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REPORTS OF ORIGINAL INVESTIGATIONS

Factors that influence the selection of sterile glove brand: a randomized controlled trial evaluating the performance and cost of gloves

Facteurs influençant le choix d'une marque de gants stériles: une étude randomisée contrôlée évaluant la performance et le coût des gants

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Abstract

Purpose *To determine whether glove use modifies tactile and psychomotor performance of health care providers when compared with no glove use and to evaluate factors that influence the selection of sterile glove brand.*

Methods *Forty-two anesthesia providers (nine anesthesiologists, seven nurse anesthetists, 20 residents, six student nurse anesthetists) enrolled in and completed this cross-over randomized trial from May 2010 until August 2011. Participants underwent standardized psychomotor testing while wearing five different types of protective gloves. Assessments of psychomotor performance included tactile, fine motor/dexterity, and hand-eye coordination tests. Subjective ratings of glove comfort and performance were reported at the completion of each glove trial. The manufacturer's suggested retail price was collected for each glove tested.*

Results *There were statistically significant differences in touch sensitivity for all nerve distributions, with all glove types resulting in less sensitivity than a bare hand. When compared with the non-sterile glove, only the thickest glove tested (Ansell Perry Orthopaedic) was found to have less touch sensitivity. Fine motor dexterity testing revealed no statistically significant differences in time to completion amongst glove types or bare handed performance. In hand-eye coordination testing across treatment conditions, the thickest glove tested (Ansell Perry® Orthopaedic) was the only glove to show a statistically significant difference from a bare hand. There were statistically significant differences in glove comfort ratings across glove types, with latex-free, powder-free (Cardinal Esteem®), and latex powder-free (Mölnlycke-Biogel®) rated highest; however, there were no statistically significant differences in subjective performance ratings across glove types.*

Conclusions *Given the observed similarities in touch sensitivity and psychomotor performance associated with five different glove types, our results suggest that subjective provider preferences, such as glove comfort, should be balanced against material costs.*

Résumé

Objectif *Déterminer si l'utilisation de gants modifiait la performance tactile et psychomotrice des professionnels de la santé par rapport à une performance à mains nues, et évaluer les facteurs influençant le choix d'une marque de gants stériles.*

Méthode *Quarante-deux professionnels des soins en anesthésie (neuf anesthésiologistes, sept infirmiers*

Author contributions *Christopher M. Duncan, James R. Hebl, Rebecca L. Johnson, Darrell R. Schroeder, Hugh M. Smith,* and *Laurence C. Torsher* were involved in the study concept and design. *Rebecca L. Johnson* was involved in the acquisition of data. *Christopher M. Duncan, James R. Hebl, Rebecca L. Johnson, Darrell R. Schroeder, Hugh M. Smith,* and *Laurence C. Torsher* were involved in the analysis and interpretation of data. *Darrell R. Schroeder* was involved in the statistical analysis. *Christopher M. Duncan, Rebecca L. Johnson, Darrell R. Schroeder, Hugh M. Smith,* and *Laurence C. Torsher* were involved in drafting the manuscript. *Christopher M. Duncan, James R. Hebl, Rebecca L. Johnson, Darrell R. Schroeder, Hugh M. Smith,* and *Laurence C. Torsher* were involved in critical revision of the manuscript for important intellectual content.

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anesthésistes, 20 résidents, six étudiants infirmiers anesthésistes) ont participé à cette étude randomisée croisée entre mai 2010 et août 2011. Les participants ont été soumis à des tests psychomoteurs standardisés en portant cinq différents types de gants de protection. L'évaluation de la performance psychomotrice a été réalisée à l'aide de tests tactiles, de motricité fine / dextérité, et de coordination main-œil. Des notes subjectives portant sur le confort et la performance des gants ont été données par les participants à la fin de chaque test de gants. Le prix de vente suggéré du fabricant a été noté pour chaque marque de gant testée.

Résultats *Des différences statistiquement significatives ont été notées au niveau de la sensibilité du toucher pour toutes les distributions nerveuses, tous les types de gants entraînant une sensibilité moindre que la main nue. Par rapport aux gants non stériles, seuls les gants les plus épais testés (Ansell Perry Orthopaedic) ont été démontrés comme possédant une sensibilité moindre au toucher. Le test de dextérité et de motricité fine n'a révélé aucune différence statistiquement significative au niveau du temps mis pour compléter le test entre les types de gants et la performance à main nue. Au niveau de la coordination main-œil pour plusieurs conditions de traitement, les gants les plus épais (Ansell Perry® Orthopaedic) étaient les seuls à afficher une différence statistiquement significative par rapport à la main nue. Des différences statistiquement significatives sont apparues dans les notes en matière de confort des gants, les gants sans latex et sans poudre (Cardinal Esteem®) et les gants sans poudre en latex (Mölnlycke-Biogel®) recevant les meilleures notes; toutefois, aucune différence statistiquement significative en matière de notes subjectives de performance n'a été notée entre les différents types de gants.*

Conclusion *Étant donné les similitudes observées en matière de sensibilité du toucher et de performance psychomotrice entre les cinq différents types de gants, nos résultats suggèrent que les préférences subjectives du professionnel d'anesthésie, telles que le confort des gants, devraient être évaluées en gardant à l'esprit les coûts matériels.*

Factors that influence the selection of sterile gloves include both personal and professional considerations. During glove selection, health care providers often consider cost, familiarity, and availability, as well as touch sensitivity and performance preferences.[1] Most major medical centres stock a wide selection of sterile gloves (e.g., latex, non-latex, powdered, and powder-free) and non-sterile styles. Many glove manufacturers advertise various "tactile sensitivity" benefits and coordination characteristics; however, there is little evidence to support claims regarding technical performance or comfort superiority. Gloves provide barrier protection for both patients and workers against the transfer of microorganisms. Despite the widespread use of sterile gloves within medicine, providers are rarely given relevant cost and provider safety information. As a result, providers are often unaware that different glove styles may impact psychomotor performance.

Beyond comfort and tactile performance, provider safety issues should be considered when selecting sterile gloves, as glove perforation and glove performance may be inversely related, i.e., thicker puncture-resistant glove types may compromise tactile feedback and manual dexterity.[2] Also, the controversy between latex and latex-free surgical gloves poses additional safety considerations. For example, chronic exposure to latex products and other sources of antigens increases rates of dermatologic sensitization and the risk of potentially serious immunologic reactions.[3,4] In contrast, in surgical specialties, there are higher rates of glove perforation in latex-free gloves, with known higher incidences of glove compromise.[5]

In the current investigation, various types of sterile and non-sterile gloves available at a large tertiary care institution are examined to determine whether glove use modifies or influences tactile and psychomotor performance compared with no glove use. Psychomotor elements essential for procedural performance include tactile sensation, bimanual coordination, and fine manual dexterity.[6-10] Standardized and objective testing for each of these parameters has been previously validated and used within private industry and the medical specialties of physical and occupational therapy. Although some evidence exists regarding glove function in isolation, the rationale of the current study is to provide an independent comprehensive assessment to determine whether glove type impacts the psychomotor performance of providers in a procedural medical specialty such as anesthesia.

Methods

After Institutional Review Board approval in May 2010, a convenience sample of anesthesia care providers (anesthesiologists, nurse anesthetists, student nurse anesthetists, anesthesiology residents) within the Mayo Clinic Department of Anesthesiology volunteered to participate in this cross-over randomized trial. The study results are reported following the 2010 Consolidated Standards of Reporting Trials (CONSORT)[11,12] guidelines. Subjects with known latex allergy or sensorimotor impairments were excluded. Anesthesia providers enrolled in the study were asked to complete three standardized psychomotor aptitude tests that assessed dexterity/fine motor skills, tactile sensation, and hand-eye coordination. Psychomotor tests were selected based on their potential impact on performance of anesthesia procedural tasks. Validated psychomotor aptitude tests included 1) Crawford Small Parts Dexterity Test (CSPDT),[7] 2) Semmes-Weinstein Monofilament (SWM),[13] and 3) Purdue Pegboard Test (PPT).[14] The CSPDT assessment evaluated fine motor dexterity and coordination; the SWM assessment evaluated tactile sensation, and the PPT assessment evaluated dexterity and speed associated with hand-eye coordination. Detailed descriptions of each test are provided in the Appendix. Demographic data, including sex, age, glove size, hand dominance, and years in clinical practice were collected on each participant. Psychomotor testing was conducted by a single physician investigator (R.L.J.) not blinded to the intervention studied (type of glove or no glove). Participants were masked to the study hypothesis and were blinded to all results during testing.

Participants performed each standardized psychomotor aptitude test six times, once with bare hands and once with each of five different glove types. The various types and brands of gloves used in the study were chosen based on their availability within the Mayo Clinic Division of Surgical Services. Participants chose a single glove size for all glove testing. Cost estimates according to manufacturer's suggested retail price (MSRP) per glove pair were collected directly from each glove manufacturer. The glove brands tested included: 1) Mölnlycke-Biogel® latex, powder-free (MSRP $18); 2) Ansell Sensi-Touch® latex, powdered (MSRP $1); 3) Cardinal-Esteem® with Neu-Thera® latex-free, powder-free (MSRP $5.75); 4) Ansell Perry® Orthopaedic latex, powdered (MSRP $3); and 5) Cardinal-Esteem Tru-Blu™ stretchy, nitrile, non-sterile, latex-free, powder-free (MSRP $0.66). Participants were requested to wash and dry their hands between each set of aptitude tests to ensure powder was removed before continuing testing with a different style of glove. To minimize bias associated with participant fatigue, the order of standardized psychomotor testing was strictly followed: CSPDT → SWM → PPT. This ordering allowed SWM to serve as a passive "rest" period between active assessments. Since glove testing required approximately 30 min per glove type, a rest period (minimum four hours) was instituted after three assessments (three glove types or two glove types + bare hand) to prevent participant fine motor fatigue. Otherwise, testing was performed consecutively with participants performing each test once per glove (or bare hand) without repeat. Standardized psychomotor testing occurred on several dates based on participant availability. Participants used a Likert scale to rate each glove separately based on their perception of *performance* and *comfort* (1 = marked negative impact, 2 = some negative impact, 3 = no impact, 4 = some positive impact, 5 = marked positive impact).

All participants were tested under each treatment condition (bare hand + five glove types), with the order of the six treatment conditions randomized using a replicated Latin square design to ensure balanced ordering across participants. A statistician blinded to the implementation process generated the randomization schedule that determined the order of treatment assignments for each of the 42 participants according to subject number. Participants were assigned a subject number in sequential order based on time of enrolment. Study data were de-identified, collected, and managed using REDCap (research electronic data capture) validated electronic data collection tools hosted at Mayo Clinic and designed to support data capture for research studies.

Statistical analyses

All analyses were performed using SAS® version 9.2 (SAS Institute Inc, Cary, NC, USA). Participant characteristics and psychomotor performance scores were summarized using descriptive statistics. Psychomotor test results were analyzed using a linear mixed model to account for the repeated measures study design. For these models, the given psychomotor test was the dependent variable, subject was the random effect, and variance components were used for the covariance structure. Glove type was the independent variable of interest, and treatment order was included as a categorical covariate. Linear contrasts were used to assess the pairwise comparisons of each glove type *vs* a bare hand using Dunnett's multiple comparison procedure. As a secondary analysis, an additional set of linear contrasts was performed to compare each sterile glove type with the non-sterile glove. Results for all between-group comparisons are summarized using a point estimate and 95% confidence interval for the difference between groups. Dunnett-adjusted P values are reported for these comparisons. All reported P values are two-sided.

A sample size of $n = 42$ participants was chosen after weighting both statistical considerations and the logistical and resource constraints involved in the proposed study. In a previous study of 21 subjects, Tiefenthaler *et al.*[1] compared touch sensitivity across three conditions (bare hand + two glove types) and reported differences in means between glove and bare hand conditions ranging from approximately 0.25-0.75 standard deviation units. For a paired Student's t test, a sample size of $n = 42$ participants would provide statistical power (two-tailed, alpha = 0.05) of 80% to detect a difference between matched pairs of 0.45 standard deviation units; therefore, a sample size of $n = 42$ was determined for the current study. No adjustments were made to the sample size to account for multiple end points or multiple treatment comparisons.

Results

Forty-two anesthesia providers (nine anesthesiologists, seven nurse anesthetists, 20 residents, six student nurse anesthetists) were assessed for eligibility and randomized, and all providers completed the study within fifteen months of open recruitment (May 2010 to August 2011). The median age of these 42 (13 female, 29 male) participants was 32.5 yr (range 27-57 yr), and the median duration in clinical practice was four years (range 1-27 yr).

The standardized psychomotor test results are presented in Table 1. Touch sensitivity (SWM test; expressed as the logarithm of ten times the grams of force needed to bend the filament) with each glove type was found to have a statistically significant reduction in tactile sensation in all nerve distributions compared with bare hands, with observed mean differences ranging from 0.25-0.42 for the radial nerve, 0.16-0.26 for the median nerve, and 0.12-0.28 for the ulnar nerve. Supplemental analyses comparing sterile glove types with the non-sterile glove showed a statistically significant reduction in touch sensitivity within the radial and median nerve distributions with the sterile Perry Orthopaedic gloves.

Results of the CSPDT assessment and fine motor dexterity are shown in Table 1 and Fig. 1. The observed mean differences from bare hands were not found to be statistically significant and ranged from 1.5-13.0 sec.

For the PPT evaluation of dexterity (speed and hand-eye coordination only), the Perry Orthopaedic glove performed in an inferior manner compared with a bare hand, with a statistically significant observed mean difference of -1.3 pegs (Table 1 and Fig. 2). The mean differences in performance observed between the other glove types and a bare hand ranged from -0.6 pegs to $+0.1$ pegs. Similarly, the Perry Orthopaedic glove showed inferior performance compared with the non-sterile glove, with a statistically significant observed mean difference of -1.4 pegs. The observed mean differences between the other glove types and the non-sterile glove ranged from -0.6 pegs to -0.3 pegs.

Comfort and performance ratings are summarized in Table 2. There were statistically significant differences in comfort ratings across glove types, with latex-free, powder-free (Esteem), and latex powder-free (Biogel) rated highest among participants (Table 2). Participant ratings resulted in no statistically significant differences between the performance of sterile and non-sterile glove types. Annual cost estimates based on the volume of glove use for each glove type are listed in Table 3.

Discussion

In contemporary health care, glove use is standard practice. The current investigation was designed to evaluate sensation, dexterity, and hand-eye coordination characteristics for various sterile glove types commonly used in surgery and anesthesia. As anticipated, compared with no glove use (bare hands), sensation is reduced by wearing gloves. Nevertheless, differences in touch sensitivity and overall psychomotor performance among sterile and non-sterile glove types compared with no glove use during standardized psychomotor testing were not statistically significant and also likely clinically unimportant. Provider ratings of comfort were highest for two of the five glove brands tested (Cardinal Esteem and Biogel). Despite the statistically significant differences in comfort ratings, the same participants did not rate improved performance for any of the five glove types. With cost differing among common surgical glove types, results from this investigation suggest that subjective provider preferences in glove selection should be balanced against other variables such as costs.

Tactile sensation is considered fundamental to procedural performance, with a loss of touch sensitivity being a primary barrier to glove compliance.[15] With a wide selection of sterile glove styles available at most institutions and with all glove manufacturers claiming performance advantages, providers are faced with many choices. Nevertheless, providers have little basis for decision-making, leaving glove selection to be influenced by familiarity and apprenticeship role modelling more than by objective evidence.[16,17] The current investigation reports a randomized clinical trial designed to examine the impact of different styles of surgical gloves on tactile sensation and performance of psychomotor skills using validated aptitude assessments previously used among anesthesia providers.[10]

Prior investigations have examined the thickness of protective gloves as a marker of touch sensitivity.[1,18] In fact, touch sensitivity has been shown to increase with the use of extra thin gloves, although these specialty items are associated with increased puncture rates and cost.[18] Calibrated Semmes-Weinstein monofilaments provide an objective and reproducible clinical assessment of tactile sensation.[6] Not surprisingly, touch sensitivity throughout median, ulnar, and radial nerve distributions was found to be inferior across all glove types when compared with bare hands. Even so, despite differences in sensation compared with bare hands, recorded deficits for all glove types remained within validated normal ranges for tactile sensation, suggesting that sensory performance is not grossly impaired by glove use. Based on this finding, glove use should *not* be avoided by health care providers based on subjective claims that sensory performance is reduced.

Standardized psychomotor tests, such as the PPT and CSPDT, evaluate speed, dexterity, control, and coordination of hands, fingers, and arms.[14] The CSPDT showed overall higher observed mean times (worse dexterity

Table 1 Standardized psychomotor test results according to treatment condition*

Test	Treatment condition					
	Bare hand	Non-sterile Tru-Blu	Biogel	Sensi-Touch	Esteem	Perry orthopaedic
Semmes-Weinstein touch sensitivity						
Radial nerve distribution						
Mean (SD)	1.98 (0.37)	2.27 (0.39)	2.32 (0.25)	2.23 (0.34)	2.27 (0.28)	2.40 (0.32)
$\Delta_{bare\ hand}$, estimate (95% CI)		0.29 (0.18 to 0.40)	0.33 (0.22 to 0.44)	0.25 (0.14 to 0.36)	0.29 (0.18 to 0.40)	0.42 (0.31 to 0.53)
$\Delta_{bare\ hand}$, P value		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
$\Delta_{non\text{-}sterile}$, estimate (95% CI)			0.05 (−0.05 to 0.15)	−0.03 (−0.13 to 0.07)	0.00 (−0.10 to 0.10)	0.13 (0.03 to 0.23)
$\Delta_{non\text{-}sterile}$, P value			0.76	0.90	1.00	0.029
Median nerve distribution						
Mean (SD)	2.16 (0.35)	2.32 (0.23)	2.38 (0.19)	2.36 (0.26)	2.38 (0.18)	2.42 (0.10)
$\Delta_{bare\ hand}$, estimate (95% CI)		0.16 (0.08 to 0.24)	0.22 (0.14 to 0.30)	0.20 (0.12 to 0.28)	0.21 (0.13 to 0.29)	0.26 (0.18 to 0.34)
$\Delta_{bare\ hand}$, P value		< 0.001	< 0.001	< 0.001	<0.001	< 0.001
$\Delta_{non\text{-}sterile}$, estimate (95% CI)			0.06 (−0.01 to 0.13)	0.04 (−0.03 to 0.11)	0.05 (−0.02 to 0.12)	0.10 (0.03 to 0.17)
$\Delta_{non\text{-}sterile}$, P value			0.36	0.70	0.45	0.033
Ulnar nerve distribution						
Mean (SD)	2.25 (0.33)	2.44 (0.23)	2.44 (0.18)	2.37 (0.21)	2.39 (0.25)	2.52 (0.31)
$\Delta_{bare\ hand}$, estimate (95% CI)		0.20 (0.11 to 0.29)	0.20 (0.11 to 0.29)	0.12 (0.03 to 0.21)	0.14 (0.05 to 0.23)	0.28 (0.19 to 0.37)
$\Delta_{bare\ hand}$, P value		< 0.001	< 0.001	0.038	0.009	< 0.001
$\Delta_{non\text{-}sterile}$, estimate (95% CI)			0.00 (−0.08 to 0.08)	−0.08 (−0.16 to 0.00)	−0.06 (−0.14 to 0.02)	0.08 (0.00 to 0.16)
$\Delta_{non\text{-}sterile}$, P value			1.00	0.19	0.47	0.19
Crawford small parts test, sec						
Mean (SD)	249.4 (38.2)	250.9 (36.8)	262.4 (37.8)	255.7 (57.8)	253.9 (32.7)	253.7 (40.4)
$\Delta_{bare\ hand}$, estimate (95% CI)		1.5 (−9.0 to 11.9)	13.0 (2.6 to 23.4)	6.4 (−4.1 to 16.8)	4.6 (−5.9 to 15.0)	4.3 (−6.1 to 14.8)
$\Delta_{bare\ hand}$, P value		0.99	0.064	0.64	0.86	0.89
$\Delta_{non\text{-}sterile}$, estimate (95% CI)			11.5 (0.7 to 22.4)	4.9 (−6.0 to 15.7)	3.1 (−7.8 to 13.9)	2.8 (−8.0 to 13.7)
$\Delta_{non\text{-}sterile}$, P value			0.12	0.79	0.95	0.96
Purdue peg board test, pegs/30 sec						
Mean (SD)	14.4 (2.1)	14.5 (1.8)	13.9 (1.6)	14.0 (2.0)	14.2 (1.9)	13.1 (1.8)
$\Delta_{bare\ hand}$, estimate (95% CI)		0.1 (−0.5 to 0.6)	−0.6 (−1.1 to 0.0)	−0.4 (−1.0 to 0.1)	−0.3 (−0.8 to 0.2)	−1.3 (−1.9 to −0.8)
$\Delta_{bare\ hand}$, P value		0.99	0.14	0.38	0.74	< 0.001
$\Delta_{non\text{-}sterile}$, estimate (95% CI)			−0.6 (−1.1 to −0.1)	−0.5 (−1.0 to 0.0)	−0.3 (−0.8 to 0.2)	−1.4 (−1.9 to −0.9)
$\Delta_{non\text{-}sterile}$, P value			0.068	0.22	0.53	< 0.001

* Each of the 42 subjects completed each test using each glove type. Analyses were performed using mixed linear models to account for the repeated measures study design. Linear contrasts were used to assess the pairwise comparisons of each glove type *vs* control bare hand using Dunnett's multiple comparison procedure. An additional set of linear contrasts was performed to compare each type of sterile glove with the non-sterile glove. For all between group comparisons, results are summarized using a point estimate and 95% confidence interval for the difference between groups along with the Dunnett-adjusted *P* value. SD = standard deviation; CI = confidence interval

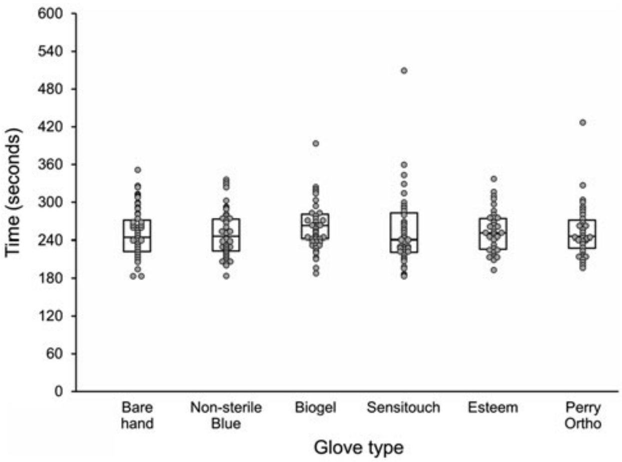

Fig. 1 Fine-motor/Dexterity Testing. Non-sterile Blu = Cardinal-Esteem Tru-Blu stretchy nitrile; Biogel = Mölnlycke-Biogel latex, powder-free sterile glove, Sensi-Touch = Ansell Sensi-Touch latex, powdered sterile glove; Esteem = Cardinal-Esteem with Neu-Thera latex-free, powder-free sterile glove; Perry Ortho = Ansell Perry Orthopaedic sterile glove. Increasing time in seconds corresponds with poorer performance. Data were analyzed using mixed linear models with linear contrasts used to assess the pairwise comparisons of each glove type *vs* bare hand and each sterile glove type *vs* the non-sterile glove. No statistically significant (Dunnett-adjusted $P < 0.05$) differences were detected

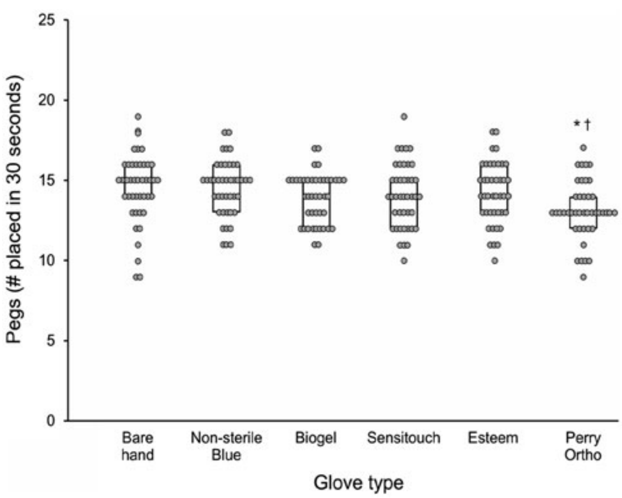

Fig. 2 Hand-eye Coordination Testing. Non-sterile Blu = Cardinal-Esteem Tru-Blu stretchy nitrile; Biogel = Mölnlycke-Biogel latex, powder-free sterile glove, Sensi-Touch = Ansell Sensi-Touch latex, powdered sterile glove; Esteem = Cardinal-Esteem with Neu-Thera latex-free, powder-free sterile glove; Perry Ortho = Ansell Perry Orthopaedic sterile. *Dunnett-adjusted $P < 0.001$ glove type compared with bare hand. †Dunnett-adjusted $P < 0.001$ glove type compared with non-sterile Blu. Increasing number of pegs corresponds with better performance. Data were analyzed using mixed linear models with linear contrasts used to assess the pairwise comparisons of each glove type *vs* bare hand and each sterile glove type *vs* the non-sterile glove

performance) with gloves compared with bare hands; however, no statistical differences in performance times were observed *between* glove types.[7] Apart from the Perry Orthopaedic glove, the Purdue Pegboard Test results showed no difference in hand-eye coordination task performance when using bare hands *vs* using all glove types. The Perry Orthopaedic glove was the thickest glove tested and resulted in slower performance times. With the exception of this outlier, there is no objective evidence supporting one glove type over another based on psychomotor performance data.

Although our study results showed no difference in psychomotor testing among sterile glove types, there were considerable differences in cost. Specifically, the MSRP of the Mölnlycke-Biogel latex powder-free glove ($18.00) is three times the cost of the next highest priced pair tested, i.e., the Cardinal-Esteem with Neu-Thera latex-free powder-free glove ($5.75), and 18-fold higher in price than the lowest priced sterile glove tested, Ansell Sensi-Touch latex powdered ($1.00). Although volume-based discounting and contracting between manufacturers and health care centres results in significant cost variation between hospitals, MSRP is perhaps the only objective means of making standardized comparisons across all glove types. Furthermore, it is reasonable to conclude that purchasing gloves with the lowest MSRP would translate to the lowest final cost for purchasing an equal volume. Thus, by switching from a glove with an $18.00 MSRP to a glove with a $1.00 MSRP, the potential cost saving in an institution purchasing 500,000 units is $3.4 million dollars per year, with no change to provider comfort or procedure performance as assessed by anesthesia providers. In the current economic climate, opportunities to reduce costs without potentially impacting provider performance represent tangible value to institutions.

A major limitation of our study would be generalizability to non-anesthesia providers and providers without prior exposure to glove use. Although a representative sample of anesthesia providers was enrolled, bias could not be fully avoided in this study, as all participants had prior exposure to the gloves tested. Additionally, no other specialty was represented in the sample population, which may limit the applicability to other medical or surgical specialties. Although the impact of glove use on psychomotor testing may be similar across medical and surgical specialties, we cannot presume that features important to anesthesia providers will be similarly important to other specialties. For example, we know that glove use varies greatly across medical and surgical specialties. Surgeons may need to wear sterile gloves for prolonged periods of time (i.e., several hours), while anesthesia providers or other medical specialties (e.g., gastroenterology) may use gloves for much shorter periods of time. Therefore,

Table 2 Participant performance and comfort ratings

	Non-sterile Tru-Blu	Biogel	Sensi-Touch	Esteem	Perry orthopaedic
Performance					
1 = marked negative, *n* (%)	3 (7)	7 (17)	1 (2)	1 (2)	7 (17)
2 = some negative, *n* (%)	20 (48)	13 (31)	20 (48)	17 (40)	23 (55)
3 = no impact, *n* (%)	17 (40)	16 (38)	15 (36)	17 (40)	6 (14)
4 = some positive, *n* (%)	1 (2)	5 (12)	6 (14)	5 (12)	6 (14)
5 = marked positive, *n* (%)	1 (2)	1 (2)	0 (0)	2 (5)	0 (0)
Mean (SD)	2.4 (0.8)	2.5 (1.0)	2.6 (0.8)	2.8 (0.9)	2.3 (0.9)
$\Delta_{\text{non-sterile}}$, estimate (95% CI)*		0.1 (−0.3, 0.4)	0.2 (−0.2, 0.5)	0.3 (0.0, 0.7)	−0.2 (−0.5, 0.2)
$\Delta_{\text{non-sterile}}$, *P* value*		0.98	0.74	0.22	0.64
Comfort					
1 = marked negative, *n* (%)	2 (5)	1 (2)	2 (5)	2 (5)	10 (24)
2 = some negative, *n* (%)	20 (48)	13 (31)	15 (36)	9 (21)	20 (48)
3 = no impact, *n* (%)	16 (38)	14 (33)	20 (48)	17 (23)	8 (19)
4 = some positive, *n* (%)	3 (7)	11 (26)	4 (10)	10 (24)	4 (10)
5 = marked positive, *n* (%)	1 (2)	3 (7)	1 (2)	4 (10)	0 (0)
Mean (SD)	2.5 (0.8)	3.0 (1.0)	2.7 (0.8)	3.1 (1.0)	2.1 (0.9)
$\Delta_{\text{non-sterile}}$, estimate (95% CI)*		0.5 (0.2, 0.8)	0.1 (−0.2, 0.5)	0.6 (0.2, 0.9)	−0.4 (−0.7, −0.1)
$\Delta_{\text{non-sterile}}$, *P* value*		0.016	0.83	0.005	0.070

*Each of the 42 subjects assessed performance and comfort of each glove type. Analyses were performed using mixed linear models to account for the repeated measures study design. Linear contrasts were used to compare each sterile glove type with the non-sterile glove. For all between group comparisons, results are summarized using a point estimate and 95% confidence interval for the difference between groups along with the Dunnett-adjusted *P* value. SD = standard deviation; CI = confidence interval

Table 3 Annual cost estimates based on volume of sterile glove use

	Cost for volume purchase based on MSRP					
Cost/pair	25,000/yr	50,000/yr	75,000/yr	100,000/yr	250,000/yr	500,000/yr
Biogel $18.00	$450,000.00	$900,000.00	$1,350,000.00	$1,800,000.00	$4,500,000.00	$9,000,000.00
Esteem $5.75	$143,750.00	$287,500.00	$431,250.00	$575,000.00	$1,437,500.00	$2,875,000.00
Perry Ortho $3.00	$75,000.00	$150,000.00	$225,000.00	$300,000.00	$750,000.00	$1,500,000.00
Sensi-Touch $1.00	$25,000.00	$50,000.00	$75,000.00	$100,000.00	$250,000.00	$500,000.00

Biogel = Mölnlycke-Biogel latex, powder-free sterile glove; Esteem = Cardinal-Esteem with Neu-Thera latex-free, powder-free sterile glove; Perry Ortho = Ansell Perry Orthopaedic sterile glove; Sensi-Touch = Ansell Sensi-Touch latex, powdered sterile glove

selection criteria for glove preference among surgeons may be based on glove features (i.e., comfort with prolonged use) that anesthesia providers may not consider important. Finally, our study did not take into account the duration of glove use, as longer duration of wear has been shown to increase the rates of glove perforation.[19,20] Our study did not address the practice of double gloving, which also limits applicability to surgical specialties where this is commonplace.

Occupational latex allergy and latex-induced asthma is an occupational hazard for anesthesia providers, and once an individual is sensitized to latex, the only treatment is cessation of exposure.[3,21,22] In a cost analysis by Phillips *et al*.[21] comparing a latex-safe approach between a tertiary care facility, a community hospital, and an outpatient clinic, it was determined that all three types of healthcare facilities benefited financially from the use of latex-free gloves. Nevertheless, critics of the latex-free movement cite concerns over the cost, protective features, and touch sensitivity of latex-free gloves.[3,23] With latex-free gloves shown to have a higher perforation rate compared with latex gloves in some surgical specialties,[2,5] the benefits of a latex-free workplace are less clear, and the potential for glove perforation should be considered along with the risks of latex exposure. Based on our data, the lack of a difference in sensation between styles of latex and latex-free gloves suggests that sensory performance should *not* be used as a primary determinant in glove purchasing decisions. Institutions are therefore left to weigh institutional costs, provider comfort, and the risks and benefits of latex and latex-free environments when considering the impact of glove choices on health care providers and their patients.

In conclusion, this study identified no statistically significant differences in touch sensitivity or psychomotor performance among common commercially available types of sterile gloves. Significant differences in the MSRP exist between the available popular styles of sterile gloves. Future studies are needed to examine the correlation between psychomotor aptitude testing and clinical outcomes. These studies should also determine if other variables, such as duration of glove use and repetitive activities (such as surgical knot-tying), may impact provider performance in the setting of differing glove types. Based on the outcomes of these studies, institutions may have an opportunity to reduce health care costs associated with purchasing sterile gloves if a clinical correlation is identified.

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Appendix: Descriptions of standardized psychomotor assessments

1) Crawford Small Part Dexterity Test (CSPDT)[7]

   - Timed assembly of pins and sleeves using tweezers; reported in seconds. Shorter time equates with fine-motor dexterity and coordination. This test was used to predict dexterity and fine motor skills critical for invasive procedural performance, bare handed or with gloves.

2) Semmes-Weinstein Monofilament (SWM)[13]

   - Calibrated monofilament testing consists of 20 monofilaments labelled from 1.65 to 6.65 which relates to the logarithm of ten times the grams of force needed to bow the filament (higher numbers represent worse sensation). The smallest filament appreciated by the subject when applied to the pulp of the fingertip proximal joint without visualization is recorded for the first digit (radial nerve distribution), second digit (median nerve), and fifth digit (ulnar nerve distribution) of the dominant hand. Filament numbers 1.65 to 2.83 represent normal tactile sensation. This test was used to determine if tactile sensation differed while wearing gloves *vs* bare hand or while wearing non-sterile gloves *vs* sterile gloves.

3) Purdue Pegboard Test (PPT)[14]

   - Placement of small pegs into holes on a board (# pegs/30 sec interval). Higher number of pegs equates to dexterity, speed, and hand-eye coordination.

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