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Modelling ready-made spectacle coverage for children and adults using a large global database

Ving Fai Chan ,[1] David M Wright ,[1] Sonia Mavi ,[1] Reshma Dabideen,[2] Mike Smith,[2] Alan Sherif,[3] Nathan Congdon [1,4]

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[1]Centre for Public Health, Queen's University Belfast, Belfast, UK
[2]Onesight Research Foundation, Mason, Ohio, USA
[3]University of Lausanne Faculty of Biology and Medicine, Lausanne, Switzerland
[4]ORBIS International, New York, New York, USA

Correspondence to
Ms Reshma Dabideen, Onesight Research Foundation, Mason, Ohio, USA;
reshma.dabideen@gmail.com

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ABSTRACT

Background/aims To model the suitability of conventional ready-made spectacles (RMS) and interchangeable-lens ready-made spectacles (IRMS) with reference to prescribing guidelines among children and adults using a large, global database and to introduce a web-based application for exploring the database with user-defined eligibility criteria.

Methods Using refractive power and interpupillary distance data for near and distance spectacles prescribed to children and adults during OneSight clinics in 27 countries, from 2 January 2016 to 19 November 2019, we modelled the expected suitability of RMS and IRMS spectacle designs, compared with custom-made spectacles, according to published prescribing guidelines.

Results Records of 18 782 presbyopic adult prescriptions, 70 619 distance adult prescriptions and 40 862 paediatric prescriptions were included. Globally, 58.7%–63.9% of adults could be corrected at distance with RMS, depending on the prescribing cut-off. For presbyopic adult prescriptions, coverage was 44.1%–60.9%. Among children, 51.8% were eligible for conventional RMS. Coverage for all groups was similar to the above for IRMS. The most common reason for ineligibility for RMS in all service groups was astigmatism, responsible for 27.2% of all ineligible adult distance prescriptions using the strictest cut-off, 31.4% of children's prescriptions and 28.0% of all adults near prescriptions globally.

Conclusion Despite their advantages in cost and convenience, coverage delivered by RMS is limited under current prescribing guidelines, particularly for children and presbyopic adults. Interchangeable designs do little to remediate this, despite extending coverage for anisometropia. Our free application allows users to estimate RMS coverage in specific target populations.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Ready-made spectacles (RMS) are inexpensive and easy to dispense. They have the potential to correct refractive errors with similar short-term advantages to custom-made spectacles in populations in resource-constrained settings.

WHAT THIS STUDY ADDS

⇒ According to the existing prescribing guidelines, RMS has limited coverage for children and presbyopic adults with astigmatism remains the major barrier. Using the available global database, a free application (https://david-m-wright.shinyapps.io/Onesight/) is subsequently developed to estimate RMS coverage in specific target populations.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ An appropriate combination of RMS and custom-made spectacles (CMS) is still needed to meet the refractive needs of communities, and the new application allows users to determine an effective combination for programme planning.

INTRODUCTION

In 2020, over a billion persons had uncorrected near or distance refractive errors (URE),[1] making this the most common cause of vision impairment in children and adults across all regions.[1] Furthermore, substantial evidence has shown that URE impacts negatively on children's academic performance,[2] social participation,[3] self-esteem,[4] quality of life and can cause significant distress.[5] This extends far into adulthood in terms of future lost educational and employment opportunities,[6] pushing vulnerable individuals and families further into poverty and social exclusion.[7] In adults, URE increases the likelihood of road traffic accidents,[8] and cognitive impairment.[9]

The lack of refractive services and spectacle provision in underserved communities can profoundly impact individuals and their families and have implications for national economies and the attainment of the Sustainable Development Goals.[10] In 2015, uncorrected myopia was estimated to cause US$244 billion of potential lost productivity worldwide.[6] Moreover, there is increasing recognition that presbyopia significantly adds to the burden of lost global productivity (estimated potential losses of US$25.367 billion or 0.037% of global gross dometic product).[11] Reddy *et al*[12] further found that providing optimal near-vision correction significantly increased work productivity (21.7%) among tea pickers in the 2018 PROSPER trial. Even though refractive errors can be safely and inexpensively treated with spectacles, many potential beneficiaries remain uncorrected due to barriers associated with cost,[13] the lack of 'felt need' for refractive correction,[14] poor access,[14] inadequately equipped health facilities[15] and negative attitudes towards spectacle wear.[16]

Traditionally, custom-made spectacles (CMS) are used to provide full refractive correction, including astigmatism and anisometropia. However, these may be more expensive and are cut and fit at

optical laboratories and hence cannot be dispensed on the spot.[17] Given these issues and the great burden of unmet refractive needs, ready-made spectacles (RMS) can be a cost-effective alternative.[18] However, RMS cannot correct astigmatism and anisometropia because they are only available in fixed lenses with the same spherical power for both eyes. These shortcomings led to the development of interchangeable-lens ready-made spectacles (IRMS), where lenses of different spherical powers can be clipped into each side of the spectacle frame, allowing correction of anisometropia. Both RMS and IRMS are cosmetically acceptable in many settings, low cost, durable, of good optical quality and consistent with on-the-spot dispensing, making them useful in increasing spectacle access in low-resource settings. Zeng *et al*[19] reported that 80% of secondary school children without significant astigmatism and anisometropia could be corrected with RMS in China.

Currently, there are no standardised, evidence-based protocols for prescribing RMS to children and adults. An appropriate combination of RMS, IRMS and CMS can contribute to meeting the refractive needs of communities. However, the challenge for programme planners is to know what proportion of children and adults can be adequately serviced with low-cost RMS or IRMS in different settings, as this is crucial for accurate budgeting. In the current paper, we model the expected suitability of RMS and different types of IRMS among children and adults for distance and near vision correction against published prescription guidelines using a global patient database covering five WHO regions. We also introduce a web-based application designed to assist users in interrogating the database for planning in specific target populations.

MATERIALS AND METHODS

Data were obtained initially to deliver service in a no-cost spectacle programme carried out by a non-governmental organisation, OneSight. All data were deidentified for the analysis of this study.

The original dataset consisted of electronic patient records collected from 184 OneSight programme clinics worldwide between 2 January 2016 and 19 November 2019. OneSight delivers refractive services to children and adults using two distinct models. The first of these ('sustainable clinic') occurs within the context of a permanent clinic, run with local partners in a health district or community setting, while the second ('charity clinic') involves one-off, free refraction clinics carried out by overseas volunteer providers together with local collaborators. All participants were assigned a unique ID number that was used at each visit. For purposes of this analysis, if a participant had multiple visits, data from the last visit was included. Data collected in both models and analysed in the current study included age (year of birth), country, interpupillary distance (IPD), spherical and cylindrical power for both eyes at near (if relevant) and distance. Participant gender was not routinely collected in all clinics and is not included in the database.

Inclusion criteria were as follows: the availability of complete patient records for children (aged 5–18 years) and adults (>18 years) receiving refractive services through OneSight at either charity or sustainable clinics. After the exclusion of records with missing data, the remaining participants were drawn from 166 clinics.

Statistical methods

We calculated the measures of astigmatism, spherical equivalent, anisometropia and decentration and classified each individual for eligibility for CMS (as a reference) and each of the four types of RMS as follows: conventional, interchangeable-lens without adjustable IPD, interchangeable-lens with adjustable IPD, interchangeable-lens without adjustable IPD. The CMS group used any value for the spherical equivalent, astigmatism and a cut-off for anisometropia (≤1.75D). The optical centre distance would be matched to the patient's record. RMS and IRMS are available in 0.50D steps from −6.00D to+6.00D. For the conventional RMS group, the frame size ranged between 64 mm and 73 mm (in 1 mm steps). For IRMS without the adjustable IPD, frames were available in 63 mm, 69 mm and 70 mm. For the IRMS with the adjustable IPD, frames were available in 66 mm, 69 mm, 72 mm and 75 mm. Interchangeable lens with a limited range of powers (0.00D to −4.50D in 1.50 steps and 0.00D to +2.50D in 1.25 steps) were available in 58.7 mm, 60.9 mm, 63.1 mm, 65.3 mm and 67.5 mm. The IRMSs have adjustable nose pads and temples, whereas RMSs are not (online supplemental figure 1).

As a modelling exercise, our analysis was not designed around any particular existing commercial spectacle product, but all of the above RMS types are currently available on the marketplace in 2021. Using the number of participants eligible for CMS as the denominator, we modelled eligibility for distance vision spectacles among children and adults and near vision spectacles among adults. Normalising eligibility figures in this way relative to CMS, we sought to eliminate persons from consideration whose vision needs could not be met with any conventional spectacles (such as those with keratoconus or very high anisometropia requiring contact lens correction). We conducted all analyses in R V.4.0.3 (R Foundation for Statistical Computing, Vienna, Austria).[20]

Our analytical model of eligibility for various types of correction was based on published prescription guidelines[21–31] for distance and near correction for children and adults. For adult distance prescriptions, we modelled both 'stricter' and 'looser' cut-offs for both astigmatism ('strict': ≤0.50D[27] and 'loose': ≤ 1.00D[29]) and anisometropia ('strict': <0.50D[29] and 'loose': <1.00D[28]). We modelled eligibility for IRMS using 'stricter' (≤ 0.50D[27]) and 'looser' (≤1.00D[29]) cut-offs for astigmatism and used an anisometropia cut-off of ≤1.75D.[30]

For adult near vision prescriptions, cut-offs were as follows: astigmatism ≤0.50D for RMS and IRMS,[27] anisometropia (for RMS: <1.00D[28] and IRMS: ≤1.75D[30]) and spherical addition ≤ +2.50D.[24] For children's prescriptions, cut-offs included spherical equivalent refractive errors ≤ ±6.00D (based on the availability of powers for RMS and IRMS, rather than prescription guidelines), astigmatism ≤0.75D,[21–23] and anisometropia for RMS ≤1.00D[21] and IRMS ≤1.75D[21 25 26] (figure 1). We modelled a cut-off for decentration in adult and children's distance and near prescriptions as ≤1.0 prism dioptre by subtracting the patient's IPD from the optical centre distance of the available RMS.

Estimates were based on country-level data for this analysis, and regional estimates were generated by grouping countries into five regions according to the WHO classification.[32]

RESULTS

General characteristics

We reviewed 111 481 records with complete data. Of the 70 619 (63.3%) adults, 18 782 (26.6%) were presbyopic adults (median age 56 years, IQR 49–62 years) receiving near/bifocal prescriptions and 51 837 (73.4%) were non-presbyopic adults (median age 47 years, IQR 34–58 years) receiving only distance prescriptions. The remaining data were from 40 862 (36.7%) children

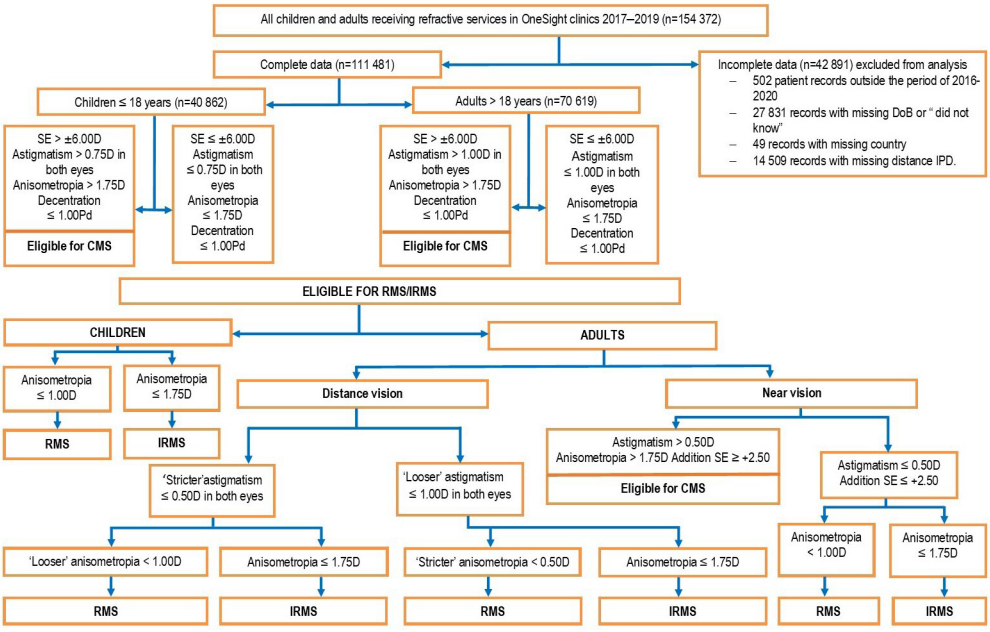

Figure 1 Analysis flow chart showing modelled eligibility for different distance and near vision corrective devices following available prescribing protocols. CMS,Custom-made spectacles; DoB, Date of Birth; D,Dioptress; RMS,Ready-made spectacles; IRMS, Interchangable-lens ready-made spectacles; SE, Spherical Equivalent; IPD, Inter-pupillary-distance.

(median age 11 years IQR 9–14 years). The Americas (n=51 693, 46.4%) had the greatest number of participants, followed by the African region (n=45 842, 41.1%) (online supplemental table 1.1).

Age and refractive characteristics of the study population, stratified by country and WHO region.

Modelling RMS coverage for children

The modelling for the 40 862 child participants with complete data shows that IRMS without adjustable IPD reached a global coverage of 54.3% (n=21 453) children suitable for correction, with the highest coverage reported in the African region (n=5673, 83.6%) and the lowest in the Americas (n=14 121, 47.3%). Conventional RMS and IRMS with adjustable IPD, however, could correct 20 465 (51.8%) and 20 175 (51.0%) children, respectively. IRMS without adjustable IPD and limited power could only correct 11 406 (28.9%) (online supplemental table 1.2).

The proportion of children eligible for distance vision services in various geographical settings using different corrective devices under recommended guidelines (n=40 862).

Modelling RMS coverage for distance correction in adults

IRMS without adjustable IPD (n=51 847, 76.2%) achieved the highest global coverage for adult distance prescriptions when a looser astigmatism guideline was applied, and this figure was similar across all regions. The conventional RMS 'looser astigmatism/stricter anisometropia' guideline achieved 63.9% coverage (n=43 443), while the IRMS without adjustable IPD with limited power 'stricter astigmatism' guideline has the lowest coverage (n=30 916, 45.4%) (online supplemental table 1.3).

The proportion of adults eligible for distance vision services in various geographical settings using different corrective devices under varying recommended guidelines (n=70 619).

Modelling RMS coverage for near correction in adults

Of the 18 782 adults requiring near vision correction, global coverage was highest for IRMS without adjustable near-IPD compared with IRMS with adjustable near-IPD and IRMS without adjustable near-IPD with limited powers—60.9% (n=11 022), 57.0% (n=10 314) and 44.1% (n=7977), respectively. Conventional RMS was able to correct 57.7% (n=10 445) of these adults. Adults from the African region reported the highest rates of coverage for near correction with RMS/IRMS of any geographical region, ranging from 54.2% (n=5773) to 68.2% (n=7259). Adults from the Americas region reported the lowest rates of coverage for near correction with RMS/IRMS, ranging from 19.2% (n=783) to 40.9% (n=1672).

The most common reason for ineligibility for RMS in all service groups was astigmatism, responsible for 27.2% of all ineligible adult distance prescriptions using the strictest cut-off, 31.4% of children's prescriptions and 28.0% of all adults near prescriptions globally. Using the same criteria, anisometropia was responsible for 2.4% of all ineligible adult distance prescriptions, 2.0% of children's prescriptions and 3.1% of all adults near prescriptions globally. The same reason for ineligibility was also observed for IRMS in all service groups. Among the different types of IRMS, a larger number of prescriptions were ineligible for IRMS without adjustable IPD, responsible for 31.2% of adult distance prescriptions using the strictest cut-off, 35.1% of children's prescriptions and 32.6% of all adults near prescriptions globally.

Rates of coverage varied substantially at country level within the same region. For example, Guatemala had the highest number (94.4%) of eligible adults within the Americas region, while 0%–27.3% of the adults in Paraguay met the eligibility criteria for near correction with RMS/IRMS (online supplemental table 1.4).

The proportion of adults eligible for near vision services in various geographical settings using different corrective devices under recommended guidelines (n=18 782).

DISCUSSION

Our model explored the potential spectacle suitability of CMS, RMS and IRMS in correcting refractive error in various age groups and populations, according to several published guidelines. Approximately 46.5% of children and 61.3% of adults requiring distance prescriptions, and 54.9% of adults requiring near prescriptions can be corrected with RMS/IRMS (online supplemental table 1.2,1.3 and 1.4). However, the suitability of RMS in meeting refractive needs varied considerably across and within all five regions.

RMS/IRMS coverage was significantly higher in the Africa region for children (range 54.5%–83.6%, depending on spectacle type), adults at distance (range 50.3%–84.7%) and adults at near (range 54.2%–68.2%). Children and adults in the Americas region exhibited the lowest coverage for distance and near RMS/IRMS, suggesting that participants in these regions might have a greater predisposition to astigmatism than their counterparts. A meta-analysis previously reported the prevalence of astigmatism (≥0.50D) to be the highest in the Americas among all six WHO regions, for all ages.[33]

The most common reason for ineligibility for RMS for distance prescriptions among both adults and children was astigmatism. A consequence was that suitability expanded by 5.2% among adults with distance prescriptions when cut-offs for astigmatism were relaxed from <0.50D to ≤1.00D, while those for anisometropia were tightened from <1.00D to <0.50D. This finding is similar to the study by Zhu *et al*[34] that reported increasing the value of astigmatism (increased from ≤0.75D to ≤1.25D) and anisometropia (≤ 0.50D to ≤1.50D), the percentage of Chinese schoolchildren eligible for RMS ranged from 85.8% to 87.4%.

Another consequence of the greater relative importance of astigmatism as opposed to anisometropia in limiting eligibility for RMS was the relatively modest additional coverage benefits of IRMS systems, with interchangeable lenses allowing for the management of anisometropia. This limited additional benefit was visible across all ages and geographical regions. For example, RMS coverage increased by 3.2% for adults at near, by 0.5%–2.6% for adults at distance and by 2.5% for children (depending on spectacle type) using RMS when the anisometropia threshold expanded from 1.00D to 1.75D.

Even with interchangeable lenses, less than two-thirds of adults with near vision impairment (NVI) could be corrected with RMS. This was due to multiple factors, including the significant prismatic effects caused by the large difference between RMS frames and participants' IPDs. Further modelling of RMS/IRMS coverage for NVI based on published guidelines excluded participants with increased accommodative needs requiring high-powered RMS (> +2.50D) and those with astigmatism exceeding >0.50D. Given recent research underscoring the substantial economic impact of near vision glasses for adults,[12] the quite limited coverage of RMS for near vision correction, when prescribing guidelines are followed, is of importance to programme designers.

One unexpected finding is that more adults and children could be corrected with the non-adjustable IPD IRMS than the adjustable models under some cut-offs. A majority of children and adults in this database had an IPD of <63 mm, more closely matching the RMS models with a fixed IPD of 63 mm, compared with the RMS with an adjustable IPD, the range of which fell above 66 mm. Our data suggest that adjusting the range of available IPDs downward might improve the suitability of these adjustable-IPD models.

This is consistent with the results of trials that have used a lower range of IPDs, which report a higher percentage of children eligible for correction with RMS. Morjaria *et al*[35] reported 86.0% (n=460/535) of children in a school-based refractive programme in India were eligible for RMS with IPDs ranging from 54 to 62 mm, while Wang *et al*[25] reported 82.3% of school children in rural China were eligible for RMS with IPDs in the range of 50–65 mm.

In order to maximise access to and usability of the continually expanding OneSight refraction service database, we created a freely downloadable Android application (https://david-m-wright.shinyapps.io/Onesight/), which allows users to define their spectacle eligibility thresholds and estimate the proportion of individuals meeting these thresholds.

Cohorts of interest can be defined in terms of country, age range and distance or near vision prescription. Criteria related to astigmatism, anisometropia, spherical equivalent, decentration (via frame sizes) and spherical powers available can be defined. Downloadable reports include the overall proportion of individuals eligible and the distribution of individuals by the specific criteria met. In this way, users can identify those criteria that render the largest proportion of individuals ineligible and estimate the numbers and specifications of spectacles likely to be required to meet needs in defined populations.

The participants in these clinics and programmes may or may not be representative of the larger population. However, in the absence of a comprehensive database for estimating the percentage of beneficiaries eligible for RMS, our analysis provides important information from a large real-world population.

Strengths and limitations of the study

The strength of this analysis is that we have used a large global dataset from an eyecare programme that spans five global regions to model eligibility for different RMS types using published prescribing guidelines among children and adults at a country and regional level. However, limitations remain.

Most significantly, the dataset does not include sex-disaggregated data, making it impossible to model potential coverage by sex for both adults and children. Sex-disaggregated analysis can provide meaningful insight into the optimal delivery of equitable refractive care services to address the possible need disparities. In addition, though the dataset is large and broad, country-level estimates are likely unstable in many cases due to small numbers. It is envisaged that the latter issue will be ameliorated over time as additional data are included in the database. Our application will allow users to benefit from improved accuracy of local estimates over time.

CONCLUSIONS

This report uses data from an existing and constantly growing international database to provide regional and country-level estimates for suitable coverage of various designs of RMS for distance and near correction in children and adults. In doing so, it references available published prescription guidelines. An important finding is that astigmatism remains the major barrier globally to the wider use of RMS, and that modest changes in eligibility cut-offs for astigmatism can significantly affect coverage rates. Anisometropia appears to be less of an issue, somewhat limiting the benefits of interchangeable-lens RMS designs. Coverage for paediatric and adult presbyopic correction remains a significant limitation for RMS designs.

Our application allows users to estimate RMS coverage in specific target populations.

Contributors VFC, DMW, RD, MS and NC were responsible for the conception, formal analysis and design. All authors interpreted the data. Drafting of the manuscript was done by VFC and SM. Critical revision of the manuscript for important intellectual content was done by all the authors. NC is responsible for the overall content as the guarantor. All authors approved the final version of the manuscript.

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Competing interests VFC is a Trustee of Vision Aid Overseas, an organisation working to provide refractive and eye care in low-income and middle-income countries. RD and MS were employed by OneSight during the course of the research. NC is the Director of Research for Orbis International, an organisation working on eye health issues in underserved areas. All other authors declare no competing interests.

Patient consent for publication Not applicable.

Ethics approval The Ethics Committee of Queen's University Belfast determined that this protocol was exempt from obtaining research consent from participants.

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ORCID iDs
Ving Fai Chan http://orcid.org/0000-0002-4968-7953
David M Wright http://orcid.org/0000-0001-8948-3691
Sonia Mavi http://orcid.org/0000-0002-1983-6671
Nathan Congdon http://orcid.org/0000-0001-9866-3416

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