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# Does Size Affect the Rate of Perforation? A Cross-sectional Study of Medical Gloves

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## Abstract

**Objectives:** Healthcare workers often have unnoticed minor abrasions on their hands, putting them at risk of contracting infectious diseases from patients, if the integrity of the medical gloves is compromised. This study aimed to compare the rate and location of glove perforation between well-fitted and ill-fitted gloves.

**Methods:** The participants of this cross-sectional study were 45 midwives in the maternity ward of a hospital in Shiraz city, Iran. A total of nine pairs of medical gloves including three pairs of fit size, three pairs of gloves with one size smaller (tight), and three pairs of gloves with one size larger (loose) were given to subjects, and asked them to use the gloves during episiotomy repair operations. After completing the task, all gloves were collected safely and gloves perforation was investigated based on water test (NF EN 455-1).

**Results:** The perforation rate of the fit, tight, and loose medical gloves was 20, 37.78, and 34.81%, respectively. The results showed a significant difference between glove perforation of different glove sizes ($P < 0.05$). In general, there was a significant difference between the perforation rate of the fit glove and ill-fitted gloves ($P = 0.013$).

**Conclusions:** Wearing the wrong size gloves may increase the glove perforation rate. Providing a wide range of glove sizes by the hospital management, and choosing the best glove size can be very effective in reducing the glove perforation and increasing safety for healthcare workers and patients.

**Keywords:** medical gloves; perforation; safety; size

**What's important about this paper**

Healthcare workers often have unnoticed abrasions on their hands, which places them at risk of contracting infectious diseases from their patients if the integrity of the medical gloves is compromised. This study found that the frequency of glove perforation was higher among ill-fitting gloves than among correctly fitting gloves worn during episiotomy repair operations (36 versus 20%). As a result, it is important that healthcare workers wear gloves that fit. This means that multiple glove sizes must be available for healthcare workers.

## Introduction

In the current era of concern among healthcare workers about the transmission of the lethal virus such as human immunodeficiency virus (HIV), hepatitis virus, and coronavirus (SARS-CoV-2) from patients, attention has again been paid on the personal protection equipment such as medical gloves. Healthcare workers often have unnoticed abrasions on their hands, which places them at risk of contracting infectious diseases from their patients if the integrity of the medical gloves is compromised (Goldman *et al.*, 2016).

The overall incidence of perforation in medical gloves was reported 14.44%, ranged from 1.8 to 63.4% in various studies (Caillot and Voiglio, 2008; de Oliveira and Gama, 2014). For this reason, some healthcare workers wear two pairs of gloves to reduce the risk of skin contamination (Arena *et al.*, 1992). However, they prefer not to use double gloves because it may reduce the touch sensitivity (Tlili *et al.*, 2018; Zare *et al.*, 2020a,b).

The high importance of this issue has led to numerous studies on problems associated with the medical gloves perforation around the world (Zare *et al.*, 2020a,b). These studies have mainly focused on the factors such as the type of operation, the duration of the operation, and the level of training (Beldame *et al.*, 2012; Andrade *et al.*, 2016). However, no study has examined the size of gloves as an important factor affecting the rate of perforation. Among the previous studies, only two studies found indirect results related to glove size. Miller and Apt found that larger size gloves can be a potential factor for increasing glove perforation (Miller and Apt, 1993). Gunasekera *et al.* studied the incidence of glove failure following elective surgery for gynecological malignancies. The healthcare workers had to use medical gloves with inappropriate size, due to lack of facilities. The rate of perforations per operation increased to 100% when ill-fitting gloves were used, compared with 71% when the proper sizes were available. They found that factors contributing to the glove fragility were: purchase of low-quality gloves, reuse, and shortage of appropriate glove sizes (Gunasekera *et al.*, 1997).

Due to the lack of hand anthropometric data of Iranian population, the size of medical gloves has been determined based on International Organization for Standardization (ISO) standard (ISO, 2008). However, no study has examined whether these dimensions are suitable for the Iranian society or not. Some studies showed that the Iranian population has different hand dimensions than other populations. For example, the results of Mirmohammadi's study showed significant differences between Iranian hand size and that of other countries including India, Jordan, Turkey, Vietnam, and Bangladesh (Mirmohammadi *et al.*, 2016). Due to the importance of preventing glove perforation, it is necessary to conduct a study on the effect of glove size on the perforation rate. As a result, with scientific evidence, the need for the healthcare workers to access the right size gloves can be justified. This study aimed to compare the rate and location of glove perforation between well-fitted and ill-fitted gloves to assess the value of fitting in preventing damage to the glove.

## Methods and materials

### Basic information

The participants of this cross-sectional study were 45 midwives (all female) in the maternity ward of a hospital in Shiraz city, Iran. Participants reported their personal details including age, work experience, type and size of gloves, dominant hand, duration of the glove use, and the number of glove replacement during a shift. Participants with an allergy to natural rubber latex, hand deformities, and disabilities were excluded from the study.

### Study procedure

In the first step, the hands sizes of the participants were determined. The glove sizes were determined based on the hand breadth in the standards (EN, 2003; ISO, 2008; ASTM, 2015). For this reason, to determine the hand size, the hand breadth was measured using traditional anthropometric tools. The distance from the most lateral point on the index finger

metacarpal to the most medial point on the little finger metacarpal was considered as the hand breadth (Jee and Yun, 2016). The hand breadth was divided into several categories and assigned codes.

In the second step, participants were asked about the size of gloves they mostly use which made them feel comfortable as 'fit glove'. Then each midwife received three pairs of the fit gloves, three pairs of gloves with one size smaller than the fit glove as 'tight glove', and three pairs of gloves with one size larger than the fit glove as 'loose glove'. A code was written on the wrist of each glove including information such as characteristics of the participant, whether the glove was left or right, and the size of the glove. Subjects were asked to use gloves during episiotomy repair operations. All participants used the same surgical technique (continuous 2.0 chromic catgut for vagina and muscles and subcuticular catgut for skin after infiltration of the tissues with 20 ml of 1% lignocaine; a vaginal tampon was employed in all cases). Each participant performed nine episiotomy repair procedures with nine pairs of gloves provided (one pair of gloves for each procedure). After completing the task, all gloves were collected safely in a plastic bag, sealed, and labeled.

All gloves were examined for perforations by the approved standardized water leak method EN 455-1 (European Committee for standardization) by a single observer (EN, 2001). The 2001 EN 455-1 European norm is permeability and mechanical resistance norm required for manufacturers, importers, and suppliers marketing disposable medical gloves. One glove was stretched over each of the cylinders up to a maximum of 4 cm and attached with a rubber seal to avoid slipping. Blood residues were removed carefully by a soft damp cloth until the major contaminants were removed and the surface of the gloves was dried. By pulling each finger of the glove, the detection of even small damages was ensured. Then gloves sold must pass a specific permeability test: 'absence of visually detectable leakage after 2–3 min when filled with 1 l of water distributed in a column 50 mm in diameter at a temperature between 15 and 35°C'. Detailed technical conditions mentioned in the NF EN 455-1 norm were reproduced in our laboratory using a PVC tube with a 50-mm interior diameter from which the gloves were suspended for 2 min. Perforations appeared as a 'small continuous stream of water' or 'drop by drop' from the perforation point. A glove was reported to be punctured or perforated when at least one hole was seen. Also, the exact location of each perforation was noted (Fig. 1). Furthermore, one hundred unused gloves were tested as controls to ascertain a background level of perforations. The perforation rate was 0%.

The study protocol was reviewed and approved by the Ethics Committee of Shiraz University of Medical Sciences (IR.SUMS.1399.107). Participation in the study was completely voluntary, and subjects were free to refuse to participate in the study or to leave the study at any time (without altering the behavior of researchers and hospital management). The consent we obtained from study participants was written.

## Statistical analysis

The frequency of the perforations in different glove and hand size was statistically analyzed using SPSS software and Pearson's chi-squared test with a 5% significance threshold.

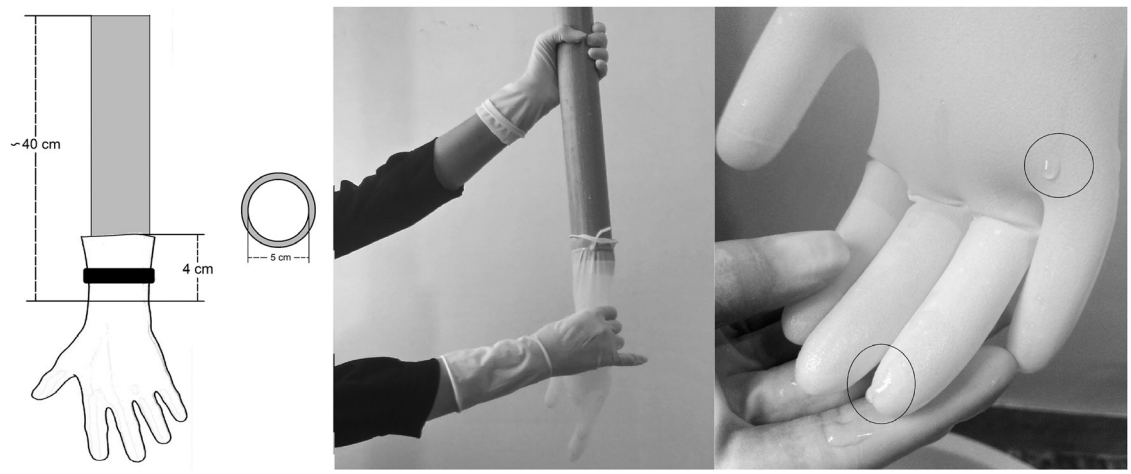


**Figure 1.** Perforation test based on the 2001 NF EN 455-1 European norm.

## Results

In total, 45 female midwives participated in this study. Demographic characteristics of the participants are shown in Table 1. All the midwives were right-handed, used the same surgical technique, and wore latex examination gloves during their daily tasks. The median of glove replacements in a work shift was three times.

A total number of 810 medical gloves (405 pairs) were analyzed (Table 2). The perforation rates of the fit ($n$ = 270), tight ($n$ = 270), and loose ($n$ = 270) medical gloves were 20% ($n$ = 54), 37.78% ($n$ = 102), and 34.81% ($n$ = 94), respectively. The results showed a significant difference between the glove perforation in different glove sizes by chi-square test ($P$ = 0.002)

There were significant differences between the perforation rate of well-fitted medical gloves and both ill-fitted sizes (Table 2). Significant differences between the perforation rate of fit medical gloves and the tight glove and the loose gloves were $P$ = 0.008 and $P$ = 0.037, respectively. In general, the perforation rate of the fit glove and the ill-fitted gloves had a significant difference ($P$ = 0.013). Moreover, the perforation rate of the tight gloves and the loose gloves has no significant differences ($P$ = 0.086).

Also, the effect of hand size on the gloves perforation was investigated in different glove sizes. As shown in Table 1, the participants were divided into four groups based on the hand size. In each group, the glove perforation in different sizes of gloves was examined, separately (Table 3). As shown in Table 3, hand breadth (hand size) had a significant effect on the gloves perforation in different glove sizes. In hand sizes of 6.5 and 8, the results showed significant differences between the glove perforation of different glove sizes ($P$ = 0.021 and $P$ = 0.030, respectively). In subjects with narrower and smaller hands (hand size of 6.5), the glove perforation rate in loose gloves (33%) was significantly higher than fit gloves (20.37%). In subjects with wider and larger hands (hand size of 8), the glove perforation rate in tight gloves (34.32%) was significantly higher than the fit gloves (14.81%). In the medium and intermediate hand sizes (hand size of 7 and 7.5), there was no significant effect of hand size on the glove perforation rate in different sizes of glove.

The distribution of glove perforation is shown in Fig. 2. As seen, the number of gloves with multiple perforations was 11, 39, and 23 for the fit, tight, and loose medical gloves respectively. The number of gloves with single perforation was 43, 63, and 71 for the fit, tight, and loose gloves, respectively.

The perforation pattern of the gloves is shown in Table 4. As seen, the number of perforations observed in the tight gloves ($n$ = 148) was more than twice the number of perforations of the fit gloves ($n$ = 69). The highest perforation rate of the fit medical gloves occurred in the non-dominant hand ($n$ = 43) and index finger ($n$ = 39). This pattern was not seen in the tight and loose gloves. In the tight gloves, the highest perforation rate was seen in the non-dominant hand ($n$ = 96) and thumb ($n$ = 76), and in the loose gloves, the highest perforation rate was seen in the dominant hand ($n$ = 79) and index finger ($n$ = 58).

**Table 1.** Demographic characteristics of the participants ($n$ = 45).

| Variables | Mean ± SD | $n$ (%) |
|---|---|---|
| Age (years) | 33.13 ± 7.48 | |
| Work experience (years) | 8.22 ± 1.34 | |
| Duration of gloves usage (hours per day) | 5.5 ± 1.9 | |
| Hand size (hand breadth) [a] | | |
| 6.5 | | 9 (20) |
| 7 | | 18 (40) |
| 7.5 | | 12 (26.66) |
| 8 | | 6 (13.34) |

[a]Distance from hand's radial edge to ulnar edge, 6.5 = 80–85 mm, 7 = 86–91 mm, 7.5 = 92–98 mm, 8 = 99–105 mm.

**Table 2.** Comparison of the perforation rates of medical gloves with different sizes.

| Glove size | Glove perforation, $n$ (%) | Chi-square test results compared with fit size |
|---|---|---|
| Fit | 54 (20) | 1 |
| Tight | 102 (37.78) | 0.008* |
| Loose | 94 (34.81) | 0.037* |
| The ill-fitted gloves (tight and loose together) | 196 (36.29) | 0.013* |

*Statistically significant ($P$ < 0.05).

## Discussion

Glove perforation is a common issue during medical procedures due to exposure to sharp objects and tissues. Healthcare workers including midwives are at risk of contracting infectious diseases from their patients if the integrity of medical gloves is compromised (Beldame *et al.*, 2012). The risk of infection after percutaneous exposure to

**Table 3.** Comparison of the perforation rates of medical gloves in different hand sizes.

| Hand size | Glove perforation, *n* (%) | | | Chi-square test |
|---|---|---|---|---|
| | Fit gloves | Tight gloves | Loose gloves | |
| 6.5 | 12 (22.22) | 21 (20.58) | 31 (33.00) | 0.021* |
| 7 | 13 (24.07) | 22 (21.56) | 20 (21.27) | 0.063 |
| 7.5 | 15 (27.78) | 24 (23.53) | 22 (23.40) | 0.057 |
| 8 | 14 (25.93) | 35 (34.33) | 21 (22.33) | 0.030* |
| Total | 54 (100) | 102 (100) | 94 (100) | — |

*Statistically significant ($P < 0.05$).

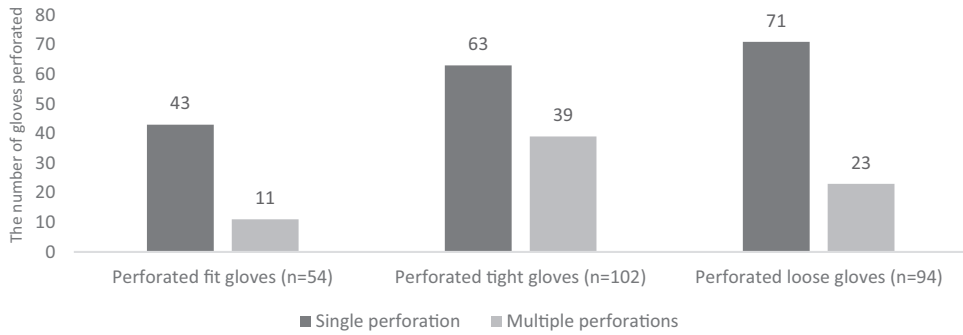


**Figure 2.** The distribution of the glove perforation in different sizes.

HIV, hepatitis B virus, and hepatitis C virus varies greatly. The percentage of medical gloves perforation in the specialty (gynecology and obstetrics processes) vary from 3% (Stitely *et al.*, 2013) to 43% (Palmer and Rickett, 1992). In this study, the incidence of glove perforation was 20% when using fit size gloves. These results were in line with the findings of Arena *et al.* that reported the rate of 20.7% for glove perforation in cesarean procedures (Arena *et al.*, 1992). Also, Faisal-Cury *et al.* found that the rate of glove perforation in the cesarean procedure was 21.3% (Faisal-Cury *et al.*, 2004).

The use of medical gloves significantly reduces the volume of the blood inoculum of suture needles. Therefore, it seems that the well-fitted glove is more efficient than ill-fitted glove (Gunasekera *et al.*, 1997). In the present study, the perforation rate for the fit gloves was significantly lower than the inappropriate size gloves ($P < 0.05$). Glove size affects hand safety, performance, comfort, all of which influence the decision to wear gloves (Torrens *et al.*, 2012; Dianat *et al.*, 2014; Hsiao *et al.*, 2015). Wearing gloves that are one size larger interferes with the ability to manipulate materials quickly and efficiently as well feels sloppy (Neiburger, 1992; Fleming *et al.*, 1997). Gloves that are too large cause the worker's hands to slide around and impair fine motor performance (Drabek *et al.*, 2013). In these cases, the hand skill and grasping ability may be decreased (Torrens *et al.*, 2012; Hsiao *et al.*, 2015). This can be attributed to the fact that loose-fitting gloves apply more force for grabbing objects, especially the smaller pieces and making it difficult to release objects, which can reduce the individual ability for doing medical tasks. Larger gloves, as expected, also distort the touch stimuli and make it harder to detect. Therefore, healthcare workers may not be able to manipulate the tools in their hand, which causes the tip of the tool to hit the hand, and eventually causes a tear or perforation. Inadequacy and looseness is one of the most common problems in designing gloves in delicate jobs (Dianat *et al.*, 2014).

A noteworthy point in the results of the present study was the incidence of perforation in the tight gloves. The perforation rate of tight medical gloves was significantly higher than well-fitting gloves. The use of gloves that are one size smaller restricts hand and finger movements, causes unpredictable pain and numbness, decreases fingertips blood flow, increases fatigue (Drabek *et al.*, 2013), and decreases dexterity, which all may decrease accuracy (Yoo *et al.*, 2011). Working with sharp tools can reduce accuracy and increase the risk of hitting the tooltip to the hands and perforating the gloves. The tight gloves may cause excessive stretching of glove material which can increase the risk of glove perforation.

**Table 4.** The location and the number of perforations observed in different size of gloves.

| The size of gloves | The location of perforations | | | | | | |
|---|---|---|---|---|---|---|---|
| | Index finger | Thumb finger | Middle finger | Ring finger | Little finger | Palm | Total |
| Fit | | | | | | | |
| Dominant hand | 13 | 9 | 2 | 1 | 1 | 0 | 26 |
| Non-dominant hand | 26 | 8 | 5 | 1 | 2 | 1 | 43 |
| Total | 39 | 17 | 7 | 2 | 3 | 1 | 69 |
| Tight | | | | | | | |
| Dominant hand | 14 | 29 | 3 | 3 | 2 | 1 | 52 |
| Non-dominant hand | 35 | 47 | 6 | 4 | 3 | 1 | 96 |
| Total | 49 | 76 | 9 | 7 | 5 | 2 | 148 |
| Loose | | | | | | | |
| Dominant hand | 36 | 26 | 9 | 3 | 3 | 2 | 79 |
| Non-dominant hand | 22 | 13 | 4 | 2 | 2 | 1 | 44 |
| Total | 58 | 39 | 13 | 5 | 5 | 3 | 123 |

In the present study, hand size was investigated as a potential factor on the rate of glove perforation. According to the results, for people with smaller hand size, the use of loose gloves is more dangerous than tight gloves. Also, for people who have wider hands, tight gloves are more likely to be perforated than loose gloves. In other words, compared with the medium hand sizes, people with small hands are at greater risk of perforation in loose gloves and individuals with large hands are at a greater risk of perforation in tight gloves. The effect of hand size on the glove size is a well-established fact. The size of the glove should be designed and selected according to the dimensions of the hand (Zschernack and Stack, 2010). Mismatch of glove size and hand dimensions increases the rate of glove perforation. However, according to the results of the present study, in some hand sizes (margins), the incompatibility of glove size with hand dimensions can increase the glove perforation exponentially. Miller and Apt stated in a brief note that large gloves can be an effective factor to increase perforation (Miller and Apt, 1993). It seems that the effect of incompatibility between glove size and anthropometric dimensions of the hand on the safety performance of gloves is not linear and has more negative effects on the 5th and 95th percentiles of the population. However, this issue needs to be examined more closely in future studies.

As shown in Table 4, the pattern of perforation was different in different glove conditions. Similar to most previous studies, most piercings occurred in the non-dominant hand as well as in index and thumb fingers (Carter *et al.*, 2012; Zaatreh *et al.*, 2016; Dorcheh *et al.*, 2017; Tlili *et al.*, 2018). The greater damage in these areas can be due to the increased use of these areas, their greater involvement with damaging and sharp objects, and their higher contact with the patients' tissues and bones (Ghadami *et al.*, 2018). The fact that the midwives handle sharp instruments using their dominant hands is a possible cause of the occurrence of accidents in the opposite hand (Oliveira and Gama, 2015). This pattern was almost the same in tight gloves, but in loose gloves, the incidence of perforation in the dominant hand was high. Creating empty spaces in gloves and looseness can get stuck in the equipment or tissues in the process of performing the task. However, this issue needs further investigation.

Research about gloves can help industries to select the types of gloves that produce the most efficient performance while providing suitable protection for a specific job. The information gained from glove studies can help to set guidelines for the workplace, equipment, and device designs. Originally, such guidelines were designed to reduce the risk of injury in the workplace for non-gloved workers. The results of the present study allow healthcare workers to find and use well-fitting gloves to perform their tasks. It is recommended to select gloves in one size larger rather than one size smaller if the suitable size is not available. Wearing correctly fitting gloves will improve safety and comfort in workplaces. While every effort must be made to minimize rates of perforation, it is also important to pay attention to the design and dimensions of medical gloves. More research on developing glove sizing systems can be effective in reducing perforation rates and increasing the safety performance of medical gloves.

The present study had several limitations. Firstly, the interfering effect of hand breadth was considered in this study, but the size of the gloves is also affected by other hand dimensions such as fingers and hand length. Although this seems to be a weakness in the present study, it could be the basis for more extensive studies in this area and improve the size of medical gloves. Secondly, the issue that only the latex examination glove type was evaluated in this study is an acknowledged limitation and the results should not be applied to all disposable glove types. Moreover, since this study was the only research in this field, comparison of the results was not possible. Future studies are needed, and currently underway, to broaden the scope of application exhibited in this study.

## Conclusion

The results of the present study attest to the importance of size fitting with medical gloves perforation. It found that wearing the wrong size gloves led to increased glove perforation rate. The number of single perforation in different sizes was almost close to each other but the number of multiple perforations in wrong glove sizes was higher than well-fitted gloves. These findings indicate a multiplier risk of exposure to biological agents when using inappropriate size gloves. It seems that providing a wide range of glove sizes by the hospital management, and the authority to choose the best glove size, can be very effective in reducing the perforation of gloves and increasing safety for the healthcare workers and patients. Finally, it is suggested that further studies need to be conducted to investigate the conformity of the size of medical gloves in Iran and the feasibility of developing a glove sizing system.

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## Conflict of interest

The authors declare no other conflict of interest relating to the material presented in this article.

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