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An assessment of the performance of grip enhancing agents used in sports applications

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Abstract

The performances of four grip enhancing agents, Powdered and Liquid Chalk, Rosin and Venice Turpentine, were assessed using a bespoke finger friction rig and compared against an agent-free finger. The effectiveness of these agents was measured in dry, damp and wet conditions, to simulate the different environments in which the agents are used. The tests were first done on a polished steel surface and then the Powdered and Liquid Chalk, and agent-free finger were tested on sandstone.

The tests on the steel showed that in a dry condition only the Venice Turpentine significantly increased the coefficient of friction, compared to no application of agent, with the Rosin and Powdered Chalk actually decreasing the coefficient of friction. It is thought that the reduction in the coefficient of friction is caused by the solid particles acting as a lubricant between the two surfaces. When the fingers were wet only the granular powder-based agents increased the coefficient of friction. This is because the Venice Turpentine cannot adhere well to a wet finger; and therefore is not as effective. When the surface is wet there is very little difference between the agents, due to the water separating the finger surface from the steel.

The tests on the sandstone showed no real difference between the lubricants or the different conditions, except for the dry, chalk-free finger, which had a decreased coefficient of friction due to the lubricating properties of the sandstone particles.

These results highlight that the use of grip enhancing agents should take into account the moisture in the contact, as in dry conditions the grip may be optimum when there is no agent used. It also shows that in different sports, different grip enhancing agents should be used.

Keywords: grip; sports; climbing; chalk

1. Introduction

The use of gripping agents to aid performance takes place within a large number of sports and the use of these agents is perceived as essential for many athletes. These agents are generally designed to reduce or absorb moisture such as sweat and/or increase grip through the adhesive properties of the agent. The application of these agents is chosen using experience of the users, through what they perceive as performance enhancement, but there is little scientific research to suggest which are the best products to use. This study was aimed at providing an independent analysis of the agents that was not based on prior experience of their use.

There have been some previous studies carried out on grip in rock-climbing, namely by Fuss et al. [1, 2] and Li et al. [3]. Li et al. found that powdered chalk (magnesium carbonate) reduced the coefficient of friction, compared to a hand with no grip agent, on the three stones tested; sandstone, granite and slate. However, Fuss and Niegl [2] contradicted these findings, showing that powdered chalk increased the coefficient of friction on a "clean surface", compared to liquid chalk. They also found that a dry hand performed better than a powder-chalked hand on a "messy" surface that was contaminated with chalk. Both studies however, found that the addition of water had no effect on the measured coefficient of friction (Fuss et al. added water and no agent to the finger and Li et al. added water to the finger and then chalk). The differences in dry results could be due to the different test methods, or the amount of moisture present in the ‘dry’ condition. Fuss and Niegl [2] measured the coefficient of friction using instrumented handholds, whereas Li et al. [3] used a flat surface moving along the finger. For the handhold method used, it is not known if there were small slips present during testing, meaning that either the dynamic or static coefficient of friction could have been measured. Secondly, there was no monitoring of the amount of moisture present on the hands. As people grip, the fingers sweat more [4, 5] so the amount of moisture could vary during the period of testing. This will also vary between people. Since there is no measure of moisture in either of the studies, and no control of moisture in the handhold tests, it is hard to draw a true comparison of the results.

Even though no effect of moisture was found in these studies, this is not the case with other studies of human skin, without contaminants. A small amount of moisture is found to increase the coefficient of friction, explained by liquid bridging [6] and water absorption [7], however past a certain point the water starts to separate the two surfaces, lowering the coefficient of friction [7]. These effects are also dependent on the surface material, especially if surface texture is present [8, 9]

This study investigated how grip enhancing agents, as used in sport, affect gripping performance under different conditions. The grip enhancing agents tested were Powdered Chalk - a powdered form of magnesium carbonate; Rosin – made from powdered tree rosin contained in a cloth bag; Liquid Chalk – a combination of powdered chalk, alcohol and thickener and Venice Turpentine – viscous liquid resin extracted from certain trees. Examples of the sports that use these agents include: climbing (powdered chalk and liquid chalk), weight lifting (powdered chalk), gymnastics and trapeze (rosin and powdered chalk) and throwing events such as the javelin (Venice Turpentine). The general claims of grip enhancement for the powdered chalk, liquid chalk and rosin are that they dry the hands, therefore reducing the negative effect of too much sweat being present. The Venice Turpentine is claimed to increase grip because it is a ‘sticky’ agent and therefore helps adhesion between the hand and the contacting object.

2. Method

The friction tests were done using a bespoke finger friction rig (Figure 1), used in previous friction experiments [7, 8, 9, 10]. The rig consists of a flat plate mounted on two load cells to measure the frictional and normal force as a finger is moved along test material, attached to the flat plate. The middle finger of the dominant (writing) hand was used throughout testing as previous testing had showed this to give the most consistent results [10]. The tests were carried out on one volunteer (male aged 22). Although it is accepted that friction measurements can vary from one human subject to another, it was felt that within the time constraints of this study, using one subject would be an appropriate method to compare the general frictional performance of the different agent-surface combinations, under the various test conditions. The volunteer was requested to move his finger along the surface in the time it takes to slowly count to five (this has been shown to be an easy, but effective way, to get low variation in speed of approximately 14 – 20 mms^{-1} [7]) , and he was asked to apply a force of between 10 and 15 N. A consistent protocol was achieved through preliminary testing. Fuss et al. [11] measured the normal force applied by the fingers on an artificial hand hold to be between 50 – 300 N, depending on the wall angle, the larger the angle the larger the force. Assuming all fingers apply the same force this would be 12.5 – 75 N. Although the force applied in our tests is in the lower end of this spectrum, it is chosen because the testing is comfortable for the volunteer and the load can be applied in a consistent, repeatable manner.

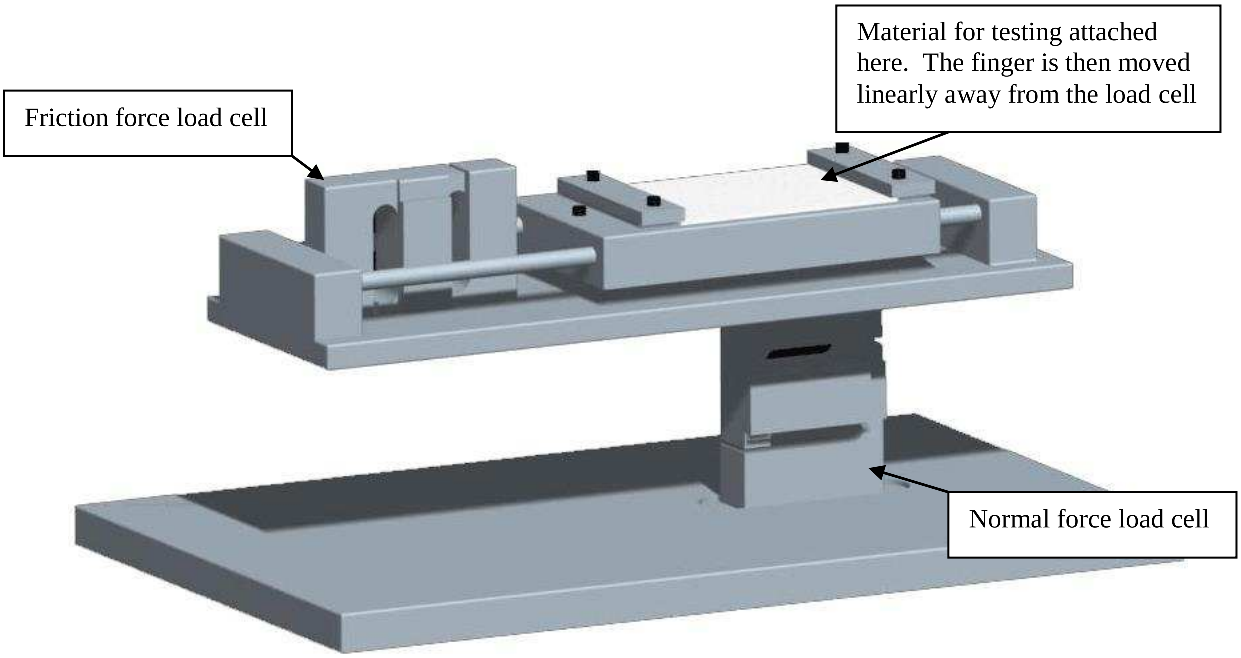

Fig. 1 – Bespoke finger friction rig

The tests were carried out first on a polished steel surface with no obvious directionality to the roughness. The roughness parameter Ra was 0.276 (measured using a contact profilometer in the same direction as used in finger-contact testing). Between each test the hands were washed with soap, and dried with a paper towel, the steel was cleaned with Janitol degreaser and both the hand and the steel were given time to air dry. Four different conditions were tested, using a bare finger and the 4 different agents (no agent, Powdered Chalk, Liquid Chalk, Rosin and Venice Turpentine). Each agent was applied according to the instructions on the packaging, and where this was not available the advice of relevant local athletes was used. For the Powdered Chalk the finger was dipped into a bag containing the chalk (as a climber would do). The Liquid Chalk was sprayed on lightly. The liquid is an alcohol that evaporates leaving the solid component adhered to the skin. For the Rosin tests, the finger to be tested was rubbed against a bag containing the powdered tree rosin. The Venice Turpentine was spread thinly on the finger pad. This, being sticky and viscous was the hardest to apply in a repeatable fashion. Firstly, the hand and the steel were tested in dry conditions (i.e. no additional water applied to either surface). Then the finger was tested damp on dry steel, the finger was made damp using a wet paper towel (water mass on finger approximately 0.0025 g), the gripping agent was then applied immediately after this. A wet finger was then tested against dry steel; the finger applied with one spray of water (water mass on finger approximately 0.015 g). Finally the dry finger (no additional water) was tested against a wet steel surface (made wet using one spray of water). All tests were repeated 10 times.

Figure 2 shows the force data from a typical friction test. Each set of force data was examined and a region chosen that exhibited a relatively consistent level of normal force, whilst containing sufficient data points for a suitable average to be taken (approximately 1000 sampled data points, see circled area in Figure 2). This sub-set of data was then used to calculate the coefficient of friction. If stick-slip occurred in any tests the coefficient of friction was calculated from the first region of consistent normal force. This was a tried-and-tested approach used in previous studies [7, 10].

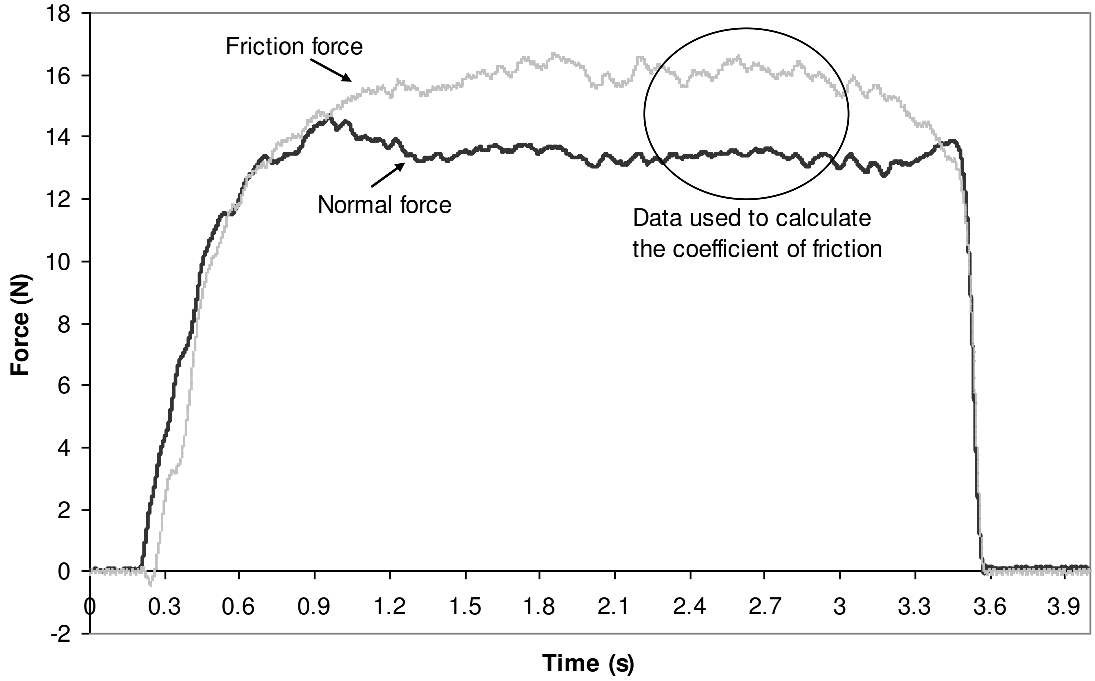

Fig. 2 – Force data from a typical friction test

3. Results and Discussion for Gripping Agents on Finger-steel Contact

The claims of the chalk drying the stratum corneum were tested using a Moistsense device (Moritex USA - see [12] for more details). This device is sold commercially to provide a measure of skin moisture and works using a measurement of capacitance, as illustrated in Figure 3. As the water level of the skin changes, the dielectric constant is changed, this therefore provides a reading for the amount of moisture in the finger. This device is meant for commercial use and it provides a value between 1-99, depending on the capacitance measured. This number is produced from taking the moisture measurements of 300 people, therefore a measurement of 50, is equivalent to the average capacitance reading from the sample of 300 people.

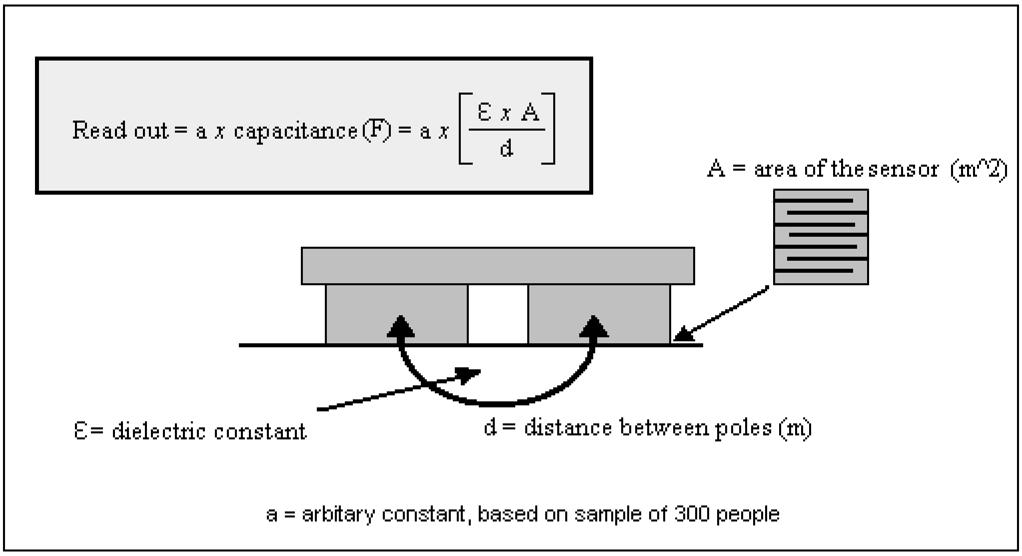

Fig. 3 – Schematic showing how the Moistsense device works (modified from Moritex promotional material)

The dielectric constant of skin has been recorded to be 28 – 48 [13] (however this depends on the depth of measurement). In this experiment if the layer of gripping agent is substantially thin and also has a much lower dielectric constant than the skin, it can be assumed that the device is measuring the capacitance of the skin. The main issue here is that the dielectric constants of the materials are not readily available.

Table 1 shows the results from the moisture testing, carried out on a cleaned and air-dried finger (using preparation method described previously) before and after the application of a grip enhancing agent. It can be seen that the chalk has no effect on the moisture level of the finger and is therefore, not working in the way suggested by the manufacturers, to "absorb moisture". Having said that, this study did not investigate the effect of chalk when high levels of natural perspiration were present, and a different result may be found in this case. This result is the same for the liquid chalk and the rosin (the change of 2 and 5 is within the errors of the Moistsense measurement). The Venice Turpentine however shows a significant drop in the Moistsense reading. Such a thin layer of Venice Turpentine would probably only affect the reading if the dielectric constant was far greater than that of the finger, and based on this assumption, the readings shown in Table 1 suggest that it is reducing the moisture of the skin. Therefore, it may be the case that the Venice Turpentine is not only acting as a sticky coating, but also drying out the finger slightly. Material data sheets for Venice Turpentine mention it as a possible cause of dermatitis, which might be linked to a skin drying effect, amongst other things. Drying of the stratum corneum can reduce finger friction as it makes the skin less supple, therefore reducing the area of contact and in turn the amount of adhesion [14].

Table 1 – Readings from the Moistsense device before and after application

Agent	Before application	After application	Change
Chalk	78	78	0
Liquid Chalk	90	92	2
Rosin	89	84	-5
Venice Turpentine	82	55	-27

Figure 4 shows the coefficient of friction readings for each of the agents on steel under different conditions. Error bars indicate ± 1 standard error. For the tests carried out with a dry finger on a dry surface there is hardly any measurable difference between the finger (agent free) and the Liquid chalk. The Powdered Chalk and Rosin agents produced significantly lower coefficients of friction. This is thought to be due to the powdered chalk / rosin particles acting a solid lubricant. The Venice Turpentine provides a very high coefficient of friction, and it was reported by the test candidate that this agent acted as a "sticky, tacky" coating, effectively providing adhesion between the finger and contact surface. This agent also showed the greatest variability with the highest standard error values, however the lowest measured coefficient of friction was still higher than for the other agents and bare finger.

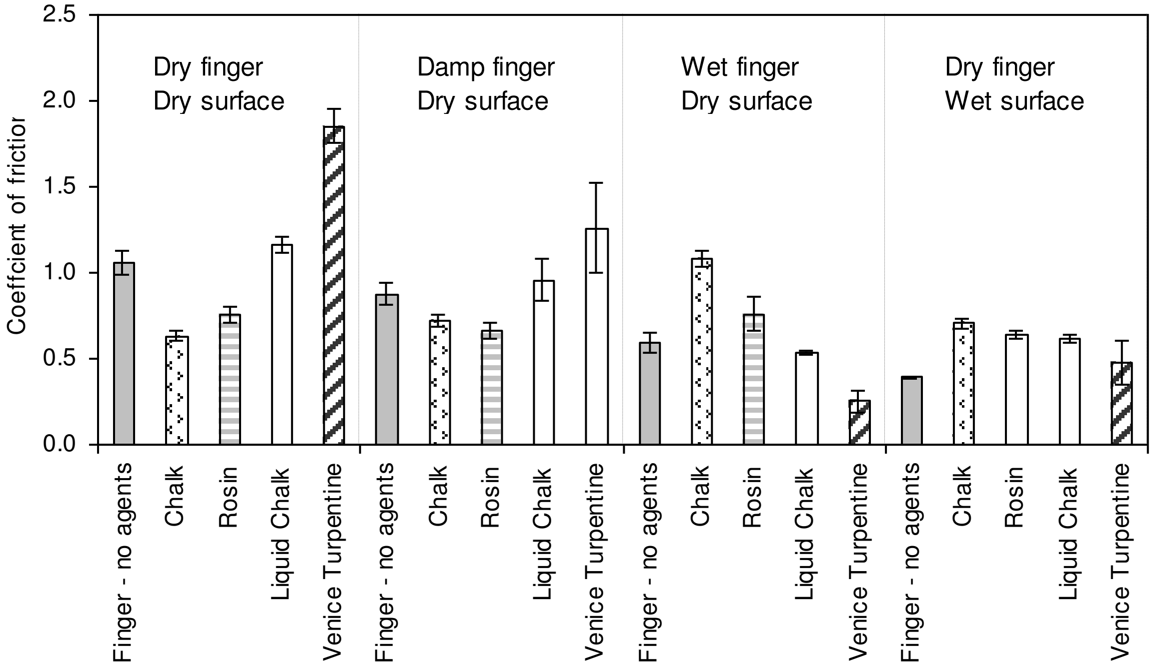

Fig. 4 - Coefficient of friction data for grip enhancing agents on steel under differing conditions

For the tests where the finger was dampened before agents were applied, the pattern was slightly different (see Figure 4). Note: the Moistsense device was not used during the friction testing as this contact test method would have acted to change the moisture condition present before first contact with the test surface. Once again the agent free finger and Liquid Chalk values for coefficients of friction showed no measurable difference, but there was a slight reduction from the dry condition coefficients of friction. The Powdered Chalk and Rosin agents still produced slightly lower coefficients of friction than the agent free finger under damp conditions, however the coefficient of friction for Powdered Chalk was slightly higher than in dry conditions. The Venice Turpentine, produced the highest coefficient of friction of all, but was less effective at providing grip than under dry conditions. It is thought that this agent is less effective at consistently adhering to damp skin, leading to a reduction in performance and a high standard error.

Previous testing has shown that in damp conditions finger friction can be higher than in the dry (see for example [6] and [7]). In the current tests no such increase was seen for the "damp" test. Comparing the amounts of water applied in these tests with those in previous work [7] indicates that for the "damp" test a Moistsense reading of 58-65 would have been expected and for the "wet" test about 95. A "dry" finger would be around 40-41. Figure 5 shows the effect of finger moisture on friction when sliding against smooth stainless steel (from [7]) similar to that used in the current study. It indicates that the difference in friction for these conditions may not have varied greatly and that in the current study the point at which the peak may have existed has been missed.

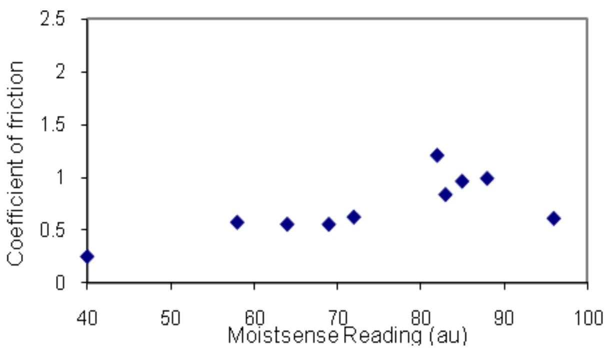

Fig. 5 - Variation of coefficient of friction with moisture for Stainless Steel (Ra = 0.25µm) (Moistsense reading error ±2; friction coefficient error ±0.4%) (from [7])

The data collected using a wet finger before agent application showed a very different trend (see Figure 4). Once again the agent free finger and Liquid chalk gave similar coefficients of friction, and these were further reduced, compared to the dry conditions. This suggests that at this level of moisture the steel and finger are separated to a greater extent than the damp condition and hydrodynamic effects were apparent, reducing the grip further. In comparison with these two agents, the Rosin produced a higher coefficient of friction and the Powdered Chalk higher still. In this condition the Powdered Chalk gave a similar coefficient of friction to that of the dry, agent free finger. Notably, the gripping performance of the Venice Turpentine dropped dramatically when the finger was wet. It is thought that this agent has difficulty in adhering to a wet finger and the unbound agent then contributes to the separation and lubrication of the surfaces.

The data collected using a wet surface indicates a drop in gripping performance for all the agents. The particulate-based agents generally had slightly higher coefficients of friction than the agent free finger, with Powdered Chalk being most effective. For all the situations tested, there would be a significant liquid layer present between the surfaces, acting to separate them. It is possible that the Powdered Chalk reduced the lubricating effectiveness of this liquid layer slightly due to mixing in of chalk particles, however this has not been confirmed to a suitable degree of confidence in this study.

Performance of Liquid Chalk

In all three finger conditions in contact with a dry surface, the performance of the liquid chalk was similar to that of the finger with no agent applied. This is perhaps not surprising. The liquid chalk will form a layer on the skin surface on application. The alcohol evaporates leaving the solid component adhered to the skin. This may cause a subtle increase in surface contact area in some of the test conditions, which may cause a slight increase due to higher adhesion. Based on advice from local athletes, only a thin layer of liquid chalk was applied during the study and it could be that this was not sufficient to cause a measurable difference anyway. Fuss et al. [1] also found little difference between the liquid chalked hand/handhold condition and the dry hand/handhold condition, but there was an decrease in the coefficient of friction for the liquid chalked hand/sandpaper compared to dry hand/sandpaper condition (no roughness values were reported). The relative roughness of the two contacting surfaces would be particularly influential. The liquid chalk would have the effect of stiffening the skin surface and therefore reducing the effects of both adhesion and deformation friction mechanisms as the ability of the skin to conform to the surface texture is reduced. This might not affect a smooth surface (such as the steel used in this study) to any great extent, but with a rough surface (such as the sandpaper used in [1]), this could be significant. Any differences between studies could also be due to the amount of agent applied (if a large amount of liquid chalk is applied this may affect the drying mechanism and therefore leave the solid component poorly adhered to the skin surface and more likely to act as a solid lubricant).

The coefficient of friction progressively reduced with added water (to the finger) for both the liquid chalk and the ‘clean’ finger. Previous studies [4, 5] have shown that with an optimum amount of water the coefficient of friction can increase, however since the "wet finger" conditions were simulating very sweaty hands, this optimum level was probably exceeded.

Performance of Powdered Chalk and Rosin

In dry conditions both Powdered Chalk and Rosin showed a decrease in the coefficient of friction compared to the agent-free finger. This is thought to be because the particles of these agents separate the finger and the steel surface to an extent, acting as a solid lubricant. When more moisture is added to the finger the coefficient of friction increases, up to the extreme of the wet finger, where Powdered Chalk has the highest coefficient of friction (a less obvious rise is seen in the Rosin data). This increase is thought to be due to the chalk particles combining with water to produce a viscous solution. Shearing of this viscous solution then contributes to increasing the coefficient of friction, as the finger moves along the steel surface. These results may explain the findings of Li et al. [3] that when the agent was applied to a wet finger, the coefficient of friction was higher than when the agent was applied to a dry finger.

Performance of Venice Turpentine

In dry conditions the Venice Turpentine has the highest coefficient of friction of all the agent-surface conditions (including the agent-free conditions). This is thought to be due to the ability of Venice Turpentine to adhere the contacting surfaces and this increase in adhesion would explain the relatively high coefficient of friction seen in dry conditions. When water is added to the finger it is thought that there is a reduction in the ability of Venice Turpentine to adhere to the skin which could explain why the friction also reduces. With increased wetting, there is then a lower coefficient of friction than the agent-free finger for wet finger conditions. This could be due to a layer of non-adhered Venice Turpentine acting to lubricate the finger-surface contact and therefore causing a significant reduction in the coefficient of friction. The reduced moisture content of the finger due to the presence of Venice Turpentine, as measured using the Moistsense device, had no obvious effect on the coefficient of friction (which would normally be expected to reduce with a reduction in moisture content, as discussed previously) and it is thought that this is due to the ability of Venice Turpentine to adhere to the skin, and therefore compensate for the change in moisture condition.

Venice Turpentine had the largest standard error compared to all the other agents and dry finger. An explanation for this is that the amount of product applied to the hands was more variable than the other application techniques for the other gripping agents. This was because it was very sticky and difficult to spread onto the finger in a uniform manner. A stick-slip mechanism was occasionally observed for

Venice Turpentine and this could have also contributed to the error. The stick-slip is likely to have been caused due to the adhering properties of the Venice Turpentine; forming strong bonds that are difficult to break, these bonds are eventually sheared and the finger moves more easily, however due to the slow movement more adhesive bonds are able to form and the stick-slip process starts again.

4. Application of Gripping Agents for Climbing Situations

When considering outdoor climbing, the material contacting the hands is not steel, but rock. Therefore the friction tests were repeated, but using sandstone instead of steel, and the two gripping agents relevant for this sport; Powdered and Liquid Chalk. Indoor climbing holds will not be considered here. It has been highlighted that differing amounts of moisture, by even a small amount can alter the results dramatically, it is therefore useful to repeat the tests done by Li et al. [3], however using our techniques of adding moisture to the finger. Li et al. only tested dry and damp conditions, whereas here wet finger and surface conditions were also studied. Wet surface conditions are important when considering outdoor climbing, because even though a climb may be called off if there is bad weather, surface water can still be present due to fine rain or previous weather conditions. Sandstone has been used in these tests as it is a common surface found in climbing.

A similar method was used as in the previous tests on steel, however this time a clamp was used on the friction rig to attach the stone to the rig, as shown in Figure 6. Suitable time was left between wet tests to allow the sandstone to dry and several pieces of stone were used to reduce the build up of chalk on the stone, which was also wiped off after each test. The sandstone used was flat and finished using grade 2 sandpaper.

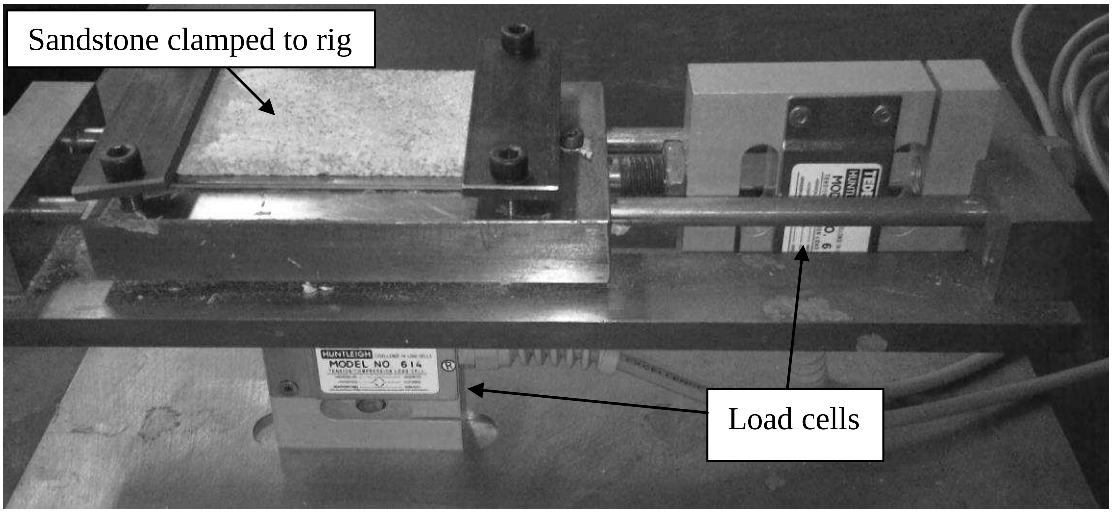

Fig. 6 – Photo of the friction rig with sandstone attached

The average coefficients of friction from each test are shown in Figure 7, with ± 1 standard error. It can be seen that there is very little difference between the Powdered and Liquid Chalk in each condition. However, the dry finger with no gripping agent does have a lower coefficient of friction than the tests in wetter conditions and also with gripping agents.

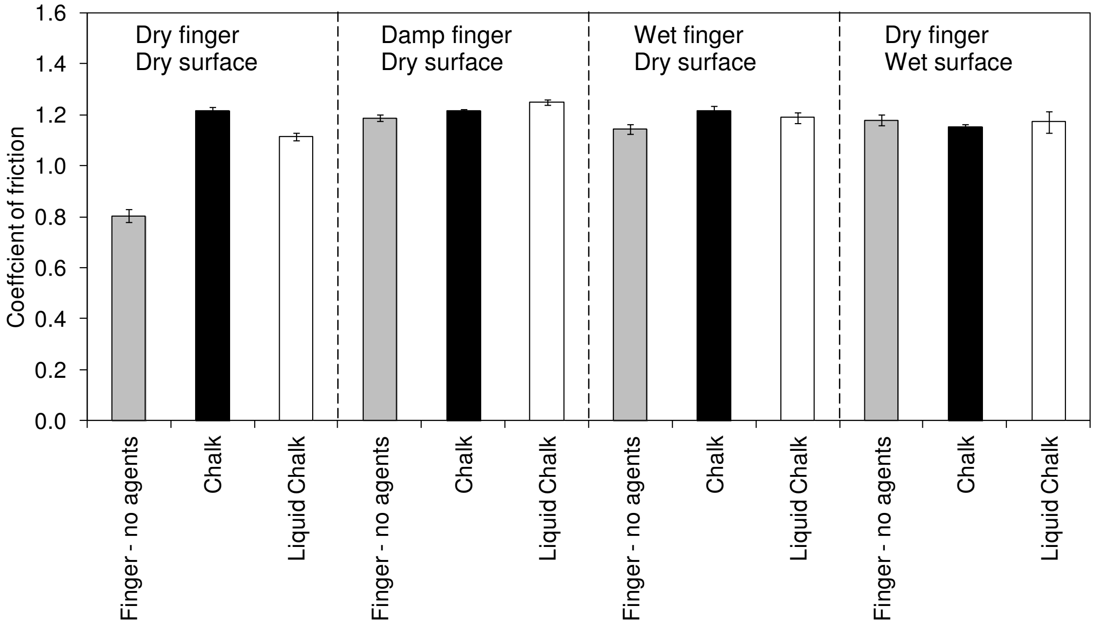

Fig. 7 – Coefficient of friction data for grip enhancing agents on sandstone under different conditions

Not only did the dry, chalk free finger have a lower coefficient of friction than the other tests, large scale stick-slip was observed for these tests. This can be seen in the force data collected from one of the tests in this condition, as shown in Figure 8.

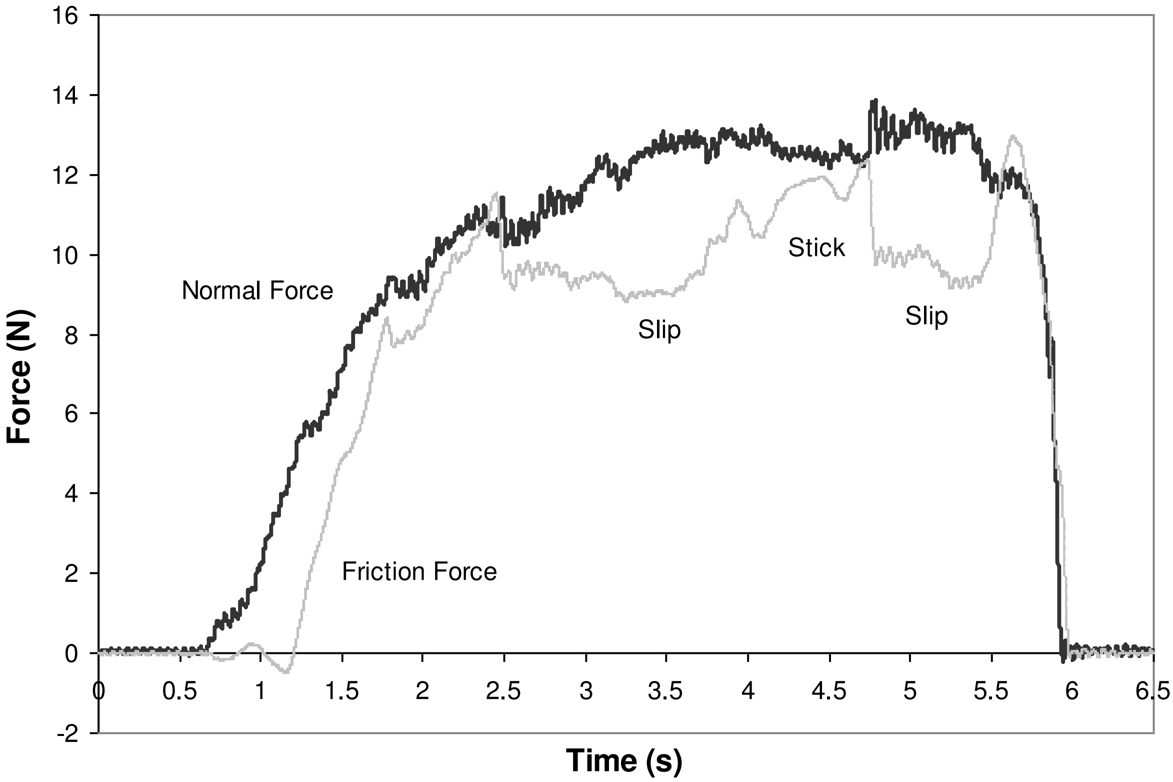

Fig. 8 – Stick-slip seen when a dry, clean finger contacts sandstone

The behaviour of the dry, chalk-free finger is interesting because it behaves very differently to the other conditions, having a lower coefficient of friction and more stick-slip present. This may be due to small stone particles detaching from the surface and causing "solid lubrication" by a rolling mechanism (with a single layer of particles probably). Rolling would be more effective than the shearing mechanism likely to be prevalent in the chalk layers (where multiple layers of particles will be interacting). The reason for the large scale "slip-stick-slip" in Figure 8 is not fully understood, but could be due to the particles building up, sticking in the sandstone "asperities" and then interlocking with the finger pad skin, therefore reducing the effectiveness of the "lubrication" system, and causing an increase in friction. The friction force is increased until this new static coefficient of friction is overcome, this loosens the build up of particles and the finger is able to slide again. This mechanism is obviously not seen with the steel because there are no small particles to rub off the steel when the finger is moved along it.

When testing the powdered chalk on steel it had a lower coefficient of friction in the dry condition because it acted as a solid lubricant, however for the sandstone it is seen to be the same as for the liquid chalk. This is thought to be due to the porosity of the sandstone surface, as seen in Figure 6 (the darker parts of the stone are larger pores, and the speckled effect seen across the surface of the stone is the smaller pores). It was observed that the chalk is able to penetrate into the pores of the sandstone (which in some cases are quite large, up to 0.3 mm), which is then removed from the finger-surface interface, reducing its effectiveness as a solid lubricant as greater skin/stone contact and subsequent interlocking can occur. However, in the dry condition, both the chalked-finger conditions gave a larger coefficient of friction than the bare finger condition. This may have been due to the chalk stopping the sandstone particles from rolling and causing them to slide along the surface in a “chalk film”.

There was little difference in results for Liquid Chalk, Powdered Chalk and chalk-free finger under any of the damp or wet conditions on sandstone, unlike the results from the steel tests. This may be because the sandstone is very good at absorbing water/solutions, so as soon as the finger touches the sandstone a lot of the surface moisture is soaked away. This means that almost straight away the slide is as though there is no moisture present. The chalk-free finger has a similar coefficient of friction, because the water is interacting with the sand particles, in a similar way to the wet chalk on steel (i.e., combining to from a viscous layer that has to be sheared). The finger will also absorb some water giving rise to an area increase which will act to increase friction to a degree. It was observed that at the end of a test using a wet, chalk-free finger, the finger felt “soft” to the touch probably due to water absorption in part and possibly also due to the presence of a thin particle-water mix on its surface.

5. Conclusions

This study has produced the following conclusions, based on tests carried out on polished steel. These findings are thought to be valid for situations when gripping non-deformable, non-porous surfaces (e.g. gymnastics rings, weight-lifting bars, etc.), but further work is required to assess gripping performance in other sports situations (e.g. contact with indoor climbing holds, tennis racket handle grips, etc.).

- The Powdered Chalk and Rosin agents performed relatively poorly under dry conditions on steel, thought to be due to solid particles causing lubrication. When the finger was wet before application, the Powdered Chalk performed very well, enhancing grip, and this is thought to be due to the increase of viscous shear forces, due to the combination of chalk and moisture producing a viscous solution.
- The Liquid chalk was not found to make any real difference to grip on steel, compared to using no agent at all. This could be due to the fact that insufficient application of this agent was used to provide an effective barrier to moisture.
- The Venice Turpentine was highly effective at enhancing grip, on steel, under dry conditions, but very poor and highly inconsistent when the finger was wet, thought to be due to ineffective adhesion under these conditions. It is recommended to dry the hand thoroughly if using this agent.
- Under dry conditions, on steel, a bare finger has been shown to provide effective grip, suggesting little need for gripping agents. If considerable grip is required, Venice Turpentine is highly effective.

- If the hands are likely to sweat, causing excess moisture to be present, for contact on a non-porous surface such as steel, Chalk and Rosin have been shown to be most effective in providing enhanced grip. Interestingly they perform best when considerable moisture is present on the finger.
- If the surface is wet, grip was generally reduced for all agents, when contacting steel. The recommendation is to keep the surface to be gripped as dry as possible, by wiping down regularly if necessary. If this is not possible, the Powdered Chalk agent is most effective.

There was no difference between the coefficients of friction measured at different moisture levels for the Powdered and Liquid Chalk, and bare finger (except for the dry bare finger), when contacting sandstone. This is due to the porosity of the material. A dry, chalk-free finger has a lower coefficient of friction probably because the fine stone particles provide a solid lubricant effect.

Acknowledgements

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