BOOK OF ABSTRACTS **Open Access**

A pedaling force vector can be represented by the sum of three elemental force vector waveforms.

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Introducion:

In recent years, we have become able to accurately measure the pedaling force vector using pedaling analyzer (Bikefitting.com, Sittard, Netherlands) or pedaling monitoring (Pioneer Corporation, Kawasaki, Japan) systems. Using these devices, mechanical pedaling characteristics can be calculated from the pedaling force vector and expressed as an efficiency index or torque effectiveness, which is also calculated from the tangential force profile during pedaling. However, these indicators only demonstrate the mechanical characteristics of pedaling and are not based on body movement. Hence, we aim to analyze the pedaling force vector waveform based on biomechanical pedaling motion. A previous study analyzing the EMG signals of the lower limb muscles demonstrated that, in trained cyclists, pedaling is accomplished by combining three similar muscle synergies. (Is interindividual variability of EMG patterns in trained cyclists related to different muscle synergies? J Appl Physiol, 108(6) 1727-36. 2010).

This study expresses the pedal force vector waveform obtained from the pedaling force analyzer system by the sum of element force vector waveforms.

Methods:

Two participants (a former professional and a top-level amateur cyclist) were given a variety of pedaling conditions (load: 100, 200, 300 W; cadence: 70, 90, 110 rpm; saddle position: back (5 mm), forward (10 mm), up (3 mm), and down (5, 10 mm); pedaling action type: normal, spinning, pulling and pushing and pulling). Pedaling force vector data was obtained every 15 degrees using a pedaling analyzer system (Bikefitting.com). Pedaling vector data were expressed as the sum of elemental vectors. Common elemental vector waveforms and parameters were determined so that the root mean square error between the sum of the elemental vector waveforms and the original vector data were minimized by changing the amplitude and phase difference. The pedaling vector data and parameters can be expressed numerically with the following equation:

$$Tan(\theta) = T_0\left\{1 + A_1 f_1(\theta - \theta_1) + A_2 f_2(\theta - \theta_2)\right\}$$

$$Rad(\theta) = T_0\left\{B_0 + B_1 g_1(\theta - \varphi_1) + B_2 g_2(\theta - \varphi_2) + B_3 g_3(\theta - \varphi_3)\right\}$$

Results & Discussion:

The force vector component in the tangential direction can be represented by the sum of two waveform components, excluding the constant average force, as shown in Figure 1. At this time, the shapes of the wave functions (f_1: 1st and f_2: 2nd component) are fixed; only their amplitude and phase angle change. In contrast, the radial direction of the vector component can be represented by the sum of three waveforms: two correspond to the amplitude and phase angle of the two waves expressed in the tangential direction, and the remaining one has an independent amplitude and phase angle.

The scatter diagram in Figure 2 was created using A_1 and A_2, which are the amplitudes of the 1st and 2nd component of functions obtained by resolving the vector component of the tangential direction. Using this scatter diagram, we can classify pedaling characteristics.

This result indicates that pedaling action can be represented by up to three elemental motions, which may correspond to muscle behavior expressed by three synergies. Importantly, this study accounted for the waveform's phase angle change. In the future, we will investigate the difference between change in the element waveform and muscle force assessment, and will study the corresponding muscle force strength and pedaling action.

Conclusion:

Pedaling force vector components in the tangential and radial directions, obtained by a pedaling analyzer system, can be represented by the sum of two or three elemental waveform components, respectively.

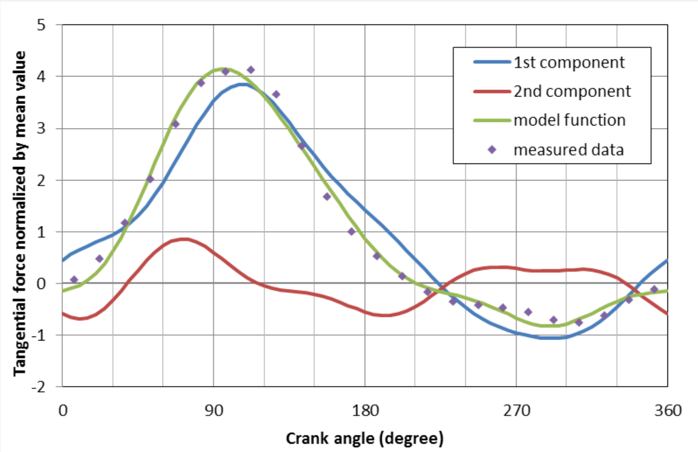

Figure 1: The vector component in the tangential direction can be represented by the sum of two waveform components.

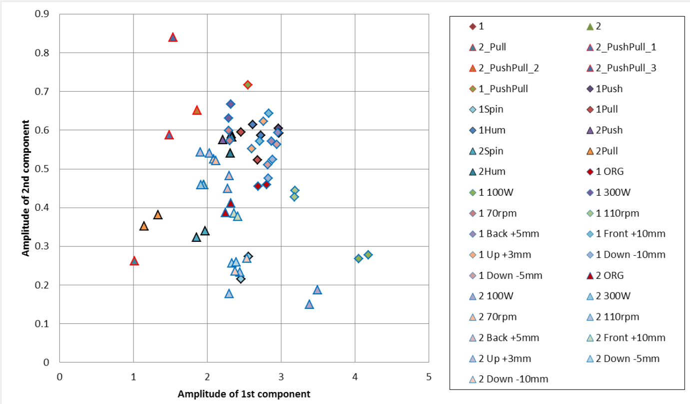

Figure 2: A scatter diagram of the amplitude of elemental vector waveforms.

Key words: Pedaling force, biomechanics, pedaling technique, mathematical analysis.

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