



## Review article

## Hand hygiene is linked to microbial keratitis and corneal inflammatory events



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## ABSTRACT

Lack of or inadequate hand washing is a risk factor in the development of contact lens related microbial keratitis and corneal inflammatory events. In the public health domain there is compelling evidence that proper hand washing with soap can save lives. The purpose of this review is to draw attention to some of the public health literature in support of hand washing and how education can influence patients' hand hygiene behavior. Contact lens wearers are also guilty of poor hand washing behavior but there is scant evidence that education of hand washing procedures of lens wearers alters patient non-compliance. It is well known that pathogenic microbial contamination of contact lenses, lens cases, care solutions and anterior ocular components have been found with contact lens wear. However while the originating source may be hands or water, it is most likely both of these. Besides proper hand washing this paper will include mitigating strategies for avoiding microbial contamination.

## 1. Introduction

Arguably, there are relatively few remaining major obstacles affecting the growth of contact lens use. These include end-of-day discomfort, visual compromise of the presbyopic contact lens wearer, and microbial keratitis (MK) and corneal inflammatory events (CIEs). Of these, prevention of MK and CIEs may be the easiest to impact, as several modifiable risk factors of these two conditions have been identified and they are often associated with poor compliance.

Modifiable risk factors are those that a wearer has some control over, as opposed to non-modifiable factors such as age and sex. The most commonly cited modifiable factors for MK and CIEs are extended wear [1–4], poor hygiene [1,3,5–8] and non-compliance. [6,7,9].

It is well established that microbes are essential etiological components of soft contact lens related MK and CIEs. Not coincidentally, the sources of the microbes that are isolated from contact lenses are purported to have originated from the lid margins, conjunctiva, hands, lens cases, care solutions and the water supply. [7,10–13] The conjunctiva and lid margin harbor normal or commensal microbes. When contact lenses are worn that are contaminated with a bioburden, (defined as the number and types of microorganisms contaminating an object such as a contact lens or ocular component e.g the conjunctiva), there is an associated increase in bioburden of the conjunctiva and lids. Bioburden can comprise of commensal and pathogenic microorganisms. The amount of bioburden differs for daily and extended wear, [14], but

Szczotka-Flynn has reported that some studies show an increase with contact lens wear whereas others do not [15]. More importantly, pathogenic organisms are associated with MK and CIEs, and it is reasonable to assume that if the lid margins, conjunctiva, tear film, the contact lens case, solutions and patients' hands are contaminated with these pathogens, the risk of developing MK and CIEs increases. An even more important question is whether patients' unwashed hands are a primary source (or not) of microbial contamination of the lid margins, conjunctiva, tear film, contact lenses, solutions and cases.

The purpose of this paper is to draw attention to poor hygiene associated with contact lens wear, and in particular how hand washing (or lack thereof) could affect the development of MK and CIEs in contact lens wearers.

## 1.1. Public Health concern of hand hygiene

This will not come as a surprise to eye care practitioners (and should serve as a useful reminder for their patients) that “hand washing halts the spread of infection and is effective in preventing the spread of some diseases”, according to the Global Burden of Disease Study 2015. [16] Proof of this dates back 150 years, when Ignaz Semmelweis published in 1861 that implementing a hand hygiene program amongst healthcare workers greatly reduced infections in newborns in a paper on the Etiology, Concept and Prophylaxis of Childbed Fever. Organizations such as the Global Handwashing Partnership (GHP) and the World

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Health Organisation (WHO) continue to espouse handwashing's benefits. The GHP is a coalition of national and international organizations committed to promoting handwashing with soap on a large scale. The GHP has proclaimed "handwashing with soap improves health and saves lives by preventing infections". The WHO has published a brochure on "Hand Hygiene: Why, How & When." [17] The message of the document is very clear: "Clean hands saves lives". The message is directed towards health care workers because "thousands of people die every day around the world from infections acquired while receiving health care" and "hands are the main pathways of germ transmission during health care". The brochure also provides information on how to clean hands (washing with soap and water or using alcohol based products) with excellent diagrams. Eye care practitioners would do well to incorporate these hand hygiene procedures in written instructions for their patients.

It appears that only about two thirds of people in the general population practice any sort of hand hygiene. Studies to determine the frequency of hand washing by the public after using the toilet or before food preparation are particularly difficult to interpret because they rely on subjective reporting by people who may be reluctant to confess their habits. However, a report was published in the UK Daily Mail in 2016 of a survey that was carried out in Europe on 100,000 people by a washroom services company. They found that 62% of men did not wash their hands after using the bathroom compared to 40% of women. In a 2003 study sponsored by the American Society of Microbiology conducted by Wirthlin Worldwide, 7541 people were observed using public washrooms at five American airports. This report found that 31% of males and 21% of females did not wash their hands after using the washrooms. [16] To illustrate the point made earlier, Wirthlin conducted a telephone survey of 1000 Americans in 2003 and 95% answered that they did wash their hands after using public washrooms, which is in stark contrast to the observational study. [18]

### 1.2. The relationship between hand hygiene education and behavior modification

Hand washing prevents the transmission of diseases such as pneumonia, diarrhoea and eye infections, and many researchers have studied the effects of education and other intervention strategies on modification of hand washing behavior. Hand hygiene promotion has been studied extensively, but the success of the procedures is questionable. Understandably, success of the process will vary significantly, but the primary outcome to be assessed is healthcare-associated infections as far as public health is concerned. For that reason, most of the research on hand washing has been conducted in association with healthcare facilities and/or through institutions. While it is of interest to study the frequency of hand washing in the general public, the dearth of information on the subject suggests that it is a difficult undertaking.

Many studies have shown that different types of intervention, including education and hand washing promotion, have had a positive effect on changing behavior and reducing infections. [19,20] Stebbins and Stark showed that students can learn and persist in positive handwashing behaviours. [21] Others found that hand hygiene compliance improved initially following education, but that hand washing compliance decreased over time. [22,23] Zolnierok and DiMatteo's meta analysis [24] found that physicians who were trained in communication resulted in significantly higher patient adherence to their advice, or conversely there is a higher risk of non-adherence by patients whose physicians communicate information poorly.

While the evidence above shows support for the impact that education has on hand hygiene behavior, there are a substantial number of papers that conclude that education has little or no effect. [25–27] A review of the handwashing behavior literature by Vindigni and colleagues in low to middle-income countries concluded that although the literature on handwashing studies is vast, none have been able to definitively document long-term behavior change. [28] Cherry and

colleagues also conducted a meta-analysis of 30 hand hygiene articles and concluded that multiple interventions were better than any single option and were required to sustain significant behavior change [29].

### 1.3. Hand washing behavior of contact lens wearers

Intuitively, contact lens wearers should be more compliant than non-wearers with regards to hand washing, as they have been instructed on lens care, insertion and removal procedures, which include the importance of hand hygiene. However, there is substantial evidence that many contact lens wearers are not compliant with hand washing procedures, up to 50% in some reports, [30–33] and this increases the risk of microbial contamination of contact lenses [34], which in turn may increase the risk of developing MK and CIEs [35–37].

A recent survey was conducted to evaluate the typical behavior of hand washing and/or drying as it relates to inserting contact lenses, and to assess beliefs about transferring bacteria to eyes during contact lens insertion [38]. This CooperVision-sponsored Internet survey was conducted by Decision Analyst, an independent market research service, from April 19–May 1, 2017. Self-described daily disposable (DD) contact lens wearers, 14 years or older and living in the U.S., were surveyed. The sample was drawn from Decision Analyst's American Consumer Opinion® panel and the agency's trusted partner panels. A total of 950 patients were surveyed (63% female and 37% male, average age 35 years). With respect to hand hygiene practices, 41% of DD contact lens wearers do not wash their hands with soap immediately before lens insertion, 15% rarely or never wash their hands or do so without soap, and 65% do not utilize a sanitary drying option after washing their hands. Eighty-eight per cent of those surveyed believe that bacteria on their fingers can transfer to their eyes during lens insertion, with 86% indicating the amounts of bacteria are 'A little' to 'some', and 7% indicating 'A lot'.

It has been proposed that employment of education strategies should improve hand-washing behavior, but there is little research to substantiate the claim. Yung's study did show an improvement in hand hygiene performance following a compliance enhancement strategy, [30] but Bui et al. concluded that education alone is not a sufficient strategy to improve behavior [39]. Claydon et al studied the effect of education on non-compliant behaviour in contact lens wear (but did not include handwashing as a variable) and found little effect from the compliance enhancement strategy. [40] Clearly more research is required to study handwashing behavior in contact lens wearers and the effect of education/reinforcement of handwashing frequency and procedures.

There is as yet no evidence of a cause (poor or no hand washing prior to handling/inserting contact lenses) and effect (MK and/or CIEs) relationship but there is unquestionable evidence of poor hand hygiene or absence of hand washing being a significant risk factor for developing MK or CIEs. [4,8,41] In the Stapleton et al study of DD contact lens wear, they found that 90% of the disease load was associated with wearers who failed to wash their hands [41] and the case control study by Lim et al in Singapore revealed that the risk of developing microbial keratitis was 13X higher for patients who did not wash their hands prior to handling lenses. [4] Poor hand hygiene (not always washing hands) was a significant risk factor for developing sterile keratitis in the case control study by Radford et al (an Odds Ratio of 1.9) [8]. Although statistically significant, this was not as strong an association as the studies mentioned above.

Handling is a microbial source of contamination of contact lenses and ensuring that patients' hands and fingers are sterile prior to lens handling is virtually impossible. However hand washing with soap is essential to minimize microbial contamination of hands [42] and resulting transfer of the contaminants on to contact lenses as discussed above and this also applies to the reduction of contamination of contact lens cases [43]. There are two papers that show contradictory results with hand washing. The first is by Mowrey-McKee [44] in a prospective

study that found there was a significantly higher microbial count on unworn handled lenses after hand washing compared to worn lenses following hand washing and lens handling. In both cases the patients washed their hands with water and soap, rinsed with tap water and dried their hands with a paper towel. This study did not compare the microbial count on lenses following handling of unwashed hands. The second had 47 patients perform different hand washing procedures and they found that hand washing with water, or soap and water, or soap and water and towel drying did not reduce microbial contaminants after lens handling compared to not washing hands [45]. A possible explanation is that hand washing may release the microbial contaminants from finger nails and hand palms that might then lodge on the lenses when handled. Despite this result, these authors still recommend hand washing with soap and water for removal of more pathogenic organisms.

Noncompliance is a term commonly used in association with contact lens wear to denote that some 50% of patients may be disregarding or neglecting to wash their hands properly whenever they use their lenses despite the instructions and education provided by their eye care practitioner. The consequences might be as drastic as MK. Unfortunately the contact lens literature on the effects of education of proper hand washing is at best scant.

The consequences of neglecting ones' health that may include smoking or obesity (as examples) may have much more dramatic consequences. These examples cannot be used analogously with hand washing behavior, as they may be addictive traits. However, it does illustrate the point of public education being somewhat less than effective, or that some people simply disregard the public health messaging. The NCD Risk Factor Collaboration found that the prevalence of obesity in 200 countries has increased substantially between 1975 and 2014; approximately 7.6% in men and 8.5% in women and the prevalence of severe obesity is also increasing [46].

Similar health hazards exist for smoking. Although the prevalence of smoking tobacco has declined in Europe over the past few decades [47], the WHO has recorded that Europe has the highest prevalence of tobacco smoking of adults (28%) in WHO regions [48]. This is despite the efforts of tobacco control policies [49], health warning and public information.

#### 1.4. Mitigating strategies of microbial contamination

If hand contact is the originating vector causing microbes to attach to lenses, cases, eyelids and the ocular surface then careful hand-washing should greatly minimize the transfer, but other strategies should be developed to prevent and combat the presence of microbial contamination. Despite the contradictions mentioned above, careful and thorough hand washing with soap and water followed by hand drying with unused paper towel should be recommended for contact lens wearers as this method has been adopted with success in reducing and preventing the spread of disease (as described by the GHP the WHO above). Unfortunately the little research that has been done on the effects of education on patients' hand washing behavior that wear contact lenses is equivocal but repeated reinforcement of hand washing instructions on an individual basis is common sense.

The use of DD lenses is a very good method to minimize repeated hand/lens interactions, which reduces contamination of the lens by disposing of the lens after each wearing period. An important indirect effect of DD lenses is that lens storage cases, a known source of microbial contamination, [10,12,50] should be eliminated unless patients are non-compliant by reusing their DD lenses and storing them in these cases [51] or elsewhere.

It is well established that soft lenses hardly move on the eye during blinking, resulting in very little tear exchange under the lens during daily wear. If microbes are entrapped in the thin post-lens tear layer [52] or attached to the post-lens surface the risk of adverse responses increases. By eliminating finger contact with the post-lens surface the

risk of contamination should be greatly reduced. Now there is evidence to support that statement. Nomachi et al. [53] described a study in which they evaluated the microbial contamination of handling a DD contact lens removed from a novel "flat pack" designed storage case. The flat pack storage container is approximately 1 mm thick and the lens is stored with its front surface "up" so that when the lens is removed from the case prior to insertion, only the front surface of the lens is touched thus protecting the posterior surface of the contact lens from contamination. The results of the study showed that the DD lens from the "flat pack" had diminished microbial contamination compared to four other DD lenses that were studied after removal from conventional blister pack containers.

All contact lenses in blister packs are sterile but the problem is that sterility is lost if the patient handles the lens with microbial-contaminated fingers and/or hands prior to insertion. Although it is not commonly advocated, the patient could rub and rinse the lens with a disinfecting solution after removal from the blister-pack, thus diminishing or eliminating microbial contamination prior to placing the lens on the eye. However, this lessens the attraction of a DD lens that is intended to be free of auxiliary solutions and storage cases and adds an unnecessary cost element. An alternative strategy would be to include a disinfecting component into the blister pack solution to combat the potential microbes from contaminated fingers. George et al. [54] have done that and in a controlled experiment found that a packaging solution containing e-poly-L-lysine (e-PL - a natural, biologically derived compound) was effective in reducing bacterial lens contamination from handling compared to a blister pack solution without the e-PL additive. This solution also did not appear to affect biocompatibility.

Other strategies such as using sterile disposable gloves or alcohol wipes to disinfect fingers prior to lens handling are sensible procedures, which by all accounts are not very commonly used practices. It is timely for a study to be conducted on contact lens wearers to determine if repeated hand hygiene education impacts the microbial load on fingers and hands prior to lens insertion and before lens removal from the eye.

#### Declaration of interest

Desmond Fonn: Consultant to CooperVision Inc. and the Centre for Ocular Research and Education, University of Waterloo.

Lyndon Jones: Consultant to and serves on the advisory boards of Alcon, CooperVision, J&J Vision, Novartis and Optecs.

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#### References

- [1] O.D. Schein, R.J. Glynn, E.C. Poggio, J.M. Seddon, K.R. Kenyon, The relative risk of ulcerative keratitis among users of daily wear and extended-wear soft contact lenses, *N Engl J Med* 321 (1989) 773–778.
- [2] J.K.G. Dart, F. Stapleton, D. Minassian, Contact lenses and other risk factors in microbial keratitis, *Lancet* 338 (1991) 650–654.
- [3] D.S.C. Lam, E. Houang, D.S. Fan, Seal D. LyonD, E. Wong, Incidence and risk factors for microbial keratitis in Hong Kong: comparison with Europe and North America, *Eye* 16 (2002) 608–618.
- [4] C.H. Lim, N.A. Carnt, M. Farook, J. Lam, D.T. Tan, J.S. Mehta, et al., Risk factors for contact lens-related microbial keratitis in Singapore, *Eye (Lond.)* 30 (2016) 447–455.
- [5] J.K.G. Dart, C.F. Radford, D. Minassian, S. Verma, F. Stapleton, Risk factors for microbial keratitis with contemporary contact lenses: a case-control study, *Ophthalmology* 115 (2008) 1647–1654.
- [6] A. Sauer, N. Meyer, T. Bourcier, French Study Group for Contact Lens-related microbial keratitis. Risk factors for contact lens-related microbial keratitis: a case-control multicenter, *Eye Contact Lens* 42 (2016) 158–162.
- [7] F. Stapleton, K. Edwards, L. Keay, T. Naduvilath, J.K. Dart, G. Brian, et al., Risk

- factors for moderate and severe microbial keratitis in daily wear contact lens users, *Ophthalmology* 119 (2012) 1516–1521.
- [8] C.F. Radford, D. Minassian, J.K. Dart, F. Stapleton, S. Verma, Risk factors for nonulcerative contact lens complications in an ophthalmic accident and emergency department: a case-control study, *Ophthalmology* 116 (2009) 385–392.
- [9] K. Richdale, D. Lam, H. Wagner, A.B. Zimmerman, B.T. Kinoshita, R. Chalmers, et al., Case-control pilot study of soft contact lens wearers with corneal infiltrative events and healthy controls, *Invest Ophthalmol Vis Sci* 57 (2016) 47–55.
- [10] L.B. Szczotka-Flynn, E. Pearlman, M. Ghannoum, Microbial contamination of contact lenses, lens care solutions, and their accessories: a literature review, *Eye Contact Lens* 36 (2010) 116–129.
- [11] Y. Jiang, M. Jacobs, S. Bajaksouzian, A.N. Foster, S.M. Debanne, R. Bielefeld, et al., Risk factors for microbial bioburden during daily wear of silicone hydrogel contact lenses, *Eye Contact Lens* 40 (2014) 148–156.
- [12] Y.T. Wu, M. Willcox, H. Zhu, F. Stapleton, Contact lens hygiene compliance and lens case contamination: a review, *Cont Lens Anterior Eye* 38 (2015) 307–316.
- [13] C.F. Radford, D.C. Minassian, Dart JK Acanthamoeba keratitis in England and Wales: incidence, outcome, and risk factors, *Br J Ophthalmol* 86 (2002) 536–542.
- [14] F. Stapleton, M.D. Willcox, C.M. Fleming, S. Hickson, D.F. Sweeney, B.A. Holden, Changes to the ocular biota with time in extended and daily-wear disposable contact lens use, *Infect Immun* 63 (1995) 4501–4505.
- [15] L.B. Szczotka-Flynn, S. Bajaksouzian, M.R. Jacobs, A. Rimm, Risk factors for contact lens bacterial contamination during continuous wear, *Optom Vis Sci* 86 (2009) 1216–1226.
- [16] <http://globalhandwashing.org/wp-content/uploads/2017/03/The-State-of-Handwashing-in-2016>. (Accessed 17 April 2017).
- [17] [http://who.int/gpsc/5may/Hand\\_Hygiene\\_Why\\_How\\_and\\_When\\_Brochure.pdf](http://who.int/gpsc/5may/Hand_Hygiene_Why_How_and_When_Brochure.pdf). (Accessed 17 April 2017).
- [18] <https://www.sciencedaily.com/releases/2003/09/030916074111.htm> (Accessed 16 May 2017).
- [19] C. O'Reilly, M.C. Freeman, M. Ravani, J. Migele, A. Mwaki, M. Ayalo, et al., The impact of a school-based safe water and hygiene programme on knowledge and practices of students and their parents: Nyanza Province, western Kenya, *Epidemiol Infect* 2008 (136) (2006) 80–91.
- [20] R.I. Ejemot-Nwadiaro, J.E. Ehiri, D. Arikpo, M.M. Meremikwu, J.A. Critchley, Hand washing promotion for preventing diarrhoea, *Cochrane Database Syst Rev* 9 (2015) CD004265.
- [21] S. Stebbins, J.H. Stark, Compliance with a multilayered nonpharmaceutical intervention in an urban elementary school setting, *J Public Health Manag Pract* 16 (2010) 316–324.
- [22] M. McGuckin, A. Taylor, V. Martin, L. Porten, R. Salcido, Evaluation of a patient education model for increasing hand hygiene compliance in an inpatient rehabilitation unit, *Am J Infect Control* 32 (2004) 235–238.
- [23] P.M. Dubbert, J. Dolce, W. Richter, M. Miller, S.W. Chapman, Increasing ICU staff handwashing: effects of education and group feedback, *Infect Control Hosp Epidemiol* 11 (1990) 191–193.
- [24] K.B. Zolnieriek, M.R. Dimatteo, Physician communication and patient adherence to treatment: a meta-analysis, *Med Care* 47 (2009) 826–834.
- [25] T.M.N. Huda, L. Unicomb, R.B. Johnston, A.L. Halder, et al., Interim evaluation of a large scale sanitation, hygiene and water improvement programme on childhood diarrhoea and respiratory disease in rural Bangladesh, *Soc Sci Med* 75 (2012) 604–611.
- [26] B.P. Loevinsohn, Health education interventions in developing countries: a methodological review of published articles, *Int J Epidemiol* 19 (1990) 788–794.
- [27] A. Biran, W.P. Schmidt, R. Wright, T. Jones, M. Seshadri, P. Isaac, et al., The effect of a soap promotion and hygiene education campaign on handwashing behaviour in rural India: a cluster randomised trial, *Trop Med Int Health* 14 (2009) 1303–1314.
- [28] S.M. Vindigni, P.L. Riley, M. Jung, Systematic review: handwashing behaviour in low- to middle-income countries: outcome measures and behavior maintenance, *Trop Med Int Health* 16 (2011) 466–477.
- [29] M.G. Cherry, J.M. Brown, G.S. Bethell, T. Neal, N.J. Shaw, Features of educational interventions that lead to compliance with hand hygiene in healthcare professionals within a hospital care setting. A BEME systematic review: BEME Guide No. 22, *Med Teach* 34 (2012) e406–20.
- [30] A.M. Yung, M.V. Boost, P. Cho, M. Yao, The effect of a compliance enhancement strategy (self-review) on the level of lens care compliance and contamination of contact lenses and lens care accessories, *Clin Exp Optom* 90 (2007) 190–202.
- [31] C.F. Radford, E.G. Woodward, F. Stapleton, Contact lens hygiene compliance in a University population, *J Br Contact Lens Assoc* 16 (1993) 105–111.
- [32] P.B. Morgan, N. Efron, H. Toshida, J.J. Nichols, An international analysis of contact lens compliance, *Cont Lens Anterior Eye* 34 (2011) 223–228.
- [33] J.L. Sokol, M.G. Mier, S. Bloom, P.A. Asbell, A study of patient compliance in a contact lens wearing population, *CLAO J* 16 (1990) 209–213.
- [34] C. Lakkis, F. Anastasopoulos, C. Terry, R. Borazjani, Time course of the development of contact lens case and contact lens contamination, *Invest Ophthalmol Vis Sci* 50 (2009) 6352 e-abstract.
- [35] S. Das, H. Sheorey, H.R. Taylor, R.B. Vajpayee, Association between cultures of contact lens and corneal scraping in contact lens related microbial keratitis, *Arch Ophthalmol* 125 (2007) 1182–1185.
- [36] B.A. Holden, D. La Hood, T. Grant, J. Newton-Howes, C. Baleriola-Lucas, et al., Gram-negative bacteria can induce contact lens related acute red eye (CLARE) responses, *CLAO J* 22 (1996) 47–52.
- [37] P.R. Sankaridurg, S. Sharma, M. Willcox, T.J. Naduvilath, D.F. Sweeney, B.A. Holden, et al., Bacterial colonization of disposable soft contact lenses is greater during corneal infiltrative events than during asymptomatic extended lens wear, *J Clin Microbiol* 38 (2000) 4420–4424.
- [38] G. Osborn, D. Fonn, A. Zucaro, Hand washing behavior of 1-Day contact lens wearers, *Optom Vis Sci* 94 (2017) E-abstract 175345.
- [39] T.H. Bui, H.D. Cavanagh, D.M. Robertson, Patient compliance during contact lens wear: perceptions, awareness, and behavior, *Eye Contact Lens* 36 (2010) 334–339.
- [40] B.E. Claydon, N. Efron, C. Woods, A prospective study of the effect of education on non-compliant behaviour in contact lens wear, *Ophthalmic Physiol Opt* 17 (1997) 137–146.
- [41] F. Stapleton, T. Naduvilath, L. Keay, C. Radford, J. Dart, K. Edwards, et al., Risk factors and causative organisms in microbial keratitis in daily disposable contact lens wear, *PLoS One* 12 (2017) e0181343.
- [42] D. Pittet, S. Dharan, S. Touveneau, S. Touveneau, V. Sauvan, Bacterial contamination of the hands of hospital staff during routine patient care, *Arch Intern Med* 159 (1999) 821–826.
- [43] Y.T. Wu, M.D.P. Willcox, F. Stapleton, The effect of contact lens hygiene behavior on lens case contamination, *Optom Vis Sci* 92 (2015) 167–174.
- [44] M.F. Mowrey-McKee, H.J. Sampson, H.M. Proskin, Microbial contamination of hydrophilic contact lenses. Part II: quantitation of microbes after patient handling and after aseptic removal from the eye, *CLAO J* 18 (1992) 240–244.
- [45] V.T. Ly, P.A. Simmons, T.B. Edrington, S. Wechsler, P.N. De Land, Efficacy of hand washing procedures on bacterial contamination of hydrogel contact lenses, *Optom Vis Sci* 74 (1997) 288–292.
- [46] NCD Risk Factor Collaboration (NCD-RisC), Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19.2 million participants, *Lancet* 387 (2016) 1377–1396.
- [47] S. Hill, A. Amos, D. Clifford, S. Platt, Impact of tobacco control interventions on socioeconomic inequalities in smoking: review of the evidence, *Tob Control* 23 (2014) e89–e97.
- [48] World Health Organization, Tobacco. Data and statistics, (2017) (Accessed 22 Oct 2018), <http://www.euro.who.int/en/health-topics/disease-prevention/tobacco/data-and-statistics>.
- [49] L. Joossens, M. Raw, The Tobacco Control Scale: a new scale to measure country activity, *Tob Control* 15 (2006) 247–253.
- [50] Y. Ogushi, H. Eguchi, T. Kuwahara, N. Hayabuchi, M. Kawabuti, Molecular genetic investigations of contaminated contact lens storage cases as reservoirs of *Pseudomonas aeruginosa* keratitis, *Jpn J Ophthalmol* 54 (2010) 550–554.
- [51] M. Boost, K.C. Poon, P. Cho, Contamination risk of reusing daily disposable contact lenses, *Optom Vis Sci* 88 (2011) 1409–1413.
- [52] N. Pritchard, D. Fonn, Postlens tear debris during extended wear of hydrogels, *Can J Optom* 60 (1998) 87–91.
- [53] M. Nomachi, K. Sakanishi, H. Ichijima, H.D. Cavanagh, Evaluation of diminished microbial contamination in handling of a novel daily disposable flat pack contact lens, *Eye Contact Lens* 39 (2013) 2354–2358.
- [54] M. George, I. Maltseva, K. Khong, Efficacy, biocompatibility, and clinical performance of a novel contact lens packaging solution additive designed to reduce handling-related bacterial contamination, *Contact Lens Anterior Eye* 41 (June) (2018) S55.