ORIGINAL ARTICLE

Assessment of the two-point method applied in field conditions for routine testing of muscle mechanical capacities in a leg cycle ergometer

Amador García-Ramos[1,2] · Milena Zivkovic[3] · Sasa Djuric[3] · Nikola Majstorovic[3] · Katarina Manovski[3] · Slobodan Jaric[3,4,5]

Abstract

Purpose The aim of this study was to compare the reliability and magnitude of the force–velocity (F–V) relationship parameters [maximum force (F0), maximum velocity (V0), F–V slope, and maximum power (P0)] obtained through the application of only two loads (i.e., two-point method) vs. six loads (i.e., multiple-point method).

Methods Ten physically active men (age 19.5 ± 0.9 years, body mass 79.0 ± 9.0 kg, height 183.9 ± 8.4 cm) conducted four testing sessions after a preliminary familiarization session with the leg cycle ergometer exercise. In a counterbalanced order, subjects performed two sessions of the multiple-point method (six loads applied for the F–V modeling) over 1 week and two sessions of the two-point method (only the lightest and heaviest loads were applied) over another week.

Results The main findings revealed that (I) the reliability of the F–V relationship parameters was very high and generally of comparable magnitude for both the multiple- [coefficient of variation (CV) range 1.91–3.94%; intraclass correlation coefficient (ICC) range 0.72–0.99] and two-point methods [CV range 1.41–4.62%; ICC range 0.76–0.95], (II) the magnitude of the same parameters obtained from both methods was highly correlated ($r > 0.80$), and (III) the P0 assessed from the multiple-point method was significantly lower than the obtained from the two-point method [$P = 0.041$; effect size (ES) 0.36] due to a significant decrease in F0 ($P = 0.039$; ES 0.41) with no significant differences observed for V0 ($P = 0.570$; ES -0.15).

Conclusions These results support the two-point method as a reliable, valid, and fatigue-free procedure of assessing the muscle mechanical capacities through the F–V relationship.

Keywords Force–velocity relationship · Maximum force · Maximum velocity · Maximum power

✉ Amador García-Ramos
  amagr@ugr.es

1 Department of Physical Education and Sport, Faculty of Sport Sciences, University of Granada, Granada, Spain

2 Department of Sports Sciences and Physical Conditioning, Faculty of Education, CIEDE, Catholic University of Most Holy Concepción, Concepción, Chile

3 The Research Centre, Faculty of Sport and Physical Education, University of Belgrade, Belgrade, Serbia

4 Department of Kinesiology and Applied Physiology, Biomechanics and Movement Science Graduate Program, University of Delaware, Newark, USA

5 Department of Human Motor Behavior, The Jerzy Kukuczka Academy of Physical Education in Katowice, Katowice, Poland

Abbreviations

A	Linear regression slope
CV	Coefficient of variation
ES	Cohen's d effect size
F_0	Regression parameter (F-intercept) depicting maximum force
F–V	Force–velocity
ICC	Intraclass correlation coefficient
L1	Load 1
L2	Load 2
L3	Load 3
L4	Load 4
L5	Load 5
L6	Load 6
P_0	Regression parameter [$(F_0 \times V_0)/4$] depicting maximum power
r	Pearson's correlation coefficient

rpm Revolutions per minute
V_0 Regression parameter (V-intercept) depicting maximum velocity

Introduction

The assessment of muscular function is of paramount importance in many fields from rehabilitation to high sports performance (Samozino et al. 2012; Cook et al. 2014). A test that has been frequently used to assess muscular function consists of the determination of the force–velocity (F–V) relationship (Jiménez-Reyes et al. 2014; Sreckovic et al. 2015; García-Ramos et al. 2017b; Zivkovic et al. 2017a). It is known that the force and velocity of individual muscle groups are inversely related and they approximately follow a hyperbolic F–V relationship (Hill 1938). However, during multi-joint tasks (e.g., jumping, running, cycling, etc.) the inverse relationship between force and velocity typically fits a linear model (Jaric 2015). The standard procedure for testing the F–V relationship during multi-joint tasks consist of performing trials of the tested task under different loading conditions (Jiménez-Reyes et al. 2014; Sreckovic et al. 2015; García-Ramos et al. 2017b). Each loading condition provides distinctive values of force and velocity (higher load = higher force and lower velocity) that can be modeled by a linear regression to determine the F–V relationship parameters depicting the maximum capacities of the muscles to produce force (F_0), velocity (V_0), and power (P_0) (Jaric 2015). The slope of the linear F–V relationship is also commonly reported and its value seems to have strong applications for training prescription when aiming to enhance ballistic performance (Samozino et al. 2012; Jiménez-Reyes et al. 2017). Therefore, the four F–V relationship parameters (i.e., F_0, V_0, F–V slope, and P_0) are commonly evaluated not only to obtain a comprehensive examination of muscular function, but also to prescribe individualized resistance training programs.

The F–V relationship during multi-joint exercises has been traditionally determined from the force and velocity data obtained under multiple (more than two) loads (multiple-point method). These studies have confirmed that the F–V relationship obtained in exercises such as vertical jumps (Cuk et al. 2014), cycling (García-Ramos et al. 2017b), sprinting (Cross et al. 2017), bench press throw (Rahmani et al. 2018), etc., is highly linear. Due to the strong linearity of the F–V relationship, Jaric (2016) hypothesized that the F–V relationship could be accurately determined from the force and velocity data collected under only two loads (two-point method). Previous studies have already confirmed the similar reliability and high validity of the F–V relationship obtained from the two-point method compared to the multiple-point method (García-Ramos et al. 2017b; Grbic

et al. 2017; Pérez-Castilla et al. 2017; Dobrijevic et al. 2017; Zivkovic et al. 2017b). However, it is important to highlight that in all previous studies the two-point method was evaluated from a testing procedure based on multiple loads. Therefore, it remains unanswered whether the two-point method could also provide reliable and valid data when it is applied in field conditions (i.e., only two loads are applied in the protocol).

The two main benefits proposed for the two-point method as compared to the multiple-point method is that it is less time consuming and that it could induce less fatigue (Jaric 2016; García-Ramos and Jaric 2017). While the first benefit is obvious since the application of a lower number of loads inevitably reduce testing time, no study has compared any measurement of fatigue between both testing methods. It is reasonable to think that during a standard test in which multiple loads are applied in an incremental order there could be a progressive development of fatigue that could result in a decrease of performance with the heavy loads. Therefore, the potential effect of a multiple-load incremental loading test could be an underestimation of F_0 since its value is mainly determined from the data provided by the heavy loads. Similarly, the testing procedure based on multiple loads could also be counterproductive if it induces an acute decrease in maximal power production when a power-oriented resistance training session is programmed after the testing session. Therefore, it would be important to determine whether the magnitudes of the F–V relationship parameters obtained from the multiple-point method are underestimated as compared to the two-point method as well as to assess the effect of both testing procedures on maximal power production.

To explore the suitability of the two-point method in field conditions, we assessed on separate occasions the F–V relationship during the leg cycle ergometer exercise using both the standard testing procedure based on multiple loads and the quicker two-point method. Specifically, the main aims of the present study were to compare the reliability and magnitude of the F–V relationship parameters (F_0, V_0, F–V slope, and P_0) obtained through the application of the two-point method with respect to the same outcomes obtained from a multiple-point method based on six loading conditions. In addition, we also aimed to assess the acute effect of both testing procedures on the capacity to generate power against the optimal load. We hypothesized that (I) the reliability of the outcomes of the F–V relationship would not differ between the multiple- and two-point methods, (II) very large correlations would be observed for the same F–V relationship parameters obtained from both methods, (III) the two-point method would provide higher F_0 and P_0 than the multiple-point method, and (IV) the testing procedure based on multiple loads, but not the testing procedure based on two loads, would elicit a decrease in the capacity to generate power against the optimal load.

Method

Participants

Ten male physical education students volunteered to participate in this study (age 19.5 ± 0.9 years, body mass 79.0 ± 9.0 kg, height 183.9 ± 8.4 cm). They were free from health problems or recent musculoskeletal injuries that could compromise the tested performance. Participants were instructed to avoid any additional strenuous exercise over the course of the study. They were informed of the study procedures and signed a written informed consent form prior to initiating the study. The study protocol adhered to the tenets of the Declaration of Helsinki and was approved by the Institutional Review Board.

Study design

A counterbalanced crossover design was used to explore the reliability and validity of a quick testing procedure based on the application of only two loads (i.e., two-point method) for determining the F–V relationship of lower body muscles in the leg cycle ergometer exercise. Participants attended to the laboratory on five occasions during three consecutive weeks. All sessions were separated by at least 48 h. First session was used to familiarize the participants with the leg cycle ergometer exercise as well as to determine the maximum (i.e., the heaviest load used for the F–V modeling) and optimal (i.e., the load that maximizes power) loads. In a counterbalanced randomized order, the F–V relationships of the participants were determined in two sessions using the multiple-point method (six loads applied), and in another two sessions from the two-point method (only two loads applied). To assess the effect of both testing procedures on maximal power production, before and after each testing method the participants performed a maximal sprint against the optimal load that was calculated in the first session. Testing sessions were performed at the same time of the day for each participant (± 1 h) and under similar environmental conditions (~ 22 °C and $\sim 60\%$ humidity).

Preliminary session (session 1)

Height (Seca 202, Seca Ltd., Hamburg, Germany) and body mass (In Body 720; USA) were assessed at the beginning of the session. Afterwards, participants were familiarized with the leg cycle ergometer testing procedure. The first step was to set the positions of the saddle and handlebar of the Monark leg cycle ergometer (Monark 894E, Varberg, Sweden). Although participants were allowed to self-select the most comfortable positions of the saddle and handlebar, a skilled investigator ensured that these positions were similar to the ones previously recommended to maximize sprint performance (Peveler et al. 2007). The same positions of the saddle and handlebar for each participant were maintained in all testing sessions. A standard crank length of 170 mm was chosen to provide standard testing conditions (Dorel et al. 2010). Following a standardized warm-up (5 min of pedaling at a low intensity and one sprint of 6 s against 2 kg), participants performed one sprint against four different loading conditions (2.5, 5, 7.5, and 10% of body mass) that were applied in an incremental order (details of the sprints procedure are provided in next subsection).

The load–velocity and load–power relationships were determined from the data collected during the first session. The maximum load applied during the testing sessions was individually adjusted for each participant. The linear load–velocity relationship was used to determine the load associated with a cadence of 120 rpm, and this was the heaviest load applied during the remaining four sessions. This decision is justified because the reliability of the F–V relationship could be compromised when a cadence below 110 revolutions per minute (rpm) is used (García-Ramos et al. 2018). The parabolic load–power relationship was used to determine the optimal load (i.e., the load that maximizes power output). The optimal load was applied before and after each testing procedure to assess the possible effects of both testing methods on maximal power production.

Testing sessions (session 2–5)

Participants were evaluated in two separate sessions over 1 week on the multiple-point method and two times more in another week using the two-point method (Fig. 1). All testing sessions began with the same standardized warm-up procedure described for the first session. After 5 min of passive rest, participants were asked to perform a sprint against the optimal load. Afterwards, they completed either sprints against six different loads (multiple-point method) or against only two loads (two-point method). Finally, participants performed one additional sprint against the optimal load. The rest period between two consecutive sprints was 5 min.

The minimum load (L1) was 2 kg for all participants. The maximum load (L6) was individually assigned as the load associated with a cadence of 120 rpm (8.6 ± 1.1 kg in our study sample). The four intermediate loads were equidistantly distributed between L1 and L6 (L2 $= 3.3 \pm 0.2$ kg, L3 $= 4.6 \pm 0.5$ kg, L4 $= 5.9 \pm 0.7$ kg, and L5 $= 7.3 \pm 0.9$ kg). Note that while for the multiple-point method the six loads were used, for the application of the two-point method only L1 and L6 were used. The optimal load was 8.8 ± 1.1 kg. The loads used for the F–V modeling were always applied in an incremental order to elucidate whether the expected progressive development of fatigue during the multiple-point

Fig. 1 Overview of the experimental protocol of a representative participant. The minimum load was the same for all participants, while the maximum load was individually selected as the load associated with a cadence of 120 rpm. Note that the multiple- and two-point methods were performed in a counterbalanced randomized order. Note also that the session duration would be reduced to ≈ 40 min (multiple-point method) and ≈ 15 min (two-point method) when the trials with the optimal load are not performed. *OL* optimal load that maximizes power output, *L* load
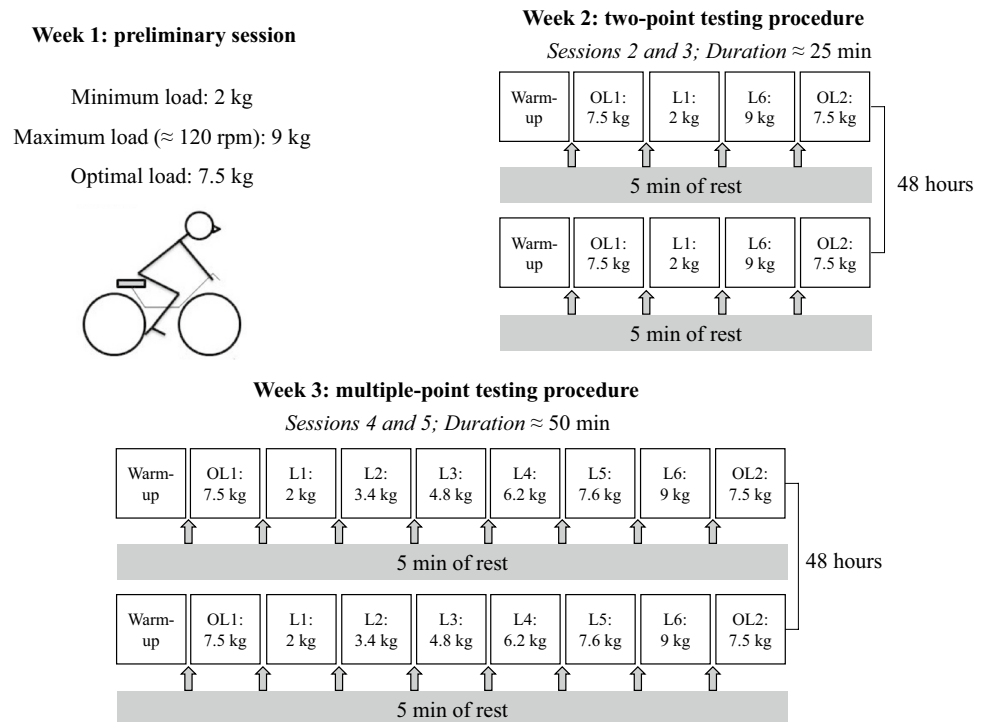
method could reduce performance with the heavy loads and consequently, underestimates F_0.

Participants initiated each sprint with their preferred leg and with the crank positioned at 45° forward. They were instructed to perform a maximal sprint from the beginning of the test (Pazin et al. 2011). To reduce the length of the acceleration phase, the load was introduced by the Monark 894E software when the participants reached a cadence of 130 rpm at the minimum load (i.e., L1), 120 rpm at L2, 110 rpm at L3, 100 rpm at L4, 90 rpm at L5, 80 rpm at L6, and 75 rpm at optimal load (García-Ramos et al. 2018). Participants were vigorously encouraged to produce the highest acceleration possible from the very beginning of the sprint to reach maximum pedaling cadence (the acceleration phase lasted about 2 s) and to maintain maximum pedaling cadence during the following 4 s. Participants remained seated on the saddle during all sprints and toe clips with straps were used to prevent the feet slipping off the pedals (Zivkovic et al. 2017b).

Data collection and analysis

The Monark 894E software was used to acquire power and the cadence data (rpm) from the 4 s interval with the maximum pedaling cadence of each sprint (García-Ramos et al. 2017b). To assess the corresponding linear measures, velocity was calculated from the cadence and the crank length (0.17 m), while force was calculated as power divided by velocity. The force and velocity data were used to determine the F–V relationship through the following equation: $F(V) = F_0 - aV$, in which F_0 represents the force intercept and a is the slope of the F–V relationship. The maximum velocity (V_0) corresponds to F_0/a. Finally, P_0 was calculated as $P_0 = F_0 \times V_0/4$. The data of both sessions were used for the reliability assessment. However, only the data of the first session of each method were considered for the remaining analyses.

Statistical analyses

Descriptive data are presented as means and standard deviations, while Pearson's correlation coefficients (*r*) are presented thought the median value and range. Prior to further statistical analysis, the normal distribution of the data (Shapiro–Wilk test) and the homogeneity of variances (Levene's test) were confirmed ($P > 0.05$). Paired sample's *T* tests and the Cohen's effect size were used to evaluate the systematic bias in the magnitude of the four F–V relationship parameters between both testing sessions conducted with the same method. The standard error of measurement was expressed in relative terms through coefficient of variation (CV), the intraclass correlation coefficient (ICC) and the corresponding 95% confidence interval were calculated to assess the reliability. The magnitudes of the F–V relationship parameters were compared (paired sample's *T* tests and ES) and correlated (*r*) between the multiple- and two-point methods. Finally, a two-way repeated measures ANOVA [test (pre-test vs. post-test) × method (multiple-point vs. two-point)]

with Bonferroni post hoc test was conducted to assess the acute effect of both testing methods on the capacity to generate power against the optimal load. The reliability analysis was performed by means of a custom spreadsheet (Hopkins 2000), while SPSS (version 22.0: SPSS, Inc., Chicago, IL, USA) was used for all other analyses. Alpha was set at 0.05.

Results

The F–V relationships obtained from the multiple-point method were strong and linear independently of whether obtained either from the data averaged across the participants ($r \geq 0.99$; Fig. 2) or from the individual force and velocity data ($r = 1.00$ [0.99, 1.00]).
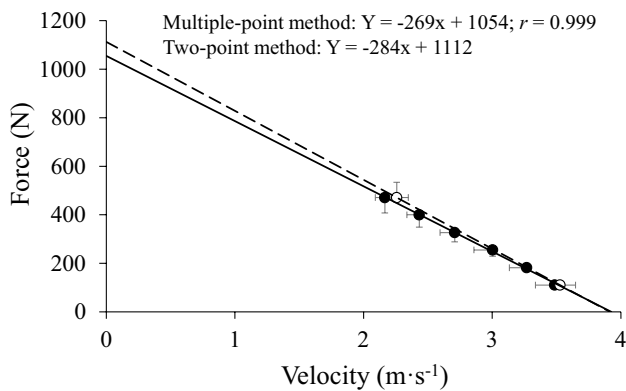

Multiple-point method: Y = -269x + 1054; r = 0.999
Two-point method: Y = -284x + 1112

Fig. 2 Force–velocity relationships obtained from the averaged across the participants force and velocity data for the multiple- (filled dots and solid line) and two-point (empty dots and dashed line) methods. The equation and the corresponding Pearson's correlation coefficients (r) are shown. Note that the two-point method cannot provide the correlation coefficients

The reliability of the F–V relationship parameters was high (CV < 5%) and generally of comparable magnitude for the multiple- and two-point methods (Table 1). The only meaningful difference in reliability was observed for P_0 that was obtained with a higher absolute reliability from the multiple-point method (CV 1.93%) as compared to the two-point method (CV 4.29%).

The magnitude of the F–V relationship parameters obtained from the multiple- and two-point methods was highly correlated (all $r > 0.80$; Fig. 3). However, P_0 obtained from the multiple-point method was significantly lower than the obtained from the two-point method ($P = 0.041$; ES 0.36) due to a decrease in F_0 ($P = 0.039$; ES 0.41).

The two-way ANOVA conducted on the power output produced against the optimal load revealed a main effect of test ($F = 12.8$, $P = 0.006$) as well as a test × method interaction ($F = 24.8$, $P = 0.001$), while the main effect of method did not reach statistical significance ($F = 1.1$, $P = 0.319$). Post hoc analyses revealed that the testing procedure based on multiple loads (pretest 1083 ± 162 W; post-test 1029 ± 159 W; $P = 0.001$; ES -0.34), but not the two-point method (pretest 1074 ± 152 W; post-test 1058 ± 149 W; $P = 0.133$; ES -0.10), elicited an acute decrease in the capacity to generate power against the optimal load.

Discussion

This study was designed to explore the suitability of a quick testing procedure based on the application of only two loads (i.e., two-point method) to determine the F–V relationship in the leg cycle ergometer exercise. The reliability and magnitude of the F–V relationship parameters as well as the acute decrease in maximal power output were compared between a standard testing procedure based on the application of six loads (i.e., multiple-point method) and the two-point

Table 1 Reliability of the force–velocity relationship parameters obtained from the multiple- and two-point methods during the leg cycle ergometer exercise

Parameter	Method	Session 1	Session 2	P	ES	SEM	CV (95% CI)	ICC (95% CI)
F_0 (N)	Multiple-point	1049 ± 134	1024 ± 146	0.054	−0.18	25.7	2.48 (1.71, 4.53)	0.98 (0.90, 0.99)
	Two-point	1112 ± 170	1084 ± 168	0.208	−0.17	46.5	4.23 (2.91, 7.73)	0.94 (0.79, 0.99)
V_0 (m s^{-1})	Multiple-point	3.94 ± 0.16	4.02 ± 0.10	0.036	0.63	0.08	1.91 (1.31, 3.49)	0.72 (0.22, 0.92)
	Two-point	3.92 ± 0.08	3.97 ± 0.12	0.081	0.47	0.06	1.41 (0.97, 2.58)	0.76 (0.30, 0.94)
F–V slope (N s m^{-1})	Multiple-point	267 ± 35	255 ± 36	0.027	−0.34	10.3	3.94 (2.71, 7.19)	0.94 (0.77, 0.98)
	Two-point	283 ± 41	273 ± 43	0.110	−0.25	12.9	4.62 (3.18, 8.44)	0.93 (0.74, 0.98)
P_0 (W)	Multiple-point	1035 ± 143	1031 ± 153	0.685	−0.03	20.0	1.93 (1.33, 3.53)	0.99 (0.95, 1.00)
	Two-point	1093 ± 179	1077 ± 173	0.476	−0.09	46.5	4.29 (2.95, 7.83)*	0.95 (0.81, 0.99)

F_0 maximum force, V_0 maximum velocity, F–V slope slope of the force–velocity relationship, P_0 maximum power, P P value, ES Cohen's d effect size [(session 2 mean − session 1 mean)/SDboth], SEM standard error of measurement, CV coefficient of variation, ICC intraclass correlation coefficient, 95% CI 95% confidence interval

*Meaningful differences in reliability with respect to the multiple-point method (i.e., CV or ICC outside the 95% CI)
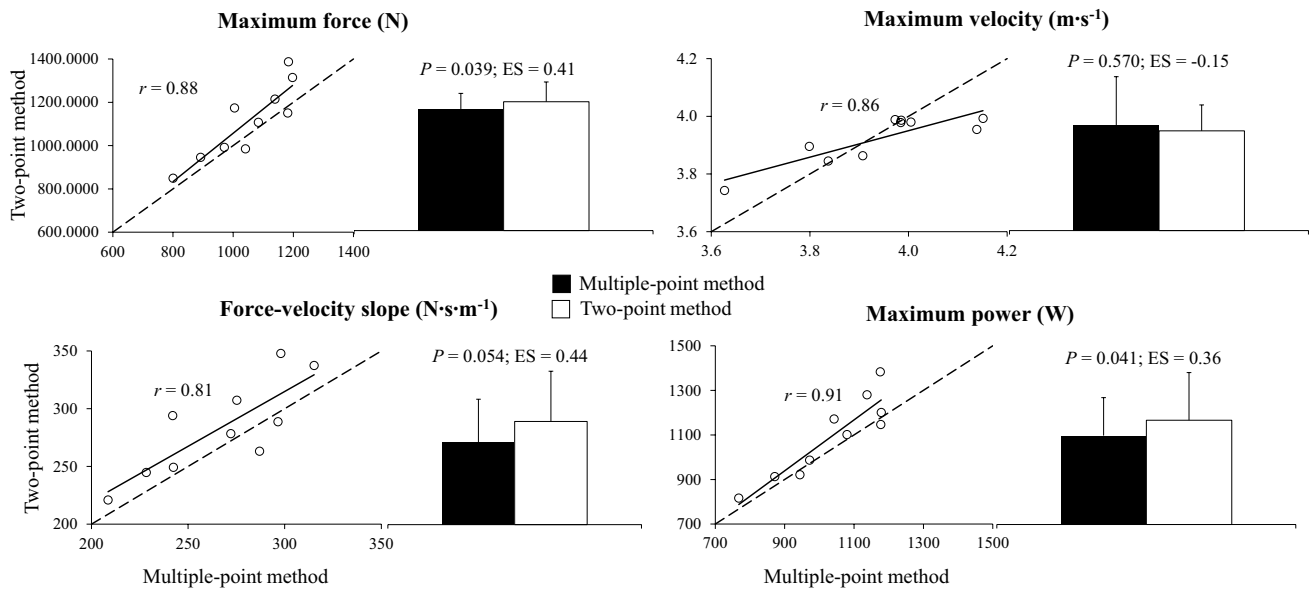
Fig. 3 Association (left hand graphs) and comparison (right hand graphs) of maximum force (upper left panel), maximum velocity (upper right panel), force–velocity slope (lower left panel), and maximum power (lower right panel) values obtained from the multiple-and two-point methods. *r* Pearson's correlation coefficient, *P P* value obtained from paired sample's *t* tests, *ES* Cohen's *d* effect size [(multiple-point mean − two-point mean)/SDboth]. The regression (straight line) and identity (dashed line) lines are depicted

method. The main findings of the present study revealed that (I) the reliability of the F–V relationship parameters was very high (CV < 5%) and generally of comparable magnitude for both the multiple- and two-point methods, (II) the magnitude of the same parameters obtained from the multiple- and two-point methods were highly correlated, (III) the P_0 assessed from the multiple-point method was significantly lower than the obtained from the two-point method due to a decrease in F_0 with no significant differences observed for V_0, and (IV) while the multiple-point method elicited an acute decrease in maximal power output, the maximal power capacity was preserved following the two-point method. These results support the two-point method as a reliable, valid, and fatigue-free procedure of assessing the muscle mechanical capacities through the F–V relationship.

Our first hypothesis was confirmed since the reliability of the four F–V relationship parameters was high for both testing methods. The high reliability of the two-point method observed in the present study is in consonance with previous studies that assessed its reliability from the data collected during testing protocols based on multiple loads (Pérez-Castilla et al. 2017; García-Ramos et al. 2018). However, as it was pointed out by García-Ramos and Jaric (2017), the distance of the experimental points to the axis intercepts decreased the reliability of the F–V relationship parameters. Namely, the CV was lower for V_0 than for F_0 since the experimental points were closer to the velocity intercept (see Fig. 2). Interestingly, while the reliability of V_0 was even slightly higher for the two-point method, the reliability of F_0

was higher for the multiple-point method. These results suggest that only one point would be needed when it is located close to the axis intercept. However, the inclusion of more points or using the average value of several trials performed with the same load could be preferable when the point is far from the axis intercept. In summary, although we should be careful not to use two experimental points that are far from the axis intercepts, the high reliability observed in the present study for the two-point method encourage its use for a quicker determination of the maximal muscle mechanical capacities through the F–V relationship of the leg cycle ergometer exercise.

Supporting our second hypothesis, very large correlations were observed for the magnitude of the F–V relationship parameters obtained from the multiple- and two-point methods (see Fig. 3). These results are also in line with previous studies that reported very high correlations for the magnitude of the same F–V relationship parameters obtained from the multiple- and two-point methods in a variety of exercises such as the vertical jump (*r* range 0.95–0.99) (Pérez-Castilla et al. 2016; Zivkovic et al. 2017b), bench press throw (*r* range 0.95–0.99) (Pérez-Castilla et al. 2017; Zivkovic et al. 2017b), leg cycle ergometer (*r* range 0.96–0.99) (García-Ramos et al. 2017b; Zivkovic et al. 2017b), bench press pull (*r* range 0.97–0.99) (Zivkovic et al. 2017b), running on a motorized treadmill (*r* range 0.89–0.98) (Dobrijevic et al. 2017), and leg extension isokinetic exercise (*r* range 0.90–0.97) (Grbic et al. 2017). Although the magnitude of the correlations was slightly weaker in our study (*r* range

0.81–0.91), it is important to highlight that this is the first study that has explored the association between the outcomes of the multiple- and two-point methods when they are implemented in separate testing sessions. These results are also in line with a previous study that reported a high level of agreement between the torque–velocity relationship modeled during the isokinetic knee extension exercise from the force values collected under three and eight velocity conditions (Lemaire et al. 2014). Therefore, the very large correlations observed in the present study, together with the results obtained in previous studies, further support the validity of the two-point method.

In agreement with our third hypothesis, we identified systematic bias in the magnitude of the F–V relationship parameters between the multiple- and two-point methods. The F_0, and consequently P_0, were higher for the two-point method, while V_0 remained unchanged. These results experimentally support for the first time one of the potential benefits commonly attributed to the two-point method; it could be less fatiguing than the multiple-point method (Jaric 2016; García-Ramos and Jaric 2017). The decrease in F_0, but not in V_0, during the multiple-point method should be explained by the application of the loads in an incremental order. Therefore, sport practitioners and researchers should be aware that the use of an incremental loading test together with the multiple-point method could underestimate F_0. Although the application of the loads in a randomized order during the multiple-point method could mitigate the underestimation of F_0, it should be noted that V_0 could be underestimated when the trials with the light loads are performed at the end of the testing procedure.

In line with our forth hypothesis, we observed a significant decrease in the power output produced against the optimal load after the multiple-point testing method, but not after the two-point testing method. This result could be important in practical settings since fitness tests are commonly performed just before a training session. Therefore, the two-point method should be recommended to minimize the degree of fatigue induced by the testing protocol, and consequently, to improve the quality of the subsequent training. Note also that the generalizability of the outcomes of the F–V relationship between different tasks (e.g., cycling, jumping, running, etc.) has been questioned (Bozic et al. 2013; Zivkovic et al. 2017a). In this regard, coaches could be interested in evaluating the F–V relationship of different tasks within the same testing session. The use of the two-point method would be especially useful when evaluating several tasks within the same testing session, not only because it is expected to induce less fatigue, but also because it would considerably reduce testing time.

Although the findings of the present study generally support the two-point method as a reliable, valid, and fatigue-free procedure, several questions related to its routine application in practical settings remain unanswered. One of the most important open questions is how to select the two optimal loads/velocities for the application of the two-point method. Previous studies assessing the F–V relationship have used the same loads/velocities for all participants (Grbic et al. 2017; García-Ramos et al. 2017a) or the loads have been relativized to body mass (Cuk et al. 2014) or strength levels (García-Ramos et al. 2016, 2018). Future studies should evaluate the procedures for selecting the optimal loads/velocities for a number of tasks (e.g., jumping, sprinting, bench press throw, isokinetic exercises, etc.) that could be routinely used in future for the assessment of capacities of the muscular system.

Conclusions

The two-point method, which consists of the application of only two different loads, represents a reliable, valid, and fatigue-free procedure of assessing the muscle mechanical capacities through the F–V relationship during the leg cycle ergometer exercise. To obtain an accurate F–V relationship in the leg cycle ergometer exercise through the two-point method, we recommend to apply a light load associated with a cadence of approximately 180–200 rpm and one heavy load associated with a cadence of approximately 110–125 rpm. The two-point method presents worthy practical applications since it provides the same information than protocols based on multiple loads, but considerably reducing testing time and the associated fatigue.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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