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UNDERSTANDING COEFFICIENT OF FRICTION AND WHY OTHER SLIDE SHEET PROPERTIES ARE ALSO IMPORTANT

by Jamar Health Products, Inc.

ABSTRACT

BACKGROUND: Discussions about slide sheets, which are meant to make patient handling and mobility tasks easier and safer for healthcare workers, often include the term coefficient of friction (COF). In the simplest terms, the lower the COF number, the slipperier the slide sheet and the less force it should take to move the patient with it. While COF should be considered when choosing a slide sheet, it is far from the only property that plays into a slide sheet's performance. Moreover, most healthcare workers may not understand that it is extremely difficult to compare two brands or styles of slide sheet solely based on COF because of the variations in testing methods used on slide sheets and the reproducibility issues between test labs.

PURPOSE: This article will define COF, describe how it's tested by the American Society of Testing and Materials and how Jamar Health Products, Inc., tested the COF of its PATRAN® slide sheet. After completing the article, readers should have a better understanding about the role of COF when it comes to slide sheets. In addition, this document will explore how size, cost, and anticipated application can help provide a better picture of how a slide sheet will perform in a real healthcare setting.

CONCLUSION: COF provides an estimate of a slide sheet's slipperiness. With the high margin for error in testing for thin plastics, it should not be the single, or even most important, consideration when choosing a slide sheet to move patients within a healthcare setting. Other properties such as the slide sheet's size and make-up also play a significant role in determining a quality slide sheet. Even economic factors deserve consideration when an organization is selecting a slide sheet.

Defining Coefficient of Friction

The Coefficient of Friction (COF) is the force required to move an object on a level surface divided by the weight of the object ($\text{Force/Weight} = \text{COF}$). For example, if a force of 30 lbs. is required to move a 100lb.

object on a level, smooth, stainless steel surface, the object/surface combination has a COF of 0.30. The lower the COF number, the less force it takes to move the object on the surface.

Different materials have different COFs. If a polycotton sheet is put over the stainless-steel surface in the example, it would likely change the COF, as would changing the surface to rubber, leather, concrete, or other materials.

To determine the force it takes to move a weight, use the formula $\text{Weight} \times \text{COF} = \text{Force}$. The lower the COF, the less force it takes to move that weight.

Testing for COF

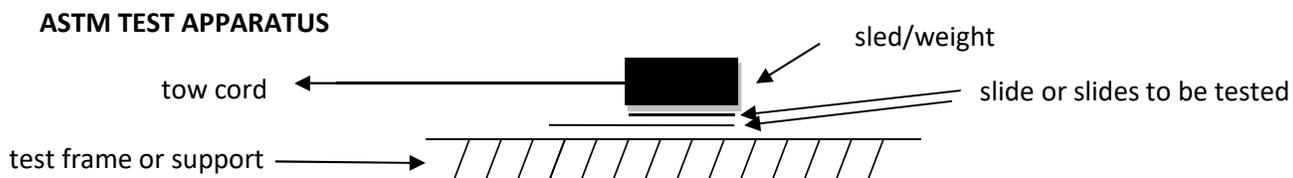
When it comes to testing for COF, the American Society of Testing and Materials (ASTM) sets the standards.¹ Unfortunately, these standards don't translate well from the testing laboratory into real-world healthcare scenarios. They are not easy to duplicate² or reproduce with plastic slide sheets. Therefore, Jamar does not test according to these standards, and nor do any other slide sheet manufacturers to our knowledge.

Jamar has been testing the COF of its PATRAN[®] slide sheet for many years for quality control purposes rather than to calculate effort. In doing so, Jamar uses heavier weights than specified by ASTM. In addition, Jamar recommends healthcare workers put bed linen between the patient and the PATRAN, so testing is conducted on polycotton sheets. These changes (as well as the differences shown in Chart 1²) make testing more applicable to use with patients. However, Jamar's standard testing does not account for differences in surfaces, such as mattresses or surgical or imaging tables typically found in healthcare settings. We have done such testing and published the results in another document.⁴

Often, slide sheet manufacturers will share a COF number but give little other data or insight into the testing method and variables that resulted in that number.

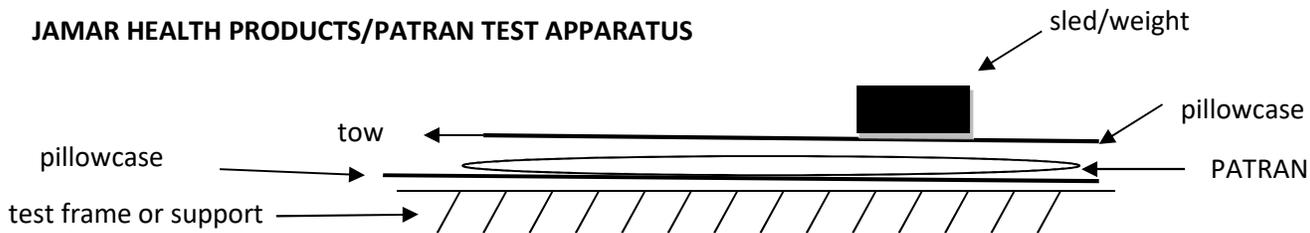
Drawings 1 and 2 show how an ASTM testing set-up differs from Jamar's approach. Chart 1 goes into more specifics about the differences in testing methods.

Drawing 1: COF testing set-up per ASTM



Drawing 2: COF testing set-up per Jamar

JAMAR HEALTH PRODUCTS/PATRAN TEST APPARATUS



Applying COF to Slide Sheets

A slide sheet's purpose is to make moving a patient easier. Therefore, a lower COF, i.e., a slipperier surface, is advantageous in a slide sheet.

The PATRAN has a published test bench kinetic COF of 0.15.

But determining the COF of a slide sheet is not easy or straightforward. The American Society of Mechanical Engineers has reported that it is difficult to test for COF on thin film – the material used to make many slide sheets – and that this can result in significant inaccuracies.

Reproducibility and Repeatability

ASTM looks to the scientific factors of repeatability and reproducibility (also known as replication) to determine whether differences in COFs are due to lack of testing method precision.

For repeatability to be applicable, the same slide material would have to be tested in the same lab by the same technician and using the same equipment on the same day. Repeatability, therefore, is not practical in comparison of different slide sheets.

As for reproducibility, different labs and technicians can test different materials and apparatuses that meet specified requirements with the hope of getting the same results, which could theoretically apply to slide sheets. However, ASTM does not listing reproducibility data for the type of plastic in PATRAN, so accurate comparison of lab tests is not possible.

Testing our own product

PATRAN® was the only disposable slide sheet when it was first sold in 1982, and for about 20 years following. Jamar tested the COF for our own quality-control purposes, so no results were published. We continue not to use an independent lab for COF tests because U.S. labs would adhere to ASTM standards. Furthermore, Croda, a major plastics additives supplier with computerized testing equipment, stated that the difference between a COF of 0.06 and 0.12 cannot be detected without extensive and repeated testing. In addition, ASTM protocol is to use a 200-gram weight (0.44 lb.) on a hard surface. Jamar wanted a heavier weight with a PATRAN placed between polycotton sheets, to better reflect a hospital bed surface. Any change in the supporting surface, bed sheets, speed of the move, or whether the

patient fits fully on the slide sheet would result in changes to the COF or its application. Therefore, we tested PATRAN on different surfaces and published the results.

Static COFs vs. Kinetic COF_k

There are actually two types of COF - static and kinetic - for slide sheets.

Static (COF_s) has to do with the force required to take a weight from dead rest to beginning motion and occurs in a very short distance of an inch or two.

Kinetic (COF_k) has to do with the force required to keep a weight in motion.

COF_k occurs over a longer distance and is therefore more important than COF_s when it comes to moving a patient.

For example, assume a patient is being transferred from a cart to bed, a distance of about 34 inches. Starting the patient in motion occurs quickly in the first two inches, which usually occurs in less than a second. Completing the transfer takes another 32 inches, or 16 times the 2-inch distance.

Realizing that Energy = Force x Distance, if the static and kinetic COF are the same, 16 times as much energy is expended during motion (COF_k) than was used starting the patient in motion (COF_s). Therefore, the cumulative wear on the caregiver is more affected by moving the patient than starting them in motion

For a PATRAN, Jamar has test bench measured static COF from 0.16 to 0.06. As for kinetic COF, the measurements came in from 0.15 to 0.05. So when the PATRAN is described as having a COF of 0.15, Jamar is taking a more conservative result of its kinetic testing results.

To explain how slide sheets from the same manufacturer and even the same lot vary slightly, one can look to the automotive industry. Cars have been manufactured for more than 100 years under strict quality-control measures. Still, there are small variances in how two cars of the same name and year will perform. Production differences and testing inaccuracies explain why there would be different outcomes, whether looking at automobiles or slide sheets.

Some slide sheet manufacturers test their product for the most favorable conditions, so it is important to look into the circumstances of the testing and whether they would be applicable to real-life usage.

For example, a slide sheet manufacturer may report a static COF on a hard surface. However, the manufacturer may not explain that a hard surface was used or give the weight, configuration, and nature of the materials involved. That COF is nearly meaningless.

Continuing the scenario, another manufacturer provides a COF of 0.20 and lists the specific mattress used. However, this manufacturer doesn't list whether it's calculated COF_s or COF_k, what weight was used, where on the mattress the test was performed, or whether it was moving downhill or uphill. Suppose the weight was 5 lbs. and had a large enough area that it didn't sink into the mattress. Furthermore, the weight was directly on the mattress ticking. Then the manufacturer uses the COF to make a calculation and states that a 200-lb. patient can be moved with 40 lbs. of force. The calculation is probably in error because the patient may sink into the mattress, the slide sheet may be on top of a fitted sheet, and other factors.

Looking Beyond Coefficient of Friction

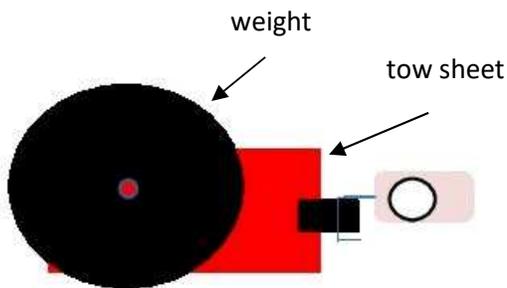
COF testing can only give an estimate of a slide sheet's slip. However, COF is just one small factor in determining how a slide sheet will perform during patient handling and movement. The physical properties of strength, size, and construction play important roles as well. In addition to performance, consideration of economic factors such as product cost, versatility, packaging, and storage can differentiate products as well.

Slide sheet size matters

Slide sheets come in a variety of sizes, but using one that is too small can mean making caregivers exert more force than is safe. Insufficient size can also result in skin shear and discomfort to the patient, not to mention potential lumbar stress due to flexing the spine sideways.

During testing for COF, most manufacturers would place the weight directly on the slide sheet so the entirety benefits from the slip. But in the case of smaller slide sheets, the results would not accurately represent the COF with a real patient's placement and movement.

Drawing 3: Undersized slide sheet simulation

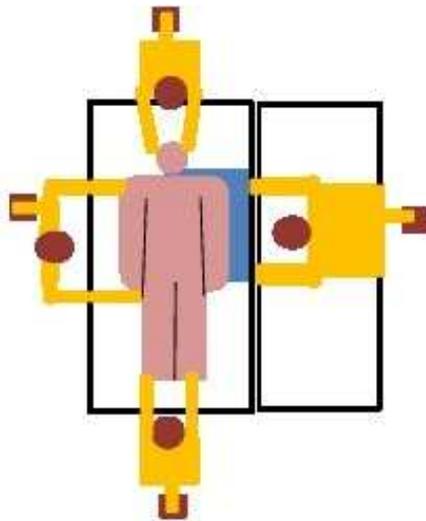


In Drawing 3, the slide sheet is underneath the tow sheet (so it can't be seen). The slide sheet has a 0.20 COF_k while it is on a table. If a 100-pound weight is placed completely on the tow sheet, the tow force once in motion would be 20 lbs. (Remember: Weight x COF = Force.) However, as this drawing illustrates, the weight is too big for the combination tow and slide sheet and will drag on the surrounding surface. The weight on the surrounding surface has a COF of 0.5. Therefore, the tow force will be higher than 20 lbs. If 50% of the weight's total area is on the tow sheet, motion tow force would equal $50 \times 0.2 + 50 \times 0.5$ or 35 lbs.

That scenario can translate to a healthcare setting where it can be common for a caregiver to try to move a patient on a small slide sheet. The patient, like the weight in the drawing, has portions of his or her body off the slide sheet, so the expected low COF of the slide sheet is no longer applicable. The overall COF goes up, meaning there is less slip and it is more difficult to move the patient. That doesn't take into account the potential effects on a patient, such as skin shear.

Drawing 4 provides a more clinically recognizable illustration of how a small slide sheet can impact patient handling and movement. Half the patient's torso lies on the blue slide sheet while his legs and head extend past it (Any linen is not shown.).

Drawing 4: Clinical scenario of transfer using small slide sheet



In Drawing 4, the small slide sheet requires one caregiver to lift the patient's head and another to lift his legs to prevent skin shear and keep his body longitudinally straight. Two more caregivers laterally transfer the patient from left to right. Like Drawing 3, the force required to move the patient in this transfer would be higher than that calculated based solely on the slide sheet's COF.

When looking at Drawing 4, assume the patient's weight is 236 lbs. with the weight composed via the following:

Head = 16 lbs.

Arms (2) = 13 lbs. each

Torso = 118 lbs.

Legs (2) = 38 lbs. each or 76 lbs.

The slide sheet has a 0.2 kinetic COF and the bed sheet a 0.3 kinetic COF. There is lever action that occurs when lifting the head and the legs, which aids in the movement. Because of the lever action, caregivers lift only part of the weight. The torso is in motion when it is exactly 50 percent on the slide sheet. The supporting surface is hard enough that the patient does not sink in enough to raise the COF. The patient does not need head or limbs stabilized. The blue square in Drawing 4 is a slide sheet (there would be linen on top of the slide sheet that is not shown).

The COF formula can be used to show the caregivers lifting the head and feet are using more force than necessary. If lifting a weight equals a COF of 1.0, the force required to lift 50 lbs. is 50×1 or 50 lbs. Moving 50 lbs. on a slide sheet with a COF of 0.2 would require 50×0.2 or 10 lbs.

The force that the caregivers will exert as a group can be calculated. Total force is 77.5 lbs. when the patient is only partially on the slide sheet.

Lifting head = 10 lbs.

Lifting legs = due to lever action, 38 lbs., which is over the recommended 35-lb. limit

Moving half the torso on the slide sheet = 11.8 lbs. (59×0.2)

Moving half the torso on the bed sheet = 17.7 lbs. (59×0.3)

Total force = 77.5 lbs. ($10 + 38 + 11.8 + 17.7$)

If the slide sheet was big enough for the patient to be fully on it through the entire move, the caregivers' total force would be 47.2 lbs. (236×0.2). Equally dividing that weight between four caregivers - all involved in push-pulling the patient - would result in each caregiver exerting 11.8 lbs. so everyone adheres to safety guidelines. Obviously, caregivers will not exert exactly the same force, so use some factor of safety. The caregivers would exert less force if they didn't lift the head and feet, instead putting them on a slide sheet. If the caregivers used a slide sheet large enough to support the patient's entire body, they would significantly reduce the total force required. With the patient entirely on the slide sheet, all four caregivers would be available to push/pull the patient, which would reduce the force required of two of the four caregivers in Drawing 4 by more than 50%.

To achieve maximum reduction of caregiver injury and patient skin shear with a small slide sheet, you must use enough slide sheets that the patient's entire body is on them during the move. Small slide sheets may individually cost less to purchase upfront, but they may cost more when you have to buy multiple sheets to use with one patient. Also, at an insufficient size they could cost more in caregiver and patient injuries over time.

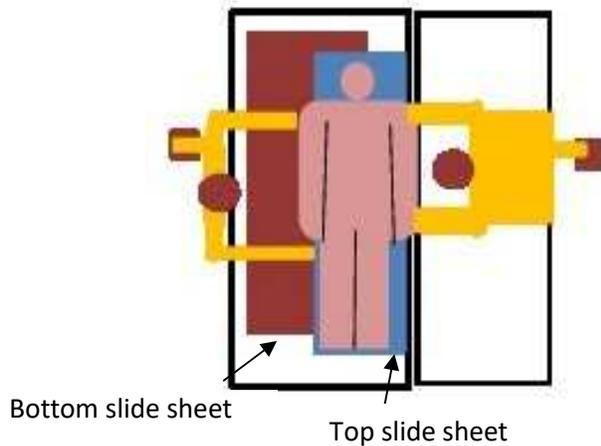
Slide sheets reduce caregiver injuries when used properly. Frequently the question arises, "Can the number of caregivers used to move patients be reduced by using slide sheets?" The answer depends on how much force it requires to move a patient. If the move required two caregivers to each use 50 lbs. of force without a slide sheet, the safe patient handling guideline of 35 lbs. is exceeded, putting the caregivers at high risk of injury.

Using a slide sheet may reduce the required force to 25 lbs. per caregiver (depending on conditions), thereby reducing injury risk. However, using that slide sheet and only one caregiver means that person must again exert 50 lbs. of force and again creates high risk of injury. Slide sheets reduce the force required to move patients, but the need remains for enough caregivers to do the job safely.

Slide sheets come in several styles

The way slide sheets are designed is important and impacts the needed size. In Drawing 5, the patient better fits on the slide sheet than as shown in the prior drawings with a small slide sheet. However, the force required to move the patient would be higher than the calculated.

Drawing 5: Using two-piece slide sheets



Manufacturers test two-piece slide devices with the weight on the top sheet, which is then placed directly on top of the bottom sheet. During testing, the part of the top slide sheet that the weight is on is always directly over the bottom slide sheet, showing optimum COF. In Drawing 5, the patient's weight is not directly over the brown bottom piece, rather it is partially over the white, higher-COF surface. Therefore, the real COF and force required to move the patient increase as the patient is moved to the right, as in a transfer from a surgical table to a gurney. Two-piece slide sheets need to be larger than single, tubular sheets to keep the patient's weight on top throughout the move.

Some slide sheets can be inserted and/or removed without log-rolling patients. Recent studies indicate that log-rolling a patient often requires too much force and puts caregivers at risk of injury. In addition, a patient's medical condition – a broken hip or injured spine, for instance - may make it uncomfortable or unsafe to log roll him or her.

Taking patient condition and comfort further into account, some slide sheets are wide, flexible, and slippery enough that caregivers can insert them without putting their hands underneath a patient.

A slide sheet's size and construction can give caregivers alternatives for safe insertion, usage, and removal.

FOOTNOTES

1. In addition to ASTM, the International Standards Organization (ISO) sets standards internationally but they have the same standards and as a result lack of plastic standards as ASTM.
2. Chart 1: Detailed look at COF testing methods

Apparatus/Condition	ASTM test standard D 1894-11	JAMAR
Sled	2.5x2.5x0.25-inch metal block with foam rubber bottom. Total weight 200 grams or 7.05 oz.	8-inch diameter painted iron cylinder with beveled edges. Weight 60 lbs.
Slide material	Top one is attached to bottom of sled. If bottom slide is to be tested (two pieces at once) it is to be 10x5 inches taped to frame. Extreme care to be used to keep fingerprints, dust, etc., off plastic that is to be wrinkle- and warp-free.	A loop 36 inches in the opening dimension and about 16 inches wide, not taped or attached to anything. It is clean just as it comes out of the box but no special care is taken. It likely wrinkles and probably has fingerprints.
Test frame	Frame top surface is polished plastic, wood, metal, or glass sheet.	Textured slip-resistant rubber
Temperature	Apparatus and material conditioned to 77 degrees F \pm 2	Approximately 70 degrees F, no conditioning
Tow speed	150 \pm 30 mm/min	Faster, but varies
Tow attachment	To sled/weight	To top pillowcase
Pillowcases		40% to 60% cotton, remainder polyester. May have wrinkles. Bottom pillowcase taped to rubber surface.

Note: ASTM states that its COFs can't be compared to ISO (International Standards Organization) COFs. Here is a quote from a large international polymer additives company engineer. *"We measure COF using a tensile tester fitted with a highly accurate calibrated load cell (0.5% accuracy). Even with this very accurate piece of equipment I could not confidently discern between 0.06 and 0.12 COF unless I had a lot of data to do some statistics on."*

3. The article, "Force Required to Move Patients Using PATRAN Slide Sheets on Different Surfaces" has been published to go into further detail about PATRAN slip and performance.
4. Assumes the cart (originating surface) is elevated above the bed as Jamar recommends when using slide sheets.