VI International Conference on Computational Bioengineering
ICCB 2015
M. Cerrolaza and S.Oller (Eds)

THE USE OF THE COEFFICIENT OF VARIATION FOR COMPARISON OF FORCE-TIME CURVES FROM HANDGRIP TESTS

JOSÉ MARQUES NOVO JR.*†, RENATO DE SOUZA LIMA JR.† AND CAIO SADAO MEDEIROS KOMINO†

*Laboratory of Innovation and Entrepreneurship for Assistive Technology, Sport and Health
Physical Education Department - Federal University of São Carlos-UFSCar
Rodovia Washington Luis, km235/SP310
CEP:13565-905 São Carlos/SP/Brazil
e-mail: marques.novojr@ufscar.br web page: http://www.ufscar.br

†Graduate Inter Bioengineering Program - São Paulo University-USP
São Carlos/SP/Brazil
email: renatosljf@hotmail.com, caio.komino@usp.br

Key words: Force-time curves, coefficient of variation, curve comparison, handgrip tests, biomechanic method

Abstract. The aim of this study was identify some characteristics of the Variation Coefficient (CV) applied to the force-time curves obtained from six handgrip tests (5s isometric test) with four subjects. This work shows the CV within the 0-1s interval, which holds the maximum force value. The CV values are arranged as a time series data, and the analysis are made by two steps: with all curves and without an anomalous curve, identified by graphical criteria. The CV´s are graphically exhibited and their lowest values were considered for measuring "similarities" of the curves. Thus, these procedures indicate that the mean curve is the best parameter for representing the performance of the subject in the handgrip test.

1 INTRODUCTION

Different methodologies, aiming at a higher reliability on the analysis of the data obtained in evaluation tests on muscular force (both quantity and qualitatively), are mentioned in this field literature. Among these mentions, we can quote the exploratory analysis through graphic methods [1], [2]. Recently, some studies that explore graphic tools of diagnosis have been applied to these signs, such as: the force-time chart itself, the differentiation and mitigation procedures, the function of autocorrelation and mathematical models identification [3], [4]. [5], [6], [7]. However, the adjustment of these models to the signs of force hasn't been enough to identify "similarities" or "verisimilitude" of force-time curves.

The use of Coefficient of Variation (CV), determined by the relation between the standard patterns and its respective mean values, has been proposed by WINTER [8] and also verified in other areas [9] as well as in investigations of this sort of data in the sense of making possible to compare and to estimate the accuracy of experiments. In order to do so, it has been common the use of limits the distribution of the CV values as follows: low (<10% or $\leq \bar{x}+s$), mean (between 10% and 20% or $\bar{x}-s<\text{CV}\leq \bar{x}+s$), high (between 20% and 30% or $\bar{x}+s<\text{CV}\leq \bar{x}+2s$), very high (above 30% or $\text{CV}\geq \bar{x}+2s$). According to GILL [9], CV values are pertinent within the ratio from 5 to 50% and values below 1% are rare.

This study proposes to apply the CV definition to each instant of the force signs (time series) focusing at identifying the behavior of this series in relation to the force-time curves and to the limits of its distribution.

2 MATERIALS AND METHODS

The data used in this study have been obtained through the following protocol: sitting subject and previous warming up of the hand and the arm involved. Subject with their shoulder in an ordinary position (90° elbow, neutral position of the wrist, forearm supported by the chair which us appropriated to the tests.) Following the commands of the researcher, the subjects executes a maximum voluntary contraction of the hand (clench mode) for up to 5 seconds. Six attempts were conducted with intervals of 1.5 minute. The force-time curves were obtained from each one of these attempts. The signs were sampled at a frequency of 420 Hz with 4 healthy subjects without any lesion, trauma or pathology in their tested hands. The subjects were 2 men and 2 women, (24.5 ± 3.1 years old). From the curves obtained during the tests was identified the point of initial effort for each curve, immediately after the stage of pre-load (the load corresponding to the value at t=0s, Figure 1), using the technique proposed by Amaral et al. [10,11].

The CV definition was applied to the force-time curves, which represents the standard pattern as a percentage of the mean and that is calculated using the following formula:

$$CV_t = \frac{s_t}{\bar{x}_t} \times 100$$

where s is the square root of the residual variance and $\bar{x}$ is the value mean of the force in all the curves, at every t instant.

For more signs of force used, it has been estimated the mean values, standard deviation and coefficient of variation for each instant of time which resulted in time series of 420 samples (during one second). The estimates of the series have been obtained in two steps: the first one using all signs of force and the second being apart from one of the six curves for each subject that had less visual similarity (different form from the rest) so it could be possible to ascertain possible changes in the behavior of the CV curves.

3 RESULTS AND DISCUSSION

The charts shown correspond to one of the subjects part of this test. The procedures for the identification of the CV curves features are presented in the figures and were equally applied to the data of every volunteer.

Figure 1 presents the six signs obtained in the tests performed displaying the values of force in the rapid phase (0 to 1 second period). It can be seen that one of the force-time curves doesn't follow the same behavior pattern of the rest which seems to indicate, at least by visual inspection, lack of similarity. Non-similarity of curves may indicate that the test wasn't performed according to the protocol required from the subject or even, in the case of patients, it may indicate an anomaly or pathology associated to the isometric effort. Thus, it is graphically possible to see the behavior of the mean curve due to the presence of a non-similar curve. The following text elucidates such procedure.

The mean value and the variation ratio referring to the association of mean ± standard deviation for every sign are displayed on Figure 2 where it is also observed the non-similar curve. In this picture it is possible to ascertain the distinction between this sign and the variation ratio obtained for every sign. This fact indicates the high CV value and low similarity between the sign displayed and other signs part of this conjunct. From the exclusion of the curve mentioned and taking into consideration only the other five curves inserted in the variation ratio, new time series were obtained for the mean value, standard deviation and CV whose curves are displayed in Figure 3. It can be observed that the variability of the variation ratio, for the interval between 0 and 0.4 second, is inferior to that one obtained for the variation ratio when every curve was being taken into consideration. By its own definition, the exclusion of the most discrepant values from the conjunct, contributes to the decreasing of CV values. This indicates that CV can be an identification parameter of the level of similarity between curves.

The values of the coefficients of variation, for the conjunct of all six signs and only for the remaining 5 signs, are displayed in Figure 4. It can be noted the changes in the CV curves apart from the isolated sign due to the variability reduction and the variation ratio of the standard deviation. From approximately 0.4 second the CV values found don’t seem to present significant differences.

Coefficients of variation present different decreasing ratios in both situations. From approximately 0.1 second the coefficients of variation (taking into consideration only the remaining 5 curves) are presented in the ratio between 10% and 5% as per GILL [9.] For the rest of the subjects, the times in which the CV values have reached the ration between 5% and 10% were: 0.7s; 0.5s and 1.0s. In every one of them, the procedure was the same: the exclusion of only one of the curves out of 6 conjuncts.

Mean CV values for definite intervals, considering all the signs and after the exclusion of the isolated sign, are displayed in Table 1 where the numerical results affirm the qualitative evaluations performed through the visual inspection. It is seen, though, that the percentage reduction obtained for the CV mean values in the intervals between zero and 0.3 seconds, after the exclusion of the isolated sign. For the other intervals, the proximity of the percentage affirms the concept of similarity between the force signs.

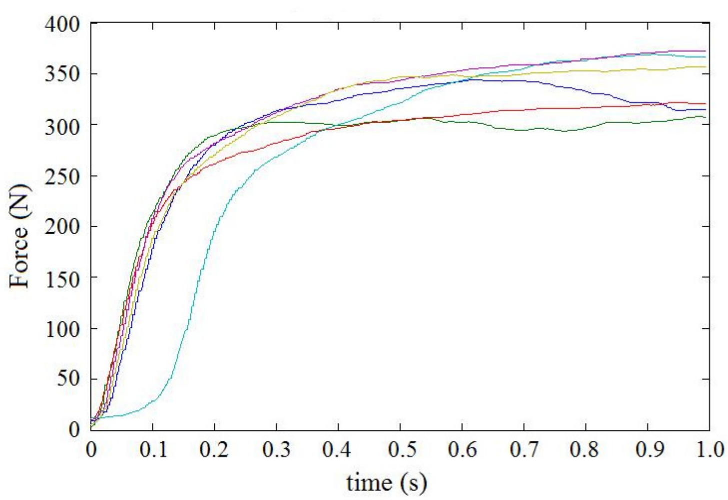

Figure 1: Six force-time curves of one of the subjects obtained in the tests of isometric clench of the hand. The chart displays only the interval 0-1 second (beginning of the test.)

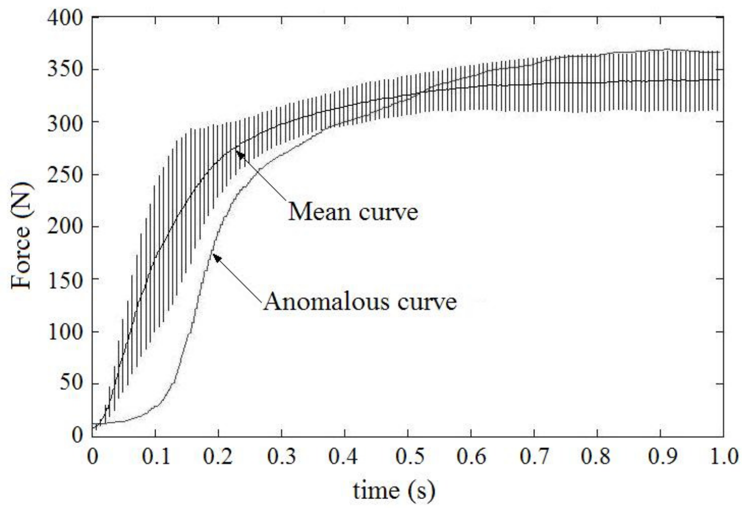

Figure 2: Mean values and its respective standard deviations for 0-1s interval considering the curve to be excluded (anomalous curve)

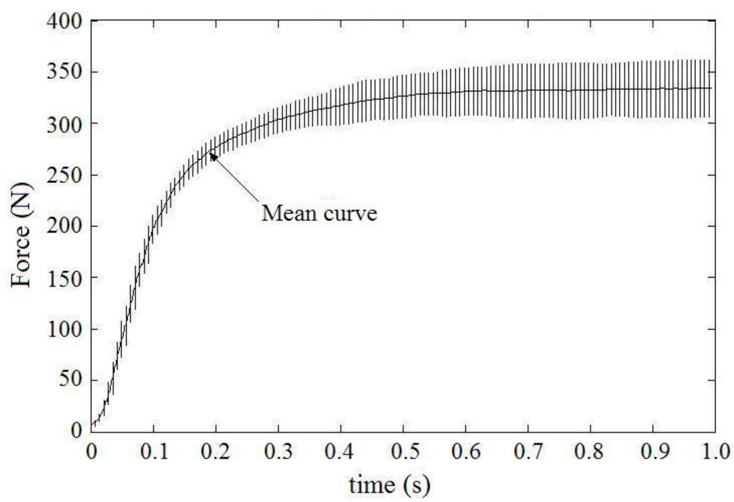

Figure 3: Mean values and its respective standard deviations considering the exclusion of one of the curves.

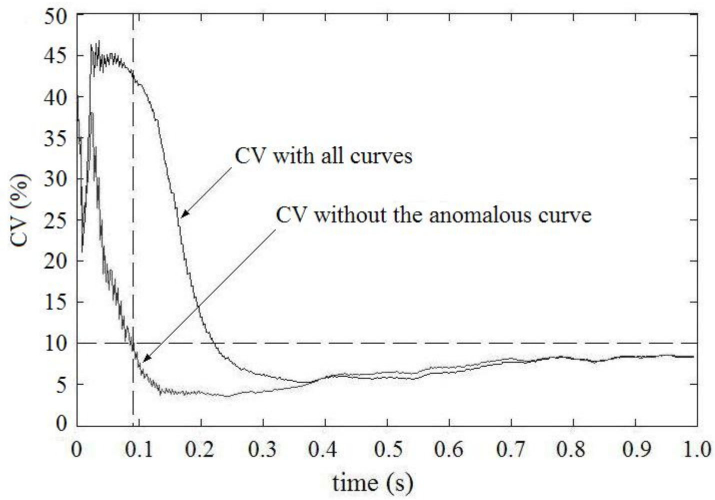

Figure 4: : CV values curves obtained before and after the exclusion of the isolated curve.

Therefore, through a qualitative analysis performed by graphic similarity, one of the curves was excluded causing to change the mean curve shape, its respective values and standard deviations and, then, the CV values as well. It was noted that, after the exclusion of the curve, the CV values in the period from 0.1 to 0.2s decreased (as already stated, for the rest of the subjects the decreasing of CV values occurred in different periods, namely: 0.7s; 0.5s and 1.0s.) However, for all the volunteers, the rest of the CV values have remained intact up to the very end of the test (5s.) The CV mean values for each interval in the test of isometric clench (5s), are displayed on Table 1.

It is also noted on Table 1 that for the rapid phase of the test (initial effort from 0 to 1.0s) the curves show more variability which does not occur from 1.0s (force maintenance phase.) Such behaviors may indicate the particularities during the performance of the test: the positioning of the hand during the test, slow variation of force at the beginning of the test, pain or even unreported/unnoticed discomfort.

Table 1: CV Mean values for definitive intervals for a volunteer.

Coefficient of Variation (mean values, %)		
time (s)	**CV (all curves)**	**CV (curve excluded)**
0-0,1	41,15	21,46
0,1-0,2	29,38	4,67
0,2-0,3	8,45	3,88
0,3-0,4	5,62	4,76
0,4-0,5	5,86	6,23
0,5-0,6	6,01	6,67
0,6-0,7	7,05	7,55
0,7-0,8	7,98	8,15
0,8-0,9	8,14	8,07
0,9-1,0	8,43	8,44
1,0-5,0	7,25	7,52

4 CONCLUSIONS

Regarding the CV definition, it can be asserted that low CV indicates low standard deviation and less data dispersion. As a consequence, it can be noted a certain level of "similarity" or "equivalence" between the curves. This way, such procedures may identify the mean curve that represents best the performance of each subject during the performance of this sort of test.

It can be concluded that, even for the very definition of CV, its values decreases when the curves present similar shapes and that the lowest values of CV (at the beginning of the rapid phase) occurred in specific times for each subject (0.1s; 0.7s; 0.5s and 1.0s). Even for this short period of time, with the exclusion of one of the curves, a higher similarity can be identified between the interval $0 \leq t \leq 0.1$s, which is an interval relatively low, coherent with the rapid muscle action in this kind of test.

Nevertheless, evaluating the behavior of the curve to be excluded (Figure 2), it can be stated that the first period of the test was conducted with an almost constant amount of force extremely close to zero. Obviously, in this case, the application of the concept of CV at every instant implicates in the problem related to the standard deviation: if it is kept constant and the curves approach zero, the CV values get much higher. It's seen that this increasing wouldn't be caused by the decreasing of the similarity between the curves in these instants, but for the fact that the curves almost reached zero (the subject didn't perform the test following the protocol stablished.) That being said, the use of the Coefficient of Variation would evidence the need to perform a new test.

In this work, it has been made clear that CV curves are an important parameter for the identification of similarity between force-time curves in its initial phase, where the rapid muscle action is required in the tests of maximum isometric clench of the hand.

Similar studies must be conducted considering the subjects who suffer from neuromuscular pathologies whose CV values might indicate specific behaviors of the muscular force in this sort of test.

ACKNOWLEDGEMENT

The authors acknowledge the financial support by CNPq, CAPES and FAPESP-BRASIL.

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