



Rho Activation Assay Biochem Kit™ (80 Assays)

Cat. # BK036

Manual Contents

Section I: Introduction

Background- Rho Activation Assay	5
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Section II: Purchaser Notification	6
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Section III: Kit Contents	7-8
---------------------------	-----

Section IV: Reconstitution and Storage of Components	9
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Section V: Important Technical Notes

A. Notes on Updated Manual Version	10
B. Growth and Treatment of Cell Lines	11-12
C. Timing and Intensity of Rho Activation	12
D. Rapid Processing of Cells	13-14
E. Protein Concentration Equivalence	14
F. Assay Linearity	14-15

Section VI: Assay Protocol

STEP 1: Control Reactions	16
STEP 2: Lysate Collection	17-18
STEP 3: Pulldown Assay	19
STEP 4: Western Blot Protocol	20

Section VII: Troubleshooting	21-22
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Section VIII: References	23
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APPENDICES

Appendix 1 Serum Starving Cells and F-actin Visualization	24-25
Appendix 2 Table of Known Rho Activators	26
Appendix 3 Protein Quantitation (with precision Red)	27-28
Appendix 4 Total RhoA ELISA	29-30
Appendix 5 Processing tissue samples for pull-down assays	31

I: Introduction

Background– Rho Activation Assay

The Rho family of small GTPases consists of at least 20 members, the most extensively characterized of which are the Rac1, RhoA and Cdc42 proteins (1-4). In common with all other small G-proteins, the Rho proteins act as molecular switches that transmit cellular signals through an array of effector proteins. This family mediates a diverse number of cellular responses including cytoskeletal reorganization (1-4), regulation of transcription (5), DNA synthesis, membrane trafficking and apoptosis (6-9).

The Rho switch operates by alternating between an active, GTP-bound state and an inactive, GDP-bound state (10-12). Understanding the mechanisms that regulate activation / inactivation of the GTPases is of obvious biological significance and is a subject of intense investigation. The fact that Rho family effector proteins will specifically recognize the GTP bound form of the protein (13) has been exploited experimentally to develop a powerful affinity purification assay that monitors Rho protein activation (14).

This assay uses the Rho binding domain (also called the RBD) of the Rho effector protein rhotekin. The RBD protein motif has been shown to bind specifically to the GTP-bound form of Rho. The fact that the RBD region of rhotekin has a high affinity for GTP-Rho makes it an ideal tool for affinity purification of GTP-Rho from cell lysates. The rhotekin-RBD protein supplied in this kit contains amino acids 7-89 of rhotekin RBD expressed as GST fusion in *E.coli* bound to colored glutathione-sepharose beads. This allows one to “pull-down” GTP-Rho complexed with rhotekin-RBD beads. This assay provides a simple means of analyzing cellular Rho activities in a variety of systems. The amount of activated Rho is determined by a Western blot using a Rho specific antibody. A typical Rho pulldown assay using GTP and GDP loaded human platelet extract or Swiss 3T3 cell extracts is shown in Figure 1.

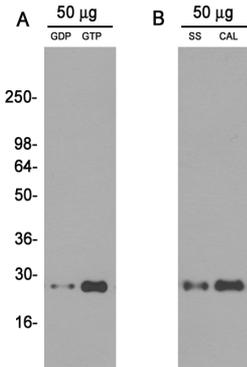


Figure 1. Rhotekin-RBD bead pulldown Assays.

A. Extract (300 µg) from human platelet cells was loaded with GTPγS (GTP lane) or GDP (GDP lane) using the method described in Section VI: Control Reactions.

B. Extract (300 µg) from serum starved (SS) and subsequent calpeptin (CAL) treated Swiss 3T3 cells. All extracts were incubated with 50 µg of rhotekin-RBD beads and processed as described in Section VI: Pulldown Assay. All bead samples were resuspended in 10 µl of 2x sample buffer and run on a 12% SDS gel. Protein was transferred to PVDF, probed with a 1:500 dilution of anti-RhoA and processed for chemiluminescent detection as described in Section VI: STEP 4.

II: Purchaser Notification

Limited Use Statement

The purchase of this product conveys to the buyer the non-transferable right to use the purchased amount of product and components of product in research conducted by the buyer. The buyer cannot sell or otherwise transfer this product or any component thereof to a third party or otherwise use this product or its components for commercial purposes. Commercial purposes include, but are not limited to: use of the product or its components in manufacturing; use of the product or its components to provide a service; resale of the product or its components.

The terms of this Limited Use Statement apply to all buyers including academic and for-profit entities. If the purchaser is not willing to accept the conditions of this Limited Use Statement, Cytoskeleton Inc. is willing to accept return of the unused product with a full refund.

III: Kit Contents

This kit contains enough reagents for approximately 80 pulldown assays. There is sufficient Rho antibody for 200 ml working strength primary antibody solution.

Table 1: Kit Contents and Storage Upon Arrival

Reagents	Cat. # or Part #*	Quantity	Storage
Rhotekin RBD beads	Cat # RT02	2 tubes, lyophilized; 2 mg of protein per tube bound to colored sepharose beads	Desiccated 4°C
Anti-RhoA monoclonal antibody	Cat # ARH04	2 tubes, lyophilized, 50 µg protein	Desiccated 4°C
His-RhoA control protein	Part # RHWT	1 tube, lyophilized; 10 µg protein (~30 kDa) as a Western Blot standard.	Desiccated 4°C
Cell Lysis Buffer	Part # CLB01	1 bottle, lyophilized; 50mM Tris pH 7.5, 10mM MgCl ₂ , 0.5M NaCl, and 2% Igepal when reconstituted	Desiccated 4°C
Wash Buffer	Part # WB01	1 bottle, lyophilized; 25 mM Tris pH 7.5, 30 mM MgCl ₂ , 40 mM NaCl when reconstituted	Desiccated 4°C
Loading Buffer	Part # LB01	1 tube, 1 ml; 150 mM EDTA solution	4°C
STOP Buffer	Part # STP01	1 tube, 1 ml; 600 mM MgCl ₂ solution	4°C
GTPγS stock: (non-hydrolysable GTP analog)	Cat # BS01	1 tube, lyophilized; 20 mM solution when reconstituted	Desiccated 4°C
GDP stock	Part # GDP01	1 tube, lyophilized; 100 mM solution when reconstituted	Desiccated 4°C
Protease Inhibitor Cocktail	Cat. # PIC02	1 tube, lyophilized; 100X solution: 62 µg/ml Leupeptin, 62 µg/ml Pepstatin A, 14 mg/ml Benzamidine and 12 mg/ml tosyl arginine methyl ester when reconstituted	Desiccated 4°C
DMSO	Part # DMSO	1 tube, 1.5ml. Solvent for protease inhibitor cocktail	4° (will freeze at 4°C)

* Items with part numbers (Part #) are not sold separately and available only in kit format. Items with catalog numbers (Cat. #) are available separately.

III: Kit Contents (Continued)

The reagents and equipment that you will require but are not supplied:

- Cell lysate (see Section V: B-D and Section VI: Step 2)
- 2X Laemmli sample buffer (125mM Tris pH6.8, 20% glycerol, 4% SDS, 0.005% Bromophenol blue, 5% beta-mercaptoethanol)
- Polyacrylamide gels (12% of 4-20% gradient gels)
- SDS-PAGE buffers
- Western blot buffers (see Section VI: Step 4)
- Protein transfer membrane (PVDF or Nitrocellulose)
- Secondary antibody (e.g. Goat anti-mouse HRP conjugated IgG, Jackson Labs. Cat# 115-035-068)
- Chemiluminescence based detection system (e.g. SuperSignal West Dura Extended Duration Substrate; ThermoFisher)
- Cell scrapers
- Liquid nitrogen for snap freezing cell lysates

IV: Reconstitution and Storage of Components

Many of the components of this kit have been provided in lyophilized form. Prior to beginning the assay you will need to reconstitute several components as detailed in Table 2. When properly stored and reconstituted, components are guaranteed stable for 6 months.

Table 2: Component Storage and Reconstitution

Kit Component	Reconstitution	Storage Conditions
Rhotekin-RBD Protein Beads	Reconstitute each tube in 600 μ l distilled water. Aliquot into 8 x 75 μ l volumes (15 μ l of beads = 50 μ g of protein, under these conditions each 75 μ l aliquot is sufficient for 5 assays). Snap freeze in liquid nitrogen.	Store at -70°C .
Anti-RhoA monoclonal antibody	Resuspend each tube in 200 μ l of PBS. Use at 1:500 dilution.	Store at 4°C .
His-RhoA control protein	Reconstitute in 30 μ l of distilled water. Aliquot into 10 x 3 μ l sizes and snap freeze in liquid nitrogen.	Store at -70°C .
Cell Lysis Buffer	Reconstitute in 100 ml of sterile distilled water. This solution may take 5-10 min to resuspend. Use a 10 ml pipette to thoroughly resuspend the buffer. To keep long term stocks of this buffer aliquot the solution into 20 x 5 ml volumes and store at -20°C .	Store at 4°C
Wash Buffer	Reconstitute in 100 ml of sterile distilled water. To keep long term stocks of this buffer aliquot the solution into 5 x 20 ml volumes and store at -20°C .	Store at 4°C
Loading Buffer	No reconstitution necessary.	Store at 4°C
STOP Buffer	No reconstitution necessary	Store at 4°C
GTP γ S stock (non-hydrolysable GTP analog)	Reconstitute in 50 μ l of sterile distilled water. Aliquot into 5 x 10 μ l volumes, snap freeze in liquid nitrogen.	Store at -70°C
GDP Stock	Reconstitute in 50 μ l of sterile distilled water. Aliquot into 5 x 10 μ l volumes, snap freeze in liquid nitrogen.	Store at -70°C
Protease Inhibitor Cocktail	Reconstitute in 1 ml of dimethyl sulfoxide (DMSO) for 100x stock.	Store at -20°C .

V: Important Technical Notes

A) **Notes on Updated Version 10.1**

The following updates should be noted:

1. The RhoA Antibody has been changed from part #ARH03 to ARH04. ARH04 is a monoclonal anti-RhoA specific antibody. It has the same specificity as Cat# ARH03 and was found to give a more robust signal than ARH03.

V: Important Technical Notes (Continued)

B) Growth and Treatment of Cell Lines

The health and responsiveness of your cell line is the single most important parameter for the success and reproducibility of Rho activation assays. Time should be taken to read this section and to carefully maintain cell lines in accordance with the guidelines given below.

Adherent fibroblast cells such as 3T3 cells should be ready at 30% confluency or for non-adherent cells, at approximately 3×10^5 cells per ml. Briefly, cells are seeded at 5×10^4 cells per ml and grown for 3-5 days. Serum starvation (see below) or other treatment should be performed when cells are approximately 30% confluent. It has been found that cells cultured for several days (3-5 days) prior to treatment are significantly more responsive than cells that have been cultured for a shorter period of time. Other cell types may require a different optimal level of confluency to show maximum responsiveness to Rho activation. Optimal confluency prior to serum starvation and induction should be determined for any given cell line (also see Appendix 2 for cell line specific references).

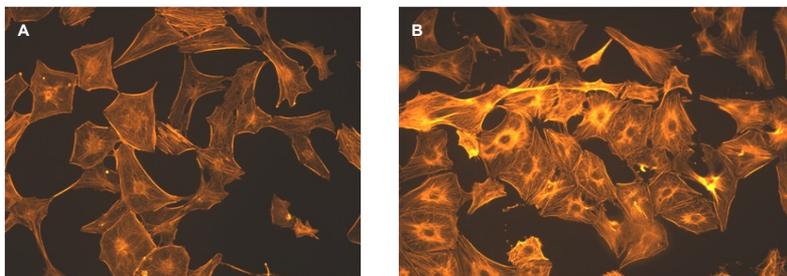
When possible, the untreated samples should have cellular levels of Rho activity in a “controlled state”. For example, when looking for Rho activation, the “controlled state” cells could be serum starved. Serum starvation will inactivate cellular Rho and lead to a much greater response to a given Rho activator. A detailed method for serum starvation is given in Appendix 1.

Cells should also be checked for their responsiveness (“responsive state”) to a known stimulus. A list of known Rho stimuli are given in Appendix 2. In many cases poor culturing technique can result in essentially non-responsive cells. An example of poor culturing technique includes the sub-culture of cells that have previously been allowed to become overgrown. For example, Swiss 3T3 cells grown to >70% confluency should not be used for Rho activation studies.

To confirm the “controlled state” and “responsive state” of your cells, it is a good idea to include a small coverslip in your experimental tissue culture vessels and analyze the “controlled state” cells versus the “responsive state” cells by rhodamine phalloidin staining of actin filaments. A detailed method for actin staining is given in Appendix 1. Figure 2 below shows rhodamine phalloidin stained Swiss 3T3 cells that have been serum starved (A) and calpeptin (Cat. # CN01) stimulated (B). Rho activation by calpeptin causes the formation of characteristic stress fibers.

V: Important Technical Notes (Continued)

Figure 2: Rhodamine Phalloidin Stained Serum-Starved and Calpeptin-Treated Cells



Swiss 3T3 cells were grown at 37°C, 5% CO₂, and 95% humidity in 100 mm dishes containing a small glass coverslip. Cells were grown in Dulbecco's modified Eagle's medium plus 10% calf bovine serum to 30% confluency. For serum starvation, media was changed to 0.5% calf bovine serum for 24 h then to 0% calf bovine serum for a further 24 h. After this time, one dish was treated with calpeptin (Cat. # CN01; 0.1 mg/ml final) for 30 min and the other dish treated with carrier only (DMSO). After incubation, the coverslips were removed from the dishes and stained with rhodamine phalloidin (A, serum starved cells; B, calpeptin treated cells). The remaining cells were lysed and processed in a G-LISA assay. G-LISA results showed calpeptin treated cells expressed 2 fold the Rho activity of the serum starved cells (data not shown).

If you are having difficulty determining a “controlled state” for your experiment then contact technical assistance at 303-322-2254 or e-mail tservice@cytoskeleton.com.

C) Timing and Intensity of Rho Activation

Upon stimulation, Rho proteins are generally activated very rapidly and transiently. Maximal activation ranges from 30 s to 30 min and declines thereafter to basal levels. Examples of known Rho activators are given in Appendix 2. For potent activators such as calpeptin or LPA, the intensity of maximal Rho activation over “control state” (serum starved) cells is generally in the order of 2-5 fold (see Appendix 2). However, using a single time point you are more likely to miss this maximum. It is therefore critical to take timed samples for at least the first experiment with an unknown activating entity. Recommended time points are 0, 1, 3, 6, 12 and 30 minutes (a time course is also recommended for RhoA inactivation studies).

In practical terms the timed experiment must be performed sequentially. This allows rapid processing of each single time point. Once on time point lysate is collected, it should be snap frozen in “experiment sized” aliquots immediately and kept in -70°C. The Activation Assay uses approximately 300-800 µg of total protein per assay; this translates to 600-1600 µl of a 0.5 mg/ml cell lysate. We recommend duplicate samples per time-point or condition, therefore 1.2– 3.2 ml aliquots are recommended for snap freezing.

V: Important Technical Notes (Continued)

D) Rapid processing of cells

GTP bound (active) Rho is a labile entity and the bound GTP is susceptible to hydrolysis by Rho-GAPs during and after cell lysis, resulting in Rho inactivation. Rapid processing at 4°C is essential for accurate and reproducible results. The following guidelines are useful for rapid washing of cells.

Washing

- Retrieve culture dish from incubator, immediately aspirate out all of the media and place firmly on ice.
- Immediately rinse cells with an appropriate volume of ice cold PBS to remove serum proteins (see Table 3 for recommended wash volumes).
- Aspirate off all residual PBS buffer. This is essential so that the Lysis Buffer is not diluted. Correct aspiration requires that the culture dish is placed at a steep angle on ice for 1 min to allow excess PBS to collect in the vessel for complete removal.

Cell Lysis

To avoid making too dilute or too concentrated lysate samples (<0.25 or >2.0 mg/ml), it is recommended to adjust the amount of Cell Lysis Buffer depending on your cell type and plate type. Table 3 gives guidelines for suitable lysis volumes for 3T3 cells which tend to give low protein yields. The exact lysis volumes for any given cell line will have to be determined empirically. NOTE: Cell Lysis Buffer should contain 1X Protease Inhibitor Cocktail.

Table 3: Recommended Wash and Lysis Volumes for 3T3 Cell Cultures

Culture Vessel	Vessel surface area (cm ²)	Volume of PBS wash (ml)	Volume of Lysis Buffer (µl)
100 mm dish	56	10.0	250
150 mm dish	148	15.0	700
T-75 Flask	75	10.0	500
T-150 Flask	150	15.0	700

The time period between cell lysis and addition of lysates to the rhotekin-RBD beads is critically important. Take the following precautions:

- Work quickly.
- Keep solutions and lysates embedded in ice so that the temperature is below 4°C. This helps to minimize changes in signal over time. The Assay Protocol (Section VI) gives very specific instructions regarding temperature and must be strictly adhered to for successful results.
- We strongly recommend that cell lysates be immediately frozen after harvest and clarification. A sample of at least 20 µl should be kept on ice for protein concentration measurement. A 20-50 µg sample should also be kept for Western

V: Important Technical Notes (Continued)

blot quantitation of total RhoA per sample or an ELISA quantitation of total RhoA (see Appendix 4). The lysates **must** be snap frozen in liquid nitrogen and stored at -70°C . Lysates can be stored at -70°C for several months.

4. Thawing of cell lysates prior to use in the G-LISA[®] assay should be in a room temperature water bath, followed by rapid transfer to ice and immediate use in the assay.

E) **Protein Concentration Equivalence**

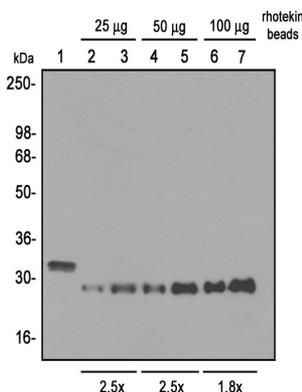
Equal protein concentration in all samples is a prerequisite for accurate comparison between samples in Rho activation assays. Cell extracts should be equalized with ice cold Cell Lysis Buffer to give identical protein concentrations. For example, cell lysates of protein concentrations ranging from 0.5–1.3 mg/ml would all need to be diluted to 0.5 mg/ml. It is not necessary to equalize protein concentrations if the variation between them is less than 10%.

F) **Assay Linearity**

There are several factors to consider when performing the RhoA activation assays:

- 1) **Bead Titration:** Rhotekin-RBD will bind to Rho-GDP with a much lower affinity than Rho-GTP. If too many rhotekin-RBD beads are added to the pull-down assay there will be significant binding to inactive (GDP-bound) RhoA. The result of this will be an underestimate of RhoA activation (see Figure 3). For this reason we highly recommend performing a bead titration to determine optimal conditions for any given RhoA activation or inactivation assay. Once optimal conditions have been established, bead titrations should no longer be necessary. We recommend 25, 50 and 100 μg bead titrations.

Figure 3. Rhotekin-RBD Bead Titration on Serum Starved and Calpeptin Treated Swiss 3T3 Cell Extracts.



Previously frozen extract (300 μg at 0.5 mg/ml) made from serum starved (samples 2, 4 and 6) or calpeptin treated (samples 3, 5 and 7) Swiss 3T3 cells (see Appendix 1) were incubated with increasing amounts of rhotekin-RBD beads (25, 50 or 100 μg) and processed as described in Section VI:STEP 3: Pulldown Assay. All bead samples were resuspended in 12 μl of 2x Laemmli sample buffer and run on a 12% SDS gel along with 20 ng (lane 1) of His-RhoA control protein. Protein was transferred to PVDF, probed with a 1:500 dilution of anti-RhoA and processed for chemiluminescent detection.

V: Important Technical Notes (Continued)

Note, in Figure 3, how increasing amounts of rhotekin-beads result in more “non-specific” RhoA signal in the serum starved samples (compare lanes 4 and 6). RhoA activation estimates of 2.5 fold are observed using 25 and 50 μg of rhotekin-beads, whereas a RhoA activation estimate of 1.8 fold is observed with the highest amount of beads (100 μg).

It is highly recommended that each user titrate the rhotekin-RBD beads for their particular experiment as cell lysate concentration, G-protein activation efficiency, bead binding and processing times can be variable and must be optimized for reproducible results.

- 2) **Strictly Maintain Experimental Conditions:** Once assay conditions are established one should strictly maintain experimental conditions. For example, lysate concentrations should be consistent between experiments. Thus, if 50 μg of beads are used to assay 400 μg of lysate at 0.5 mg/ml protein concentration, it is recommended to keep subsequent assays at 0.5 mg/ml lysate rather than using half the volume of a 1 mg/ml lysate to give 400 μg total protein. As a further example, the growth and treatment of cell lines should be consistent between experiments; this point can not be over-emphasized and is discussed in detail in Section V: B.
- 3) **Densitometric Quantitation:** The linear range of X-ray film is very narrow. Multiple exposures of the western blot may be required to analyze data in the linear range of the film. As a general guideline, protein bands that appear grey rather than black will be within the linear range of the film.

VI: Assay Protocol

STEP 1: Control Reactions

The correct control reactions are key components of the Rho Activation Assay. The following control assays should be performed as an integral part of each experiment:

1. Whole Cell Lysate Protein:

Total RhoA present in each sample should be determined by Western quantitation or ELISA (see Appendix 4). Usually 20 – 50 µg of cell lysate will result in a good signal. The total RhoA should not differ by more than 10-20% between samples.

2. Positive Cellular Protein Control:

Total cell lysate (300 – 800 µg) should be loaded with GTPγS as a positive control for the pull-down assay. The following reaction details how to load endogenous RhoA with the non-hydrolysable GTP analog (GTPγS), this is an excellent substrate for rhoteikin-RBD beads and should result in a strong positive signal in a pulldown assay.

- a. Perform GTP loading on 300 – 800 µg of cell lysate by adding 1/15th volume of Loading Buffer (70 µl Loading Buffer per ml of lysate).
- b. Immediately add 1/100th volume of GTPγS (10 µl GTPγS per 990 µl of lysate) to give a 200 µM final GTPγS concentration. Under these conditions 5 - 10% of the Rho protein will load with non-hydrolysable GTPγS and will be “pulled-down” with the rhoteikin-RBD beads in the assay (see Figure 1).
- c. Incubate the control sample at room temperature for 15 min with gentle rotation.
- d. Stop the reaction by transferring the tube to 4°C and adding 1/10th volume of STOP Buffer (100 µl STOP Buffer per 900 µl of lysate).
- e. Use this sample immediately in a pulldown assay as detailed in STEP 3.

3. Negative Cellular Protein Control:

This reaction should be performed in an identical manner to the Positive Control reaction except that 1/100th volume of GDP (1 mM final concentration) should be added to the reaction in place of the GTPγS. Loading endogenous RhoA with GDP will inactivate Rho and this will bind very poorly to rhoteikin-RBD beads.

4. His-RhoA Protein Control:

The kit supplies 10 µg of His-RhoA control protein; this will be reconstituted to a 0.33 mg/ml stock solution and stored at -70°C (as 10 x 3 µl aliquots). Storage of the protein at lower concentrations than 0.33 mg/ml or freeze/thaw cycles will result in denaturation, precipitation of the protein and incorrect quantitations or no signal in the western blot. The Rho family proteins have a molecular weight of between 20-25 kDa; the His-tagged control protein has a molecular weight of approximately 30 kDa. We recommend that 20 ng of His-RhoA control protein be run on the gel as a positive control and as a quantitation estimate for endogenous Rho (see STEP 4).

VI: Assay Protocol (Continued)

STEP 2: Lysate Collection

We strongly recommend that you snap freeze your cell lysates in liquid nitrogen right after you harvest and clarify. This is especially necessary if you have many samples. It is recommended to freeze lysates in 1-3 ml aliquots and to save a small amount of each lysate (approximately 20 – 30 μ l) for protein quantitation. Details of lysates processing are given below:

Cells Grown in Tissue Culture Vessels as Monolayers

1. Grow cells in appropriate culture conditions. It is important to keep cells in a “controlled state” prior to Rho activation. See Section V (B): Important Technical Notes.
2. Treat cells with Rho activator (or inactivator) as your experiment requires.
3. After treatment, place culture vessel on ice, aspirate media, wash with ice cold PBS. See Table 3, Section V: D for recommended volumes.
4. Aspirate off PBS. Tilt plates on ice for an additional 1 min to remove all remnants of PBS. Residual PBS will adversely affect the assay.
5. Lyse cells in an appropriate volume of ice-cold Cell Lysis Buffer (Lysis Buffer should be supplemented with 1X Protease Inhibitor Cocktail). See Table 3, Section V: D for recommended volumes.
6. Harvest cell lysates with a cell scraper. It is useful to incline the culture plate for this method because the Lysis Buffer is spread thinly on the surface.
7. Transfer lysates into the pre-labeled sample tubes on ice.
8. Immediately clarify by centrifugation at 10,000 x g, 4°C for 1 min.
9. At this point each lysate volume should not exceed 130% of the original Cell Lysis Buffer volume.
10. Save at least 20 μ l of lysate for protein quantitation and 20-50 μ g of lysate for Western blot or ELISA quantitation of total RhoA.
11. Aliquot and snap freeze the remaining cell lysates in liquid nitrogen. Store at -70°C for future use. It is recommended to aliquot into 1-3 ml of lysate per tube (This should be sufficient for duplicate assays of 300-800 μ g per assay).
12. Measure lysate protein concentrations. We recommend using Precision Red Advanced Protein Assay (Cat. # ADV02) for quantitations (see Appendix 3):
 - Add 20 μ l of each lysate or Lysis Buffer into disposable 1 ml cuvettes.
 - Add 1 ml of Precision Red™ Advanced Protein Assay Reagent (Cat # ADV02) to each cuvette.
 - Incubate for 1 min at room temperature.
 - Blank spectrophotometer with the Cell Lysis Buffer at 600 nm.
 - Read absorbance of lysates samples.
 - Multiply the absorbance by 5 to obtain the protein concentration in mg/ml.

VI: Assay Protocol (Continued)

13. Calculate how to equalize the cell extracts with ice cold Lysis Buffer to give identical protein concentrations. It is essential to have equal protein concentration in each sample for a successful assay. It is also important that the equalized protein concentration is not higher than 2.0 mg/ml or below 0.25 mg/ml. It is not necessary to equalize protein concentration if the sample variation is less than 10%.

The volume of cold cell lysis buffer to be added to the more concentrated samples can be calculated as follows:

$$\frac{A - B}{B} \times (\text{volume of A}) = \text{_____ } \mu\text{l}$$

Where A is the higher concentration lysates (mg/ml) and B is the concentration of the most dilute sample (mg/ml)

NOTE: You can dilute the lysates to a given concentration (e.g. 0.5 mg/ml) prior to snap freezing aliquots. This makes subsequent pulldown assays simpler. Be aware of the length of time cell lysates stay on ice (should not exceed 10 min), since Rho GTP hydrolysis will occur.

VI: Assay Protocol (Continued)

STEP 3: Pulldown Assay

1. If using freshly prepared cell lysates, use as soon as possible after lysis and protein equalization and always maintain samples at 4°C. If using frozen lysates (recommended), thaw in a room temperature water bath and remove immediately to ice upon thawing. Use immediately.
2. Add equivalent protein amounts of lysate (300 – 800 µg total cell protein) to a pre-determined amount of rhotekin-RBD beads from your bead titration test (see Section V.F.1 and Figure 3).

NOTE: In general, a 50 µg (15 µl) bead pulldown will yield optimal results. Under these conditions the 4 mg of rhotekin-RBD beads supplied in the kit are sufficient for 80 assays. We do however recommend a bead titration (25, 50 & 100 µg) to determine optimal pulldown conditions.

3. Incubate at 4°C on a rotator or rocker for 1 h.
4. Pellet the rhotekin-RBD beads by centrifugation at 3-5,000 x g at 4°C for 1 min.
5. Very carefully remove 90% of the supernatant. Do not disturb the bead pellet. If you do disturb the pellet simply re-centrifuge the sample as in step 4.
6. Wash the beads once with 500 µl each of Wash Buffer. **NOTE:** Add the buffer to the bead pellet in a manner that completely resuspends the beads. **DO NOT invert the tube as the beads will disperse over the surface of the tube and protein will be lost. This step should take less than 1 min to perform.**
7. Pellet the rhotekin-RBD beads by centrifugation at 3-5,000 x g at 4°C for 3 min.
8. Very carefully remove the supernatant. Do not disturb the bead pellet. If you do disturb the pellet simply re-centrifuge the sample as in step 7.
9. Add 10-20 µl of 2x Laemmli sample buffer to each tube and thoroughly resuspend the beads. Boil the bead samples for 2 min.
10. The samples are now ready to be analyzed by SDS-PAGE and Western blot analysis (see STEP 4).

NOTE: The samples can be centrifuged (14K rpm, 2 minutes, room temperature) to pellet the beads, in this case only the supernatant will be loaded onto the gel. Alternatively, the whole sample including the beads can be loaded onto the gel. It is recommended that the necessary control samples be run on each gel.

VI: Assay Protocol (Continued)

STEP 4: Western Blot Protocol

1. Run the test protein samples and controls on a 4-20% or 12% SDS gel until the dye front reaches the bottom of the gel.
2. We recommend running a lane containing 20 ng of His-RhoA control protein as a positive control. To do this the protein should be diluted as follows;
 - a) Thaw one of the 3 μ l aliquots of His-Rho control protein (see Table 2).
 - b) Dilute to 4ng/ μ l by adding 247 μ l of Cell Lysis Buffer.
 - c) Dilute to 2ng/ μ l by adding 250 μ l of 2X Laemmli sample buffer (125mM Tris pH6.8, 20% glycerol, 4% SDS, 0.005% Bromophenol blue, 5% beta-mercaptoethanol).
 - d) Load 10 μ l (20ng).
 - e) Discard any unused control protein as it will "crash out" during storage at 4°C or frozen.
3. Equilibrate the gel in Western blot buffer (See recipe below) for 15 min at room temperature prior to electro-blotting.
4. Transfer the protein to a PVDF membrane for 45 minutes at 75V.
5. Wash the membrane once with TBS (10 mM Tris-HCl pH 8.0, 150 mM NaCl).
6. Allow the membrane to air dry for 20-30 minutes.
7. Transfer the membrane to TBST (10 mM Tris-HCl pH 8.0, 150 mM NaCl, 0.05% Tween 20) at room temperature for 15 minutes to rehydrate the membrane.
8. Block the membrane surface with 5% nonfat-dry milk in TBST for 30 min at room temperature with constant agitation.
9. Incubate the membrane with a 1:500 dilution of anti-RhoA antibody (Cat. # ARH04, provided with kit) diluted in TBST (no blocking agent) for 2-3 h at room temperature or overnight at 4°C with constant agitation.
10. Rinse the membrane in 50 ml TBST for 1 min.
11. Incubate the membrane with an appropriate dilution (eg. 1:20,000) of anti-mouse secondary antibody (eg. goat anti-mouse HRP conjugated IgG from Jackson Labs., Cat. # 115-035-068) in TBST for 30 min-1 h at room temperature with constant agitation.
12. Wash the membrane 5 times in TBST for 10 min each.
13. Use an enhanced chemiluminescence detection method to detect the RhoA signal (eg. SuperSignal West Dura Extended Duration Substrate; ThermoFisher)

Recipe for Western Blot Buffer (1 L)

1 M Tris pH 8.3	25 ml	(25 mM final)
Glycine	14.4 g	(192 mM final)
Methanol	150 ml	(15% final)
Distilled water to 1 L		

VII: Troubleshooting

Observation	Possible cause	Possible Remedy
No signal from the His-tagged RhoA control protein.	<ol style="list-style-type: none"> 1. Storage of the stock control protein at concentrations that are too low (<0.33mg/ml). 2. Repeated freeze/thaw cycles of the reconstituted positive control stock protein. 3. Attempts to store the diluted stock at 4°C or frozen for future use. 	<ol style="list-style-type: none"> 1. The kit supplies 10 µg of His-RhoA protein, this should be reconstituted to a 0.33 mg/ml stock solution and stored at -70°C (as 10 x 3 µl aliquots, see Table 2). Storage of the protein at lower concentrations will result in denaturation and precipitation of the protein and incorrect quantitations or no signal at all. 2. The stock protein must be aliquoted as described in Table 2. Repeated freeze thaws of the stock will result in denaturation and precipitation. 3. We recommend loading 20 ng of the positive control on the gel as a positive control and quantitation estimate for endogenous Rho (for 20 ng of recombinant protein, dilute one 3 µl aliquot of protein stock with 247 µl of Cell Lysis Buffer and then 250 µl of 2x Laemmli sample buffer; load 10 µl of this on the SDS gel). The diluted protein is unstable and will precipitate. Unused protein must be discarded. <p>The Rho family proteins have a molecular weight of between 20-25 kDa; the His-tagged control protein has a molecular weight of approximately 30 kDa.</p>
No difference in signal between GTPγS positive control and GDP negative control assay	<ol style="list-style-type: none"> 1. Protein lysate concentrations were not equalized. 2. Titration of Rhotekin-RBD Beads not performed. 3. GDP requirements are higher for your cell line. 	<ol style="list-style-type: none"> 1. The absolute amount of protein in lysates can have a dramatic effect upon RhoA signal. It is therefore very important to have equal amounts of cell lysate protein in each reaction. See section V (E). 2. Perform bead titration per section V (F). In cases where there is a high signal in both GTPγS and GDP lanes, using half the amount of rhotekin-RBD beads will often result in a better differential signal. 3. Some cell lines have very high levels of endogenous GTP and exchange of GDP requires addition of greater than the 1 mM GDP outlined in this manual. We recommend trying 10 mM GDP in these cases.
No detectable RhoA activation in the positive control (GTPγS) assay	<ol style="list-style-type: none"> 1. STOP buffer not added to the reactions. 2. Leaving the lysates for >10 minutes before use. 	<ol style="list-style-type: none"> 1. Follow the instructions carefully, for example, STOP buffer must be added to the reaction or you will not get a RhoA signal. 2. GTPγS AND GDP loaded lysates should be used within 2-3 minutes after STOP buffer has been added.

VII: Troubleshooting (cont.)

Observation	Possible cause	Remedy
No detectable signal in the experimental samples	<ol style="list-style-type: none"> Control reaction not performed for GTPγS. His-RhoA control protein not used during Western blot. Insufficient cell lysate used Lysates not processed rapidly at 4°C 	<ol style="list-style-type: none"> Always run a GTPγS control to make sure the rhotekin-RBD beads are working and always run the recombinant His-RhoA control protein to make sure that the Western blot / RhoA antibody is working correctly. Once these controls are working you can go on to determine the likely cause of a lack of signal or a lack of activation in the experimental samples. Titrate the protein amount used in the assay. We recommend 300-800 μg lysate, however, in some cases more lysate may be required. RhoA is still able to hydrolyze GTP during lysate preparation; hydrolysis is stopped only when the rhotekin-RBD beads are bound to RhoA-GTP. The temperature and speed of lysate preparation are therefore very important parameters in this assay .
RhoA activation signal does not change upon experimental activation stimulus.	<ol style="list-style-type: none"> Titration of Rhotekin-RBD Beads not performed. Culture conditions have caused cells to become unresponsive to RhoA activators. Selected RhoA activator may not work with your cell line. Western blot is overexposed leading to inaccurate readings. 	<ol style="list-style-type: none"> Make sure that your control GDP and GTPγS lanes give a clear positive and negative response; this indicates that the bead and cell lysate levels are in the correct linear range to detect differential RhoA activation states. This may require titrating bead and / or lysate levels. Continuous overgrowing of a cell line can result in unresponsive cells. Swiss 3T3 cells should only be used for 10 passages and then discarded as their properties change if they are passaged longer than this (17). Cells seeded at low densities, grown for 3 days to 30-40% confluency, then serum starved by a serum-step down procedure often respond better than cells grown to higher densities. See Appendix 1 for a cell culture protocol. Use a known RhoA activator (eg. Calpeptin) or inhibitor (eg. Cell permeable C3 transferase, Cat. # CT04) to check the responsiveness of your cell line. A list of some RhoA activators are given in Appendix 2. Note that the cell line used for the activation assay is important as response to any given activator can vary considerably between cell lines. It may also be useful to examine actin morphology via rhodamine-phalloidin labeling of cells. (See Appendix 1). The serum starved cells should have very few actin stress fibers while stimulated cells should have a large number of stress fibers (see Figure 1, Appendix 1). As a general guideline, you should expose the film so that the RhoA signal gives a grey band rather than a black band. Alternatively, the RhoA G-LISA® Activation Assay Kit (Cat. # BK124) can be used to obtain quantitative results within 3 h.

VIII: References

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Appendix 1: Observation of Actin Morphology By Rhodamine-Phalloidin Staining

Reagents needed

- Suitable growth media
- Calpeptin stock solution (20 mg/ml in PBS)
- PBS solution pH 7.4 (150 mM NaCl, 2.7 mM KCl, 8.1 mM Na₂PO₄, 1.47 mM KH₂PO₄)
- Rhodamine-phalloidin stock (14 mM in methanol, Cat. # PHDR1)
- Paraformaldehyde stock (6% stock in PBS, stored aliquoted at -20°C)

Method

Serum starvation for Swiss 3T3 cells and addition of growth factors

1. Swiss 3T3 cells are seeded at low density of 3 – 5 x 10⁴ cells in DMEM plus 10% FCS on a 10 cm diameter plate containing two 13 mm diameter glass coverslips.
2. Once cells are 30-40% confluent (usually 3 days) the media is replaced with DMEM plus 1% FCS and cultured for 24 h.
3. The media is again replaced with DMEM without FCS and the cells are incubated for 16 - 20 h.
4. After serum starvation remove one coverslip and process for actin staining as described below.
5. Add fresh calpeptin to the remaining cells to 100 µg/ml for 20 min.
6. Remove the coverslip and process for actin staining as described below.

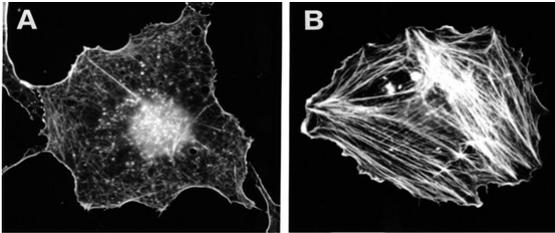
Actin Staining

1. Wash the cells once with PBS and fix for 20 min at room temperature in 3% paraformaldehyde diluted in PBS.
2. Wash the cells once for 30 s with PBS to remove excess fixative.
3. Incubate the cells with 0.2% Triton-X 100 in PBS for 5 min at room temperature to permeabilize cells.
4. Wash twice in PBS for 30 s each.
5. Incubate with 200 µl of 0.1 µg/ml Rhodamine-phalloidin for 30 min at room temperature in the dark.
6. Wash five times with PBS for 30 s each.
7. Invert the cells into mounting medium (eg. Polyvinyl alcohol mounting medium, Fluka Chemie) and allow the coverslip to set for 30 min.
8. View actin filaments with a 63 – 100X oil immersion objective.
9. Examples of serum starved and calpeptin treated cells are shown in Figure 1.

NOTE: All the required reagents for fixing cells and staining F-actin can be found in the F-actin Visualization Kit (Cat. # BK005).

Appendix 1: Observation of Actin Morphology By Rhodamine-Phalloidin Staining (Continued)

Figure 1. Rhodamine-Phalloidin Staining of the Actin Cytoskeleton in Serum Starved and Calpeptin Treated Cells.



Swiss 3T3 cells were serum starved for 40-44h (according to the method in this section) prior to actin filament staining with rhodamine-phalloidin. B) Cells treated for 20 min with 100 μ g/ml calpeptin after serum starvation and subsequently stained with rhodamine-phalloidin. RhoA activation by calpeptin treatment results in a marked increase in actin stress fibers (compare Fig. 1A and 1B).

Appendix 2: Known Rho Activators

Activator*	Treatment	Cell line used	Response	Type of Assay Used	Ref.
Calpeptin (Cat. # CN01) (protease inhibitor, protein tyrosine phosphatase inhibitor)	100 µg/ml	REF-52 fibroblasts & Swiss 3T3 cells adherent	Maximal activation after 5 to 10 min with extended activation time up to 30 min, decreasing thereafter to basal levels after 60 min.	Actin morphology	20
Bombesin	10 nM	Swiss 3T3 cells	Maximal activation of 2-3 fold after 1 min which is sustained for at least 30 min	Actin morphology	1
Colchicine (microtubule destabilizer)	10 µg/ml	Swiss 3T3 cells, adherent or suspension	Maximal activation of 2-4 fold activation after 30 min	Rhotekin-RBD pulldown	14
Cytochalasin D (actin filament destabilizer)	0.5 µg/ml	Swiss 3T3 cells, adherent or suspension	Maximal activation of 1-2 fold after 30 min	Rhotekin-RBD pulldown	14
Fibronectin (extracellular matrix protein)	Culture plate is coated with fibronectin	Swiss 3T3 cells	Biphasic regulation after plating cells on fibronectin coated plates. Initial period of low RhoA activity (10-20 min) followed by a 1-7 fold activation peaking at 60-90 min and then dropping to basal levels after 6 h.	Rhotekin-RBD pulldown	14
Lysophosphatidic acid (LPA) (serum lipid & G-protein coupled receptor agonist)	1 µg/ml	Swiss 3T3 cells, adherent & suspension	Maximal activation of 2-6 fold after 1 min then dropping to basal after 30 min	Rhotekin-RBD pulldown	14
Lysophosphatidic acid (LPA)	1 µM	N1E-115 neuronal cells	Maximal activation of 3-5 fold after 3 min	Rho-kinase pull down assay	19
Nocodazole (microtubule destabilizer)	10 µM	MG63 human osteosarcoma cells & HeLa cells	Maximal activation of 2-3 fold activation after 30 min	Actin morphology & Rhotekin-RBD pulldown	16, 17
Serum	5 - 10%	Swiss 3T3 cells, adherent or suspension	Maximal activation of 2-6 fold (10%) & 1-2 fold (5%) after 1-5 min	Rhotekin-RBD pulldown	14
Sphingosine-1-phosphate (serum lipid & G-protein coupled receptor agonist)	1 µg/ml	Swiss 3T3 cells, adherent or suspension	Maximal activation of 1-2 fold after 2 min for 3T3 cells and 20 min for HUVEC cells	Rhotekin-RBD pulldown	14, 18
Thrombin (protease, G-protein coupled receptor agonist)	10 nM	HUVEC human endothelial primary cells	Maximal activation of 14 fold after 2 min, dropped to basal after 30 min	Rhotekin-RBD pulldown	18
Vinblastine (microtubule destabilizer)	50 µM	MG63 human osteosarcoma cells	Maximal activation of 2-4 fold activation after 30 min	Actin morphology	16

Appendix 3: Protein Quantitation (with Precision Red Reagent)

Background

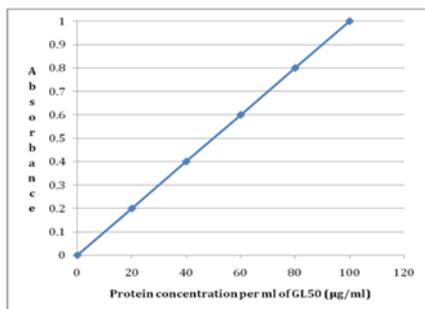
The Precision Red Advanced Protein Assay Reagent is a simple one step procedure that results in a red to purple/blue color change characterized by an increase in absorbance at 600 nm. The reagent is not supplied in this kit, it is sold separately as Cat. # ADV02. Precision Red Advanced Protein Assay Reagent is supplied in the G-LISA activation assays (Part# GL50).

The assay exhibits low variance in readings between different proteins of the same concentration and high reproducibility of the colorimetric response. This allows one to utilize a generally applicable standard curve (Fig. 1) for protein quantitation. The assay can also be performed in approximately 1-2 minutes. These properties are particularly valuable when applied to the labile lysates required for activation assays.

Quick Protein Concentration Method for 1 ml Cuvette (recommended)

- Add 20 μ l of each lysate or Lysis Buffer into disposable 1 ml cuvettes.
- Add 1 ml of Precision Red™ Advanced Protein Assay Reagent (Cat# ADV02) to each cuvette.
- Incubate for 1 min at room temperature.
- Blank spectrophotometer with 1 ml of ADV02 plus 20 μ l of Lysis Buffer at 600 nm.
- Read absorbance of lysate samples.
- Multiply the absorbance by 5 to obtain the protein concentration in mg/ml

Fig. 1: Standard Curve for Protein Quantitation in a 1ml Cuvette



Legend: The standard curve shown in Fig. 1 represents the average absorbance reading of several common proteins (e.g., actin, BSA, casein) measured in a 1 ml cuvette format using 1 ml of ADV02 reagent. The protein reading pathlength for a cuvette is 1 cm. Linear range of this assay is 0.05 - 0.6.

Example Calculation

Assume a 20 μ l sample of cell lysate added to 1 ml of ADV02 gives an absorbance reading of 0.1.

$$C = \frac{A}{\epsilon l} = \frac{0.1}{10 \times 1} \times 50 = 0.5 \text{ mg/ml}$$

Where c = protein concentration (mg/ml), A = absorbance reading, l = pathlength (cm), ϵ = extinction coefficient ($[\text{mg/ml}]^{-1} \text{cm}^{-1}$) and the multiplier of 50 is the dilution factor for the lysate in ADV02 (20 μ l lysate in 1 ml ADV02).

Thus, for a 20 μ l sample in 1 ml ADV02, the equation becomes $C = A \times 5$

For a 10 μ l sample in 1 ml ADV02, the equation becomes $C = A \times 10$

Appendix 3: Protein Quantitation (with Precision Red Reagent)

Quick Protein Concentration Method for 96 Well Plate

- Add 10 μ l of each lysate or Lysis Buffer into the well of a 96 well plate.
- Add 290 μ l of Precision Red™ Advanced Protein Assay Reagent to each well.
- Incubate for 1 min at room temperature.
- Blank spectrophotometer with 290 μ l of ADV02 plus 10 μ l of Lysis Buffer at 600 nm.
- Read absorbance of lysate samples.
- Multiply the absorbance by 3.75 to obtain the protein concentration in mg/ml

96 Well Plate Method

The linear range of this assay is 0.05 - 0.4 and is recommended when lysates are below the linear range of the 1 ml cuvette method. The pathlength for 96 well plate readings is 0.8 cm, hence the equation is modified as shown in the example below:

Example Calculation for 96 Well Plate Measurement

Assume a 10 μ l sample of cell lysate added to 290 μ l of ADV02 gives an absorbance reading of 0.1

$$C = \frac{A}{\epsilon l} = \frac{0.1}{10 \times 0.8} \times 30 = 0.375 \text{ mg/ml}$$

Where c = protein concentration (mg/ml), A = absorbance reading, l = pathlength (cm), ϵ = extinction coefficient ($[\text{mg/ml}]^{-1} \text{ cm}^{-1}$) and the multiplier of 30 is the dilution factor for the lysate in ADV02 (10 μ l lysate in 290 μ l ADV02).

Thus, for a 10 μ l sample in 290 μ l ADV02, the equation becomes $C = A \times 3.75$

For a 5 μ l sample in 295 μ l ADV02, the equation becomes $C = A \times 7.5$

NOTE: The protein concentrations generated by using the standardized protein curve (Fig.1) will generate approximate lysate concentrations. Data will be highly reproducible from lysate to lysate and will generate excellent values for relative concentrations of a series of lysates. It should be noted for activation assays, the relative protein concentration between experimental extracts is far more important than the absolute protein quantitation. However, if desired, one can create a standard curve using BSA or IgG protein standards for each experiment. The standard curve should be performed prior to lysate preparations due to the labile nature of the lysates.

Appendix 4: Total RhoA ELISA Method

Normalization of Active RhoA against Total RhoA is required for comparison of RhoA activity between samples (1-4). Normalization of active RhoA signal is particularly important in studies that involve prolonged exposure of cells to conditions that might affect RhoA pathways, e.g., transfections or drug studies.

In order to avoid the need to perform poorly reproducible and semi-quantitative western blot analysis, Cytoskeleton Inc. has developed an ELISA assay to allow rapid and quantitative determination of Total RhoA (Cat # BK150). It is generally accepted that active RhoA comprises between 0.5-5% of total RhoA in normal cellular transduction processes (5).

Method

Swiss 3T3 cells were grown to 30% confluency in DMEM media plus 10% FCS. They were then serum starved for 48h. Half of the cells were treated with 0.1 mg/ml calpeptin (Cat# CN01) for 30 minutes to activate RhoA. The other half were not treated. All cells were subsequently lysed in Cell Lysis Buffer (Part# CLB01) and frozen as 12.5 µg aliquots ready for analysis by ELISA (Fig. 1) or 900 µl aliquots ready for analysis by the RhoA pull-down assay (data not shown).

Results

The Rho ELISA data in Fig.1 show 12.5 µg lysate contained 12 ng Total RhoA in calpeptin treated cells and 11 ng Total RhoA in serum starved cells.

RhoA pull-down assays showed that 450 µg of lysate contained 13.3 ng active RhoA (0.37ng in 12.5 µg lysate) in calpeptin treated cells and 3.6 ng of Active RhoA (0.1ng in 12.5 µg lysate) in serum starved cells (data not shown).

Data Analysis

The fold activation of calpeptin treated cells can be determined using the simple formula given below:

$$\frac{\text{Pull-down value (ng)}}{\text{ELISA value (ng)}} \times 100 = \text{normalized \% Active RhoA in a given lysate}$$

For serum starved lysates

$$\frac{0.10}{11} \times 100 = 0.91\% \text{ Active RhoA in untreated cells}$$

For calpeptin treated lysates

$$\frac{0.37}{12} \times 100 = 3.1\% \text{ Active RhoA in stimulated cells}$$

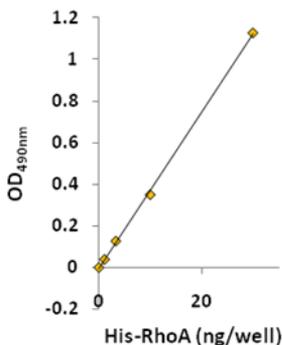
Thus, the normalized fold activation for calpeptin treated cells compared to untreated serum starved cells is **3.4 fold**

Appendix 4: Total RhoA ELISA Method

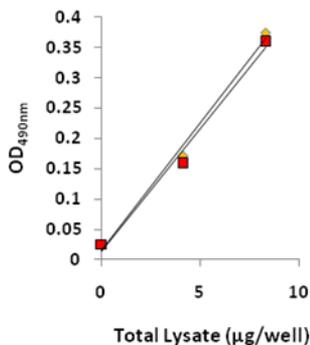
It can be seen that Total RhoA is very similar in the calpeptin and serum starved samples. This is to be expected with lysates from cells that have only been briefly treated with an activator. In this case the purpose of the normalization is simply to confirm that equal amounts of lysate have been analysed. In transfection experiments or more prolonged drug treatments, it cannot be assumed that Total Rho levels will be identical in equivalent amounts of cell lysate.

Figure 1: Determination of Total RhoA by ELISA

2A: Standard RhoA curve



2B: ELISA of calpeptin and serum starved lysates



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Appendix 5: Processing Tissue Samples for Pull-Down Assays

Tissue lysates can be used in pull-down assays (1). Recommendations regarding tissue lysates are given below;

- 1) Rho family GTPases are labile proteins that will hydrolyze bound GTP during sample handling. Tissues should therefore be processed quickly and at 4°C if possible. Tissues should be processed immediately using 4°C buffers or cut into small chunks (3-5 mm diameter), snap frozen in liquid nitrogen and stored at -70°C for later processing.
- 2) Tissues can be extracted using a micro-pestel on ice. Homogenates should be clarified by a 1 minute centrifugation at 4°C. Lysates can be used immediately in an activation assay or snap frozen in “experiment-sized” volumes. The Activation Assay uses approximately 300-800 µg of total protein per assay; this translates to 600-1600 µl of a 0.5 mg/ml cell lysate. We recommend duplicate samples per time-point or condition, therefore 1.2– 3.2 ml aliquots are recommended for snap freezing.
- 3) When possible tissues should be extracted in Cell Lysis Buffer (Part# CLB) as this is the recommended buffer for pull-down assays.
- 4) It is recommended that lysis buffer be supplemented with protease inhibitors and phosphatase inhibitors. Recommended inhibitors include; Cytoskeleton protease inhibitor cocktail (Cat# PIC02), sodium fluoride (50 mM final), sodium pyrophosphate (20 mM final), p-Nitrophenyl phosphate (1 mM final) and microcystin LR (1 µM final).
- 5) A final lysate protein concentration of 0.5 mg/ml is recommended.

Reference

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NOTES
