Data Article

Ultra-fast force-clamp spectroscopy data on the interaction between skeletal muscle myosin and actin

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\textbf{ABSTRACT}

Ultrafast force-clamp spectroscopy is a single molecule technique based on laser tweezers with sub-millisecond and sub-nanometer resolution. The technique has been successfully applied to investigate the rapid conformational changes that occur when a myosin II motor from skeletal muscle interacts with an actin filament. Here, we share data on the kinetics of such interaction and experimental records collected under different forces \cite{1}. The data can be valuable for researchers interested in the mechanosensitive properties of myosin II, both from an experimental and modeling point of view. The data is related to the research article \textquotedblleft ultrafast force-clamp spectroscopy of single molecules reveals load dependence of myosin working stroke\textquotedblright; \cite{2}.

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1. Data

Data shared here are from a set of 18 measurements of 100 s in which forces in the range about $7 \mu \text{N} < F < +7 \mu \text{N}$ where applied during the interaction between a single skeletal muscle myosin S1 subfragment and an actin filament in the presence of 15 $\mu$M [ATP]. Lifetimes of the interactions were analysed as in Refs. [2,5]. Cumulative distributions of the lifetime duration were well fitted by a triple exponential function and the three detachment rates are reported in Fig. 1 as a function of force (for the interpretation of the three detachment rates, see Capitanio et al. [2]). The supplemental files of this data article include a data table (k1k2k3.csv) with the values reported in Fig. 1, together with Matlab scripts to read (readUFCSheader.m and readUFCSdata.m), plot and convert the raw data (ViewUFCSFiles.m), as explained in the following section. The whole raw data set of 18 measurements can be downloaded in Ref. [1], together with a table describing the applied force for each measurement (measurements.xlsx).

The experimental parameters contained in the raw data are described in Fig. 2. Example plots of position and force signals as displayed by the ViewUFCSFiles.m script are depicted in Fig. 3. Table 1 describe the raw data file header, which contains the values of the experimental parameters used during data acquisition.

2. Experimental design, materials, and methods

Data are acquired using ultrafast force-clamp spectroscopy, which is extensively described elsewhere [2,5]. Briefly, a single actin filament is trapped between two 0.5 μm diameter beads (forming a structure named herein “dumbbell”) and brought in close proximity to a third bead attached on the coverslip surface, where a single skeletal muscle myosin S1 subfragment is present. Two voltage signals ($V_1, V_2$) proportional to the displacement of each of the two beads from the trap center along the filament direction ($x_{\text{bead1}}, x_{\text{bead2}}$) are recorded from two quadrant photodiodes (QPD) (Fig. 2). These
signals are also proportional to the applied forces, as \( F_{1,2} = -k_{1,2}x_{\text{bead1,2}} \), where \( k \) is the trap stiffness and indices 1,2 refers to the two traps. The two traps can be moved independently along \( x \) by using two acousto-optic deflectors (AOD), where the position of the two traps in the sample plane along the

**Fig. 1.** Detachment rates of a single skeletal muscle myosin S1 from actin at various forces and 15 \( \mu \text{M (ATP). Following Capitanio et al. [2]}, k_1 \) is the rate of detachment of myosin from actin after ATP binding, that is, at the end of the acto-myosin interaction cycle; \( k_2 \) is the rate of detachment of myosin from actin at the very beginning of the cycle, when ADP and inorganic phosphate are still bound; \( k_3 \) represents a premature unbinding of myosin from actin in the ADP or in the ADP and inorganic phosphate strong-binding state.

**Fig. 2.** Sketch of the ultrafast force-clamp spectroscopy measurement. The figure shows voltage signals from the QPD (\( V_1, V_2 \)) and their relation to the bead displacements \( x_{\text{bead1}}, x_{\text{bead2}} \) through the detector calibration factors \( b_1, b_2 \). The figure also shows the frequencies \( f_1, f_2 \) of the acoustic waves generated inside the two AODs and their relation with the trap positions \( x_{\text{trap1}}, x_{\text{trap2}} \) through the calibration factors \( a_1, a_2 \).

**Fig. 3.** Example of a record portion as shown by the Matlab script ViewUFCSFiles.m. **A)** Force signals obtained from the voltage signals \( V_1, V_2 \) as \( F_{1,2} = -k_{1,2}x_{\text{bead1,2}} = -k_{1,2}b_{1,2}V_{1,2} \). **B)** Position signals obtained from the frequency signals \( f_1, f_2 \) as \( x_{\text{trap1,2}} = a_{1,2}f_{1,2} \).
direction of the actin filament \((x_{\text{trap1}}, x_{\text{trap2}})\) is proportional to the AOD frequency \((f_1, f_2)\). A double feedback loop is then applied to the two AODs to maintain a constant net force on the filament \(F = F_1 + F_2\) by changing the AODs frequencies \(f_1, f_2\) to maintain \(x_{\text{bead1}}, x_{\text{bead2}}\) constant. The force \(F\) is alternated back and forth to maintain the dumbbell within a preset spatial interval as the dumbbell moves in a triangular wave (Fig. 3). When myosin binds the filament, interactions are detected from the stall of the dumbbell movement as the attached myosin counterbalances the force applied by the traps.

The voltage signals \(V_1, V_2\) from the QPDs are recorded together with feedback signals consisting in the frequencies \(f_1, f_2\) of the acoustic waves generated inside the two AODs. Data is organized in a proprietary raw format (named “UFCS”, from ultrafast force-clamp spectroscopy) consisting in a header that contains all the experimental parameters used during data acquisition, followed by raw data formed by 4 channels (2 QPD voltages + 2 AOD frequencies). Calibration of the trap stiffness \(k_{1,2}\) and the detector calibration factors \(b_1, b_2\) were obtained before measurements using a power spectrum method \([15]\) and are recorded in the file header. We provide a Matlab script to read the header (readUFCSHeader.m), a script to read the data (readUFCSdata.m), and a script that use both readUFCSHeader.m and readUFCSdata.m to load and visualize the data (ViewUFCSFiles.m). Data can be also saved as an ASCII table that can be imported in Excel, Origin, or similar analysis software. The file to be read must be in the current folder of Matlab and the filename written in a text file named UFCSfiles.txt. Table 1 shows a description of the header. Fig. 3 shows an example of a portion of a record visualized through the ViewUFCSFiles.m script.

### Table 1
Description of the UFCS files header.

| Header element number | Format       | Description                                                                 |
|-----------------------|--------------|-----------------------------------------------------------------------------|
| 1                     | uint32       | header length (bytes)                                                       |
| 2                     | uint32       | filetype: 0, measurement data (not applicable to these data)                |
|                       |              | 1, simulation data (not applicable to these data)                           |
|                       |              | 2, measurement data with force clamp                                        |
|                       |              | 3, simulation data with force clamp (not applicable to these data)          |
|                       |              | 4, calibration data (not applicable to these data)                         |
| 3                     | uint32       | acquisition sample rate (Hz)                                               |
| 4                     | float32      | record duration (s)                                                        |
| 5                     | uint32       | number of channels                                                         |
| 6                     | float64      | date                                                                        |
| 7                     | float32      | bead radius (nm)                                                           |
| 8                     | float32      | buffer viscosity (SI)                                                      |
| 9                     | float32      | temperature (°K)                                                           |
| 10                    | float32      | net force (pN)                                                             |
| 11                    | float32      | half-amplitude of the oscillation of the dumbbell when it moves in a confined spatial interval during force-clamp (default 72 nm) |
| 12                    | int32        | proportional gain (default 60, arbitrary units)                            |
| 13                    | int32        | integral gain (default 0)                                                  |
| 14                    | int32        | differential gain (default 0)                                              |
| 15                    | float32      | actin pre-tension measured on ch0 (pN)                                     |
| 16                    | float32      | actin pre-tension measured on ch1 (pN)                                     |
| 17                    | float32      | \(b_1\) (nm/V)                                                             |
| 18                    | float32      | \(b_2\) (nm/V)                                                             |
| 19                    | float32      | stiffness \(k_1\) (pN/nm)                                                  |
| 20                    | float32      | stiffness \(k_2\) (pN/nm)                                                  |
| 21                    | float32      | pre-displacement ch0 (nm)                                                  |
| 22                    | float32      | pre-displacement ch1 (nm)                                                  |
| 23                    | uint32       | generation scan rate (ticks)                                               |
| 24                    | uint32       | AOD power ch1 (0–255), value proportional to the amplitude of the acoustic wave in the AOD of trap1 |
| 25                    | uint32       | AOD power ch2 (0–255), value proportional to the amplitude of the acoustic wave in the AOD of trap2 |
| 26                    | float32      | distance between traps (MHz)                                               |
| 27                    | float32      | laser power (W), at the exit of the laser                                  |
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Transparency document

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dib.2019.104017.

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