Basas: a Graphical Tool to Investigate Variability, Repeatability and Asymmetries in Squat

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September 6, 2021

BASAS: A GRAPHICAL TOOL TO INVESTIGATE VARIABILITY, REPEATABILITY AND ASYMMETRIES IN SQUAT

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Assessment of athletic gestures plays a critical role in sports' performance evaluation and rehabilitation. In this context, it is important to know how to evaluate the repeatability and variability of the gesture, as well as the possible presence of asymmetries.
In this pilot study, squats performed at different loads by an athlete (female, 55 kg) are analyzed. Trials at different weights were performed with 5 reps per set. Kinematic data are collected from an Xsens suit (Enschede, The Netherlands). To evaluate the gesture, a graphical tool combining a functional data analysis approach [1] with non-parametric bootstrapping [2] is proposed (Bootstrap Analysis of Speed and Angles in Squat, BASAS). For this analysis the knee flexion angles (left and right), and exercise speed (the suit's output *t8 speed*) were used.
Briefly, the BASAS algorithm divides the exercise between repetitions of the same length (*T*) and after setting the labels and axes' limits for the plots, it repeats the following steps for each weight:

1. For each leg $l \in \{right, left\}$ and repetition $r \in \{1,2,..,5\}$, draw *gray* lines to connect $\left(speed(t,r), angles(t,l,r)\right)$ over different time points $t \in \{1,2,..,T\}$;
2. For $b \in \{1,2,..,500\}$ do: a. Sample with replacement a sample of size 5 from the available repetitions; b. For the re-sampled repetitions, align the curves of knee angles and speed with respect to the maximum angle of the right leg; c. Compute the mean $\hat{a}^b_{right}(t)$ and $\hat{a}^b_{left}(t)$ for the knee angles (right and left leg) and $\hat{s}^b(t)$ for *t8* speed at each time point $t \in \{1,2,..,T\}$, using the aligned and re-sampled repetitions; d. Draw with different colors the lines to connect the points $\left(\hat{s}^b(t), \hat{a}^b_{right}(t)\right)$ and $\left(\hat{s}^b(t), \hat{a}^b_{left}(t)\right)$, respectively, for $t \in \{1,2,..,T\}$.

After creating the chart panels, Step 1 allows to visualize the true series. Step 2 is the bootstrap resampling scheme. Aligning the curves allows to compute the mean without bias due to the presence of shifting in the registrations of the curves [1]. Further misalignment is caused by low repeatability of the exercise.

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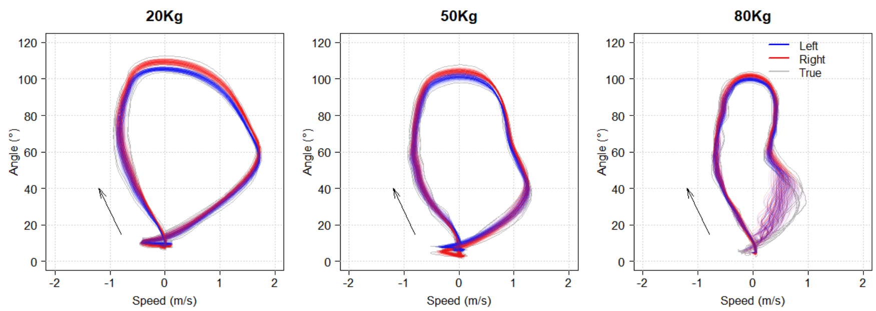

Fig. 1: BASAS output for selected weights.

Looking at the results of the BASAS in Fig.1 a pronounced variability between sets similar to that of a deflating balloon is noticeable. This behavior is firstly due to a progressive decrease of the execution speed as the barbell weights increase, in particular for what concerns the concentric phase (positive speed) of the exercise. As the weight increases, the relationship between angles and speed changes, and the presence of different sticking points (points in which the lift becomes harder and the bar velocity in the trials drops) is visible [3]. By looking at a specific weight, identifying phases where the red and blue lines do not overlap allows to identify the phases of the exercise where there is mean asymmetry between the knee angles over different repetitions. The width of the colored bands is related to the uncertainty involved in computing the means and provides a relative degree of confidence in evaluating the differences between legs. The larger the bands are, the larger is the uncertainty in that region. A graphical measure of reliability in computing the means is provided by the gray lines in the background, corresponding to the true data. Perfectly aligned curves between reps of the same set are characterized by colored lines overlapping the gray ones. The misalignment present in the squats at 80 kilograms, indicates a lower repeatability of the gesture in the concentric phase between different repetitions, caused by the onset of fatigue during the set.
The approach is versatile and applicable to other activities. In addition, it provides understandable results with few trials. Future developments include calculating performance indices to complement other standard methods used in the field.

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