Data in brief 25 (2019) 104017

Contents lists available at ScienceDirect

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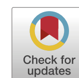
Data Article

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



Manuela Maffei [a], Diego Beneventi [b], Monica Canepari [a], Roberto Bottinelli [a], Francesco Saverio Pavone [b, c, d], Marco Capitanio [b, c, *]

[a] *Department of Molecular Medicine, University of Pavia, Pavia, Italy*
[b] *LENS - European Laboratory for Non-linear Spectroscopy, Via Nello Carrara 1, 50019 Sesto Fiorentino, Italy*
[c] *Department of Physics and Astronomy, University of Florence, Via Sansone 1, 50019 Sesto Fiorentino, Italy*
[d] *National Institute of Optics—National Research Council, Largo Fermi 6, 50125 Florence, Italy*

A R T I C L E I N F O

Article history:
Received 19 March 2019
Received in revised form 30 April 2019
Accepted 10 May 2019
Available online 23 May 2019

Keywords:
Optical tweezers
Force-clamp spectroscopy
Myosin
Single molecule biophysics

A B S T R A C T

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 [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 “ultrafast force-clamp spectroscopy of single molecules reveals load dependence of myosin working stroke” [2].

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* Corresponding author. LENS - European Laboratory for Non-linear Spectroscopy, Via Nello Carrara 1, 50019 Sesto Fiorentino, Italy.

E-mail address: capitanio@lens.unifi.it (M. Capitanio).

https://doi.org/10.1016/j.dib.2019.104017
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Specifications Table

Subject area	*Biophysics*
More specific subject area	*Single molecule force spectroscopy*
Type of data	*Position records from an optical tweezers instrument*
How data was acquired	*Custom double optical tweezers instrument*
Data format	*Raw and graph*
Experimental factors	*Actin filaments were polymerized from a mixture of biotinylated and non-biotinilated G-actin. Full-length myosin was digested to isolate the S1 motor unit subfragment. No pretreatment of data*
Experimental features	*A single actin filament was stretched between streptavidin-coated beads and interactions with a single S1 myosin head were recorded under forces in the range* -7 pN < F < $+7$ pN.
Data source location	*Sesto Fiorentino, Italy, LENS - European Laboratory for Non-linear Spectroscopy*
Data accessibility	The raw data files are provided in the Data in Brief Dataverse, https://doi.org/10.7910/DVN/AVYONR [1]. *All other data is with this article*
Related research article	*Capitanio* et al. *"ultrafast force-clamp spectroscopy of single molecules reveals load dependence of myosin working stroke", Nature Methods 9, 1013–1019 (2012)*

Value of the data

- Ultrafast force-clamp spectroscopy is a unique technique with a temporal resolution about 2 order of magnitude higher than conventional single molecule techniques [2–4]. Therefore, the shared data might contain valuable information on rapid mechanosensitive states and conformational changes occurring during the acto-myosin interaction.
- Although the authors developed methods to analyze ultrafast force-clamp data [5,6], improvements in data analysis, for example using differential detection between the two trap channels [7], correlative detection [8], step detection algorithms [9], might reveal hidden properties on the acto-myosin interaction.
- Models of acto-myosin interaction rely to a great extent on single molecule data [10–14]. Single molecule high-resolution data are therefore fundamental to define and test such models.

1. Data

Data shared here are from a set of 18 measurements of 100 s in which forces in the range about -7 pN $< F < +7$ pN where applied during the interaction between a single skeletal muscle myosin S1 subfragment and an actin filament in the presence of 15 μM [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 (View-UFCSFiles.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_{bead1}, x_{bead2}) are recorded from two quadrant photodiodes (QPD) (Fig. 2). These

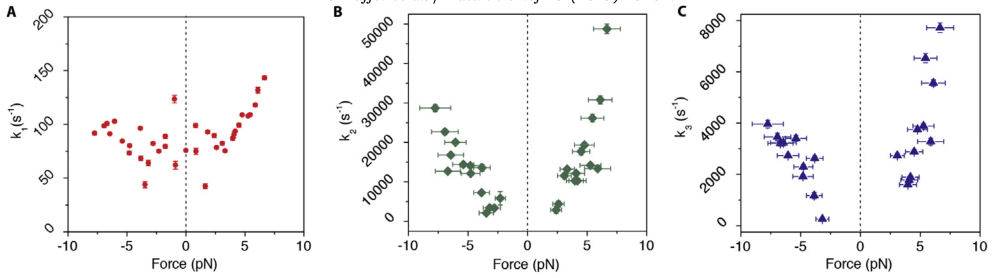

Fig. 1. Detachment rates of a single skeletal muscle myosin S1 from actin at various forces and 15 μM [ATP]. Following Capitanio et al. [2], k_1 is the rate of detachment of myosin from actin after ATP binding, that is, at the end of the acto-myosin interaction cycle; k_2 is the rate of detachment of 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.

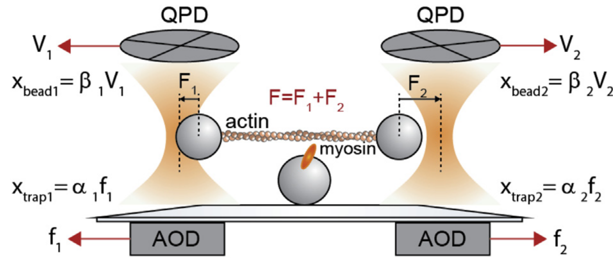

Fig. 2. Sketch of the ultrafast force-clamp spectroscopy measurement. The figure shows voltage signals from the QPD (V_1, V_2) and their relation to the bead displacements x_{bead1}, x_{bead2} through the detector calibration factors β_1,β_2. The figure also shows the frequencies f_1, f_2 of the acoustic waves generated inside the two AODs and their relation with the trap positions x_{trap1}, x_{trap2} through the calibration factors α_1,α_2.

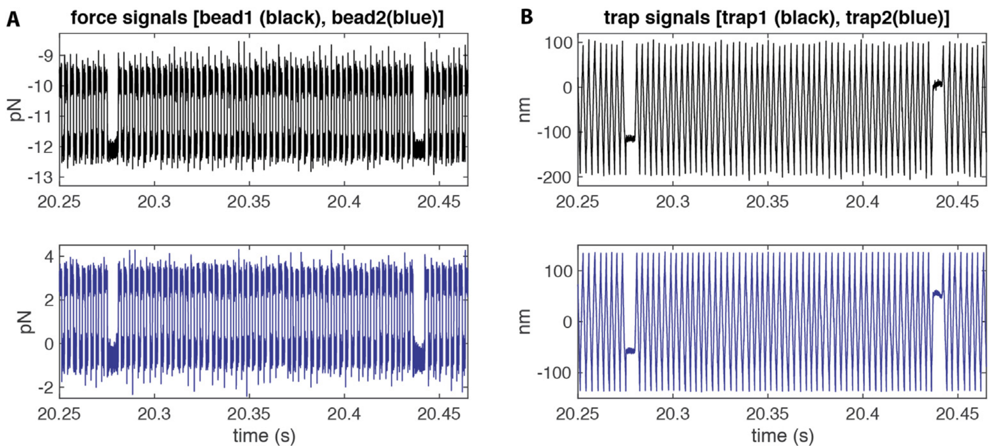

Fig. 3. Example of a record portion as shown by the Matlab script ViewUFCSFiles.m. **A)** Force signals obtained from the voltage signals V_1, V_2 as $F_{1,2} = -k_{1,2}\, xbead_{1,2} = -\, k_{1,2}\, \beta_{1,2}\, V_{1,2}$. **B)** Position signals obtained from the frequency signals f_1, f_2 as $x_{trap1,2} = \alpha_{1,2}\, f_{1,2}$.

signals are also proportional to the applied forces, as $F_{1,2} = -k_{1,2}x_{bead1,2}$, 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

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	β_1 (nm/V)
18	float32	β_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

direction of the actin filament (x_{trap1}, x_{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_{bead1}, x_{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 β_1,β_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.

Acknowledgments

This work was supported by the European Union's Horizon 2020 research and innovation program under grant agreement no. 654148 Laserlab-Europe and by Ente Cassa di Risparmio di Firenze.

Transparency document

Transparency document associated with this article can be found in the online version at https://doi.org/10.1016/j.dib.2019.104017.

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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