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Prediction of weightlifter's motor behavior to evaluate snatch weightlifting techniques based on a new method of investigation of consumed energy

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ABSTRACT

Using proper technique in different sports is an inevitable factor. In this study, available techniques for snatch weightlifting are mathematically evaluated. The optimal motion trajectory is a technique used by weightlifters, which could be determined based on minimizing specific object functions. Object functions based on total kinetic energy, total torque and total power and some new multi-objective functions are minimized using genetic algorithm and the minimax principle. Some important motion characteristics of 13 professional weightlifters were extracted and used to validate the mathematical results. The double knee bending (DKB) technique was studied as a benchmark test. Some important movement features of the technique were shown by the mathematical analysis when applying an object function, that minimized joint torques and powers of different muscles independently. An object function based on joint forces did not show these features.

Finding the optimal technique for a weightlifter is a main issue for coaches. Traditionally, two methods have been used for this purpose. In the first method, an optimal technique is inferred from the record of motion of the champion weightlifters (Baumann, Gross, Quade, Galbierz, & Schwirtz,

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1988; Campos, Poletaev, Cuesta, Pablos, & Carratala, 2006; Garhammer, 1980, 1982, 1985, 1989, 2003; Hiskia, 1997; Vorobyev, 1978). Fig. 1 shows three main techniques that were found by Vorobyev (1978). The point is that the best technique should be determined for each weightlifter. It is reasonable to assume that the optimum technique varies among athletes, since the anthropometric body dimensions vary. The movement pattern has been analyzed with the following conclusions, in general:

1. During the snatch phase, the force is exerted on the barbell to attain the maximum possible vertical velocity (Campos et al., 2006, pp. 843).
2. A small velocity loss appears during the transition phase (Campos et al., 2006, pp. 849).
3. A dynamic force of explosive nature is applied in the second pull in order to push the barbell vertically (Campos et al., 2006, pp. 849).

The second method is a mathematical one, in which an optimal trajectory is found by minimizing some chosen object functions subjected to constraints on the motion trajectory. Three object functions are commonly applied: (a) summed kinetic energy of the body segments, (b) summed squared torque in joints, and (c) summed squared power in joints. These were studied by Garhammer (1985); Nejadian, Rostami, and Towhidkhah (2008); Zahran, Vieten and Riehle (2002), respectively. Torque is the cross product of the muscle force vector and its arm. Power is the cross product of the torque and the angular velocity of the corresponding joint. It has also been forecasted that the object function should include joint forces, since optimal human motion may be created by minimizing joint forces. The joint forces have been widely considered as the object function in bone remodeling by biomechanics researchers (Andreaus, Colloca, & Iacoviello, 2012; Hambli, Katerchi, & Benhamou, 2011; Pang et al., 2012). However, despite the efforts by various researchers, there is still no agreement on the object function.

The optimization method needs simplification of the weightlifter's body. In Fig. 2 the body has been described by a symmetric five-link two dimensional sagittal model made of shank, thigh, trunk, upper arm and forearm (L1–L5).

A common technique among weightlifters is the double knee bending technique (DKB). Here, the weightlifter's knee angle shows a peak value in the middle of the lifting. Theoretical justifications have been presented by sport biomechanics researchers for using the "double knee bending" style of weightlifting in terms of leverages and utilization of knee extensor muscles in their greatest force producing range of motion. This technique facilitates the use of the elastic energy stored in lifter's musculature (Bobbert, Gerritsen, Litjens, & Van soest, 1996; Enoka, 1979; Newton et al., 1997). The exact reason for using DKB technique is still not fully recognized. A benchmark test for the mathematical procedure in this study is to investigate this technique and explains why it appears.

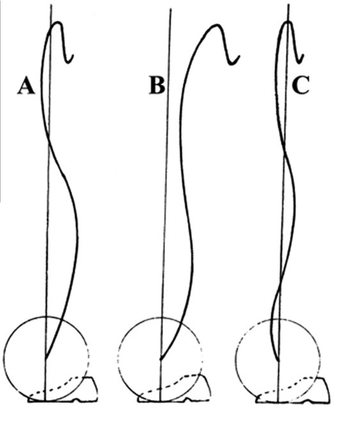

Fig. 1. Different barbell trajectories for World and European champions (Vorobyev, 1978).