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Biomechanics

Water-induced finger wrinkles improve handling of wet objects

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Upon continued submersion in water, the glabrous skin on human hands and feet forms wrinkles. The formation of these wrinkles is known to be an active process, controlled by the autonomic nervous system. Such an active control suggests that these wrinkles may have an important function, but this function has not been clear. In this study, we show that submerged objects are handled more quickly with wrinkled fingers than with unwrinkled fingers, whereas wrinkles make no difference to manipulating dry objects. These findings support the hypothesis that water-induced finger wrinkles improve handling submerged objects and suggest that they may be an adaptation for handling objects in wet conditions.

1. Introduction

The glabrous skin on human fingers and toes forms wrinkles in response to immersion in water. This wrinkling was previously thought to be the result of osmotic swelling of the stratum corneum, the outermost layer of skin [1]. However, more recent evidence has shown that it is in fact due to a reduction in the volume of the fingertip pulp, caused by vasoconstriction, which in turn is controlled by the autonomic nervous system [2–5]. In combination with the mechanical properties of the glabrous finger skin, this reduction in pulp volume results in the typical pattern of ridges and valleys on the tips of fingers and toes [1]. The dependence of finger wrinkling on the autonomic nervous system has led to the use of finger wrinkles as a clinical indicator of autonomic function [2,6–9].

Such an actively regulated response to immersion is likely to be a functional adaptation to wet conditions, but what function does it serve? Whereas hydrated skin has a higher friction coefficient than dry skin, very wet or submerged conditions can lead to a very low friction coefficient owing to aqueous lubrication [10]. One recent hypothesis, therefore, suggests that wrinkles may function to improve the manipulation of very wet or submerged objects [11]. This is consistent with the fact that wrinkling happens mostly on the skin surfaces that are normally in contact with surfaces or objects to be manipulated. In the current study, we aim to experimentally test the prediction that handling of submerged objects is more efficient with wrinkled fingers than without.

2. Material and methods

Participants were informed about the practical aspects of the trials, but not about the specific hypothesis to be tested. All participants gave informed consent and received £5.00 in compensation for their time. Twenty participants (age range 21–34 years old; 13 females) manipulated submerged and dry objects both with wrinkled and with unwrinkled fingers, in a counter-balanced, within-subject 2×2 factorial design. The order in which dry and submerged objects were handled was counter-balanced across participants, as was the order in which wrinkled versus unwrinkled hands were tested. Wrinkling was induced by immersing both hands in 10 l of 40°C tap water for 30 min [12]. The water was kept in a polystyrene container with a polystyrene cover through which two holes allowed access for both hands. This kept the temperature from dropping too quickly during the immersion. For those who underwent the wrinkled condition first, unwrinkling was achieved by washing the hands with

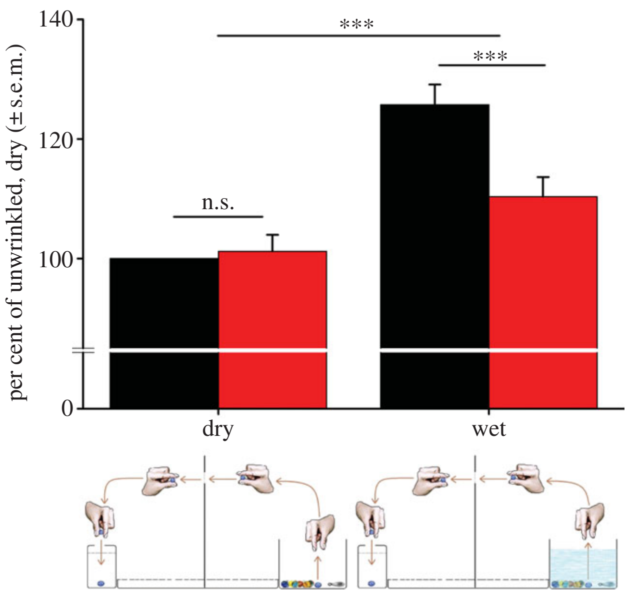

Figure 1. Transfer time (standardized to the time taken to transfer dry objects with unwrinkled fingers) is shortest for dry objects, independent of wrinkling, but faster for submerged objects with wrinkled (red bar) fingers than with unwrinkled (black bar) fingers (***$p < 0.001$). Items are picked up with thumb and index finger of the right hand, passed through a hole to the left hand, and put into a box with a hole in the lid.

soapy water, drying them and then waiting for the wrinkles to disappear, which took 10–20 min.

The task was inspired by the Tyneside Pegboard Test (AP Basu 2012, personal communication). We measured the time it took to transfer a total of 45 objects (39 glass marbles of different diameters: 30 of 16 mm, three of 24 mm, three of 35 mm, two of 42 mm and one of 50 mm diameter; and six lead fishing weights: two of 227 g, two of 340 g and two of 454 g) from one container to another, by taking the objects between thumb and index finger, passing them through a 5×5 cm hole from the right to the left hand and putting them into a 5×5 cm hole in the lid of a target box (figure 1). Objects dropped along the way were put back in the starting container and transferred again while the timer continued. The only difference between the conditions was that in the submerged condition, the objects were taken out of 20 cm of water. To reduce effects of water refraction on reaching for the object in the submerged condition, participants were asked to stand at a predetermined position that minimized the refraction effects. They stood in this position for all conditions. The raw data are available as electronic supplementary materials.

3. Results

It took participants anywhere between 72 s (fastest person) and 198 s (slowest person) to transfer all the items. All participants transferred dry objects more quickly than submerged objects, taking on average 17 per cent (±2.3% s.e.m.) more time to transfer submerged objects ($F_{1,16} = 35.80$, $p < 0.001$). With wrinkled fingers, transfer of submerged objects happened in 12 per cent (±2.3% s.e.m.) less time than with unwrinkled fingers. There was no difference in the time it took to transfer dry objects with or without wrinkles on the fingers (interaction: $F_{1,16} = 44.10$, $p < 0.001$; figure 1). This finding shows a clear advantage of having wrinkled fingers when manipulating submerged objects, but not dry objects.

4. Discussion

Our results are clear experimental evidence for the hypothesis that water-induced wrinkles improve the handling of submerged or wet objects. It does not, however, show how this is accomplished. One possibility is that the wrinkles channel the evacuation of water from between the finger pad and the object, as suggested by the rain tread hypothesis [11]. Another possibility is that there are changes in skin properties, such as flexibility, adhesion or an increase in the friction coefficient, which all could improve performance under submerged conditions. Whatever the mechanism, it is not effective in dry conditions, as shown by the current experiment. Future studies should be able to differentiate among the different possible mechanisms.

Our finding raises the question why finger pads are not constantly wrinkled. The most likely explanation is that there must be a cost to wrinkled fingers that out-weighs its benefits under dry conditions. This is unlikely to be a cost in terms of handling objects, because there was no detrimental effect of wrinkling on the handling of dry objects in our experiment. More likely, the cost may be in terms of a loss of somatosensory sensitivity in the fingertips or increased vulnerability to damage by catching on objects. Both hypotheses remain to be tested.

Wrinkled toes may serve a similar function to wrinkled fingers, providing better footing in wet conditions. The lack of wrinkles on toes under dry conditions could again be explained by an increased vulnerability to damage. Loss of somatosensation seems a less likely explanation in this case. It is unclear at present whether the wrinkling of wet glabrous skin evolved in our ancestors to support walking in wet conditions, manipulation of objects or both. Further experiments, combined with a comparative study to investigate which other species share this feature with humans, will provide deeper insights into how long ago it may have evolved, and for which primary function.

The study was approved by the Faculty of Medical Sciences Ethics Committee at Newcastle University (no. 00519/2012).

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