Efficiency of Donning and Doffing Medical Examination Gloves

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Abstract

Quickly donning and doffing medical gloves is of vital limportance for high-pressure environments. The efficiency of glove donning, however, is sometimes hindered because of moisture on the hand. A variety of commercial glove coatings exist that are said to enable a smoother donning process, however, no previous studies have examined the differences in time taken to don or doff gloves manufactured using different materials and coatings. The aim of this new study was to compare the efficiency of donning and doffing different glove types. 14 participants were timed on their efficiency to don and doff chlorinated latex and nitrile gloves, as well as polymer coated latex and nitrile gloves. All glove types were studied in both dry and wet hand conditions, leading to a total of 8 different glove condition combinations. The results indicate that polymer coated latex gloves are desirable when a quick glove change is required as there was no statistically significant difference between the average time taken to don these gloves in dry and wet hand conditions. Higher incidences of sticking were found amongst the wet hands, particularly in the polymer coated nitrile, which took the longest to don. However, little differences were found between all glove types, suggesting that neither the material itself, nor the internal coating, have an effect on the overall donning process when hands are dry. Discrepencies in best fit size were also noticed between the reccomended sizes based on anthropometric measurements and the participants preffered glove size.

Keywords: Medical Examination Gloves, Donning, Glove Fit, Latex, Nitrile.

1. INTRODUCTION

Medical examination gloves are often the first line of defense for people dealing with substances which could cause infection or skin damage. In high pressure environments, such as medical fields, a change of gloves is pertinent to avoid cross contamination, especially given the 2020 covid-19 pandemic [1]. Throughout the literature it is stressed that gloves should not be used as a replacement for hand washing, and hands should be washed both prior to glove use and after removal [2]. Hand washing is recommended; before and after touching a patient; before cleaning/sterilizing areas on patients or equipment; after body fluid exposure; and after touching the surroundings of a patient [3, 4]. Performing basic hand washing between glove use decreases the risks of infection between patients as the gloves could wear down, contain pinholes, or break during use, leading to the hand being contaminated [4]. With natural rubber latex gloves, this also decreases the chance of contact dermatitis and prevents transfer of latex particles after glove removal, minimizing the risk of triggering allergic reactions in those who have latex allergies [5].

However, the use of hand hygiene is considered unnecessary by some, and it has been shown that washing prior to and after glove use does not reduce pathogen transmissions [6,7]. Although, in the current coronavirus crisis, this hand hygiene routine is ever more important [8].

The donning capability of gloves is lightly touched upon in a recent review of medical glove performance by Mylon et al. [9] and Preece et al. [10] which shows only a few studies exist looking at the inner friction of glove materials and suggests how this may affect donning [11-13]. Another review of gloves by Dianat et al. [14] overlooks the donning process altogether, indicating it is an unobserved area that requires exploration. Previous studies have shown that a quick change of gloves is problematic, and the gloves become harder to don due to the presence of moisture [15-19]. The studies found the gloves stick to the hand more, and in many cases the gloves tear. However, these studies were assessing the forces applied when donning gloves, and not assessing the entire donning process. It is unlikely that glove users will just continue to apply force until the glove fits or ruptures. Nevertheless, the studies reveal that the moisture induces more adhesion of the material to the skin. This adhesion and enhanced friction can increase the time taken to don gloves and/or leads to ill-fitting gloves with loose material in areas. It is imperative that gloves are donned to fit perfectly to the hand for maximum performance. In the medical field, the loss of dexterity through ill-fitting gloves can lead to decreases in ability and performance which could lead to poor healthcare [20]. The industrial issues would be loss of money due to frequent glove changes and decreased safety risk as gloves may not even be donned. However, in emergency situations, this donning of gloves needs to be seamless, thus not consuming valuable time. In standard medical examination gloves, the internal glove face is treated with chlorine, to reduce the surface tack [21]. Over the years, more ‘advanced’ polymer coatings have been created and applied to gloves. These coatings are marketed in a way to state that the donning of the glove is easier than the traditional chlorinated method [5, 22]. The cost of these gloves, however, tends to be higher than the chlorinated materials. There is little work that has been conducted to state whether these coatings and treatments do increase the ease of donning.

1.1. Glove Fit

A vital part of the ability to don a glove is the fit of the glove to the hand. The perception of fit has been indicated as a reason for some users preferring natural rubber latex gloves over synthetic nitrile butadiene rubber gloves [23]. Recent reviews have found limited studies on the sizing and fit of gloves with respect to the anthropometry of the population, however many studies have been found looking at the effects of fit on performance of dexterity and sensitivity [9, 14]. Gloves should conform to the hands and essentially become like a second layer of skin. If too large, the glove will be easier to don, but the excess, loose material can cause issues with dexterity and sensitivity. Too small, the gloves can be difficult to don and restrict movement of the fingers [20]. No studies could be found looking at glove sizes, specifically regarding how they are sized and how that relates to the general population. Government protective glove size guides provide recommendations for Europe and the United States only, but no information is given as to how these sizes are ascertained [24]. As the only difference between the two sizes provided are the units, it is feasible that the terms EU and US are only referring to the units of measurement. To determine the best fit of a glove, the Health and Safety Executive (HSE) recommends that two measurements are taken. Finger length is measured as the base of the palm (adjacent to the wrist) to the tip of the middle finger. Then, the palm circumference is measured just below the knuckles to obtain a hand width measurement. A glove size is inferred from these two measurements, shown in Table 1. This protocol appears to be universally adapted. However, no reference is provided as to where this protocol has been obtained.

TABLE 1: Finger and palm measurement sizes for selecting the best sized gloves in Europe (EU) and the United States (US) [24].

Finger Measurement (cm)	Palm Circumference (cm)	US Size	EU size
16.0	15.2-17.8	XS	6
17.1	17.8-20.3	S	7
18.2	20.3-22.9	M	8
19.2	22.9-25.4	L	9
20.4	25.4-27.9	XL	10
21.5+	27.98+	XXL	11

1.2. Aims

To bypass the issues with donning gloves with dry/wet hands, glove manufacturers developed polymer coated gloves. By coating the inner surface of gloves with a polymer, such as hydrogel, a lubricant film is created. This film facilitates the donning process with dry or wet hands [17]. A previous study by Pavlovich et al. [15] showed that wet hands require more force to don surgical gloves. However, in the ‘wet hands’ condition, no drying took place, which is not replicative of the real-world conditions, which is the case for many studies of this ilk [16-19]. Moist skin has been shown to have higher friction coefficients when compared to dry skin [25]. Another study conducted by Roberts and Brackley [11] showed that there was more friction present with chlorinated gloves, but significant friction decreases were observed with a hydrogel coated glove. It can be argued that as the market trends have moved towards the acrylonitrile butadiene rubber material [22], and the more polymer coated (acrylic and polyurethane) gloves have been introduced into these markets [5, 26], there is a requirement for research within this area. The aim of this study is to investigate the effects of donning different glove materials with dry and wet hand conditions, replicating the real-world donning scenarios. This will highlight the differences between different glove treatments, materials and hand conditions as well as informing better glove selection. Glove users finding gloves which are easier to don after washing hands are more likely to be more compliant with hand hygiene recommendations [7]. Gloves will also be assessed for their fit of the hands to assess discrepancies between the perceived best fit size and the recommended size.

2. MATERIALS AND METHOD

2.1. Glove Selection

Four types of commercially available medical examination gloves were used in this study. Both chlorinated (Cl) and polymer coated (PC) nitrile and natural latex materials were selected (Figure 1). To blind both the participants and the researcher to which gloves were used, the gloves were numbered 1-4 and placed into separate bags. Thus, it was unknown by the participants and the principal researcher which glove belonged to which brand until the end of the study, as suggested by Watson et al. [27].

FIGURE 1: Glove selection used in this study. From left to right, chlorinated latex, polymer coated latex, chlorinated nitrile, and polymer coated nitrile.

2.2. Glove Thickness and Size Measurements

Glove thickness was measured using a micrometer (Mitutoyo, quick mini ± 0.01 mm). A total of 20 samples of each glove type were measured around the palm, finger, and fingertip. Finger/fingertip measurements were changed randomly and not isolated to one finger. Each measurement was repeated 3 times in each area per glove (9 measurements per glove). Glove sizes were measured using a ruler in three areas: from the distal middle finger to top of the palm, and to the cuff, as well as the width across the palm, as shown in Figure 2. These measurements were conducted on 10 gloves from each glove type.

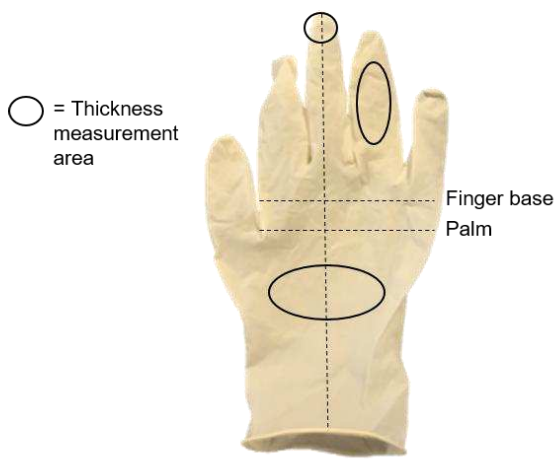


FIGURE 2: Depiction of areas of glove taken for measurement.

2.3. Participants

Seven males and seven females participated in this experiment (n=14). Ages ranged between 22-40. All participants were given the option of selecting the size of gloves based on their own perception of 'best-fit'. Participants were recruited from a forensic drug analysis laboratory, who routinely don gloves as per their work.

2.4. Perception Questions

To assess the perception of the glove users, participants were asked for their feedback on whether the gloves used were easy to don and doff as well as whether they thought the gloves were well fitting. For simplification and speed, the questions asked were ‘yes’ or ‘no’ answer questions, which were asked after each glove performance was measured. The questions were as follows:

- Did the gloves fit well?
- Were the gloves easy to don?
- Were the gloves easy to doff?

2.5. Method

Cameras were set up as in Figure 3 to capture the donning and doffing process. Participants hands were measured for length, width, and circumference by adapting a procedure used in Jee and Yun [28]. Participants were asked to ensure their hands were washed and thoroughly dried around 15 minutes prior to starting. No gloves were worn in this 15-minute period. Gloves were removed from the bags and placed side by side on a stool in front of the participants. Participants were asked to don the gloves once the cameras were switched on and they were signaled verbally to do so. Participants were instructed to don gloves in the manner and speed with which they normally would. Once participants had donned the gloves, they were asked to hold their hands out with the palms down to signal they had completed the test. They were then asked to remove (doff) the gloves and hold out the hands once again to signal that they had finished the doffing process. To measure the donning efficiency with wet hands, participants were asked to wash their hands with liquid soap and water and pat them dry, but still visibly retaining some moisture on the skin surface. The donning and doffing procedure was then repeated. This was repeated for the remaining 3 types of gloves throughout the trial in a forced randomized fashion. Ethical approval for the study was confirmed by the University of Sheffield Department of Mechanical Engineering.

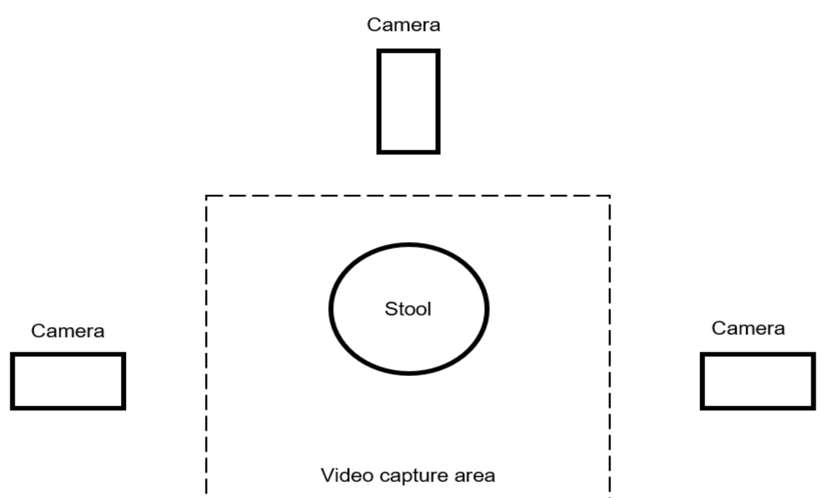


FIGURE 3: Schematic of the equipment set up for capturing the donning and doffing process.

2.6. Statistical Analysis

All data was assessed for normal distribution using the Shapiro-Wilks test for normality. Where data was found to be normally distributed, data was analyzed using one-way analysis of variance (ANOVA) and further subjected to a Tukey’s Honestly Significant Difference (HSD) test to assess where differences occur [29, 30]. Where data was found to be non-parametric, significance was tested for via the Kruskal-Wallis test, before conducting a post-hoc Dunn’s Multiple Comparison Test where required [31]. Statistical differences between the dry and wet conditions for each glove was assessed using a two-headed paired t-test (where parametric) or Wilcoxon signed-rank test (where non-parametric) [32]. Results are found to have significant differences with a $p<0.05$.

3. RESULTS
3.1. Glove Properties
3.1.1. Glove Thickness
The average glove thicknesses at each measured location are shown in Table 2, along with the average thickness. The gloves have a similar thickness overall, except for the Cl nitrile butadiene glove, which is just over half thinner than the other glove materials.

TABLE 2: Gloves used and Thickness Measurement.

Glove Type	**Material**	**Treatment**	**Average Thickness (mm)**			
			Palm	Finger	Finger -tip	Average
Cl Nitrile	Acrylo-nitrile butadiene rubber	Chlorinated	0.06 (±0.006)	0.05 (±0.003)	0.08 (±0.005)	0.06 (±0.005)
PC Latex	Natural Rubber Latex	Polymer	0.10 (±0.012)	0.11 (±0.006)	0.11 (±0.007)	0.11 (±0.008)
Cl Latex	Natural Rubber Latex	Chlorinated	0.10 (±0.010)	0.10 (±0.005)	0.11 (±0.006)	0.10 (±0.008)
PC Nitrile	Acrylo-nitrile butadiene rubber	Polymer	0.10 (±0.011)	0.12 (±0.006)	0.11 (±0.006)	0.11 (±0.007)

± denotes standard deviation, Cl = chlorinated, PC = polymer coated

3.1.2. Glove Size
The results from the measured glove sizes are displayed in Table 3. Measured sizes are similar between gloves of the same sizing. Large gloves show a slightly higher length and width to the medium size.

TABLE 3: Measurements of gloves used in this study.

Glove Type	Glove length (cm)		Finger to knuckle (cm)		Palm width (cm)	
	M	L	M	L	M	L
Cl nitrile	24.7 (±0.18)	26.3 (±0.12)	8.1 (±0.10)	9.0 (±0.23)	9.2 (±0.08)	9.4 (±0.25)
PC latex	25.3 (±0.12)	25.3 (±0.17)	8.0 (±0.18)	8.3 (±0.16)	9.5 (±0.18)	10.2 (±0.20)
Cl latex	24.8 (±0.25)	24.9 (±0.18)	7.8 (±0.12)	8.3 (±0.11)	9.3 (±0.21)	9.7 (±0.31)
PC nitrile	24.2 (±0.21)	25.9 (±0.15)	7.6 (±0.19)	7.9 (±0.15)	9.2 (±0.03)	10.2 (±0.21)
Average	24.75 (±0.45)	25.60 (±0.62)	7.88 (±0.22)	8.38 (±0.46)	9.30 (±0.14)	9.88 (±0.39)

± denotes standard deviation, Cl = chlorinated, PC = polymer coated

3.1.3. Glove Fit

The participants perceived best fit of gloves was compared against the HSE recommended size in Table 4. There was one participant who had a recommended size which matches the best fit exactly. 12 of the participants had a preference to wear gloves larger than that recommended based on their finger and/or palm size. Only one participant wore gloves that were a size smaller than that recommended based on sizing their hands. No participants chose gloves that were sized either small or extra-large.

TABLE 4: Comparison of perceived best fit gloves used by participants to HSE glove size recommendations from hand sizing.

Perceived best fit size	Recommended size	
	Finger	Palm
M	S	S
L	S	M
M	M	M
L	L	M
M	M	S
M	S	S
M	S	S
M	S	S
M	S	M
M	S	M
L	L	XL
L	M	L
M	S	S
M	S	S

S = Small, M = Medium, L = Large and XL = Extra Large

3.2 Donning

The average times taken for the participants to don and doff the glove pairs are shown in Table 5. This shows the time taken to pick up the gloves, insert their hand into the glove, and pull the glove to fit over their hands, as well as any manipulation of the glove, such as material pulling or arranging the cuff. When comparing the materials, PC nitrile takes overall the longest to don in both dry and wet condition, whereas PC latex is the quickest. Very little differences exist between the total doffing times between all of the gloves. As the time taken to pick up the glove does not affect the key donning action, this time has been removed for these analyses. Therefore, it was found that there are three key stages to donning a glove once the glove has been picked up. Examples of these are shown in Figure 4 and consist of the following:

- Preparation: Time taken to orient and open the glove whilst preparing to insert the hand.
- Hand insertion: Time taken for the fingers to reach the end of the fingertips of the glove.
- Material pulling/manipulation: Time taken to manipulate the glove after hand insertion, such as pulling the material to ensure fit and manipulating/unrolling the cuff.

TABLE 5: Average time taken to don and doff one glove.

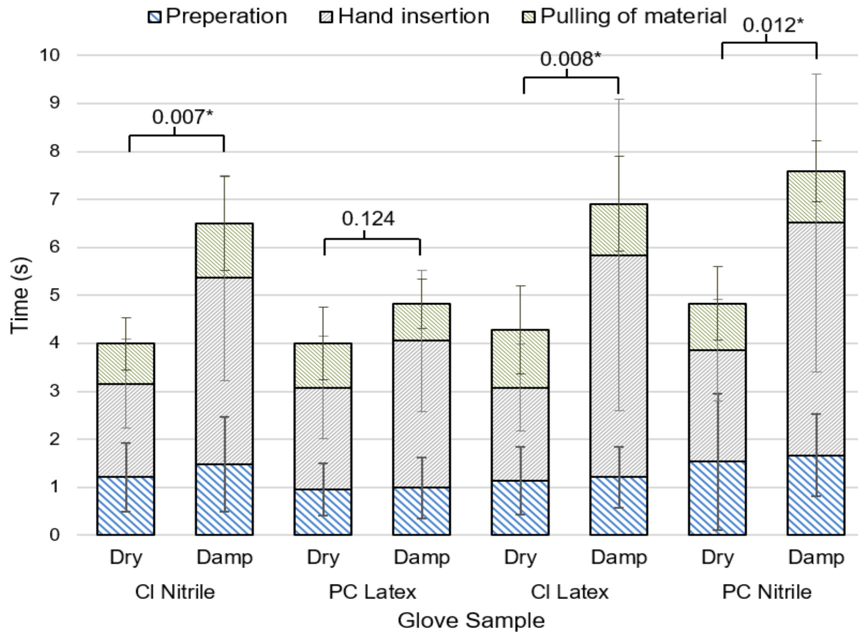
Glove	Average time (s)			
	Dry		Wet	
	Don	Doff	Don	Doff
Cl nitrile	5.91 (±1.48)	1.81 (±0.41)	8.60 (±4.13)	1.80 (±0.46)
PC latex	5.71 (±1.71)	1.64 (±0.40)	6.43 (±1.70)	1.78 (±0.65)
Cl latex	5.78 (±1.18)	1.69 (±0.45)	8.43 (±3.34)	1.83 (±0.8)
PC nitrile	6.69 (±2.74)	1.93 (±0.55)	9.67 (±4.63)	1.79 (±0.79)

± denotes standard deviation, Cl = chlorinated, PC = polymer coated.

(a) (b) (c)

FIGURES 4A-4C: Glove donning stages. Where (a) shows the preparation of the glove to insert the hand, (b) shows the insertion of hand into the glove and (c) shows the pulling of material down the fingers to comfortably fit hands.

Figure 5 displays the breakdown of the average donning time of one glove into these three stages whilst in the dry and wet hand conditions. From the results, it is notable that Cl nitrile and PC latex are the quickest to don overall when in dry conditions. In wet conditions, PC latex gloves are quickest to don. Table 6 shows the results from conducting ANOVA on both the dry and wet hand conditions. No statistically significant differences are shown in the wet conditions ($p>0.05$) for either the total time or any of the key stages. There were, however, statistically significant differences found in the total donning times across the dry gloves ($p=0.009$). Table 7 shows the results of the post-hoc (Tukey's HSD) test. The test shows statistically significant differences between Cl nitrile and PC nitrile ($p=0.023$) as well as PC Latex and PC nitrile ($p=0.012$). However, no significant differences were found between any of the key stages that make up the total donning time ($p>0.05$). Data was also checked for differences between the dry and wet conditions for each glove type (Table 8). Statistically significant differences are found between all the total times between the wet and dry conditions ($p<0.05$), except for the PC latex material ($p=0.124$). Statistically significant differences between the dry and wet conditions occur in the hand insertion step with all gloves ($p<0.05$). This is likely to be due to an increase in material sticking to the hands/friction due to more contact with the material.



* Indicates statistical significance (p<0.05)

FIGURE 5: Average results of time taken to don one medical glove broken down into the three key tasks. T-test results between the dry and wet conditions are shown above the bars. Error bars denote standard deviation. Cl = chlorinated, PC = polymer coated.

TABLE 6: Results from ANOVA tests conducted across the total donning time, and each step of the donning process in both dry and wet conditions.

Donning stage	p-value	
	Dry	Wet
Total	0.009*	0.176
Prep	0.101	0.064
Hand insertion	0.340	0.529 [A]
Pulling of material	0.717 [A]	0.329

* Indicates statistical significance (p<0.05). [A] Denotes the use of Kruskal-Wallis test due to non-normal distribution of data. Cl = chlorinated, PC = polymer coated

TABLE 7: Post-hoc Tukey's (HSD) test results conducted on the total time in the dry condition.

		Glove Sample		
		PC Latex	Cl Latex	PC Nitrile
Glove Sample	Cl Nitrile	0.90	0.90	0.026*
	PC Latex		0.834	0.012*
	Cl Latex			0.086

* Indicates statistical significance (p<0.05). Cl = chlorinated, PC = polymer coated

TABLE 8: Results of paired t-tests comparing dry to wet in all glove types at each step of the donning process.

Donning stage	Glove material			
	Cl Nitrile	PC latex	Cl Latex	PC Nitrile
Total	0.005*	0.001*	0.003*	0.093
Prep	0.194	0.884	0.931	0.754
Hand insertion	0.003* [A]	0.002*	0.002* [A]	0.013* [A]
Pulling of material	0.083	0.395 [A]	0.377	0.083 [A]

* Indicates statistical significance (p<0.05). [A] Denotes the use of Kruskal-Wallis test due to non-normal distribution of data. Cl = chlorinated, PC = polymer coated

3.3. Doffing

Figure 6 shows the time taken to doff the gloves with an average time range of 1.68-1.93 seconds across the eight conditions. ANOVA tests conducted show there are no statistically significant differences shown between any of the gloves being donned in the dry or wet conditions. Paired t-tests also show no statistically significant differences between the dry or wet conditions of each glove, which is shown on the graph (p>0.05).

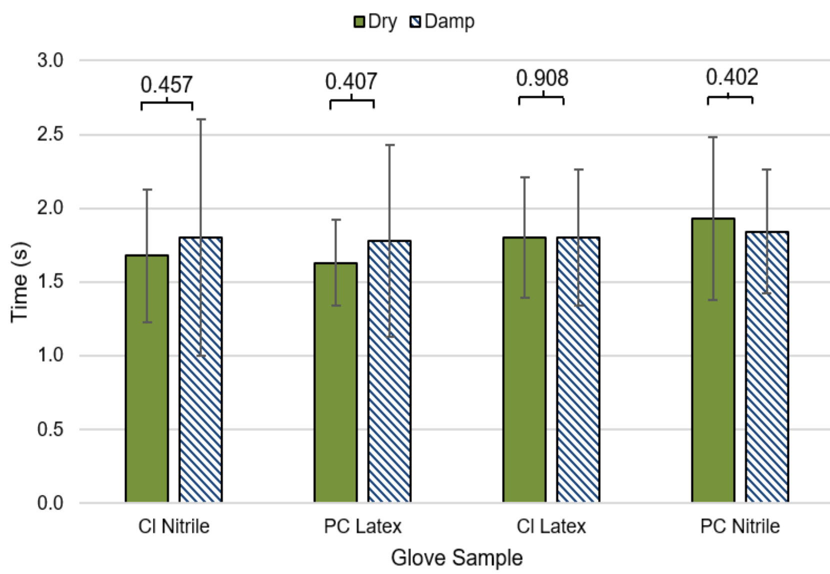


FIGURE 6: Average results of time taken to doff one medical glove. Error bars denote standard deviation. T-test results are shown above. Cl = chlorinated, PC = polymer coated.

3.4. Glove Sticking

When reviewing the videos, it was noted that, as the hands were being placed into the gloves, there were a number of occurrences where the materials stuck to the fingers, decreasing the efficiency of placing the glove on the hand. A total of 329 incidences of sticking were seen across the 14 participants. A sticking 'incidence' is counted as one where the glove material was being pulled onto the hand, but the fingers/hand did not move up the glove. Each time this occurred, the location of this sticking was recorded. Figure 7 shows the different hand locations where sticking or friction occurs, which results in the glove stopping movement. Figure 8 shows the number of incidences of sticking or friction at each section of the glove. Some incidences of sticking were fixed quickly by harder pulling of the material, which lasted 0.2 seconds. However, some required the cessation of pulling and the material, where stuck, to be straightened out or unrolled in order to properly don the gloves.

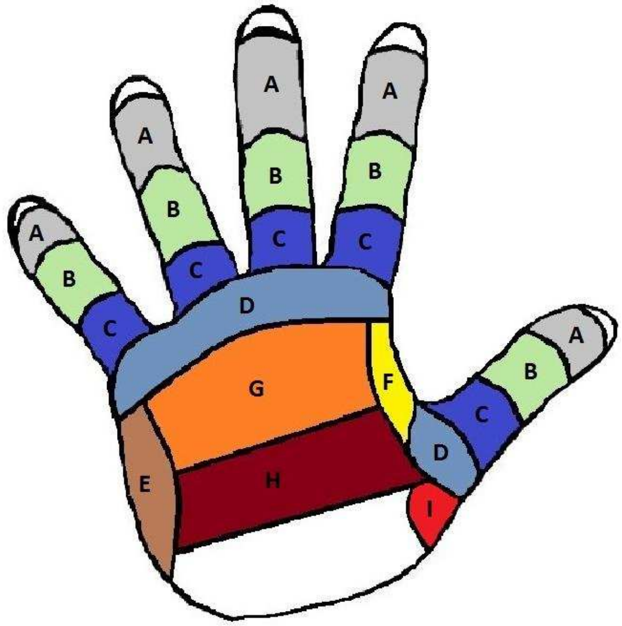


FIGURE 7: Map of the glove showing areas where sticking of the fingers/hand occurred on the glove throughout the study.

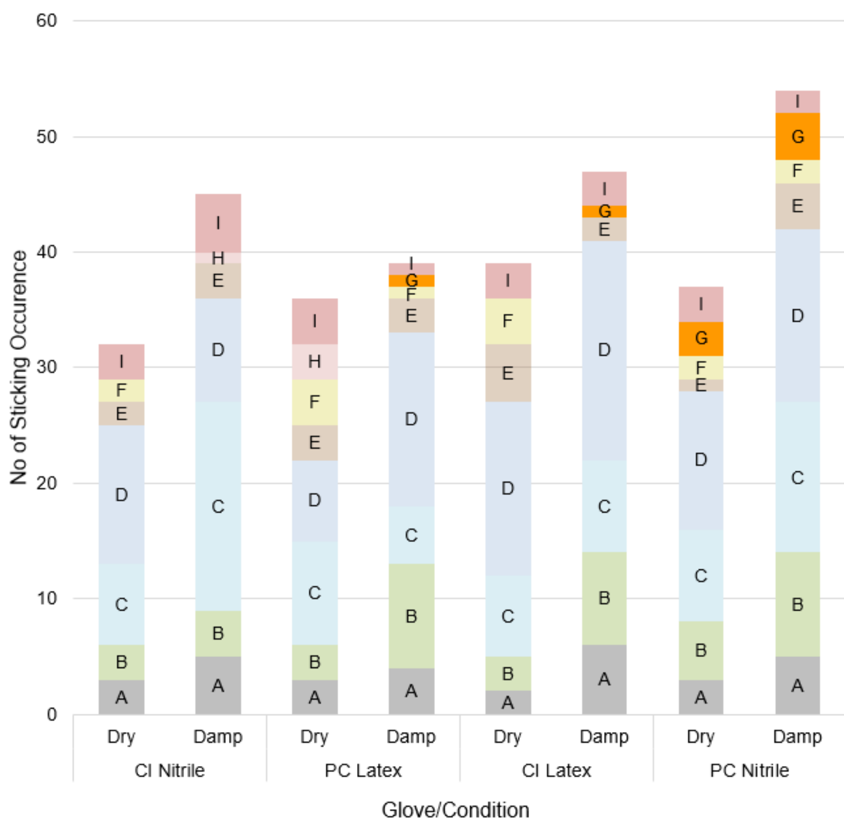


FIGURE 8: Incidences of sticking in the different areas shown in Figure 7. Cl = chlorinated, PC = polymer coated.

3.5. Perception of Fit, Donning and Doffing

Results from the participant questionnaire after donning/doffing the gloves are shown in Figure 9. Cl latex has a good overall reported fit with 9 out of the 14 participants, whereas the PC latex material had the poorest reported fit (n=4). Perceived issues with doffing occur more when the hands are wet, with 3 participants stating that the Cl nitrile was not easy to remove. The general comments made on the gloves were that the PC latex material was perceived to be much thicker than the other materials.

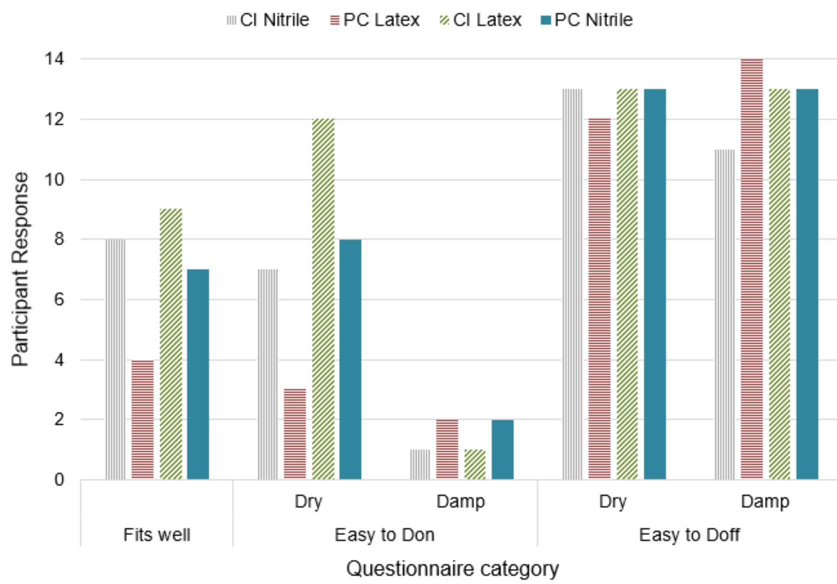


FIGURE 9: Responses of the participant questionnaire regarding the fitting of the gloves and the ease of donning and doffing. Cl = chlorinated, PC =polymer coated.

4. DISCUSSION

4.1. Donning and Sticking

From the gloves used in this study, it is shown that there is little difference between the times taken to don different glove materials with different coatings when the hands are dry. Differences only arise in the dry condition with the overall total time taken to don the PC latex and the Cl nitrile being statistically quicker than that of the PC nitrile material. Although statistically significant, it took the PC nitrile on average 0.83 seconds longer to don compared to the PC latex and Cl nitrile. Which is not a huge difference between the results. Differences are exhibited, however, between the dry and wet conditions. This reflects the real-world issue of donning gloves with sweaty or wet hands from washing, causing problems with the gloves sticking [15-19]. This results in a failure to get ill-fitting gloves, which have stuck to the hands, to the natural contours of the fingers, which is salient for performance [33]. These issues took a lot of time to rectify, which may be vital time in the medical profession. This, as suggested, is a likely reason for non-compliance with hand hygiene [7]. PC latex was the only glove type found to be unaffected by the wet hand, as indicated by the lack of a statistically significant difference between the two hand conditions. When broken down into the three key stages present within donning, statistically significant differences are found in the hand insertion step with all glove materials. As this is the step where more glove-skin contact is present, this is arguably the most prominent step of the donning process. There is a greater frequency of sticking/high friction at the top of the palm (location D, Figure 7) and the first location of the fingers (location C, Figure 7). This could be due to a combination of the nature of glove packaging as well as the behavior of the participants when donning the gloves. Medical examination gloves are normally compressed into boxes for packaging. In some cases, this causes the materials to stick together which is only separated by mechanical action prior to donning the glove, or whilst the glove is being donned. Separating the glove to insert the hand takes time, and when the gloves are manipulated by the participants in the preparation stage (before the hand is inserted), the participants had a tendency to open the glove, either by rubbing or pulling the material, at the palm or cuff only. The sticking/friction then occurs as the participant opens the finger holes using their fingers from inside the gloves. This appears to be more problematic in the wet hand condition, as this took longer to don on average. The greater difficulty to don the gloves once moisture was introduced is also noted in previous studies looking at force-donning relationships [15-19]. However, in many of these studies, the gloves were tearing due to the force applied. In these studies, the gloves were statically held in place as to measure the force being applied. Tearing was not apparent in this study. This is likely due to the participants being free to move their other hand to manipulate the glove and pull it further up the hand to aid the donning process, which was not apparent in the other studies.

The application of the polymer coatings is, for the most part, to aid the absorption of moisture [5]. It is possible that the addition of the moisture causes more sticking due to this absorption. Thus, as the fingers slides up and into the finger region of the glove, more incidences of friction and sticking are likely (due to the increase in contact area), causing the issues present in donning. However previous studies have shown that polymer coatings reduce friction [11-13]. Although, it must be considered that studies of this ilk are conducted using only one finger of participants or using a tribometer. This study highlights the incidences of sticking due to multiple interactions as the glove conforms to the hand, which is a byproduct of the physical properties of the materials. There are some differences in the 'preparation' step of the donning process with dry and wet hands, although none of the differences are statistically significant, this is likely to be due to participants not being able to grip and/or open the gloves as efficiently than with the dry hands. Another noticeable issue was the rolling of the material on the back of the hand when donning, as shown in Figure 10. This adds time to the 'manipulation/material pulling' stage of donning as participants take the time to unroll the material and bring the cuff up the wrist. This rolling was most seen in the latex material. As the material begins to roll up the back of the hand, the latex will continue to roll with it due to its elastic nature. The nitrile butadiene material, however, is stiff compared to that of the natural rubber and appeared to roll on the back of the hand less frequently and not as severely [34].

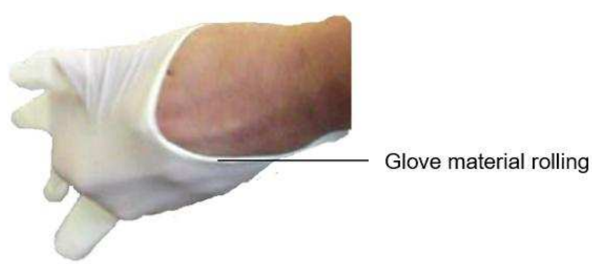


FIGURE 10: Rolling of material on the back of the hand when donning.

4.2. Fit and Perception

When compared to the recommended glove sizes, the participants did not appear to wear the correct recommended sizes. The literature shows that these gloves need to be a good fit to ensure maximum comfort, dexterity, and tactile sensitivity [20, 35]. It was clear for three of the participants that the gloves were slightly larger than needed when fitted, as there was a little excess material. These three participants wore medium gloves and said that when smaller gloves are used, they are difficult to put on, and too tight once donned. Most of the participants indicated that all the gloves were easy to doff, but a few commented that the PC gloves 'felt thicker' and perceived that to be a slight hindrance upon removal. Participant perception does not correlate to the donning performance, which may infer bias towards certain materials with some participants. CI latex was perceived to be the easiest to don, but the performance results indicate similar donning times to the CI nitrile in the dry condition. Some participants stated that the PC latex gloves were harder to put on because they felt thicker than the other gloves. However, the thickness was similar to the PC nitrile and Cl latex. Very few participants thought that the different materials and coatings affected their ability to remove the gloves, indicating that doffing is not an issue with these glove users.

5. STUDY LIMITATIONS

In this study, gloves were placed onto the hand and then removed quickly after, which is unrealistic of how long gloves would normally be worn for. This could be the reason for no differences being observed with the doffing of the materials. However, as gloves have also been doffed in a wet hand condition, which could act as a simulation of the sweat generated from wearing gloves, this may be more simulative of the real-world results. However, no differences were found between the dry and wet conditions with regards to the doffing. Knowledge of the specific processes used to create and coat the medical gloves would be advantageous to studies of this ilk. It is possible that, of the polymer coated gloves, the latex material was coated with a different polymer to the nitrile material. Similarly, of the chlorinated gloves, the chlorination strength and time, as well as finishing's (such as silica dipping) will affect the frictional properties of the glove material [5, 21, 22]. As manufacturers do not disclose these manufacturing methods with the materials, this study is limited by the knowledge available on the glove materials. That is; it is only known if the gloves have undergone chlorination or have been polymer coated. The study could be improved through testing gloves which have the same thicknesses, as the effects of thickness on the donning process is not widely discussed in the literature [15-19].

6. CONCLUSIONS

- This study has shown that, through the breakdown of donning stages, there is an increase in time taken to don the PC nitrile material. Although this increase is statistically significant with the PC latex and the Cl nitrile, it must be considered that the overall increase in time taken to don the glove is not great. This suggests there is little to no difference in the overall donning time between any of these materials. On the other hand, the study finds that when moisture is introduced, the donning time is increased due to increased incidence of friction/sticking. However, the donning time of the PC latex is shown to be unaffected by the wet condition.

- Doffing has been shown to be unaffected by glove material, coating, or the presence of moisture.

- This study has highlighted major issues with glove size amongst some glove users. Size recommendations match only one participant in both palm and finger size. A separate study looking at the time taken to don gloves which are the 'best fit' sizes selected by participants, and then comparing the performance to the recommended sizes by the HSE would be interesting. This would allow greater exploration of whether the size differences between perceived and measured 'best fit' have a great effect on the donning process.

- Further studies should be conducted looking specifically at known coatings to look for specific differences (e.g. known chlorination strengths or known compositions of polymer coatings) to draw further conclusions. Understanding the properties of the gloves and how they may affect the performance is salient to comprehending how different gloves affect the donning and doffing processes. As the glove market moves more toward the nitrile material, more studies should place focus here to develop a better understanding of the donning process with different coatings.

- The current framework of glove performance assessment focuses on how gloves effect dexterity and sensitivity, which are vital for glove performance. However, this study highlights that the donning performance is an important factor which should not be overlooked when designing and purchasing medical gloves. The authors recommend that hands are washed, and hand hygiene routines are followed. Drying the hands as thoroughly as possible is key to a smoother donning process.

7. ACKNOWLEDGEMENTS AND FUNDING

The authors would like to thank the SOCOTEC forensics team for their participation in the research. This research was fully funded by the Engineering and Physical Science Research Council (EPSRC) though the integrated Tribology Centre for Doctoral Training (iT-CDT) and Synthomer (UK) Ltd.

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