The Journal of Biological Chemistry JBC ASBMB
About JBC | This Article | Submissions | Subscriptions | Contact

J Biol Chem. 2009 August 21; 284(34): 22926–22937. PMCID: PMC2755700
Published online 2009 June 11. doi: 10.1074/jbc.M109.019232

Drug Effect Unveils Inter-head Cooperativity and Strain-dependent ADP Release in Fast Skeletal Actomyosin*[S]

Nuria Albet-Torres,[‡1] Marieke J. Bloemink,[§1] Tom Barman,[¶] Robin Candau,[‖] Kerstin Frölander,[‡] Michael A. Geeves,[§] Kerstin Golker,[‡] Christian Herrmann,[¶2] Corinne Lionne,[¶] Claudia Piperio,[**] Stephan Schmitz,[**] Claudia Veigel,[**] and Alf Månsson[‡3]

From the [‡]School of Pure Applied Natural Science, University of Kalmar, SE-391 82 Kalmar, Sweden, the [§]Department of Biosciences, University of Kent, Canterbury, Kent CT2 7NJ, United Kingdom, [¶]Unité Mixte de Recherche 5236 CNRS, University of Montpellier I and II, Institut de Biologie, 34000 Montpellier, France, [‖]Unité Mixte de Recherche 866 INRA, University of Montpellier I, 34060 Montpellier, France, and the [**]National Institute for Medical Research, Mill Hill, London NW7 1AA, United Kingdom
[1] To whom correspondence should be addressed. Tel.: Phone: 46-480-446243; Fax: 46- 480-446262; E-mail: alf.mansson@hik.se.
[1]Both authors contributed equally to this work.
[2]Supported by an INSERM fellowship. Present address: Physikalische Chimie 1, Ruhr-Universitat Bochum, Universitat Strasse 150, D-44780 Bochum, Germany.

Received February 26, 2009; Revised May 9, 2009

Author's Choice—Final version full access.

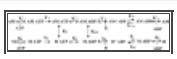
Abstract

Other Sections▼

Amrinone is a bipyridine compound with characteristic effects on the force-velocity relationship of fast skeletal muscle, including a reduction in the maximum shortening velocity and increased maximum isometric force. Here we performed experiments to elucidate the molecular mechanisms for these effects, with the additional aim to gain insight into the molecular mechanisms underlying the force-velocity relationship. *In vitro* motility assays established that amrinone reduces the sliding velocity of heavy meromyosin-propelled actin filaments by 30% at different ionic strengths of the assay solution. Stopped-flow studies of myofibrils, heavy meromyosin and myosin subfragment 1, showed that the effects on sliding speed were not because of a reduced rate of ATP-induced actomyosin dissociation because the rate of this process was increased by amrinone. Moreover, optical tweezers studies could not detect any amrinone-induced changes in the working stroke length. In contrast, the ADP affinity of acto-heavy meromyosin was increased about 2-fold by 1 mM amrinone. Similar effects were not observed for acto-subfragment 1. Together with the other findings, this suggests that the amrinone-induced reduction in sliding velocity is attributed to inhibition of a strain-dependent ADP release step. Modeling results show that such an effect may account for the amrinone-induced changes of the force-velocity relationship. The data emphasize the importance of the rate of a strain-dependent ADP release step in influencing the maximum sliding velocity in fast skeletal muscle. The data also lead us to discuss the possible importance of cooperative interactions between the two myosin heads in muscle contraction.

Other Sections▼

Muscle contraction, as well as several other aspects of cell motility, results from cyclic interactions between myosin II motors and actin filaments. These force-generating interactions are driven by the hydrolysis of ATP at the myosin active site as outlined in Scheme 1 (1–3). In the absence of actin, the P_i and ADP release steps (k_4 and k_5) are rate-limiting for the entire cycle at high (>12 °C) and low temperatures, respectively (4–6). In the presence of actin, the rate of P_i release increases significantly, and the overall cycle is accelerated more than 2 orders of magnitude. The sliding velocity of myosin-propelled motors is generally believed to be rate-limited by actomyosin dissociation (rate constant k'_5, k'_6, or k'_2 in Scheme 1) (7). Alternatively, some studies (8, 9) have suggested that the sliding velocity is determined by the fraction of myosin heads in the weak-binding states, AM[4] ATP and AM ADP P_i. However, it is worth emphasizing that K_T is very low under physiological conditions (1, 3) with low population of these states. For the same reason, the rate of dissociation of the AM complex is governed by K'_1 and k'_2.



SCHEME 1.
Simplified kinetics scheme for MgATP turnover by myosin (*lower row*) and

Simplified kinetics scheme for MgATP turnover by myosin (*lower row*) and actomyosin (*upper row*). Inorganic phosphate is denoted by P_i; MgATP is denoted by *ATP*, and MgADP is denoted by *ADP*; myosin is denoted by *M*. The states AM*ADP and AM ADP correspond (more ...)

For the study of contractile mechanisms in both muscle and other types of cells, drugs may be useful as pharmacological tools affecting different transitions or states in the force-generating cycle. Whereas the use of drugs as tools may be less specific than site-directed mutagenesis, it also has advantages. The motor protein function may be studied *in vivo*, with maintained ordering of the protein components, *e.g.* as in the muscle sarcomere, allowing more insight into the relationship between specific molecular events and contractile properties of muscle. A drug that has been used quite extensively in this context is butanedione monoxime. The usefulness of this drug is based on firm characterization of its effect on actomyosin function on the molecular level (3, 10–13). More recently other drugs, like *N*-benzyl-*p*-toluene sulfonamide (14, 15) and blebbistatin (16), have been found to affect myosin function, and their effects at the molecular level have also been elucidated in some detail (14, 15, 17, 18). Both these drugs appear to affect the actomyosin interaction in a similar way as butanedione monoxime by inhibiting a step before (or very early in) the myosin power stroke, leading to the inhibition of actomyosin cross-bridge formation and force production.

In contrast to the reduced isometric force, caused by the above mentioned drugs, the bipyridine compound amrinone (Fig. 1*A*) has been found to increase the isometric force production of fast intact skeletal muscles of the frog (19, 20) and mouse (21) and also of fast (but much less slow) skinned muscle fibers of the rat (22). In all the fast myosin preparations, the effect of about 1 mM amrinone on isometric force was associated with characteristic changes of the force-velocity relationship (Fig. 1*B*), including a reduced maximum velocity of shortening (19–22) and a reduced curvature of the force-velocity relationship (19–22). The latter effect was accompanied (20, 21) by a less pronounced deviation of the force-velocity relationship from the hyperbolic shape (23) at high loads. There have been different interpretations of the drug effects. It has been proposed (20–22) that amrinone might competitively inhibit the MgATP binding by myosin. However, more recently, results from *in vitro* motility assay experiments (24) challenged this idea. These results showed that amrinone reduces the sliding velocity (V_{max}) at saturating MgATP concentrations but not at MgATP concentrations close to, or below, the K_m value for the hyperbolic relationship between MgATP concentration and sliding velocity. Such a combination of effects is consistent with a reduced MgADP release rate (24) but not with competitive inhibition of substrate binding. However, effects of amrinone on the MgADP release rate have not been directly demonstrated. Additionally, in view of the uncertainty about what step actually determines the sliding velocity at saturating [MgATP] (see above and Refs. 7–9), it is of interest to consider other possible drug effects that could account for the data of Klinth *et al.* (24). These include the following: 1) an increased drag force, *e.g.* because of enhancement of weak actomyosin interactions; 2) a reduced step length; and 3) effects of the drug on the rate of MgATP-induced dissociation of actomyosin.

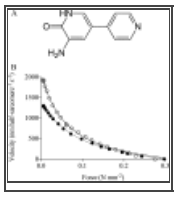


FIGURE 1.
A, structure of amrinone. *B*, experimental force-velocity data obtained in the presence (*filled symbols*) and absence (*open symbols*) of 1.1 mM amrinone. The data, from intact single frog muscle fibers, were obtained at 2 °C and fitted by Hill's (more ...)

To differentiate between these hypotheses for the amrinone effects, and to gain more general insight into fundamental aspects of muscle function (*e.g.* mechanisms underlying the force-velocity relationship), we here study the molecular effects of amrinone on fast skeletal muscle myosin preparations in the presence and absence of actin.

In vitro motility assay studies at different ionic strengths suggest that drag forces, caused by increased fraction of myosin heads in weak binding states, are not important for the effect of amrinone on sliding velocity. Likewise, optical tweezers studies showed no effect of the drug on the myosin step length. Finally, ideas that amrinone should reduce sliding velocity by reduced rate of MgATP-induced dissociation could be discarded because the drug actually increased the rate of this process. Instead, we found an amrinone-induced increase in the MgADP affinity of heavy meromyosin (HMM) in the presence of actin. Interestingly, similar effects of amrinone were *not* observed using myosin S1. As discussed below, this result and other results point to an amrinone-induced reduction in the rate of a strain-dependent MgADP release step. Simulations, using a model modified from that of Edman *et al.* (25), support this proposed mechanism of action. The results are discussed in relation to fundamental mechanisms underlying the force-velocity relationship of fast skeletal muscle, including which step determines shortening velocity and the possible importance of inter-head cooperativity.

MATERIALS AND METHODS

Other Sections▼

Protein Preparations

Actin was prepared from rabbit skeletal muscle (26) as described previously and, for some experiments, labeled with pyrene (27) and phalloidin or with TRITC-Ph (Invitrogen) (28). Myosin was purified from fast rabbit skeletal muscle (either white leg or psoas muscles).

For the *in vitro* motility assay and steady-state MgATP turnover experiments, fresh myosin was cleaved by α-chymotrypsin to obtain HMM (24, 28) or by papain (in the presence of Mg^{2+}) (28) to obtain papain

α-chymotrypsin to obtain HMM (24, 28) or by papain (in the presence of Mg^{++}) (28) to obtain papain subfragment 1 (papain S1). Aliquots of both HMM and S1 were frozen in liquid nitrogen and stored at −80 °C until use.

For transient kinetics experiments, S1 and HMM were prepared by α-chymotryptic digestion of rabbit skeletal muscle myosin based on the protocols of Weeds and Taylor (29) and Margossian and Lowey (30). Papain S1 for transient kinetics and optical tweezers studies was prepared according to Margossian and Lowey (30). Both HMM and S1 for the kinetics experiments were purified by ion exchange on DEAE-Sephacryl using a linear KCl gradient. Protein concentrations were measured spectrophotometrically (28).

Myofibrils

Myofibrils were prepared from rabbit psoas muscle (10, 31) and stored at 4 °C for up to 3 days in a storage buffer (50 mM Tris, 100 mM potassium acetate, 5 mM KCl, 2 mM magnesium acetate, 2 mM dithiothreitol, 0.5 mM sodium azide, 0.2 mM phenylmethylsulfonyl fluoride, 10 μM leupeptin, and 5 μM pepstatin, adjusted to pH 7.4 at room temperature with acetic acid). Pyrene-labeled myofibrils were prepared as described by Ma and Taylor (32), and myosin head concentration was measured according to Houadjeto *et al.* (33). Control experiments showed that the steady-state ATPases in the presence of Ca^{2+} or EGTA for pyrene-labeled myofibrils are the same as for the unlabeled myofibrils (34) suggesting the lack of major myofibril function alteration with pyrene labeling.

Amrinone Solutions

Stock solutions of amrinone were prepared in lactic acid (24). Several control experiments (*e.g.* myosin ATPase, motility assays; see also Klinth *et al.* (24)) suggested that lactic acid *per se* did not affect actomyosin or myosin function (provided that pH was controlled). However, despite this fact we took care to ensure similar concentrations of lactic acid in solutions with and without amrinone.

Steady-state ATPase

The steady-state ATPase activity of myosin or HMM was obtained by the method of Kodama *et al.* (35) (room temperature, 20–25 °C in different experiments). Myosin or HMM was diluted in a buffer (Buffer A: 50–500 mM KCl, 20 mM MOPS, 10 mM $MgCl_2$ (pH 7.2)). The final protein concentration was 1 mg ml^{-1} (2 μM) for myosin or 120 μg ml^{-1} (0.34 μM) for HMM. The reaction was initiated by addition of MgATP to a final concentration of 1 mM (pH 7.2) and was quenched after different time periods by addition of perchloroacetic acid at a final concentration of 0.3 M. A "zero time blank" was obtained for each concentration of amrinone by adding perchloroacetic acid to the mixture of myosin, drug, and MgATP immediately after addition of MgATP to the myosin/drug mixture. After centrifugation for 1 min at 17,900 × *g*, a sample was withdrawn from each perchloroacetic acid-treated reaction solution. This sample was transferred to a 96-well plate and allowed to react with malachite green-molybdate reagent (35) followed by reading of absorbance at 620 nm. In each experiment the absorbance was related to that of a phosphate standard where a solution of KH_2PO_4 (P_i) at different concentrations had been mixed and allowed to react with the malachite green-molybdate reagent as described above. Generally, the relationship between [P_i] and absorbance was highly linear ($r^2 > 0.998$) and not affected by the presence of lactic acid or amrinone. For studies of calcium-ATPase, $MgCl_2$ was exchanged for $CaCl_2$. The ionic strength was calculated using the software winmaxc 3.2, version 2.05, with stability constants for metal complexes obtained from the NIST Standard Reference Data base 46 version 8.0 (NIST Standard Reference Data, Gaithersburg, MD).

Transient Kinetics, Chymotryptic S1 in the Absence of Actin

Transient kinetics with S1 were carried out in a home-built, thermostatically controlled, rapid quench flow apparatus (5). The procedure was to mix S1 with [γ-^{32}P]ATP in the apparatus. With ADP displacement technique, the procedure was to preincubate S1 and ADP and to mix them with [γ-^{32}P]ATP. In both experimental conditions, the reaction mixtures were quenched at different times in acid (22% trichloroacetic acid, 1 mM KH_2PO_4), and the total P_i concentrations were determined by the filter paper method (36). This type of experiment allows the measurement of the kinetics of total P_i formation, *i.e.* free P_i plus myosin head bound P_i. The kinetics was fitted using linear or nonlinear regression. It is important to note that the measurement error estimated from the residuals of the fits is lower than total experimental error, including mass and volume imprecision during S1 suspension and ATP solution preparations. To minimize this source of error, amrinone and control experiments were performed on the same day with the same buffers and preparations.

Transient Kinetics with Actin, Myofibrils, HMM, and S1

All kinetic measurements were done with a High-Tech Scientific SF-61 DX2 stopped-flow system. Experiments on acto-HMM or acto-S1 were performed at 20 °C in 20 mM MOPS, 100 mM KCl, 5 mM $MgCl_2$, and 1 mM azide (pH 7), unless indicated otherwise. Pyrene actin fluorescence was excited at 365 nm, and emission was detected after passing through a KV389 nm cutoff filter (Schott, Mainz, Germany). The stated concentrations of reactants are those after mixing in the stopped-flow observation cell unless indicated otherwise.

For studies of myofibrils, changes in either pyrene fluorescence or tryptophan fluorescence were observed. In the latter case the excitation wavelength was 295 nm, and emission was higher than 320 nm. A series of 20–30 shots was performed and averaged for each experimental condition. The dependences of rate constant of the fast component (k_{obs}) on the MgATP concentration were hyperbolic and fitted using the equation $k_{obs} = k_{obs(max)} \times [ATP]/(K_{0.5} + [ATP])$, where $K_{0.5}$ is the concentration of ATP giving 50% of the $k_{obs(max)}$ value. Stopped-flow data were analyzed using the software provided by Hi-Tech (KinetAsyst, Bradford-on-Avon, UK) and the Origin software (OriginLab Corp.).

In Vitro Motility Assay

In vitro Motility Assay

Flow cells were prepared, and motility assays were performed essentially as described previously (24, 37), using assay solutions of the following composition (with or without amrinone): 20 mM MOPS (pH 7.2), 1 mM Na_2ATP, 2 mM $MgCl_2$, 5–150 mM KCl, 0.1 mM EGTA, 10 mM dithiothreitol, and an anti-photobleach mixture of 3 mg ml^{-1} glucose, 20 units ml^{-1} glucose oxidase, 920 units ml^{-1} catalase (24). In assay solutions of ionic strength >40 mM, methylcellulose was added at a final concentration of 0.6%. For rinsing between incubation steps, a wash solution of the following composition was used: 25 mM imidazole-HCl (pH 7.4), 4 mM $MgCl_2$, 25 mM KCl, 1 mM EGTA, 1 mM dithiothreitol. *In vitro* motility assay experiments were retained for analysis only if the fraction of motile filaments in the control solution exceeded 0.60, and generally, this fraction was >0.8. The temperature varied between 23 and 30 °C between experiments as described below but was constant to within ±0.7 °C during a given experiment. Filament sliding was recorded by a Nikon Eclipse TE300 inverted microscope equipped with a cooled CCD camera (37), and the sliding velocities were analyzed as described previously (24, 38).

Optical Tweezers Experiment

The optical tweezers transducer was built around a Zeiss Axiovert microscope (39). Experiments were performed with flow cells made from a microscope slide and pieces of coverslip. Glass beads (2 μm diameter) were applied to the coverslip surface as a suspension in 0.1% (w/v) nitrocellulose/amyl acetate. Papain S1 was allowed to bind to the coverslip surface, with 0.5 mg ml^{-1} of protein in buffered salt solution (containing (in mM): 25 KCl, 25 imidazole, 4 $MgCl_2$, 1 EGTA (pH 7.4), 23 °C). The solution was replaced by one containing TRITC-Ph-labeled actin filaments and 1.1-μm diameter polystyrene beads that had been precoated with *N*-ethylmaleimide-modified myosin. The salt solution was supplemented with (in mM) 2 creatine phosphate, 20 dithiothreitol, 0.01 to 0.1 ATP, and (in mg ml^{-1}) 1 creatine phosphokinase, 0.5 bovine serum albumin, 3 glucose, 0.1 glucose oxidase, 0.02 catalase. An actin filament (average length ~4 μm) was bound at either end to 1.1-μm polystyrene beads held in optical tweezers. A pretension of ~2 pN was applied to the suspended actin filament by moving one of the traps in parallel to the actin filament axis. The bead-actin-bead assembly was then positioned in the vicinity of a surface-bound glass bead. Interactions between actin filament and myosin were recorded by casting the image of the polystyrene beads onto four-quadrant photodetectors. With the actin filament pulled taut but in the absence of myosin binding, the root mean square amplitude of the thermal motion was $(k_bT/2\kappa_{trap})^{0.5}$ ~12 nm, with k_bT being the thermal energy and κ_{trap} being the optical tweezers stiffness = 0.015–0.02 pN·nm^{-1}. When myosin bound to actin, the motion of the beads parallel to the actin filament axis was restrained by the trap stiffness κ_{trap} plus an additional stiffness κ_{add}, which reduced the root mean square amplitude of thermal motion to $(k_bT/\kappa_{tot})^{0.5}$, with $\kappa_{tot} = 2\kappa_{trap} + \kappa_{add}$ (39, 40). Brownian motion of the trapped beads showed a Lorentzian power density distribution with a roll-off frequency $f_c = \kappa_{tot}/2\pi\beta$ ~500 Hz (where $\beta = 6\pi\eta r$; η = solution viscosity, r = bead radius = 0.55 μm). Data were collected at 1 kHz, whereas a 100-nm amplitude sine wave oscillation was applied to one of the traps (41). Changes in the amplitude in this signal pick up were used as a sensitive indicator of system stiffness, *i.e.* myosin binding events. All experiments were carried out at 23 °C.

Simulation of Force-Velocity Data of Muscle

The model of Edman *et al.* (25), in its original form, accounts for the nonhyperbolic shape of the force-velocity relationship as well as for isometric tension transients and the time course of tension development during an isometric tetanus. For the present purposes, the model was modified as described in the supplemental material. To simulate steady-state force-velocity data, systems of ordinary differential equations were solved (25) by numerical integration using the fourth order Runge-Kutta-Fehlberg method implemented in the software Simnon (version 1.3; SSPA, Gothenburg, Sweden). Increasing the time step in the numerical integration 10 times did not appreciably affect the outcome of the simulations. For further details, see supplemental material and Edman *et al.* (25).

Statistical Analysis and Graphics

Experimental and simulated force-velocity data were fitted to the Hill (42) hyperbolic equation for forces <80% of the maximum (isometric) force as shown in Equation 1,

$$v = \frac{(P_0^* - P)\cdot b}{P + a} \qquad \text{(Eq. 1)}$$

Here, v is shortening velocity; P is measured force, and P_0^* is the maximum force obtained by extrapolation of the Hill equation to the force axis. The quantities a and b are constants that are related to the curvature of the force-velocity relationship. Here we use the ratio a/P_0^* as a measure of this curvature. Moreover, we use the ratio P_0^*/P_0 as a measure of the deviation of the force-velocity relationship from the Hill hyperbola at high force (see Ref. 20). As P_0 is the measured maximum (isometric) force, a large value of the ratio, P_0^*/P_0, suggests a large deviation of the force-velocity data from a hyperbola.

If not otherwise stated, statistical analyses, including linear and nonlinear regression (Levenberg-Marquardt algorithm), were performed using the GraphPad Prism software (versions 4.0 and 5.0 GraphPad Software, San Diego). Data are given as means ± S.E. unless otherwise stated.

RESULTS

Other Sections▼

Amrinone Increases Basal MgATPase of HMM

Fig. 2 shows that the basal MgATPase activity of HMM (fast leg muscle) exhibited a concentration-dependent increase in response to amrinone. The effects of the drug on the MgATPase activity of HMM and full-length myosin were compared in separate experiments and were found to exhibit quantitatively similar magnitude and concentration dependence (data not shown).

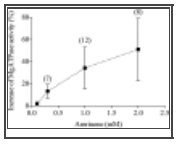


FIGURE 2.

Effects of amrinone on HMM MgATPase. Effect of amrinone concentration (*error bars*, 95% confidence intervals) on basal MgATPase of HMM (white rabbit leg muscle). Because altered ionic strength did not influence the amrinone effect (supplemental Fig. 1 (more ...)

Detailed studies in the absence of actin were performed using chymotryptic S1, and the results have been summarized in supplemental Table 2. Quench flow studies at low temperature (see supplemental Figs. 2 and 3) suggested that the rate constant of the transition limiting MgADP release (k_5) increases slightly, from 0.016 s^{-1} to 0.026 s^{-1} upon addition of amrinone (1–2 mM). There was also a small effect on the rate constant of P_i release (k_4), which increased from 0.087 s^{-1} (no amrinone) to 0.108 s^{-1} (with amrinone). Rapid quench flow experiments with MgADP displacement from chymotryptic S1 were conducted at 4 and 25 °C (Fig. 3). Each curve is biphasic; a P_i burst phase that is followed by a steady-state turnover phase. The presence of 1 mM amrinone did not alter the P_i burst phase either at 4 (Fig. 3*A*) or 25 °C (Fig. 3*B*) suggesting that amrinone has no effect on the actual MgADP release step (K_6 in Scheme 1) (10). Neither was there a significant effect of amrinone on the steady-state turnover phase (Fig. 3), consistent with very small effects of amrinone on both k_4 and k_5. To summarize, the main results of this section are that amrinone increases the basal MgATPase activity of HMM, but the effects on MgATP turnover by S1 are less consistent.

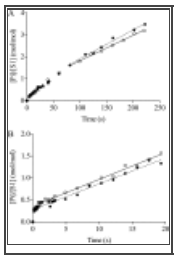


FIGURE 3.

Displacement of MgADP from S1 by MgATP. Data in the control solution (○) and in the presence of 1 mM amrinone (●) at 4 °C (*A*) and 25 °C (*B*) S1 (2 μM) plus MgADP (5 μM) were mixed with [γ-^{32}P]MgATP (more ...)

Amrinone Enhances Actomyosin Dissociation

The effect of amrinone on the MgATP-induced dissociation of acto-S1 (chymotryptic S1) is depicted in Fig. 4. Here 0.5 μM acto-S1 (using pyrene-labeled actin) in the presence or absence of 1 mM amrinone was rapidly mixed with various MgATP concentrations. The pyrene fluorescence signal could be fitted to a single exponential, and the resulting rate constant, k_{obs}, is plotted as a function of ATP concentration (Fig. 4*A*). From the slope, one can determine the MgATP-induced dissociation rate constant $K'_1k'_2$. This was increased from 1.09 ± 0.02 μM^{-1} s^{-1} in the absence of drug to 1.52 ± 0.09 μM^{-1} s^{-1} in the presence of 1 mM amrinone. Fig. 4*B* shows the results after incubating acto-S1 with variable amounts of amrinone before rapidly mixing with 25 μM ATP. In the presence of amrinone, the observed rates (k_{obs}) increased slightly from k_{obs} = 38 s^{-1} (no amrinone present) to k_{obs} = 52 s^{-1} (1.6 mM amrinone). The measured amplitudes were reduced at high amrinone concentrations, because of an inner filter effect of amrinone at 365 nm (data not shown). The increase of the MgATP-induced dissociation rates in the presence of amrinone was also seen with HMM using MgATP concentrations in the range 25–100 μM (data not shown).

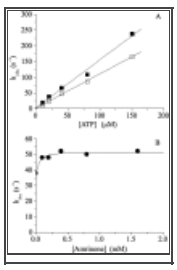


FIGURE 4.

Effect of amrinone on the MgATP-induced dissociation of acto-S1. *A*, 0.5 μM acto-S1 in the presence (■) or absence (□) of 1 mM amrinone was rapidly mixed with various MgATP concentrations. The fluorescence signal could be fitted (more ...)

The increase in ATP-induced dissociation in the presence of amrinone was corroborated using stopped-flow studies of myofibrils at low temperature (4 °C). After rapidly mixing myofibrils (3 μM; myosin head concentration) in the presence or absence of amrinone (100 μM) with variable amounts of MgATP, the

intrinsic tryptophan fluorescence signal could be fitted to a double exponential. The fast component of tryptophan fluorescence kinetics gives information about myosin head detachment induced by the MgATP binding, whereas the slow component is because of the ATP cleavage step (step 3 in Scheme 1) (8). The maximum amrinone concentration that could be studied using intrinsic tryptophan fluorescence changes was 100 μM because higher concentrations markedly decreased the signal magnitude due to an inner filter effect caused by amrinone at 295 nm. At 100 μM amrinone, no effect could be determined for the slow component. However, for the fast phase, an increase in MgATP-induced dissociation rate was found, compared with controls (Fig. 5*A*). To test the effect of higher amrinone concentrations (2 mM) on MgATP-induced detachment, pyrene-labeled myofibrils were used because the dependences of pyrene rate and tryptophan fast rate constants are very similar and report the same phenomenon, *i.e.* cross-bridge detachment. There was no slow phase in the pyrene signal. A fit to a hyperbola (Fig. 5*B*) suggests that 2 mM amrinone increases $k_{obs(max)}$ from 213 ± 7 to 381 ± 18 s^{-1}. These values would be expected to correspond directly to the rate constant k'_2 in Scheme 1. The hyperbolic fits also show that 2 mM amrinone increase the constant $K_{0.5}$ to 1.29 ± 0.12 mM from the control value of 0.55 ± 0.06 mM, corresponding to an ~2-fold reduction in the association constant K'_1 (Scheme 1). The key result of this section is the finding that amrinone increases the rate constant k_2'.

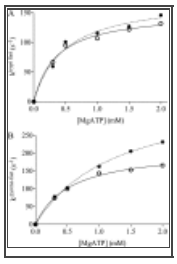


FIGURE 5.
Effect of amrinone on the ATP-induced actomyosin dissociation in myofibrils, measured using intrinsic tryptophan fluorescence (*A*) or pyrene fluorescence (*B*). *A*, myofibrillar tryptophan fluorescence fast rate constants as a function of MgATP concentration (more ...)

Amrinone Increases MgADP Affinity of HMM but Not of S1

The effect of amrinone on the MgADP affinity (K_{AD}) of actomyosin was investigated using stopped-flow techniques. Here K_{AD} is related to K'_6 (association constant) and $K'_5 = k'_5/k'_{-5}$. In the experiments (Fig. 6 *A*), 0.25 μM pActo-HMM, incubated with or without amrinone, was rapidly mixed with 100 μM MgATP and varying concentrations of MgADP. Without amrinone, the change in pyrene fluorescence could be fitted to a double exponential with k_{obs} = 158 s^{-1} for the fast phase (amplitude = 32%) and 21 s^{-1} for the slow phase (amplitude = 3.3%), and both fast and slow rate constants decreased with increasing MgADP concentration. In the presence of 1 mM amrinone the fluorescence change could also be fitted to a double exponential, resulting in slightly faster rates for the fast and the slow phase compared with the rates measured in the absence of amrinone (about 20% increase in both k_{obs}). Plots of the relative rate constant (k_{obs}/k_0) *versus* MgADP concentration are shown in Fig. 6*A*. Without amrinone present, the K_{AD} value was 152 ± 7 and 227 ± 41 μM for the fast and slow phase, respectively. The presence of 1 mM amrinone resulted in an ~2-fold increase of the MgADP affinity, *i.e.* the K_{AD} was 81 ± 10 μM for the fast phase and 78 ± 11 μM for the slow phase.

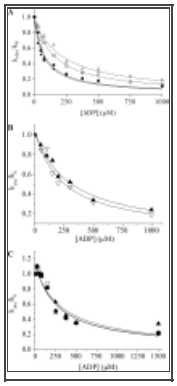


FIGURE 6.
Effect of amrinone on the ADP affinity of rabbit psoas HMM (*A*), papain S1 (*B*), and chymotryptic S1 (*C*). *A*, 0.25 μM phalloidin-stabilized pyrene-labeled actin was incubated with HMM (containing an equimolar amount of myosin heads) in the presence (more ...)

The effect of amrinone on the MgADP affinity was also investigated using chymotryptic S1 (without the regulatory light chain) or papain S1 (with intact regulatory light chains). The pyrene-labeled acto-S1 complex, in the presence or absence of amrinone, was rapidly mixed with 100 μM MgATP and varying concentrations of MgADP. The observed pyrene fluorescence signal could also be fitted to a double exponential with a fast phase (amplitude = 48%) and a slow phase (amplitude = 4.5%). Both fast and slow rate constants decreased with increasing MgADP concentration as depicted in Fig. 6, *B* and *C*, for the two S1 complexes. For clarity, only the fast phase is shown because it has a relative amplitude >90%.

In contrast to the situation with HMM, the MgADP affinity (K_{AD}) of the acto-S1 complexes was very similar in the presence and absence of 1 mM amrinone. This can be seen for papain S1 in Fig. 6*B* and for chymotryptic S1 in Fig. 6*C*. Thus, amrinone increases MgADP affinity of acto-HMM but not of acto-S1.

Amrinone Reduces Actin Filament Sliding Velocity

The effect of amrinone on actin filament sliding velocity was studied using *in vitro* motility assays and HMM from fast leg muscle isoforms IIx and IIb (24). The presence of amrinone reduced the sliding velocity

significantly, as is depicted in Fig. 7 at various ionic strengths. It can be seen in Fig. 7*A* that 1–2 mM amrinone reduced the sliding velocity at all ionic strengths studied, from control values ranging from 3.5 μm s^{-1} at the lowest ionic strength to ~10 μm s^{-1} at 100 mM ionic strength. The percentage reduction of sliding velocity (mean, 31.0 ± 2.5%; *n* = 15 experiments) in the presence of 1 mM amrinone was similar at different ionic strengths (20–160 mM) of the assay solution (Fig. 7*B*). It is also shown in Fig. 7*A* that the effect of amrinone was fully reversible. Thus sliding velocities measured in a given flow cell were virtually identical in a control assay solution before and after incubation of the cell with an amrinone-containing assay solution.

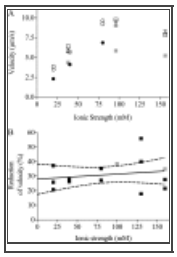


FIGURE 7.
Effects of 1–2 mM amrinone on the HMM-induced actin filament sliding velocity at pH 7. 2. *A*, sliding velocities at different ionic strengths of the assay solution without amrinone (*open symbols*) and in the presence of the drug (*filled symbols* (more ...)

By reducing the pH from 7.2 to 6.7, the solubility of amrinone was increased, allowing studies at higher drug concentrations (supplemental Table 1). At pH 6.7 we found a similar decrease in sliding velocity at 1 mM amrinone (average reduction 28.3 ± 10.4%) as at pH 7.2. At higher amrinone concentrations (3 mM) there was a moderate further increase in sliding velocity. This indicates that the effect of amrinone may not be fully saturated at the concentration of 1–2 mM, as used throughout in the present work for practical reasons.

Data from *in vitro* motility assay experiments at 23 and 29 °C are compared in a Table 1 both for HMM from fast leg muscles (MHC IIb and MHC IIx) (24) and psoas muscle (MHC IIx) (43). It can be seen that amrinone (1 mM) reduced the sliding velocity by ~30% at both temperatures (see also Fig. 7) for HMM from leg muscle. The effect of the drug on the sliding velocity for two HMM preparations (two different myosin preparations) from musculus psoas major, was slightly lower than for the leg muscle, an effect that was enhanced at the lowest temperature. *In vitro* motility assays were also performed using two different papain-S1 preparations from psoas muscles (29 °C). The average sliding velocity in the control solution was 3.35 ± 0.08 μm s^{-1} (*n* = 4 experiments), and there was a reduction in velocity in response to amrinone. Although the effect of 1 mM amrinone was small (reduction by 7.8 ± 3.6%), it occurred in all experiments. Moreover, as shown in one experiment, the effect was fully reversible. In this case the velocity was reduced from 3.57 ± 0.05 μm s^{-1} (n_f = 27 filaments) in the control solution to 3.35 ± 0.05 μm s^{-1} (n_f = 26) in 1 mM amrinone and then back to 3.58 ± 0.04 μm s^{-1} (n_f = 49) after re-immersion in amrinone-free solution.

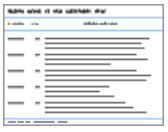


TABLE 1
***In vitro* motility data using HMM and showing the effect of myosin isoform composition and temperature on the amrinone-induced reduction in sliding velocity**

To conclude this section, amrinone reduces the sliding velocity of actin filaments propelled by both HMM and S1. Whereas the effect was larger with HMM, it was reversible with both HMM and S1. The effect of amrinone on sliding velocity was similar over a range of ionic strengths.

Optical Tweezers Experiments

Optical tweezers experiments were performed to elucidate the effects of amrinone on the working stroke produced by the interactions of a single muscle myosin motor head (papain S1) with F-actin. Fig. 8 shows that the drug had no clear effect on the amplitude of the myosin working stroke or on the rate constant of MgATP-induced detachment. Consistent with other results in this work, there was a slight increase of the MgATP-dependent rate constant for detachment in the presence of amrinone (from 3.5 to 4.1 μM^{-1} s^{-1}).

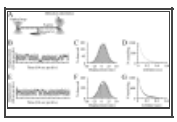


FIGURE 8.
Optical tweezers study. *A*, schematic representation of the three-bead assay used in the single molecule mechanical experiments. A single actin filament is suspended between two 1.1-μm polystyrene beads, held in the optical tweezers. The actin (more ...)

Modeling of the Force-Velocity Relationship

The three attached cross-bridge states in the modified version of the model of Edman *et al.* (25) (Fig. 9 and supplemental material) may be readily identified with the AMADP·P_i, (A_0) AM*ADP (A_1) and AMADP/AM/AMATP (A_2) states in Scheme 1 (see Ref. 44). Attempts to use the original version of the model (25) to account for the amrinone effects were not successful. We therefore introduced minor modifications (supplemental material). Simulation of amrinone effects by a mechanism involving a reduced rate constant of a strain-dependent MgADP release step could be achieved in either of two ways. Thus, either the free energy of the A_1 (AM*ADP) state is reduced, or the free energy of the A_2 (AM ADP, AM, and AM ATP) state is increased (Fig. 9). Both changes predict the main effects of amrinone on the force-velocity relationship (supplemental material). However, the increase in free energy of the A_2 state is also, in a straightforward

way, consistent with an increased rate of MgATP-induced detachment of actomyosin. It can be seen in Fig. 10, *A* and *B*, that an increase in free energy of the state A_2 both predicts a reduced maximum velocity of shortening and an increased maximum isometric tension. Moreover, there is a tendency toward a reduced curvature of the force-velocity relationship at low forces, and there is a reduced deviation of the force-velocity relationship from a hyperbolic form (23, 42) at high forces. In this simulation it was assumed that $k'_6 \ll k'_2$ leaving the effect of amrinone on k'_2 without any appreciable effect on the rate function $k_{23}(x)$ in the model (see further supplemental material and "Discussion").

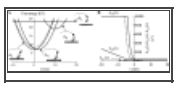


FIGURE 9.

Free-energy diagrams (*A*) and important rate constants (*B*) in modified cross-bridge model of Edman *et al.* (25). *A*, state A_0 is assumed to correspond to biochemical state AM ADP P_i, whereas the detached state A_3 would correspond to the M ATP and M ADP P (more ...)

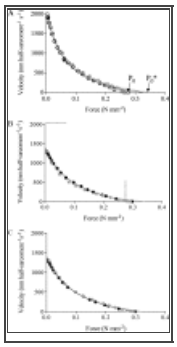


FIGURE 10.

Simulation of the force-velocity relationship of muscle on basis of modified cross-bridge model of Edman *et al.* (25) designed to simulate mechanical properties of frog muscle fibers. *A*, simulated force-velocity data for control conditions (*gray open circles* (more ...)

In the model of Edman *et al.* (25), and also in the modified model used here, the rate constant of cross-bridge attachment is increased with the sliding velocity (supplemental Fig. 4*F*). The assumption of an amrinone-induced increase of the rate constant of cross-bridge attachment during shortening (but not in isometric contraction) leads to improved model behavior in certain important respects. Thus the model better reproduces both the amrinone-induced reduction in curvature of the force-velocity relationship at low forces (with a higher ratio a/P_0* in the Hill equation (42)) and the reduced deviation of the force-velocity relationship from the Hill hyperbola at high forces (Fig. 10*C*).

DISCUSSION

Other Sections▼

In accordance with earlier results for the CaATPase (22) and preliminary studies of basal MgATPase activity (24), amrinone moderately increased the MgATP turnover rate of myosin and HMM in the absence of actin. This suggests (see Introduction) that amrinone increases the rate constant k_4 (Scheme 1). Whereas a small increase in the basal MgATPase activity cannot, *per se*, cause lower sliding velocity, the combination of reduced velocity and an increased basal MgATPase have been observed in response to several point mutations within the myosin motor domain (45–47). A similar combination of effects has also been observed by exchanging regular MgATP for a fluorescent MgATP analogue (48). The different effects of amrinone on HMM and S1 is considered in the supplemental material.

The fact that the 30% reduction in HMM-induced sliding velocity was independent of the ionic strength of the assay solution indicates that the effect on velocity is not because of drag forces caused by myosin cross-bridges in weak binding states (9, 34). Such forces are expected to increase at reduced ionic strength, which would have resulted in greater reduction of sliding velocity by amrinone under these conditions (49).

The studies of actomyosin kinetics focused on dissociation from strongly bound, force-producing states. Thus the steps in this process (1′–2′ and 5′–6′ in Scheme 1) have been implicated (7, 50) as important determinants of the maximum sliding speed. Results with myofibrils, HMM and S1, suggest that amrinone produces a small to moderate increase of the rate constant, k'_2, for ATP-induced detachment. Clearly such an effect cannot account for the amrinone-induced reduction in sliding velocity. However, it may play a modulatory role (supplemental material). For example, for psoas myosin there are suggestions (7) that the rate-limiting step for actomyosin dissociation may change from k'_6 to k'_2 at temperatures below about 25 °C. This may be related to the generally lower effect of amrinone on sliding velocity with the psoas preparation (Table 1). The finding that amrinone does not affect the myosin step length is consistent with previous conclusions (24) from studies of sliding velocity at different ATP concentrations.

An amrinone-induced increase of the MgADP affinity was observed with HMM but not with papain S1 (which, like HMM, has an intact regulatory light chain region). This is consistent with the view that mechanically strained myosin heads, with MgADP at the active site, are important for the amrinone effect. In solution, such strained heads would exist only with two-headed myosin motor fragments (51). In contrast, strain occurs also with one-headed motor fragments in the *in vitro* motility assay because several surface-immobilized S1 motors can act asynchronously on the same actin filament. Therefore, amrinone effects on a strain-dependent MgADP release step can account for the amrinone-induced reduction in actin sliding velocity also with S1.

The lack of amrinone effects on the MgADP affinity of S1 agrees with the idea that the drug does not affect the actual MgADP release step (k'_6 in Scheme 1; related to $K'_6 = k'_{-6}/k'_6$) but alters the preceding

the actual MgADP release step (k'_6 in Scheme 1, related to $k'_6 = k'_{-6}/k'_6$) but alters the preceding isomerization step (k'_5/k'_{-5}). The existence of such an isomerization between a state with a closed (AM*ADP) and open (AM ADP) nucleotide pocket has been explicitly incorporated into statistical cross-bridge models of muscle contraction (44, 52, 53). It has also been proposed to account for the strain sensitivity and slow MgADP release of several slow myosin II isoforms (54–56). As proposed for these slow isoforms (7), the AM*ADP-AM ADP transition may also influence the measured value of K_{AD}. Thus, the idea that amrinone affects this transition would be consistent with the drug-induced reduction of K_{AD} for acto-HMM. Preliminary transient kinetics results with acto-HMM are consistent with this conclusion (supplemental material). These results suggest that 1 m_M amrinone markedly alters the multiexponential time course of acto-HMM dissociation following displacement of MgADP at the active site with MgATP. Amrinone increased the amplitude of slow exponential processes at the expense of fast ones and reduced the slow rates but not the fast rates.

In general agreement with the idea of a mechanically strained AM*ADP state, an MgADP-induced structural change in angle of the myosin light chain binding domain has been observed for slow muscle myosin isoforms and for non-muscle myosin classes (57–62). Moreover, in a series of optical tweezers studies (40, 63–65), slow muscle myosin isoforms as well as non-muscle myosins (classes I, V, and VI) were all found to exhibit a power stroke in two steps, probably coupled to the release of P_i and MgADP. Furthermore, single molecule mechanical experiments on smooth muscle and non-muscle myosin class V showed that the dwell time preceding the second step of the working stroke is load-dependent (40, 66). This is consistent with the idea of a load-dependent isomerization preceding the MgADP release step.

The presence of two actomyosin ADP states in skeletal muscle has been implicated before (67, 68), but the properties of these states have been largely unknown (55). Thus, in contrast to the situation for various slow myosin classes, MgADP-induced ultrastructural changes have not been observed for fast skeletal muscle myosin (58, 59). Neither could the existence of a second step be detected in previous optical tweezers studies (63). As pointed out earlier (55), this does not necessarily mean that such a step does not exist. Instead, the population of the state may be low (because of an unfavorable equilibrium), and the kinetics may be fast. Consistent with these ideas, recent optical tweezers studies with improved time resolution (69) have demonstrated two-step force generation also in fast skeletal muscle myosin. The idea that the second step represents the above mentioned isomerization in skeletal muscle was discussed (69) but could not be unambiguously verified. Here, amrinone might be of value as a pharmacological tool in future studies.

The above discussion suggests that the AM* ADP state becomes more heavily populated during muscle contraction in the presence of amrinone. This is in accordance with the increased isometric force production in response to the drug (19–22) because the AM* ADP state is likely to be the main force-producing state (40, 63, 69). Amrinone also affects the shape of the force-velocity relationship (see Introduction and Fig. 1) (19–21). The amrinone effects were well simulated by the modified model of Edman *et al.* (25) (see Figs. 9 and 10). Here amrinone was assumed to reduce the rate constant, k'_5, of the AM*ADP to AM ADP transition as a result of increased free energy of the state A_2. The amrinone effects were well reproduced (Fig. 10) without any extensive attempts for optimization of the model. Indeed, the only experimental parameter quantitatively fitted in the simulations was the reduction in maximum sliding velocity.

Simulation of the amrinone effects by increased free energy of the state A_2 rather than by reduced free energy of the state A_1 was favored. In this way both the increase of the rate constant k'_2 and the reduction of the rate constant k'_5 may be accommodated without the need to postulate that the drug affects the free energy of more than one state (see supplemental material). The fact that the amrinone effect on k'_2, unlike the effect on K_{AD} (related to K'_5 and K'_6), was observed in both one- and two-headed motor fragments does not preclude that both effects are due to binding to the same site (see supplemental material). Thus, even if an effect on k'_5 exists also with S1 (*cf. in vitro* motility assay data above) a two-headed myosin fragment is needed in solution experiments to significantly populate the AM*ADP state, thus enabling the probing of the strain-dependent AM*ADP-AM ADP transition.

The potential importance of cooperativity between the two heads of skeletal muscle myosin II is emphasized by the difference in the amrinone effects between S1 and HMM. In analogy with these effects, amrinone might also modulate cooperative effects existing in shortening muscle (*e.g.* due to prolonged binding of one head in the AM*ADP state positioning the other head for rapid binding to the next actin site). It is therefore interesting to note that an improved fit of the force-velocity data in the presence of amrinone was obtained by the assumption of an increase of the attachment rate constant at high sliding velocity in the presence of the drug. Whether this corresponds to effects of the drug on inter-head cooperativity deserves further investigation. (*cf.* Refs. 70, 71).

In conclusion, this study not only addresses the mechanism of action of the myosin inhibitor amrinone but also elucidates several long standing issues of general relevance for mechanistic insight into skeletal muscle biochemistry and physiology. Of particular interest is the finding that the amrinone-induced reduction in sliding velocity can be attributed to inhibition of a strain-dependent MgADP release step. Such a step, associated with a significant population of the AM* ADP state, has not previously been convincingly demonstrated in fast skeletal muscle. Incorporation of this idea into a simple statistical model allowed faithful simulation of the unique set of amrinone effects on the force-velocity relationship. This provides general support for the validity and explanatory power of the statistical model used and deeper insight into fundamental mechanisms of muscle contraction. It is important to point out that those results that are of greatest general relevance to the understanding of muscle function do not rely on knowledge of the exact binding site of amrinone. Moreover, because determination of this site is very challenging (see supplemental material), it is outside the scope of the present investigation but may be of interest to

supplemental material), it is outside the scope of the present investigation but may be of interest to elucidate in future studies.

Supplementary Material

Supplemental Data

Click here to view.

*This work was supported in part by The Swedish Research Council Projects 621-2004-3449 and 621-2007-6137 (to A. M.), The Carl Trygger Foundation, The Knowledge Foundation (KK-stiftelsen), The Crafoord Foundation, Faculty of Natural Sciences and Engineering at the University of Kalmar (to A. M. and N. A.-T.), Program Grant 070021 from the Wellcome Trust (to M. A. G. and M. J. B.), and Biotechnology and Biological Sciences Research Council and Medical Research Council (United Kingdom) (to C. P., S. S., and C. V.).

S The on-line version of this article (available at http://www.jbc.org) contains supplemental Results, Discussion, Tables 1 and 2, Figs. 1–6, and additional references.

[4]The abbreviations used are:

AM	actomyosin
HMM	heavy meromyosin
TRITC	tetramethylrhodamine isothiocyanate
TRITC-Ph	TRITC conjugated with phalloidin
MOPS	4-morpholinepropanesulfonic acid
MHC	myosin heavy chain.

REFERENCES

Other Sections▼

1. Woledge R. C., Curtin N. A., Homsher E. (1985) *Energetic Aspects of Muscle Contraction*, Academic Press, London.

2. Geeves M. A., Holmes K. C. (2005) *Adv. Protein Chem.* 71,161–193. [PubMed]

3. Howard J. (2001) *Mechanics of Motor Proteins and the Cytoskeleton*, Sinauer Associates, Inc., Sunderland, MA.

4. Biosca J. A., Travers F., Hillaire D., Barman T. E. (1984) *Biochemistry* 23,1947–1955. [PubMed]

5. Barman T. E., Travers F. (1985) *Methods Biochem. Anal.* 31,1–59. [PubMed]

6. Trentham D. R., Eccleston J. F., Bagshaw C. R. (1976) *Q. Rev. Biophys.* 9,217–281. [PubMed]

7. Nyitrai M., Rossi R., Adamek N., Pellegrino M. A., Bottinelli R., Geeves M. A. (2006) *J. Mol. Biol.* 355,432–442. [PubMed]

8. Stehle R., Brenner B. (2000) *Biophys. J.* 78,1458–1473. [PMC free article] [PubMed]

9. Amitani I., Sakamoto T., Ando T. (2001) *Biophys. J.* 80,379–397. [PMC free article] [PubMed]

10. Herrmann C., Wray J., Travers F., Barman T. (1992) *Biochemistry* 31,12227–12232. [PubMed]

11. Bagni M. A., Cecchi G., Colomo F., Garzella P. (1992) *J. Muscle Res. Cell Motil.* 13,516–522. [PubMed]

12. Horiuti K., Higuchi H., Umazume Y., Konishi M., Okazaki O., Kurihara S. (1988) *J. Muscle Res. Cell Motil.* 9,156–164. [PubMed]

13. McKillop D. F., Fortune N. S., Ranatunga K. W., Geeves M. A. (1994) *J. Muscle Res. Cell Motil.* 15,309–318. [PubMed]

14. Cheung A., Dantzig J. A., Hollingworth S., Baylor S. M., Goldman Y. E., Mitchison T. J., Straight A. F. (2002) *Nat. Cell Biol.* 4,83–88. [PubMed]

15. Shaw M. A., Ostap E. M., Goldman Y. E. (2003) *Biochemistry* 42,6128–6135. [PubMed]

16. Straight A. F., Cheung A., Limouze J., Chen I., Westwood N. J., Sellers J. R., Mitchison T. J. (2003) *Science* 299,1743–1747. [PubMed]

17. Allingham J. S., Smith R., Rayment I. (2005) *Nat. Struct. Mol. Biol.* 12,378–379. [PubMed]

18. Kovács M., Tóth J., Hetényi C., Málnási-Csizmadia A., Sellers J. R. (2004) *J. Biol. Chem.* 279,35557–35563. [PubMed]

19. Månsson A., Edman K. A. (1984) *Acta Physiol. Scand.* 120,473–475. [PubMed]

20. Månsson A., Edman K. A. (1985) *Acta Physiol. Scand.* 125,481–493. [PubMed]

21. Månsson A., Mörner J., Edman K. A. (1989) *Acta Physiol. Scand.* 136,37–45. [PubMed]

22. Bottinelli R., Cappelli V., Morner S. E., Reggiani C. (1993) *J. Muscle Res. Cell Motil.* 14,110–120. [PubMed]

23. Edman K. A. P. (1988) *J. Physiol.* 404,301–321. [PubMed]

24. Klinth J., Arner A., Månsson A. (2003) *J. Muscle Res. Cell Motil.* 24,15–32. [PubMed]

25. Edman K. A., Månsson A., Caputo C. (1997) *J. Physiol.* 503,141–156. [PubMed]

26. Pardee J. D., Spudich J. A. (1982) *Methods Cell Biol.* 24,271–289. [PubMed]

27. Criddle A. H., Geeves M. A., Jeffries T. (1985) *Biochem. J.* 232,343–349. [PubMed]

28. Kron S. J., Toyoshima Y. Y., Uyeda T. Q., Spudich J. A. (1991) *Methods Enzymol.* 196,399–416. [PubMed]

29. Weeds A. G., Taylor R. S. (1975) *Nature* 257,54–56. [PubMed]

30. Margossian S. S., Lowey S. (1982) *Methods Enzymol.* 85,55–71. [PubMed]

31. Stehle R., Lionne C., Travers F., Barman T. (1998) *J. Muscle Res. Cell Motil.* 19,381–392. [PubMed]

32. Ma Y. Z., Taylor E. W. (1994) *Biophys. J.* 66,1542–1553. [PMC free article] [PubMed]

33. Houadjeto M., Travers F., Barman T. (1992) *Biochemistry* 31,1564–1569. [PubMed]

34. Stehle R., Lionne C., Travers F., Barman T. (2000) *Biochemistry* 39,7508–7520. [PubMed]

35. Kodama T., Fukui K., Kometani K. (1986) *J. Biochem.* 99,1465–1472. [PubMed]

36. Reimann E. M., Umfleet R. A. (1978) *Biochim. Biophys. Acta* 523,516–521. [PubMed]

37. Sundberg M., Balaz M., Bunk R., Rosengren-Holmberg J. P., Montelius L., Nicholls I. A., Omling P., Tågerud S., Månsson A. (2006) *Langmuir* 22,7302–7312. [PubMed]

38. Månsson A., Tågerud S. (2003) *Anal. Biochem.* 314,281–293. [PubMed]

39. Veigel C., Bartoo M. L., White D. C., Sparrow J. C., Molloy J. E. (1998) *Biophys. J.* 75,1424–1438. [PMC free article] [PubMed]

40. Veigel C., Molloy J. E., Schmitz S., Kendrick-Jones J. (2003) *Nat. Cell Biol.* 5,980–986. [PubMed]

41. Batters C., Arthur C. P., Lin A., Porter J., Geeves M. A., Milligan R. A., Molloy J. E., Coluccio L. M. (2004) *EMBO J.* 23,1433–1440. [PMC free article] [PubMed]

42. Hill A. V. (1938) *Proc. R. Soc. Lond. B Biol. Sci.* 126,136–195.

43. Hämäläinen N., Pette D. (1993) *J. Histochem. Cytochem.* 41,733–743. [PubMed]

44. Duke T. A. (1999) *Proc. Natl. Acad. Sci. U.S.A.* 96,2770–2775. [PMC free article] [PubMed]

45. Sasaki N., Sutoh K. (1998) *Adv. Biophys.* 35,1–24. [PubMed]

46. Patterson B., Ruppel K. M., Wu Y., Spudich J. A. (1997) *J. Biol. Chem.* 272,27612–27617. [PubMed]

47. Suzuki Y., Ohkura R., Sugiura S., Yasuda R., Kinoshita K., Jr., Tanokura M., Sutoh K. (1997) *Biochem. Biophys. Res. Commun.* 234,701–706. [PubMed]

48. Balaz M., Sundberg M., Persson M., Kvassman J., Månsson A. (2007) *Biochemistry* 46,7233–7251. [PubMed]

49. Brenner B., Chalovich J. M., Greene L. E., Eisenberg E., Schoenberg M. (1986) *Biophys. J.* 50,685–691. [PMC free article] [PubMed]

50. Siemankowski R. F., Wiseman M. O., White H. D. (1985) *Proc. Natl. Acad. Sci. U.S.A.* 82,658–662. [PMC free article] [PubMed]

51. Kovács M., Thirumurugan K., Knight P. J., Sellers J. R. (2007) *Proc. Natl. Acad. Sci. U.S.A.* 104,9994–9999. [PMC free article] [PubMed]

52. Smith D. A., Geeves M. A. (1995) *Biophys. J.* 69,524–537. [PMC free article] [PubMed]

53. Duke T. (2000) *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 355,529–538. [PMC free article] [PubMed]

54. Berger C. E., Fagnant P. M., Heizmann S., Trybus K. M., Geeves M. A. (2001) *J. Biol. Chem.* 276,23240–23245. [PubMed]

55. Nyitrai M., Geeves M. A. (2004) *Philos. Trans. R. Soc. Lond. B Biol. Sci.* 359,1867–1877. [PMC free article] [PubMed]

56. Bloemink M. J., Adamek N., Reggiani C., Geeves M. A. (2007) *J. Mol. Biol.* 373,1184–1197. [PMC free article] [PubMed]

57. Whittaker M., Wilson-Kubalek E. M., Smith J. E., Faust L., Milligan R. A., Sweeney H. L. (1995) *Nature* 378,748–751. [PubMed]

58. Gollub J., Cremo C. R., Cooke R. (1996) *Nat. Struct. Biol.* 3,796–802. [PubMed]

59. Iwamoto H., Oiwa K., Kovács M., Sellers J. R., Suzuki T., Wakayama J., Tamura T., Yagi N., Fujisawa T. (2007) *J. Mol. Biol.* 369,249–264. [PMC free article] [PubMed]

60. Jontes J. D., Wilson-Kubalek E. M., Milligan R. A. (1995) *Nature* 378,751–753. [PubMed]

61. Wells A. L., Lin A. W., Chen L. Q., Safer D., Cain S. M., Hasson T., Carragher B. O., Milligan R. A., Sweeney H. L. (1999) *Nature* 401,505–508. [PubMed]

62. Volkmann N., Liu H., Hazelwood L., Krementsova E. B., Lowey S., Trybus K. M., Hanein D. (2005) *Mol. Cell* 19,595–605. [PubMed]

63. Veigel C., Coluccio L. M., Jontes J. D., Sparrow J. C., Milligan R. A., Molloy J. E. (1999) *Nature* 398,530–533. [PubMed]

64. Veigel C., Wang F., Bartoo M. L., Sellers J. R., Molloy J. E. (2002) *Nat. Cell Biol.* 4,59–65. [PubMed]

65. Lister I., Schmitz S., Walker M., Trinick J., Buss F., Veigel C., Kendrick-Jones J. (2004) *EMBO J.* 23,1729–1738. [PMC free article] [PubMed]

66. Veigel C., Schmitz S., Wang F., Sellers J. R. (2005) *Nat. Cell Biol.* 7,861–869. [PubMed]

67. Dantzig J. A., Hibberd M. G., Trentham D. R., Goldman Y. E. (1991) *J. Physiol.* 432,639–680. [PubMed]

68. Sleep J. A., Hutton R. L. (1980) *Biochemistry* 19,1276–1283. [PubMed]

69. Capitanio M., Canepari M., Cacciafesta P., Lombardi V., Cicchi R., Maffei M., Pavone F. S., Bottinelli R. (2006) *Proc.*

Natl. Acad. Sci. U.S.A. 103,87–92. [PMC free article] [PubMed]

70. Conibear P. B., Geeves M. A. (1998) *Biophys. J.* 75,926–937. [PMC free article] [PubMed]

71. Månsson A., Nicholls I. A., Omling P., Tågerud S., Montelius L. (2007) in *Controlled Nanoscale Motion*; Nobel Symposium 131 (Linke H., Månsson A., editors. , eds) pp. 385–406, Lecture Notes in Physics711, Springer Verlag, Berlin.

Cited By - displaying 1 of 1 citations • Web of Science® times cited (2)- subscription required

Actomyosin-ADP states, interhead cooperativity, and the force-velocity relation of skeletal muscle.
(PMID:20371323)

Cites the following - displaying 71 of 71 citations

Title not supplied – full information unavailable
(Energetic Aspects of Muscle Contraction)
Woledge R., Curtin N., Homsher E..
[1985] - Academic Press (London)

The molecular mechanism of muscle contraction.
(PMID:16230112)
Geeves MA, Holmes KC.
Adv. Protein Chem. [2005]

Title not supplied – full information unavailable
(Mechanics of Motor Proteins and the Cytoskeleton)
Howard J..
[2001] - Sinauer Associates, Inc. (Sunderland, MA)

Cryoenzymic studies on myosin subfragment 1: perturbation of an enzyme reaction by temperature and solvent.
(PMID:6232952)
Biosca JA, Travers F, Hillaire D, Barman TE.
Biochemistry [1984]

The rapid-flow-quench method in the study of fast reactions in biochemistry: extension to subzero conditions.
(PMID:3160914)
Barman TE, Travers F.
Methods Biochem Anal [1985]

Kinetic analysis of ATPase mechanisms.
(PMID:183232)
Trentham DR, Eccleston JF, Bagshaw CR.
Q. Rev. Biophys. [1976]

What limits the velocity of fast-skeletal muscle contraction in mammals?
(PMID:16325202)
Nyitrai M, Rossi R, Adamek N, Pellegrino MA, Bottinelli R, et al.
J. Mol. Biol. [2006]

Cross-bridge attachment during high-speed active shortening of skinned fibers of the rabbit psoas muscle: implications for cross-bridge action during maximum velocity of filament sliding.
(PMID:10692331)
Stehle R, Brenner B.
Biophys. J. [2000]

Link between the enzymatic kinetics and mechanical behavior in an actomyosin motor.
(PMID:11159410)
Amitani I, Sakamoto T, Ando T.
Biophys. J. [2001]

Effect of 2,3-butanedione monoxime on myosin and myofibrillar ATPases. An example of an uncompetitive inhibitor.
(PMID:1457420)
Herrmann C, Wray J, Travers F, Barman T.

Biochemistry [1992]

Effects of 2,3-butanedione monoxime on the crossbridge kinetics in frog single muscle fibres.
(PMID:1460080)
Bagni MA, Cecchi G, Colomo F, Garzella P.
J. Muscle Res. Cell. Motil. [1992]

Mechanism of action of 2, 3-butanedione 2-monoxime on contraction of frog skeletal muscle fibres.
(PMID:2458382)
Horiuti K, Higuchi H, Umazume Y, Konishi M, Okazaki O, et al.
J. Muscle Res. Cell. Motil. [1988]

The influence of 2,3-butanedione 2-monoxime (BDM) on the interaction between actin and myosin in solution and in skinned muscle fibres.
(PMID:7929796)
McKillop DF, Fortune NS, Ranatunga KW, Geeves MA.
J. Muscle Res. Cell. Motil. [1994]

A small-molecule inhibitor of skeletal muscle myosin II.
(PMID:11744924)
Cheung A, Dantzig JA, Hollingworth S, Baylor SM, Goldman YE, et al.
Nat. Cell Biol. [2002]

Mechanism of inhibition of skeletal muscle actomyosin by N-benzyl-p-toluenesulfonamide.
(PMID:12755615)
Shaw MA, Ostap EM, Goldman YE.
Biochemistry [2003]

Dissecting temporal and spatial control of cytokinesis with a myosin II Inhibitor.
(PMID:12637748)
Straight AF, Cheung A, Limouze J, Chen I, Westwood NJ, et al.
Science [2003]

The structural basis of blebbistatin inhibition and specificity for myosin II.
(PMID:15750603)
Allingham JS, Smith R, Rayment I.
Nat. Struct. Mol. Biol. [2005]

Mechanism of blebbistatin inhibition of myosin II.
(PMID:15205456)
Kovacs M, Toth J, Hetenyi C, Malnasi-Csizmadia A, Sellers JR.
J. Biol. Chem. [2004]

Effects of amrinone on twitch, tetanus and force-velocity relationship in frog skeletal muscle.
(PMID:6611016)
Mansson A, Edman KA.
Acta Physiol. Scand. [1984]

Effects of amrinone on the contractile behaviour of frog striated muscle fibres.
(PMID:3878658)
Mansson A, Edman KA.
Acta Physiol. Scand. [1985]

Effects of amrinone on twitch, tetanus and shortening kinetics in mammalian skeletal muscle.
(PMID:2773661)

Mansson A, Morner J, Edman KA.
Acta Physiol. Scand. [1989]

Effects of amrinone on shortening velocity and force development in skinned skeletal muscle fibres.
(PMID:8478421)
Bottinelli R, Cappelli V, Morner SE, Reggiani C.
J. Muscle Res. Cell. Motil. [1993]

Double-hyperbolic force-velocity relation in frog muscle fibres.
(PMID:3267024)
Edman KA.
J. Physiol. (Lond.) [1988]

Cardiotonic bipyridine amrinone slows myosin-induced actin filament sliding at saturating [MgATP].
(PMID:12953834)
Klinth J, Arner A, Mansson A.
J. Muscle Res. Cell. Motil. [2003]

The biphasic force-velocity relationship in frog muscle fibres and its evaluation in terms of cross-bridge function.
(PMID:9288682)
Edman KA, Mansson A, Caputo C.
J. Physiol. (Lond.) [1997]

J. Physiol. (Lond.) [1997]

Purification of muscle actin.
(PMID:7098993)
Pardee JD, Spudich JA.
Methods Cell Biol. [1982]

The use of actin labelled with N-(1-pyrenyl)iodoacetamide to study the interaction of actin with myosin subfragments and troponin/tropomyosin.
(PMID:3911945)
Criddle AH, Geeves MA, Jeffries T.
Biochem. J. [1985]

Assays for actin sliding movement over myosin-coated surfaces.
(PMID:2034132)
Kron SJ, Toyoshima YY, Uyeda TQ, Spudich JA.
Meth. Enzymol. [1991]

Separation of subfragment-1 isoenzymes from rabbit skeletal muscle myosin.
(PMID:125854)
Weeds AG, Taylor RS.
Nature [1975]

Preparation of myosin and its subfragments from rabbit skeletal muscle.
(PMID:6214692)
Margossian SS, Lowey S.
Meth. Enzymol. [1982]

Probing the coupling of Ca2+ and rigor activation of rabbit psoas myofibrillar ATPase with ethylene glycol.
(PMID:9635281)
Stehle R, Lionne C, Travers F, Barman T.
J. Muscle Res. Cell. Motil. [1998]

Kinetic mechanism of myofibril ATPase.
(PMID:8061203)
Ma YZ, Taylor EW.
Biophys. J. [1994]

Ca(2+)-activated myofibrillar ATPase: transient kinetics and the titration of its active sites.
(PMID:1531296)
Houadjeto M, Travers F, Barman T.
Biochemistry [1992]

Kinetics of the initial steps of rabbit psoas myofibrillar ATPases studied by tryptophan and pyrene fluorescence stopped-flow and rapid flow-quench. Evidence that cross-bridge detachment is slower than ATP binding.
(PMID:10858300)
Stehle R, Lionne C, Travers F, Barman T.
Biochemistry [2000]

The initial phosphate burst in ATP hydrolysis by myosin and subfragment-1 as studied by a modified malachite green method for determination of inorganic phosphate.
(PMID:2940237)
Kodama T, Fukui K, Kometani K.
J. Biochem. [1986]

Selective precipitation of 32Pi onto filter papers. Application to ATPase and cyclic AMP phosphodiesterase determination.
(PMID:207336)
Reimann EM, Umfleet RA.
Biochim. Biophys. Acta [1978]

Selective spatial localization of actomyosin motor function by chemical surface patterning.
(PMID:16893230)
Sundberg M, Balaz M, Bunk R, Rosengren-Holmberg JP, Montelius L, et al.
Langmuir [2006]

Multivariate statistics in analysis of data from the in vitro motility assay.
(PMID:12654315)
Mansson A, Tagerud S.
Anal. Biochem. [2003]

The stiffness of rabbit skeletal actomyosin cross-bridges determined with an optical tweezers transducer.
(PMID:9726944)
Veigel C, Bartoo ML, White DC, Sparrow JC, Molloy JE.
Biophys. J. [1998]

Load-dependent kinetics of force production by smooth muscle myosin measured with optical tweezers.
(PMID:14578909)

Veigel C, Molloy JE, Schmitz S, Kendrick-Jones J.
Nat. Cell Biol. [2003]

Myo1c is designed for the adaptation response in the inner ear.
(PMID:15014434)
Batters C, Arthur CP, Lin A, Porter J, Geeves MA, et al.
EMBO J. [2004]

Title not supplied – full information unavailable
(Proc. R. Soc. Lond. B Biol. Sci.)
Hill A..
[1938]

The histochemical profiles of fast fiber types IIB, IID, and IIA in skeletal muscles of mouse, rat, and rabbit.
(PMID:8468455)
Hamalainen N, Pette D.

J. Histochem. Cytochem. [1993]

Molecular model of muscle contraction.
(PMID:10077586)
Duke TA.
Proc. Natl. Acad. Sci. U.S.A. [1999]

Structure-mutation analysis of the ATPase site of Dictyostelium discoideum myosin II.
(PMID:9949764)
Sasaki N, Sutoh K.
Adv. Biophys. [1998]

Cold-sensitive mutants G680V and G691C of Dictyostelium myosin II confer dramatically different biochemical defects.
(PMID:9346898)
Patterson B, Ruppel KM, Wu Y, Spudich JA.
J. Biol. Chem. [1997]

Modulation of actin filament sliding by mutations of the SH2 cysteine in Dictyostelium myosin II.
(PMID:9175779)
Suzuki Y, Ohkura R, Sugiura S, Yasuda R, Kinoshita K Jr, et al.
Biochem. Biophys. Res. Commun. [1997]

Effects of surface adsorption on catalytic activity of heavy meromyosin studied using a fluorescent ATP analogue.
(PMID:17523677)
Balaz M, Sundberg M, Persson M, Kvassman J, Mansson A.
Biochemistry [2007]

Stiffness of skinned rabbit psoas fibers in MgATP and MgPPi solution.
(PMID:3022835)
Brenner B, Chalovich JM, Greene LE, Eisenberg E, Schoenberg M.
Biophys. J. [1986]

ADP dissociation from actomyosin subfragment 1 is sufficiently slow to limit the unloaded shortening velocity in vertebrate muscle.
(PMID:3871943)
Siemankowski RF, Wiseman MO, White HD.
Proc. Natl. Acad. Sci. U.S.A. [1985]

Load-dependent mechanism of nonmuscle myosin 2.
(PMID:17548820)
Kovacs M, Thirumurugan K, Knight PJ, Sellers JR.
Proc. Natl. Acad. Sci. U.S.A. [2007]

Strain-dependent cross-bridge cycle for muscle.
(PMID:8527667)
Smith DA, Geeves MA.
Biophys. J. [1995]

Cooperativity of myosin molecules through strain-dependent chemistry.
(PMID:10836506)
Duke T.
Philos. Trans. R. Soc. Lond., B, Biol. Sci. [2000]

ADP binding induces an asymmetry between the heads of unphosphorylated myosin.
(PMID:11301326)
Berger CE, Fagnant PM, Heizmann S, Trybus KM, Geeves MA.
J. Biol. Chem. [2001]

Adenosine diphosphate and strain sensitivity in myosin motors.
(PMID:15647162)

Nyitrai M, Geeves MA.
Philos. Trans. R. Soc. Lond., B, Biol. Sci. [2004]

Kinetic analysis of the slow skeletal myosin MHC-1 isoform from bovine masseter muscle.
(PMID:17900618)
Bloemink MJ, Adamek N, Reggiani C, Geeves MA.
J. Mol. Biol. [2007]

A 35-A movement of smooth muscle myosin on ADP release.
(PMID:7501026)
Whittaker M, Wilson-Kubalek EM, Smith JE, Faust L, Milligan RA, et al.
Nature [1995]

ADP release produces a rotation of the neck region of smooth myosin but not skeletal myosin.
(PMID:8784354)
Gollub J, Cremo CR, Cooke R.
Nat. Struct. Biol. [1996]

Diversity of structural behavior in vertebrate conventional myosins complexed with actin.
(PMID:17433365)
Iwamoto H, Oiwa K, Kovacs M, Sellers JR, Suzuki T, et al.
J. Mol. Biol. [2007]

A 32 degree tail swing in brush border myosin I on ADP release.
(PMID:7501027)
Jontes JD, Wilson-Kubalek EM, Milligan RA.
Nature [1995]

Myosin VI is an actin-based motor that moves backwards.
(PMID:10519557)
Wells AL, Lin AW, Chen LQ, Safer D, Cain SM, et al.
Nature [1999]

The structural basis of myosin V processive movement as revealed by electron cryomicroscopy.
(PMID:16137617)
Volkmann N, Liu H, Hazelwood L, Krementsova EB, Lowey S, et al.
Mol. Cell [2005]

The motor protein myosin-I produces its working stroke in two steps.
(PMID:10206648)
Veigel C, Coluccio LM, Jontes JD, Sparrow JC, Milligan RA, et al.
Nature [1999]

The gated gait of the processive molecular motor, myosin V.
(PMID:11740494)
Veigel C, Wang F, Bartoo ML, Sellers JR, Molloy JE.
Nat. Cell Biol. [2002]

A monomeric myosin VI with a large working stroke.
(PMID:15044955)
Lister I, Schmitz S, Walker M, Trinick J, Buss F, et al.
EMBO J. [2004]

Load-dependent kinetics of myosin-V can explain its high processivity.
(PMID:16100513)
Veigel C, Schmitz S, Wang F, Sellers JR.
Nat. Cell Biol. [2005]

Cross-bridge kinetics in the presence of MgADP investigated by photolysis of caged ATP in rabbit psoas muscle fibres.
(PMID:1886072)
Dantzig JA, Hibberd MG, Trentham DR, Goldman YE.
J. Physiol. (Lond.) [1991]

Exchange between inorganic phosphate and adenosine 5'-triphosphate in the medium by actomyosin subfragment 1.
(PMID:6892994)
Sleep JA, Hutton RL.
Biochemistry [1980]

Two independent mechanical events in the interaction cycle of skeletal muscle myosin with actin.
(PMID:16371472)
Capitanio M, Canepari M, Cacciafesta P, Lombardi V, Cicchi R, et al.
Proc. Natl. Acad. Sci. U.S.A. [2006]

Cooperativity between the two heads of rabbit skeletal muscle heavy meromyosin in binding to actin.
(PMID:9675193)
Conibear PB, Geeves MA.

Biophys. J. [1998]

Title not supplied – full information unavailable
(Controlled Nanoscale Motion)
Månsson A., Nicholls I., Omling P., Tågerud S., Montelius L..
[2007] - Springer Verlag (Berlin)

Genes & Proteins

Identified 4 unique Genes/Proteins in the Full Text

- actin (34)
- myosin II (3)
- serum albumin (1)
- chymotrypsin (1)

Gene Ontology (GO) Terms

Identified 17 unique GO Terms in the Full Text

- myosin (50)
- Actomyosin (18)
- myofibrils (15)
- binding (11)
- muscle myosin (8)
- muscle contraction (5)
- non-muscle myosin (3)
- myosin binding (2)
- behavior (1)
- development (1)
- phosphokinase (1)
- ATPase activity (1)
- digestion (1)
- sarcomere (1)
- mutagenesis (1)
- nucleotide binding (1)
- cell motility (1)

Species

Identified 5 unique Species in the Full Text

- rabbit (6)
- musculus (2)
- rat (2)
- mouse (2)
- bovine (1)

Diseases

Identified 2 unique Diseases in the Full Text

- tetanus (1)
- white leg (1)

Chemicals

Identified 32 unique Chemicals in the Full Text

- HMM (45)
- ADP (36)
- pyrene (17)

KCl (6)	
MgCl2 (5)	
lactic acid (5)	
polystyrene (4)	
MOPS (3)	
EGTA (3)	
TRITC (3)	
molybdate (2)	
azide (2)	
acetate (2)	
phalloidin (2)	
bipyridine (2)	
N-ethylmaleimide (1)	
nitrocellulose (1)	
imidazole (1)	
methylcellulose (1)	
trichloroacetic acid (1)	
CaCl2 (1)	
Ca2+ (1)	
acetic acid (1)	
phenylmethylsulfonyl fluoride (1)	
sodium (1)	
magnesium (1)	
potassium acetate (1)	
Tris (1)	
DEAE (1)	
sulfonamide (1)	
toluene (1)	
benzyl (1)	

Reviews - displaying 29 of 29

Adenosine diphosphate and strain sensitivity in myosin motors.
(PMID:15647162)
Nyitrai M, Geeves MA
Philosophical transactions of the Royal Society of London. Series B, Biological sciences [2004 Dec 29;359(1452):1867-77]

Coupling between phosphate release and force generation in muscle actomyosin.
(PMID:15647167)
Takagi Y, Shuman H, Goldman YE
Philosophical transactions of the Royal Society of London. Series B, Biological sciences [2004 Dec 29;359(1452):1913-20]

Smooth muscle myosin: regulation and properties.
(PMID:15647168)
Somlyo AV, Khromov AS, Webb MR, Ferenczi MA, Trentham DR, He ZH, Sheng S, Shao Z, Somlyo AP
Philosophical transactions of the Royal Society of London. Series B, Biological sciences [2004 Dec 29;359(1452):1921-30]

Using optical tweezers to relate the chemical and mechanical cross-bridge cycles.
(PMID:15647161)
Steffen W, Sleep J
Philosophical transactions of the Royal Society of London. Series B, Biological sciences [2004 Dec 29;359(1452):1857-65]

The cross-bridge cycle and skeletal muscle fatigue.
(PMID:18162480)
Fitts RH
Journal of applied physiology (Bethesda, Md. : 1985) [2008 Feb;104(2):551-8]

Force and power generating mechanism(s) in active muscle as revealed from temperature perturbation studies.
(PMID:20660565)
Ranatunga KW
The Journal of physiology [2010 Oct 1;588(Pt 19):3657-70]

Age-related decline in actomyosin structure and function.
(PMID:17706387)
Prochniewicz E, Thompson LV, Thomas DD
Experimental gerontology [2007 Oct;42(10):931-8]

Spontaneous oscillatory contraction (SPOC) of sarcomeres in skeletal muscle.
(PMID:1755363)
Ishiwata S, Okamura N, Shimizu H, Anazawa T, Yasuda K
Advances in biophysics [1991;27:227-35]

Advances in biophysics [1991;27:227-53]

Modulation of the actomyosin interaction during fatigue of skeletal muscle.
(PMID:17823954)
Cooke R
Muscle & nerve [2007 Dec;36(6):756-77]

Force transmission in skeletal muscle: from actomyosin to external tendons.
(PMID:9213097)
Patel TJ, Lieber RL
Exercise and sport sciences reviews [1997;25:321-63]

Force-velocity relationships in actin-myosin interactions causing cytoplasmic streaming in algal cells.
(PMID:12756278)
Sugi H, Chaen S
The Journal of experimental biology [2003 Jun;206(Pt 12):1971-6]

Sarcomere dynamics during muscular contraction and their implications to muscle function.
(PMID:17530424)
Telley IA, Denoth J
Journal of muscle research and cell motility [2007;28(1):89-104]

In vitro assays of molecular motors--impact of motor-surface interactions.
(PMID:18508618)
Mansson A, Balaz M, Albet-Torres N, Rosengren KJ
Frontiers in bioscience : a journal and virtual library [2008 May 1;13:5732-54]

Actomyosin systems of biological motility.
(PMID:15627371)
Levitsky DI
Biochemistry. Biokhimiia [2004 Nov;69(11):1177-89]

Imaging and nano-manipulation of single actomyosin motors at work.
(PMID:10744353)
Ishii Y, Kimura Y, Kitamura K, Tanaka H, Wazawa T, Yanagida T
Clinical and experimental pharmacology & physiology [2000 Mar;27(3):229-37]

Molecular basis of the catch state in molluscan smooth muscles: a catchy challenge.
(PMID:19039672)
Galler S
Journal of muscle research and cell motility [2008;29(2-5):73-99]

The molecular basis of contractility. II.
(PMID:4603206)
Goody RS, Mannherz HG
Basic research in cardiology [1974 Mar-Apr;69(2):204-13]

The muscle motor: 'simultaneous' levers or sequential impulses?
(PMID:9352373)
Elliott GF, Worthington CR
International journal of biological macromolecules [1997 Oct;21(3):271-5]

Disproportionate changes in skeletal muscle strength and size with resistance training and ageing.
(PMID:19724146)
Degens H, Erskine RM, Morse CI
Journal of musculoskeletal & neuronal interactions [2009 Jul-Sep;9(3):123-9]

Analysis of single-molecule mechanical recordings: application to acto-myosin interactions.
(PMID:11473786)
Knight AE, Veigel C, Chambers C, Molloy JE
Progress in biophysics and molecular biology [2001;77(1):45-72]

Tropomyosin and the steric mechanism of muscle regulation.
(PMID:19209816)
Lehman W, Craig R
Advances in experimental medicine and biology [2008;644:95-109]

Mysteries of muscle contraction.
(PMID:18309178)
Herzog W, Leonard TR, Joumaa V, Mehta A
Journal of applied biomechanics [2008 Feb;24(1):1-13]

Temperature change as a probe of muscle crossbridge kinetics: a review and discussion.
(PMID:19364742)
Woledge RC, Barclay CJ, Curtin NA
Proceedings. Biological sciences / The Royal Society [2009 Aug 7;276(1668):2685-95]

The efficiency of muscle contraction.
(PMID:15561300)
Smith NP, Barclay CJ, Loiselle DS
Progress in biophysics and molecular biology [2005 May;88(1):1-58]

Cell and molecular biology of the fastest myosins.
(PMID:19584016)
Higashi-Fujime S, Nakamura A
International review of cell and molecular biology [2009;276:301-47]

Muscle after spinal cord injury.
(PMID:19705475)
Biering-Sørensen B, Kristensen IB, Kjaer M, Biering-Sørensen F
Muscle & nerve [2009 Oct;40(4):499-519]

Calcium-induced calcium release in skeletal muscle.
(PMID:19789379)
Endo M
Physiological reviews [2009 Oct;89(4):1153-76]

Calcium inhibition of Physarum myosin as examined by the recombinant heavy mero-myosin.
(PMID:17278371)
Kawamichi H, Zhang Y, Hino M, Nakamura A, Tanaka H, Farkas L, Nyitray L, Kohama K
Advances in experimental medicine and biology [2007;592:265-72]

Five models for myosin V.
(PMID:19273200)
Vilfan A
Frontiers in bioscience : a journal and virtual library [2009 Jan 1;14:2269-84]

Other Related Articles - displaying 100 of 477

Cardiotonic bipyridine amrinone slows myosin-induced actin filament sliding at saturating [MgATP].
(PMID:12953834)
Klinth J, Arner A, Månsson A
Journal of muscle research and cell motility [2003;24(1):15-32]

What limits the velocity of fast-skeletal muscle contraction in mammals?
(PMID:16325202)
Nyitrai M, Rossi R, Adamek N, Pellegrino MA, Bottinelli R, Geeves MA
Journal of molecular biology [2006 Jan 20;355(3):432-42]

Kinetics of nucleoside triphosphate cleavage and phosphate release steps by associated rabbit skeletal actomyosin, measured using a novel fluorescent probe for phosphate.
(PMID:9305974)
White HD, Belknap B, Webb MR
Biochemistry [1997 Sep 30;36(39):11828-36]

Isolation and kinetic characterisation of myosin and myosin S1 from the Drosophila indirect flight muscles.
(PMID:14870964)
Silva R, Sparrow JC, Geeves MA
Journal of muscle research and cell motility [2003;24(8):489-98]

Effect of phosphorylation on the binding of smooth muscle heavy meromyosin X ADP to actin.
(PMID:2951383)
Greene LE, Sellers JR
The Journal of biological chemistry [1987 Mar 25;262(9):4177-81]

Mechanism of inhibition of skeletal muscle actomyosin by N-benzyl-p-toluenesulfonamide.
(PMID:12755615)
Shaw MA, Ostap EM, Goldman YE
Biochemistry [2003 May 27;42(20):6128-35]

Actomyosin-ADP states, interhead cooperativity, and the force-velocity relation of skeletal muscle.
(PMID:20371323)
Månsson A
Biophysical journal [2010 Apr 7;98(7):1237-46]

Cooperativity between the two heads of rabbit skeletal muscle heavy meromyosin in binding to actin.
(PMID:9675193)
Conibear PB, Geeves MA
Biophysical journal [1998 Aug;75(2):926-37]

Kinetics of ADP dissociation from the trail and lead heads of actomyosin V following the power stroke.
(PMID:17965414)
Forgacs E, Cartwright S, Sakamoto T, Sellers JR, Corrie JE, Webb MR, White HD
The Journal of biological chemistry [2008 Jan 11;283(2):766-73]

Mutational analysis of the role of the N terminus of actin in actomyosin interactions. Comparison with other mutant actins and implications for the cross-bridge cycle.
(PMID:8987990)
Miller CJ, Wong WW, Bobkova E, Rubenstein PA, Reisler E
Biochemistry [1996 Dec 24;35(51):16557-65]

In vitro actomyosin motility in deuterium oxide.
(PMID:15098666)
Chaen S, Yamamoto N, Shirakawa I, Sugi H

Advances in experimental medicine and biology [2003;538:183-92; discussion 192]

Predominant attached state of myosin cross-bridges during contraction and relaxation at low ionic strength.
(PMID:6384526)
Nagano H, Yanagida T
Journal of molecular biology [1984 Aug 25;177(4):769-85]

Evidence for increased low force cross-bridge population in shortening skinned skeletal muscle fibers: implications for actomyosin kinetics.
(PMID:8519957)
Iwamoto H
Biophysical journal [1995 Sep;69(3):1022-35]

Kinetics of muscle contraction and actomyosin NTP hydrolysis from rabbit using a series of metal-nucleotide substrates.
(PMID:15611022)
Burton K, White H, Sleep J
The Journal of physiology [2005 Mar 15;563(Pt 3):689-711]

ADP dissociation from actomyosin subfragment 1 is sufficiently slow to limit the unloaded shortening velocity in vertebrate muscle.
(PMID:3871943)
Siemankowski RF, Wiseman MO, White HD
Proceedings of the National Academy of Sciences of the United States of America [1985 Feb;82(3):658-62]

Probing actomyosin interactions with 2,4-dinitrophenol.
(PMID:15769593)
Ribeiro AS, Salerno VP, Sorenson M
Biochimica et biophysica acta [2005 May 15;1748(2):165-73]

The effect of genetically expressed cardiac titin fragments on in vitro actin motility.
(PMID:8534821)
Li Q, Jin JP, Granzier HL
Biophysical journal [1995 Oct;69(4):1508-18]

Mutational analysis of the role of hydrophobic residues in the 338-348 helix on actin in actomyosin interactions.
(PMID:8619986)
Miller CJ, Doyle TC, Bobkova E, Botstein D, Reisler E
Biochemistry [1996 Mar 26;35(12):3670-6]

Mechanism of nucleotide binding to actomyosin VI: evidence for allosteric head-head communication.
(PMID:15247304)
Robblee JP, Olivares AO, de la Cruz EM
The Journal of biological chemistry [2004 Sep 10;279(37):38608-17]

Kinetics of the interaction between actin, ADP, and cardiac myosin-S1.
(PMID:6715335)
Siemankowski RF, White HD
The Journal of biological chemistry [1984 Apr 25;259(8):5045-53]

Effects of amrinone on shortening velocity and force development in skinned skeletal muscle fibres.
(PMID:8478421)
Bottinelli R, Cappelli V, Morner SE, Reggiani C
Journal of muscle research and cell motility [1993 Feb;14(1):110-20]

The direct molecular effects of fatigue and myosin regulatory light chain phosphorylation on the actomyosin contractile apparatus.
(PMID:20089714)
Greenberg MJ, Mealy TR, Jones M, Szczesna-Cordary D, Moore JR
American journal of physiology. Regulatory, integrative and comparative physiology [2010 Apr;298(4):R989-96]

Chemomechanical transduction in the actomyosin molecular motor by 2',3'-dideoxydidehydro-ATP and characterization of its interaction with myosin subfragment 1 in the presence and absence of actin.
(PMID:8756479)

Gopal D, Pavlov DI, Levitsky DI, Ikebe M, Burke M
Biochemistry [1996 Aug 6;35(31):10149-57]

Kinetic studies on the effects of ADP and ionic strength on the interaction between myosin subfragment-1 and actin: implications for load-sensitivity and regulation of the crossbridge cycle.
(PMID:10730576)
Conibear PB
Journal of muscle research and cell motility [1999 Nov;20(8):727-42]

Effects of amrinone on twitch, tetanus and shortening kinetics in mammalian skeletal muscle.
(PMID:2773661)
Månsson A, Mörner J, Edman KA
Acta physiologica Scandinavica [1989 May;136(1):37-45]

On the mechanism of actomyosin ATPase from fast muscle.
(PMID:6454140)
Midelfort CF
Proceedings of the National Academy of Sciences of the United States of America [1981 Apr;78(4):2067-71]

Myosin regulatory light chain phosphorylation and strain modulate adenosine diphosphate release from smooth muscle Myosin.
(PMID:15041670)
Khromov AS, Webb MR, Ferenczi MA, Trentham DR, Somlyo AP, Somlyo AV
Biophysical journal [2004 Apr;86(4):2318-28]

ATP analogs and muscle contraction: mechanics and kinetics of nucleoside triphosphate binding and hydrolysis.
(PMID:9635759)
Regnier M, Lee DM, Homsher E
Biophysical journal [1998 Jun;74(6):3044-58]

Dimethyl sulphoxide enhances the effects of P(i) in myofibrils and inhibits the activity of rabbit skeletal muscle contractile proteins.
(PMID:11535124)
Mariano AC, Alexandre GM, Silva LC, Romeiro A, Cameron LC, Chen Y, Chase PB, Sorenson MM
The Biochemical journal [2001 Sep 15;358(Pt 3):627-36]

Actin cross-linking and inhibition of the actomyosin motor.
(PMID:11772006)
Kim E, Bobkova E, Hegyi G, Muhlrad A, Reisler E
Biochemistry [2002 Jan 8;41(1):86-93]

The role of surface loops (residues 204-216 and 627-646) in the motor function of the myosin head.
(PMID:8637864)
Bobkov AA, Bobkova EA, Lin SH, Reisler E
Proceedings of the National Academy of Sciences of the United States of America [1996 Mar 19;93(6):2285-9]

X-ray diffraction evidence for the lack of stereospecific protein interactions in highly activated actomyosin complex.
(PMID:11162098)
Iwamoto H, Oiwa K, Suzuki T, Fujisawa T
Journal of molecular biology [2001 Jan 26;305(4):863-74]

Effects of actin and calcium ion on chymotryptic digestion of skeletal myosin and their implications to the function of light chains.
(PMID:7006689)
Oda S, Oriol-Audit C, Reisler E
Biochemistry [1980 Nov 25;19(24):5614-8]

Effects of substituting uridine triphosphate for ATP on the crossbridge cycle of rabbit muscle.
(PMID:11744764)
Seow CY, White HD, Ford LE
The Journal of physiology [2001 Dec 15;537(Pt 3):907-21]

Regulatory proteins alter nucleotide binding to acto-myosin of sliding filaments in motility assays.
(PMID:12885651)
Homsher E, Nili M, Chen IY, Tobacman LS
Biophysical journal [2003 Aug;85(2):1046-52]

Two independent mechanical events in the interaction cycle of skeletal muscle myosin with actin.
(PMID:16371472)
Capitanio M, Canepari M, Cacciafesta P, Lombardi V, Cicchi R, Maffei M, Pavone FS, Bottinelli R
Proceedings of the National Academy of Sciences of the United States of America [2006 Jan 3;103(1):87-92]

Kinetic and spectroscopic evidence for three actomyosin:ADP states in smooth muscle.
(PMID:10827085)
Rosenfeld SS, Xing J, Whitaker M, Cheung HC, Brown F, Wells A, Milligan RA, Sweeney HL
The Journal of biological chemistry [2000 Aug 18;275(33):25418-26]

Actomyosin kinetics and in vitro motility of wild-type Drosophila actin and the effects of two mutations in the Act88F gene.
(PMID:7612841)

Anson M, Drummond DR, Geeves MA, Hennessey ES, Ritchie MD, Sparrow JC
Biophysical journal [1995 May;68(5):1991-2003]

The influence of 2,3-butanedione 2-monoxime (BDM) on the interaction between actin and myosin in solution and in skinned muscle fibres.
(PMID:7929796)
McKillop DF, Fortune NS, Ranatunga KW, Geeves MA
Journal of muscle research and cell motility [1994 Jun;15(3):309-18]

Mutual sensitization of ATP and GTP in driving F-actin on the surface-fixed H-meromyosin.
(PMID:8956480)
Oda T, Shikata Y, Mihashi K
Biophysical chemistry [1996 Oct 30;61(2-3):63-72]

Magnesium regulates ADP dissociation from myosin V.
(PMID:15579901)
Rosenfeld SS, Houdusse A, Sweeney HL
The Journal of biological chemistry [2005 Feb 18;280(7):6072-9]

Kinetics of binding and hydrolysis of a series of nucleoside triphosphates by actomyosin-S1. Relationship between solution rate constants and properties of muscle fibers.
(PMID:8486675)
White HD, Belknap B, Jiang W
The Journal of biological chemistry [1993 May 15;268(14):10039-45]

Rescue of in vitro actin motility halted at high ionic strength by reduction of ATP to submicromolar levels.
(PMID:8950375)
Kellermayer MS, Pollack GH
Biochimica et biophysica acta [1996 Nov 12;1277(1-2):107-14]

Interaction of actin and ADP with the head domain of smooth muscle myosin: implications for strain-dependent ADP release in smooth muscle.
(PMID:9485324)
Cremo CR, Geeves MA
Biochemistry [1998 Feb 17;37(7):1969-78]

Electrostatic changes at the actomyosin-subfragment 1 interface during force-generating reactions.
(PMID:1731895)
Highsmith S, Murphy AJ
Biochemistry [1992 Jan 21;31(2):385-9]

ADP binds similarly to rigor muscle myofibrils and to actomyosin-subfragment one.
(PMID:6468650)
Johnson RE, Adams PH
FEBS letters [1984 Aug 20;174(1):11-4]

Loop I can modulate ADP affinity, ATPase activity, and motility of different scallop myosins. Transient kinetic analysis of S1 isoforms.
(PMID:9585566)
Kurzawa-Goertz SE, Perreault-Micale CL, Trybus KM, Szent-Györgyi AG, Geeves MA
Biochemistry [1998 May 19;37(20):7517-25]

Direct inhibition of the actomyosin motility by local anesthetics in vitro.
(PMID:8913610)
Tsuda Y, Mashimo T, Yoshiya I, Kaseda K, Harada Y, Yanagida T
Biophysical journal [1996 Nov;71(5):2733-41]

Modulation of actomyosin motor function by 1-hexanol.
(PMID:15160491)
Komatsu H, Shigeoka T, Ohno T, Kaseda K, Kanno T, Matsumoto Y, Suzuki M, Kodama T
Journal of muscle research and cell motility [2004;25(1):77-85]

Both heads of tissue-derived smooth muscle heavy meromyosin bind to actin in the presence of ADP.
(PMID:12464606)
Ellison PA, DePew ZS, Cremo CR
The Journal of biological chemistry [2003 Feb 14;278(7):4410-5]

Differing ADP release rates from myosin heavy chain isoforms define the shortening velocity of skeletal muscle fibers.
(PMID:11590173)
Weiss S, Rossi R, Pellegrino MA, Bottinelli R, Geeves MA
The Journal of biological chemistry [2001 Dec 7;276(49):45902-8]

The biochemical kinetics underlying actin movement generated by one and many skeletal muscle myosin molecules.
(PMID:11916869)
Baker JE, Brosseau C, Joel PB, Warshaw DM
Biophysical journal [2002 Apr;82(4):2134-47]

Contraction of myofibrils in the presence of antibodies to myosin subfragment 2.
(PMID:2217176)

(PMID:2217176)
Harrington WF, Karr T, Busa WB, Lovell SJ
Proceedings of the National Academy of Sciences of the United States of America [1990 Oct;87(19):7453-6]

Mechanics of actomyosin bonds in different nucleotide states are tuned to muscle contraction.
(PMID:16785439)
Guo B, Guilford WH
Proceedings of the National Academy of Sciences of the United States of America [2006 Jun 27;103(26):9844-9]

Effect of deuterium oxide on actomyosin motility in vitro.
(PMID:11779555)
Chaen S, Yamamoto N, Shirakawa I, Sugi H
Biochimica et biophysica acta [2001 Nov 1;1506(3):218-23]

Functional, structural, and chemical changes in myosin associated with hydrogen peroxide treatment of skeletal muscle fibers.
(PMID:18003749)
Prochniewicz E, Lowe DA, Spakowicz DJ, Higgins L, O'Conor K, Thompson LV, Ferrington DA, Thomas DD
American journal of physiology. Cell physiology [2008 Feb;294(2):C613-26]

Effects of Amrinone on shortening velocity, force development and ATPase activity of demembranated preparations of rat ventricular myocardium.
(PMID:1442124)
Mörner SE, Canepari M, Bottinelli R, Cappelli V, Reggiani C
Acta physiologica Scandinavica [1992 Sep;146(1):21-30]

Influence of ionic strength on the actomyosin reaction steps in contracting skeletal muscle fibers.
(PMID:10827990)
Iwamoto H
Biophysical journal [2000 Jun;78(6):3138-49]

Regulatory light chains modulate in vitro actin motility driven by skeletal heavy meromyosin.
(PMID:20946876)
Vikhoreva NN, Månsson A
Biochemical and biophysical research communications [2010 Dec 3;403(1):1-6]

Cardiac myosin binding protein-C modulates actomyosin binding and kinetics in the in vitro motility assay.
(PMID:18482734)
Saber W, Begin KJ, Warshaw DM, VanBuren P
Journal of molecular and cellular cardiology [2008 Jun;44(6):1053-61]

Skeletal regulatory proteins enhance thin filament sliding speed and force by skeletal HMM.
(PMID:15711882)
Clemmens EW, Regnier M
Journal of muscle research and cell motility [2004;25(7):515-25]

The effect of hydrostatic pressure on the interaction of actomyosin subfragment 1 with nucleotides.
(PMID:1835384)
McKillop DF, Geeves MA, Balny C
Biochemical and biophysical research communications [1991 Oct 31;180(2):552-7]

A single-fiber in vitro motility assay. In vitro sliding velocity of F-actin vs. unloaded shortening velocity in skinned muscle fibers.
(PMID:10730581)
Thedinga E, Karim N, Kraft T, Brenner B
Journal of muscle research and cell motility [1999 Nov;20(8):785-96]

Single turnovers of adenosine 5'-triphosphate by myofibrils and actomyosin subfragment 1.
(PMID:6457629)
Sleep JA
Biochemistry [1981 Aug 18;20(17):5043-51]

Catalytic cooperativity induced by SH1 labeling of myosin filaments.
(PMID:1824816)
Root DD, Cheung P, Reisler E
Biochemistry [1991 Jan 8;30(1):286-94]

Magnesium, ADP, and actin binding linkage of myosin V: evidence for multiple myosin V-ADP and actomyosin V-ADP states.
(PMID:15952789)
Hannemann DE, Cao W, Olivares AO, Robblee JP, De La Cruz EM
Biochemistry [2005 Jun 21;44(24):8826-40]

The ADP release step of the smooth muscle cross-bridge cycle is not directly associated with force generation.
(PMID:10388765)
Dantzig JA, Barsotti RJ, Manz S, Sweeney HL, Goldman YE
Biophysical journal [1999 Jul;77(1):386-97]

ADP inhibits the sliding velocity of fluorescent actin filaments on cardiac and skeletal myosins.
(PMID:8187272)

(PMID:8187272)
Yamashita H, Sata M, Sugiura S, Momomura S, Serizawa T, Iizuka M
Circulation research [1994 Jun;74(6):1027-33]

Comparative single-molecule and ensemble myosin enzymology: sulfoindocyanine ATP and ADP derivatives.
(PMID:10827983)
Oiwa K, Eccleston JF, Anson M, Kikumoto M, Davis CT, Reid GP, Ferenczi MA, Corrie JE, Yamada A, Nakayama H, Trentham DR
Biophysical journal [2000 Jun;78(6):3048-71]

Quick-freeze deep-etch electron microscopy of the actin-heavy meromyosin complex during the in vitro motility assay.
(PMID:9571057)
Katayama E
Journal of molecular biology [1998 May 1;278(2):349-67]

Mechanism of regulation of phosphate dissociation from actomyosin-ADP-Pi by thin filament proteins.
(PMID:12486217)
Heeley DH, Belknap B, White HD
Proceedings of the National Academy of Sciences of the United States of America [2002 Dec 24;99(26):16731-6]

The effect of adenosine diphosphate on the interaction of actin-myosin-adenosine triphosphate.
(PMID:6545638)
Szöör A, Kónya L, Csabina S
Acta biochimica et biophysica; Academiae Scientiarum Hungaricae [1984;19(3-4):311-7]

A kinetic mechanism for the fast movement of Chara myosin.
(PMID:12729766)
Kimura Y, Toyoshima N, Hirakawa N, Okamoto K, Ishijima A
Journal of molecular biology [2003 May 9;328(4):939-50]

Actomyosin interactions in a novel single muscle fiber in vitro motility assay.
(PMID:11032346)
Hook P, Larsson L
Journal of muscle research and cell motility [2000 May;21(4):357-65]

The slow skeletal muscle isoform of myosin shows kinetic features common to smooth and non-muscle myosins.
(PMID:17130133)
Iorga B, Adamek N, Geeves MA
The Journal of biological chemistry [2007 Feb 9;282(6):3559-70]

Troponin is a potential regulator for actomyosin interactions.
(PMID:16452317)
Mizuno H, Honda H
Journal of biochemistry [2006 Feb;139(2):289-93]

Evidence for the essential role of myosin subfragment-2 in the ATP-dependent actin-myosin sliding in muscle contraction.
(PMID:9852347)
Tsuchiya T, Tanaka H, Shirakawa I, Karr T, Sugi H
The Japanese journal of physiology [1998 Oct;48(5):383-7]

The inhibitory action of the light meromyosin component on the myofibrillar and actomyosin atp-ase.
(PMID:123341)
Kalamkarova MB, Kofman EB, Nankina VP

Physiologia Bohemoslovaca [1975;24(1):35-40]

Two-headed binding of the unphosphorylated nonmuscle heavy meromyosin.ADP complex to actin.
(PMID:15065866)
Kovács M, Tóth J, Nyitray L, Sellers JR
Biochemistry [2004 Apr 13;43(14):4219-26]

Effects of amrinone on the contractile behaviour of frog striated muscle fibres.
(PMID:3878658)
Månsson A, Edman KA
Acta physiologica Scandinavica [1985 Nov;125(3):481-93]

Effects of rapamycin on cardiac and skeletal muscle contraction and crossbridge cycling.
(PMID:15306636)
Schoffstall B, Kataoka A, Clark A, Chase PB
The Journal of pharmacology and experimental therapeutics [2005 Jan;312(1):12-8]

CaATP as a substrate to investigate the myosin lever arm hypothesis of force generation.
(PMID:10692332)
Polosukhina K, Eden D, Chinn M, Highsmith S
Biophysical journal [2000 Mar;78(3):1474-81]

Regulation of force development studied by photolysis of caged ADP in rabbit skinned psoas fibers.
(PMID:11423418)

Lu Z, Swartz DR, Metzger JM, Moss RL, Walker JW
Biophysical journal [2001 Jul;81(1):334-44]

Endothermic force generation, temperature-jump experiments and effects of increased [MgADP] in rabbit psoas muscle fibres.
(PMID:15975981)
Coupland ME, Pinniger GJ, Ranatunga KW
The Journal of physiology [2005 Sep 1;567(Pt 2):471-92]

Analysis of the bound nucleotide in the acto-heavy meromyosin in vitro motility assay.
(PMID:9091891)
Kellermayer MS
Physiological chemistry and physics and medical NMR [1996;28(3):143-51]

The unique properties of tonic smooth muscle emerge from intrinsic as well as intermolecular behaviors of Myosin molecules.
(PMID:12756257)
Baker JE, Brosseau C, Fagnant P, Warshaw DM
The Journal of biological chemistry [2003 Aug 1;278(31):28533-9]

Strain-dependent cross-bridge cycle for muscle.
(PMID:8527667)
Smith DA, Geeves MA
Biophysical journal [1995 Aug;69(2):524-37]

Effects of surface adsorption on catalytic activity of heavy meromyosin studied using a fluorescent ATP analogue.
(PMID:17523677)
Balaz M, Sundberg M, Persson M, Kvassman J, Månsson A
Biochemistry [2007 Jun 19;46(24):7233-51]

ATP hydrolysis and sliding movement of actomyosin complex in the presence of ethanol.
(PMID:7608109)
Hatori K, Honda H, Matsuno K
Journal of biochemistry [1995 Feb;117(2):264-6]

Intermonomer cross-linking of F-actin alters the dynamics of its interaction with H-meromyosin in the weak-binding state.
(PMID:16640554)
Hegyi G, Belágyi J
The FEBS journal [2006 May;273(9):1896-905]

Nonlinear force-length relationship in the ADP-induced contraction of skeletal myofibrils.
(PMID:17890380)
Shimamoto Y, Kono F, Suzuki M, Ishiwata S
Biophysical journal [2007 Dec 15;93(12):4330-41]

Myosin aggregates as a requirement for contraction and a proposal to the mechanism of contraction of actomyosin systems.
(PMID:765324)
Hayashi T, Maruyama K
Journal of biochemistry [1975 Nov;78(5):1031-8]

The essential light chain is required for full force production by skeletal muscle myosin.
(PMID:7809049)
VanBuren P, Waller GS, Harris DE, Trybus KM, Warshaw DM, Lowey S
Proceedings of the National Academy of Sciences of the United States of America [1994 Dec 20;91(26):12403-7]

Nonlinear elasticity and an 8-nm working stroke of single myosin molecules in myofilaments.
(PMID:20689017)
Kaya M, Higuchi H
Science (New York, N.Y.) [2010 Aug 6;329(5992):686-9]

ADP binding induces an asymmetry between the heads of unphosphorylated myosin.
(PMID:11301326)
Berger CE, Fagnant PM, Heizmann S, Trybus KM, Geeves MA
The Journal of biological chemistry [2001 Jun 29;276(26):23240-5]

Interactions of the two heads of scallop (Argopecten irradians) heavy meromyosin with actin: influence of calcium and nucleotides.
(PMID:12441001)
Nyitrai M, Szent-Györgyi AG, Geeves MA
The Biochemical journal [2003 Mar 15;370(Pt 3):839-48]

Observation of steady streamings in a solution of Mg-ATP and acto-heavy meromyosin from rabbit skeletal muscle.
(PMID:149116)
Yano M
Journal of biochemistry [1978 Apr;83(4):1203-4]

Evidence for a novel, strongly bound acto-S1 complex carrying ADP and phosphate stabilized in the G680V mutant of Dictyostelium myosin II.

(PMID:12135375)
Uyeda TQ, Tokuraku K, Kaseda K, Webb MR, Patterson B
Biochemistry [2002 Jul 30;41(30):9525-34]

Evidence that phosphate release is the rate-limiting step on the overall ATPase of psoas myofibrils prevented from shortening by chemical cross-linking.
(PMID:12403632)
Lionne C, Iorga B, Candau R, Piroddi N, Webb MR, Belus A, Travers F, Barman T
Biochemistry [2002 Nov 5;41(44):13297-308]

Fluorescent coumarin-labeled nucleotides to measure ADP release from actomyosin.
(PMID:11509369)
Webb MR, Corrie JE
Biophysical journal [2001 Sep;81(3):1562-9]

Back to results

Formats

- Abstract
- Full Text
- *PDF*
- **Export** citation (RIS)
  Email citation

Journal and Issue

- Journal ListJ Biol Chemv.284(34); Aug 21, 2009

BioEntities in Full Text

Genes/Proteins
actin (34)
myosin II (3)
serum albumin (1)
1 more…
Gene Ontology (GO)
myosin (50)
Actomyosin (18)
myofibrils (15)
14 more…
Species
rabbit (6)
musculus (2)
rat (2)
2 more…
Diseases
tetanus (1)
white leg (1)
Chemicals
HMM (45)
ADP (36)
pyrene (17)
29 more…