allowed a jump height of ≈10 cm), and 31.0 (6.3) kg (L2; equidistant intermediate load). Only L1 and L3 were used for the 2-point method, and L2 was added to the multiple-point method.	• The multiple- (averaged CV = 6.52%) and 2-point (averaged CV = 6.90%) methods provided the F–V relationship parameters with comparable reliability. • The F–V relationship parameters were highly correlated between both methods ($r > .99$). • Trivial differences between the multiple- and 2-point methods were detected for F_0 ($\Delta = 0.8\%$), v_0 ($\Delta = -1.7\%$), and P_{max} ($\Delta = -0.8\%$).
Miras-Moreno et al[54]	Twenty-three men completed 2 sessions of the bench pull exercise, one using the concentric-only technique and another using the eccentric concentric technique, and the L–V relationships variables (L_0, v_0, and A_{line}) were assessed. Four loads were applied in the following order: 14 kg (L1), 72.0 (10.9) kg (L4; 85% of the 1RM), 33.2 (3.6) kg (L2; equidistant intermediate light load), and 51.9 (7.5) kg (L3; equidistant intermediate heavy load). Only L1 and L4 were used for the 2-point method, while L2 and L3 were added to the multiple-point method.	• The L–V relationship variables were highly correlated between both methods ($r = .97$–.98 for L_0, .99–1.00 for v_0, and .98–.99 for A_{line}). • The magnitude of L_0 ($\Delta = 5.7\%$), v_0 ($\Delta = 1.9\%$), and A_{line} ($\Delta = 7.9\%$) were greater when obtained by the 2-point method compared to the multiple-point method ($P < .05$).
Miras-Moreno et al[53]	Twenty-three men completed 4 sessions using the Smith machine bench pull exercise to determine the L–V relationship variables: • Two sessions using the multiple-point method (6 loads applied in an incremental order). • Two sessions using the 2-point method (only the lightest and heaviest loads applied).	• The 2-point method provided with greater reliability than the multiple-point method both L_0 (CV = 2.22% and 3.32%, respectively) and v_0 (CV = 2.47% and 4.00%, respectively), while the reliability of A_{line} (CV = 2.69% and 2.59%, respectively) was comparable for both methods. • The L–V relationship variables were highly correlated between both methods ($r = .95$–.97 for L_0, .82–.84 for v_0, and .94–.95 for A_{line}). • The magnitude of L_0 ($\Delta = 5.5\%$), v_0 ($\Delta = 3.4\%$), and A_{line} ($\Delta = 9.9\%$) were greater when obtained by the 2-point method compared with the multiple-point method ($P < .05$).

Abbreviations: 1RM, 1-repetition maximum; A_{line}, area under the L–V relationship line; CV, coefficient of variation; F_0, maximal theoretical force; F–V, force–velocity; ICC, intraclass correlation coefficient; L_0, maximal theoretical load; L–V, load–velocity; P_{max}, maximal power output; r, Pearson correlation coefficient; SJ, squat jump; v_0, maximal velocity. Note: $\Delta(\%) = $ (2-point method − multiple-point method)/multiple-point method × 100. Note that only in the study of García-Ramos et al[52] and Miras-Moreno et al,[53] the multiple- and 2-point methods were implemented in separate sessions, while in the 2 remaining studies the intermediate loads were applied after the 2-point method was applied under field conditions.

intermediate load far enough from both the lightest measured load and the heaviest expected load. The estimation of the heaviest expected load can be derived from inquiring about the subject's prior experience with the exercise, closely observing their warm-up procedure that typically involves a range of loads and analyzing their mechanical performance against the lightest load. Once these repetitions are performed, a 2-point method can be constructed to estimate the load that should be prescribed to locate the experimental point associated to the heaviest load in the desired portion of the F–V or L–V relationship (eg, at 110 rpm in the leg cycle ergometer exercise, jump height of 10 cm, or 0.30 $m \cdot s^{-1}$ above the minimal velocity threshold to estimate the 1RM). After completing 1 to 2 repetitions with the heaviest load, the final F–V (or L–V) relationship should be modeled considering the 2 most representative experimental points, which will be the 2 most distant points for the assessment of the maximal neuromuscular capacities but for 1RM prediction they can be the intermediate and heavier experimental points. Thereafter, in future testing sessions, only the 2 loads associated with the 2 most representative experimental points will be tested. It should be noted that the magnitude of these loads is not constant forever but must be modified when the characteristics of the experimental points deviate from the optimal ones. For example, if, as a result of training, an athlete is able to jump 15 cm with the heavier load, its magnitude must be increased to allow only a jump height of 10 to 12 cm.[45]

Practical Applications

This section provides practical guidelines for implementing the 2-point method under field conditions to determine the F–V and L–V relationships.

Warm-Up

One of the most common and fierce criticisms of the 2-point method is that it is potentially dangerous to perform a repetition against a light resistance (eg, unloaded jump) and immediately after perform another repetition against a heavy resistance (eg, jumping against an external load of 80 kg). Of course, this procedure is dangerous if athletes do not complete a proper warm-up preceding the test. However, our opinion is that the warm-up must be designed to guarantee that the subjects can develop their fullest potential with the 2 loads, which requires subjects to perform repetitions against loads similar or even greater than those used in the F–V and L–V tests.[39,52–54] There is a risk of underestimating performance against light loads (and consequently v_0) if these repetitions are somehow considered part of the warm-up.

Selection of the Loads

When the maximal neuromuscular capacities are tested through the F–V or L–V relationships, practitioners are encouraged to select 1 experimental point as close as possible to the velocity-intercept and another experimental point as close as possible to the force-intercept (or load-intercept). When estimating the 1RM through the individualized L–V relationship, it is very important that one experimental point (ie, the heaviest load) is located close to the minimal velocity threshold represented by the 1RM (mean velocity difference <0.35 $m{\cdot}s^{-1}$), while another experimental point (ie, the lightest load) should allow a mean velocity 0.40 to 0.60 $m{\cdot}s^{-1}$ faster than the heaviest load.[43] The reason of the 0.40 to 0.60 $m{\cdot}s^{-1}$ difference is to ensure a consistent slope of the L–V relationship, while avoiding very light loading conditions that could promote less reliable velocity output.[57] Finally, it is crucial to determine, for each exercise, whether there exists an upper or lower threshold beyond which the experimental points are obtained with significantly lower reliability. It is advisable to avoid collecting experimental points beyond these thresholds to ensure the reliability and precision of the parameters estimated from both the F–V and L–V relationships.

Sequence of the Loads

The order of application of the 2 loads should not meaningfully influence the outcomes of the F–V and L–V relationships provided that an appropriate warm-up has been performed. However, we tend to apply the loads more often in an incremental order because our subjects are more habituated, and also to minimize the effect of the greater fatigue that is expected to be induced by the heavier load.

Characteristics of the Trials

Three repetitions are generally performed against the light load and 2 repetitions against the heavy load. To more faithfully represent the maximal neuromuscular capacities the trial with the highest velocity or force with each load or velocity, respectively, should be used for the modeling of the relationships. However, when the reliability of the experimental points is not high (CV > 5%), the average value of different trials might be preferable. Augmented feedback should be provided immediately after performing each trial to increase subjects' motivation and optimize mechanical performance and data consistency.[58,59]

Conclusions

The linear-regression model should be the preferred choice for modeling the F–V and L–V relationships, not only because the experimental points that can be directly recorded in field testing fit a straight line almost perfectly, but also because it provides their main outcomes with the highest simplicity, reliability, accuracy, and apparent physiological meaning. In this regard, the 2-point method was proposed as a simplified (quicker and less prone to fatigue) testing procedure for modeling the linear F–V and L–V relationships compared to the traditionally applied multiple-point method. There is a strong theoretical basis and convincing experimental data that the 2-point method, compared to the multiple-point method, is capable of providing the outcomes of the F–V and L–V relationships with comparable reliability and high concurrent validity when (1) the experimental points considered by both methods come from the same test and (2) the 2-point method is constructed from the 2 most distal experimental points of the multiple-point method. There is also preliminary evidence showing that when the 2-point method applied under field conditions (only 2 different conditions applied in the testing protocol) and the standard multiple-point method are implemented in separate sessions, their outcomes (1) present a comparable reliability, (2) are highly correlated, and (3) tend to be of greater magnitude for the 2-point method. Although these results strongly support the use of the 2-point method to simplify the testing procedures of the F–V and L–V relationships, it is important that researchers and practitioners carefully select the 2 experimental points because the reliability and accuracy of the main outcomes derived from the F–V and L–V relationships are affected by the (1) distance between the 2 extreme experimental points, (2) distance from the variable of interest to the closest experimental point, and (3) reliability of the experimental points.

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