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. The squat is an exercise used to strengthen the lower body, acting against the resistance offered by a bar loaded with weights placed on the upper back. Trials at different weights were performed with 5 reps per set. Kinematic data are collected from an Xsens MVN Link 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). Bootstrapping method is a convenient technique when the sample size is insufficient for straightforward statistical inference, and the theoretical distribution of a statistic of interest is complicated or unknown [2]. For this analysis the knee flexion angles (left and right, given as an output by the suit) and exercise vertical speed (assumed to be the suit's output *t8 speed*, eighth thoracic vertebra vertical speed) were used to evaluate the relationship between exercise speed and a specific joint angle.
The BASAS algorithm is a multi-step algorithm. Firstly, the observed data (true data) are represented in the Cartesian axes. Secondly, lines representing the bootstrap means of speed and angles are superimposed, distinguishing left and right leg. Bootstrap means are computed after aligning the curves with respect to the maximum angle of the right leg (reference leg), to avoid misleading inference due to the presence of shifting in the registrations of the curves [1]. Further misalignment, which is caused by low repeatability of the exercise, can be checked in the plot. The procedure described is an application of the bootstrapping method to this particular case study and allows an intuitive visualization of the gesture. Further details on the procedure and the code can be provided by the authors, upon request.
Looking at the results of the BASAS in Fig.1, a pronounced variability is noticeable between sets, similar to that of a deflating balloon. This behaviour is firstly due to

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a progressive decrease of the execution speed as the barbell weights increase, particularly in 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 exercise speed in the trials drops) is visible [3]. By looking at a specific weight, some regions where the red and blue lines do not overlap can be noticed. This allows the identification of phases of the exercise where there is a 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.

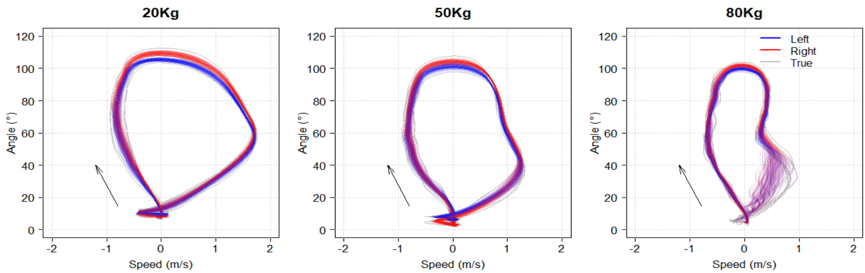

Fig. 1: BASAS output for selected weights. The arrows provide information on movement sequency and direction. Positive speed represents concentric phase.

If the measurements are carried out properly, the use can be versatile. For example, similar figures can be obtained using different joint angles for the squat, or additionally, a similar approach can be used in the bench press, where the speed of the bar is compared with the angle of the elbow. Performance indicators can be defined from the shape of the balloon described by the gesture (e.g. computation on areas). These aspects will be considered as future developments.

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