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A User-Centered Design Study to Investigate the Design Parameters for Prescription Swimming Goggles

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Introduction

- Swimming goggles aid swimmers in protecting their eyes from impact, preventing exposure to hazardous materials present in the pool water, and in providing clear vision in the swimming environment.
- Prescription swimming goggles (PSGs) feature a prescription lens work like prescription glasses to correct and support your vision, allowing you to enjoy the same clarity of vision you have wearing your glasses during your swim.

Introduction

Today’s swim goggle was born from motorcycle goggles.

The first known swimmer to use them in this way was Tom Burgess, an enterprising Channel-crosser who strapped on a pair of motorcycle goggles while swimming breaststroke from France to England in 1911 [www.yourswimlog.com].

The overall shape and design of this particular piece of swim equipment—two big sockets and an elastic band around the head—hasn’t really changed much since then. The materials, size, colors and marketing, on the other hand, absolutely have.

Figure 1. Tom Burgess [www.yourswimlog.com]

Introduction

In 1935, buoyed by the rising popularity of scuba diving and the need for better masks and goggles, inventor Walter G. Farrell patented an “underwater eye protector” designed to help divers swim around that grandfathered many of the current goggle designs.

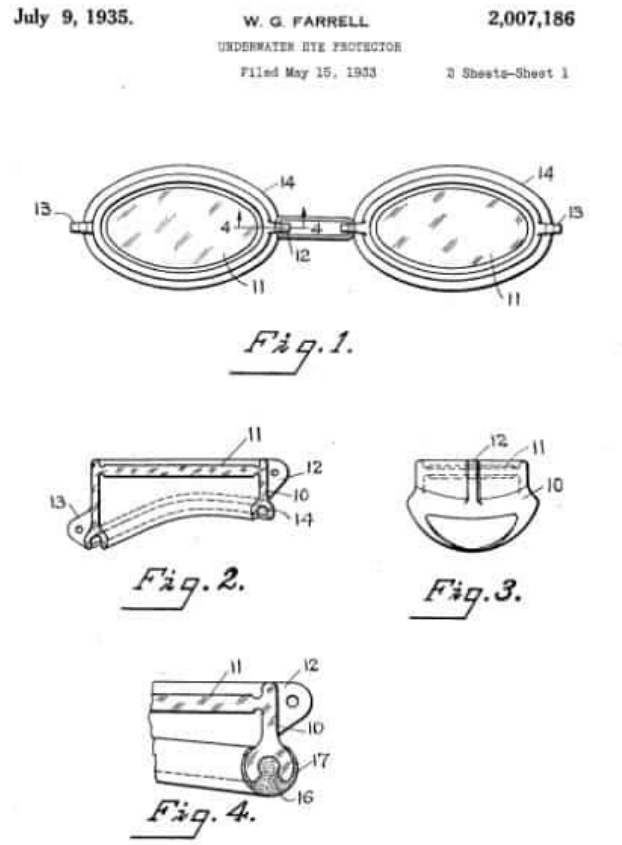


Figure 2. First patent [www.patents.google.com/patent/US2007186A/en]

Introduction

In 1968 the modern swimming goggles was first introduced to the competitive swimming masses with limited enthusiasm.

In modern competition it was the breaststroker David Wilkie of Great Britain who put on a pair of goggles (and a cap!) at the 1970 Commonwealth Games.

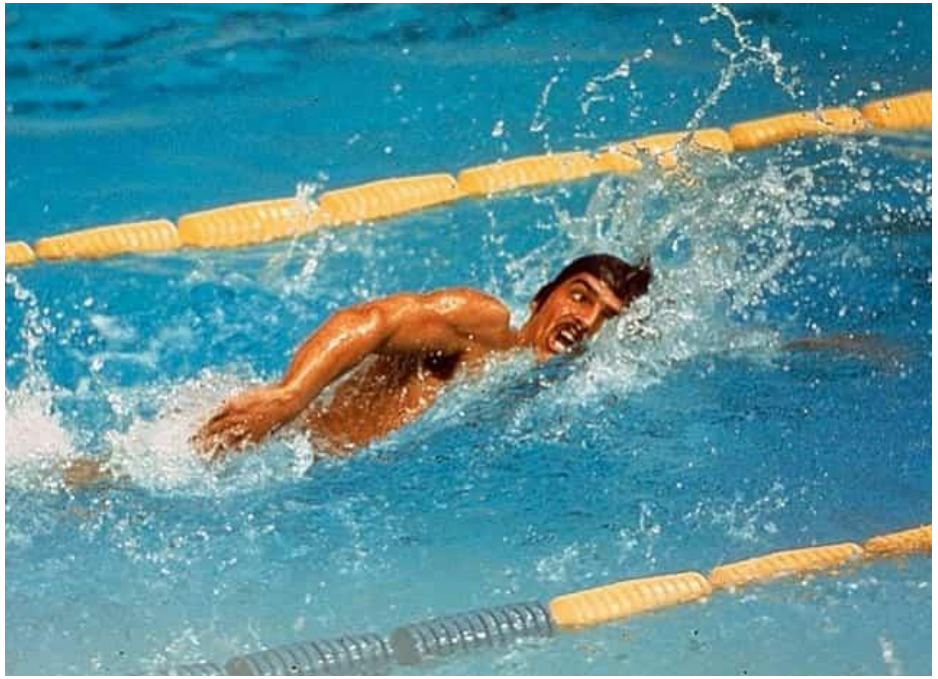


Figure 3. Mark Spitz, who won 7 Olympic gold medals in 1972 at the Munich Olympics with no goggles [https://www.yourswimlog.com/swim-goggles/]

Introduction

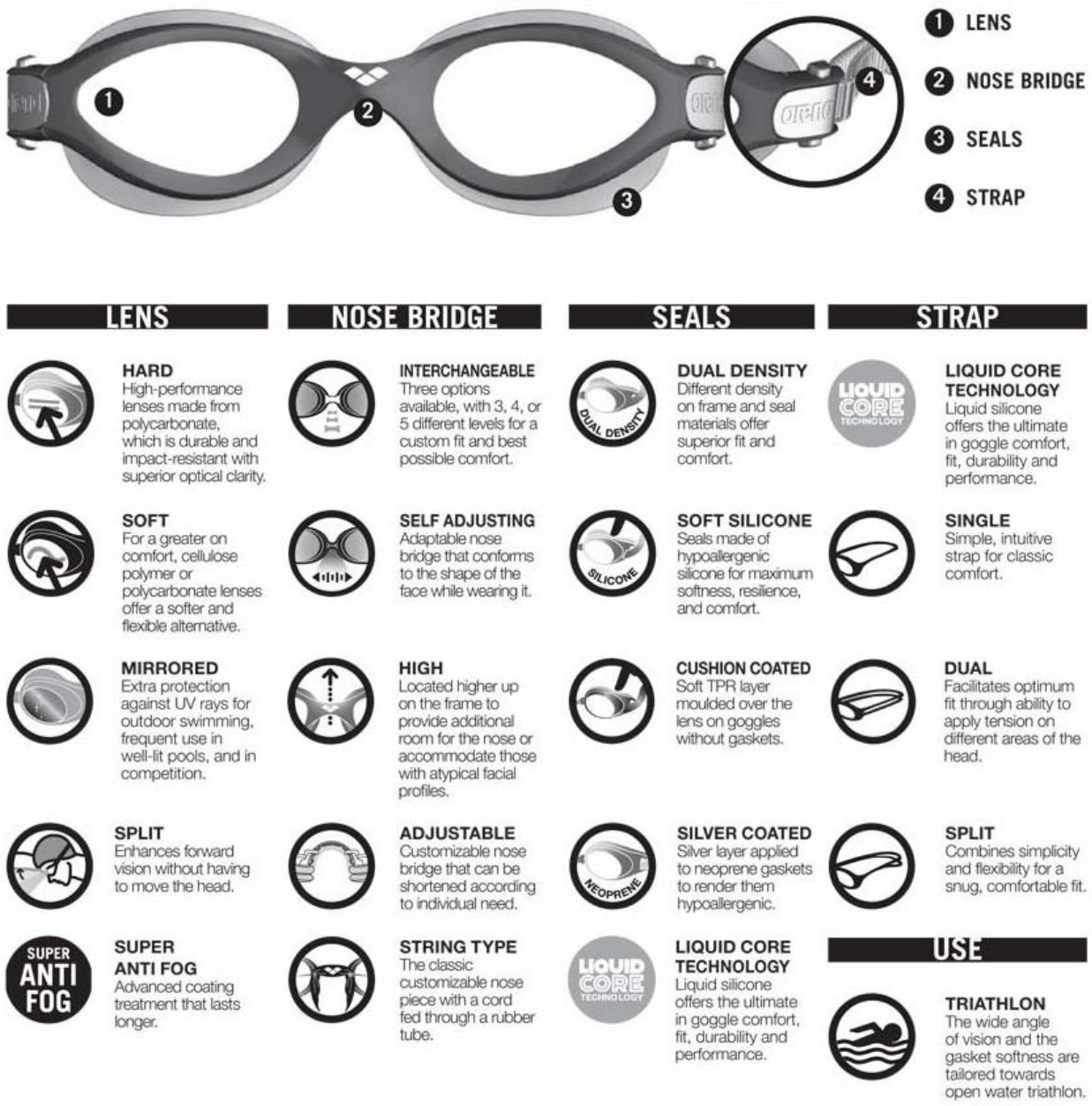


Figure 4. Primary components [www.arenaswimwearstore.com]

Introduction

Some ways to categorize swimming goggles:

1. Leisure Swimming or Open Water Goggles (Frame goggles)
2. Training or Competition Goggles
3. Swedish Type Goggles
4. Mask Type

Figure 5. Four categories of swimming goggles [www.loneswimmer.com/2015/02/04/how-to-understand-and-choose-between-the-different-types-of-swimming-googles/; www.speedo.com/on/demandware.store/Sites-spdgbgbp-Site/en_JE/GeoShow-Content?cid=a0b20ad0-ea8a-4c15-88e0-f6455777ce0d]

Introduction

Categories of swimming goggles (specifications):

1. Regular swimming goggles

Features:

Adjustable strap; Adjustable flange; Lens colour; Leakage proof; Good cushion; Anti-fog lens; Flip proof

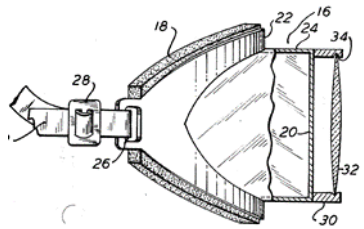
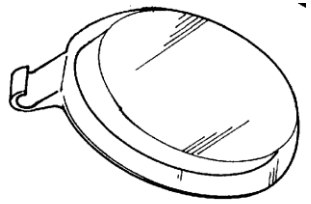
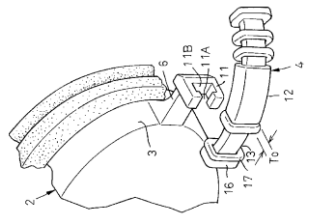
2. Prescription swimming goggles

Features in addition to those in 1:

UV protection lens; Anti-allergic pad; Power lens

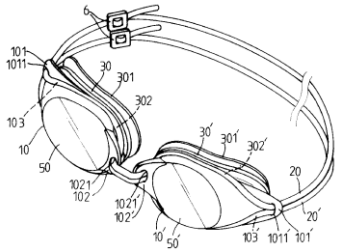
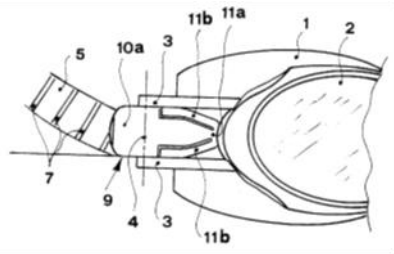
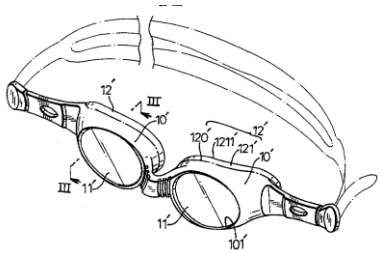
Literature

Few important patents

Title	Inventor	Modification	Figure
Optically corrected swimming goggles	**Decorato, F. (1976)**	Removable Power lens assembly in front of transparent lens	
Swimming goggles frame	**Chou, T. (1998)**	Curvilinear shape of lens	
Swimming Goggles	**Fukasawa, S. (1999)**	Adjustable nose bridge flange	

Literature

Few important patents

Title	Inventor	Modification	Figure
Swimming Goggles	**Chiang, H. (1999)**	Cushion pad assembly with air filled member	
Device for regulating the length of a swimming goggle strap	**Godoy, C. (1999)**	Adjustable strap length	
Swimming goggles	**Chiang, H. (2001)**	Combination of two straps assembly	

Literature

Literature on design parameters for a PSG can be categorized into three groups based on the most important user-concerns in focus within the work:

1. Physiological Parameters
2. Physical Parameters
3. Psychological Parameters

Table 1. Parameters and concern area of study for design of PSG.

S. No.	**Parameters**	**Concerned area of study**
1	Physiological parameters	Effect of swimming context on the health of users (physiology).
2	Morphological parameters	Concerns with the product architecture and interaction with the hands, face, head, other body parts.
3	Psychological parameters	Concerns with subjective perceptions of users such as color, form choices.

Literature

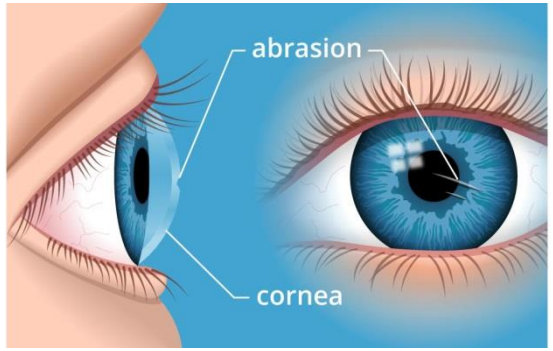


Figure 6. Corneal damage [https://www.allaboutvision.com/conditions/corneal-abrasion.htm]

1. Physiological parameters

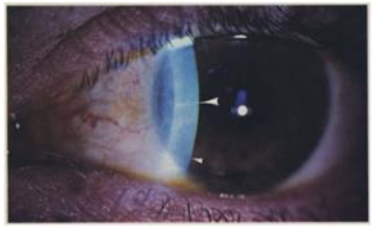
Title	Author/s	Preface of Work	Result	Conclusion
Effects of swimming pool water on the cornea	**Haag, J. R., & Gieser, R. G. (1983)**	Slit lamp test was done taking 50 Participants (male = 37; female = 13)	The symptoms of punctate of corneal epithelium was seen through the slit lamp test.  **Figure x.** Symptoms of punctate corneal epithelium	Factors responsible for corneal changes are: • Chlorine concentration • pH of swimming pool water • Tonicity of water • Chorine derived compounds

Figure 7. Typical text set-up [www.stantonoptical.com/blog/slit-lamp-eye-test/]

Literature

1. Physiological parameters

Title	Author/s	Preface of Work	Result	Conclusion
Deleterious effects of swimming pool chlorine on the corneal epithelium	**Ishioka et al. (2008)**	Confocal microscopy of chlorine irrigated eyes of 10 volunteers was done with fluorophotometric assessment.	Confocal microscopy showed corneal epithelium cell damage in eye rinsed with physiological salt solution (PSS) with Chlorine.	Chlorine was determined to be potentially harmful to the corneal epithelium barrier.

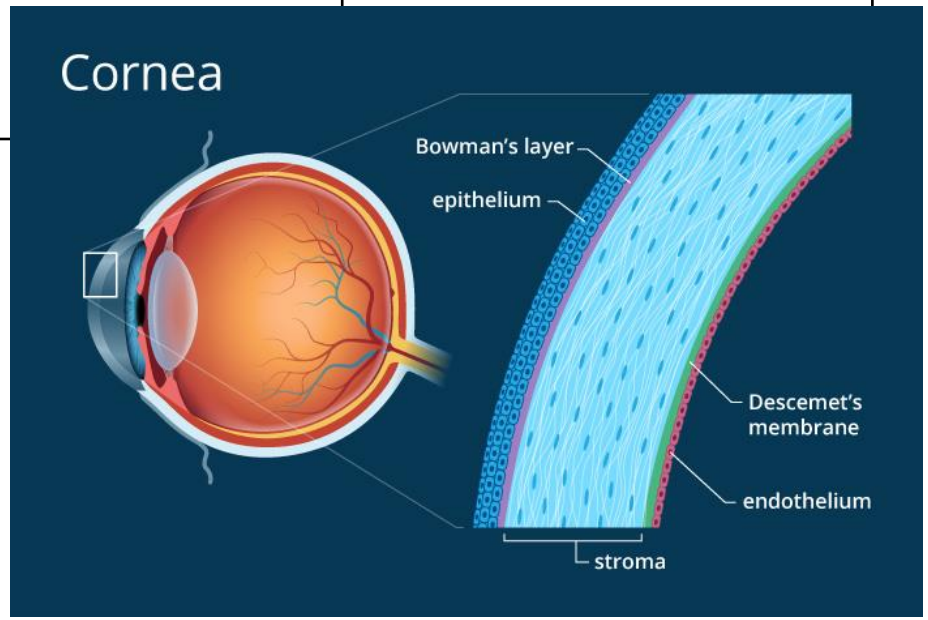


Figure 8. Cornea [https://www.allaboutvision.com/resources/cornea.htm]

Literature

1. Physiological parameters

Title	Author/s	Preface of Work	Result	Conclusion
Wearing swimming goggles can elevate intraocular pressure	**Morgan et al. (2008)**	The effect of various types of swimming goggles (goggles area) on Intraocular Pressure (IOP) was optimized.	A smaller goggles area was consistently associated with greater IOP elevation.	It is better to use large frame structure goggles to minimize the elevation in IOP

Literature

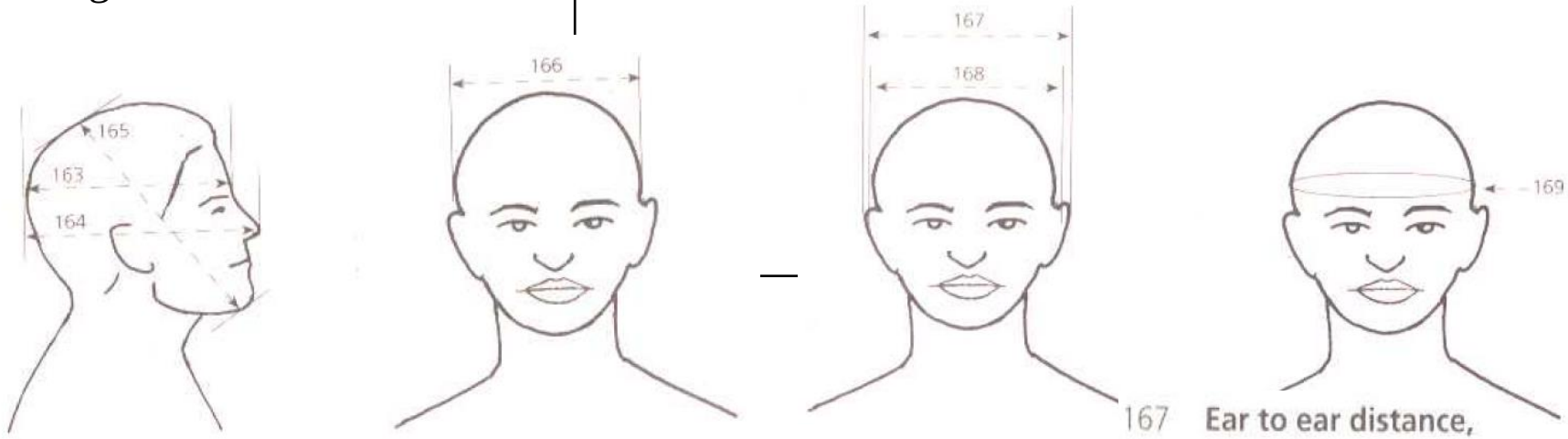
1. Physiological parameters

Title	Author/s	Preface of Work	Result	Conclusion
Health effects of disinfection by-products in chlorinated swimming pools	**Florentin et al. (2011)**	Swimming pool water is polluted by the external matters like chemical, cosmetic organic materials, human body materials (urine, skin particle, hair, perspiration, etc.) and other type of biota results formation of Disinfection by-products (DBPs).	Formation of Disinfection by-Products like: ➢ Chloramines ➢ Tri – halomethanes (THMs) ➢ Haloacetic Acids (HAAs)	• Eyes irritate while swimming in the presence of DBPs. • DBPs are responsible for several types of epidermal diseases (mostly related to the skin and respiratory system).

Literature

2. Physical parameters

Title	Author/s	Preface of Work	Result	Conclusion
Indian anthropometric dimensions for ergonomic design practice	**Chakrabarti, D. (1997)**	Various data are collected for the Indian people to design a product with ergonomics concern.	**Figure 9.** Head and face anthropometry	



163 Head length

164 Head length, maximum

165 Vertex to chin distance

166 Head breadth

167 Ear to ear distance, normal

168 Ear to ear distance, pressed

169 Head circumference

Literature

2. Physical parameters

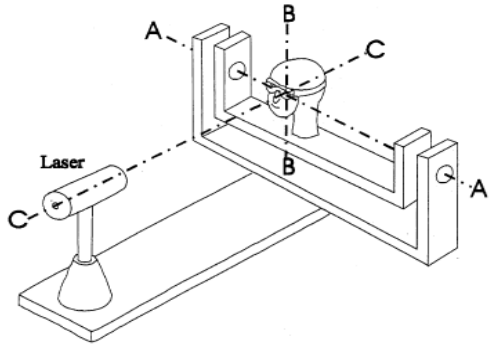


Figure 10. Test set-up.

Title	Author/s	Preface of Work	Result	Conclusion
Protective area of laser eye protectors	**Sutter, E., & Schirmacher, A. (2001)**	➢ 27 different structures of goggles (laser eye protectors) are studied in this study. ➢ Min. area of goggles that fulfill the desired need was identified.	The images tracing by the apparatus is shown for various type of goggle structure.	Interface points of goggles and mannequin are: ▪ Sellion ▪ Glabella ▪ Orbital surface ▪ Zygion ▪ Midnasale bridge ▪ Maxillonasale

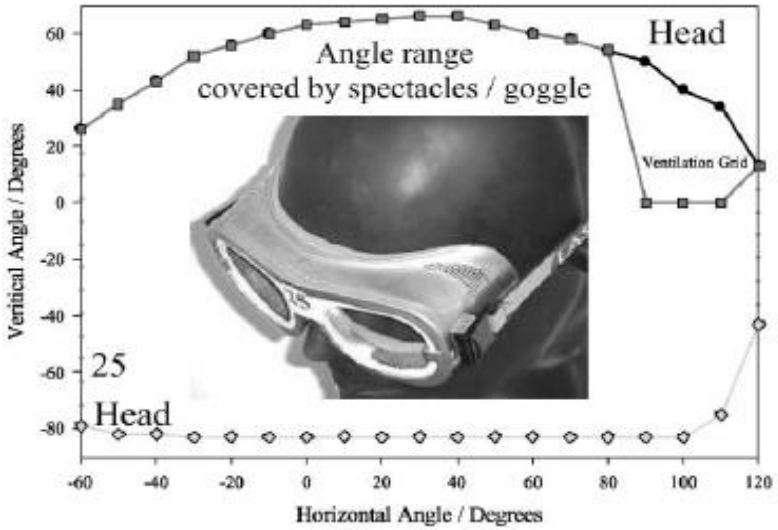


Figure 11. Sample measurement

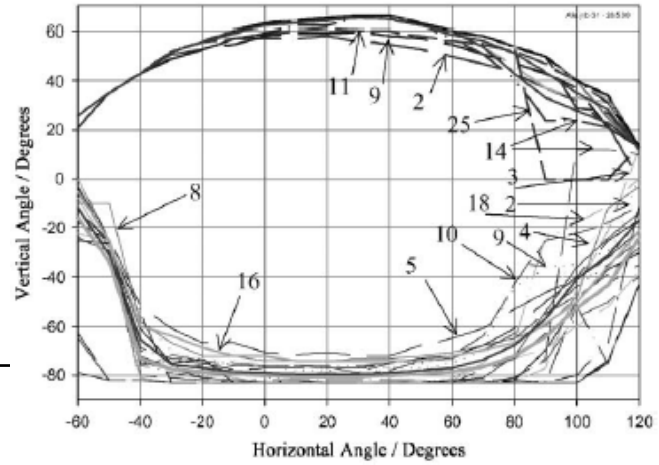


Figure 12. Compilation measurement of various type of 27 goggles.

Literature

2. Physical parameters

Title	Author/s	Preface of Work	Result	Conclusion
Theoretical model for design and analysis of protectional eyewear	**Zezler et al. (2013)**	➢ Study was done to identify the suitable lens structure for 3 safety goggles. ➢ Optical testing was carried out to measure the spherical power. ➢ Lens geometry was modeled in raytracing software ASAP.	Optimal radius of curvatures calculated for 2 stimulus angles of incidence.	➢ Lens should be sphero cylindrical in shape for increasing the visibility. ➢ Frontal thickness of lens should be 2 mm.

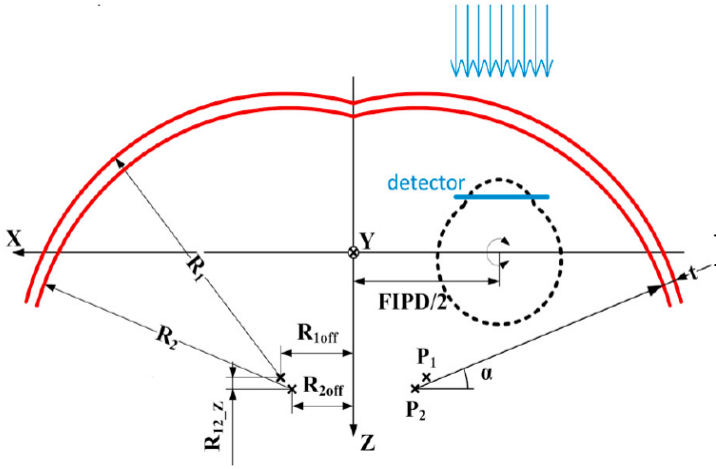


Figure 13. Test set-up.

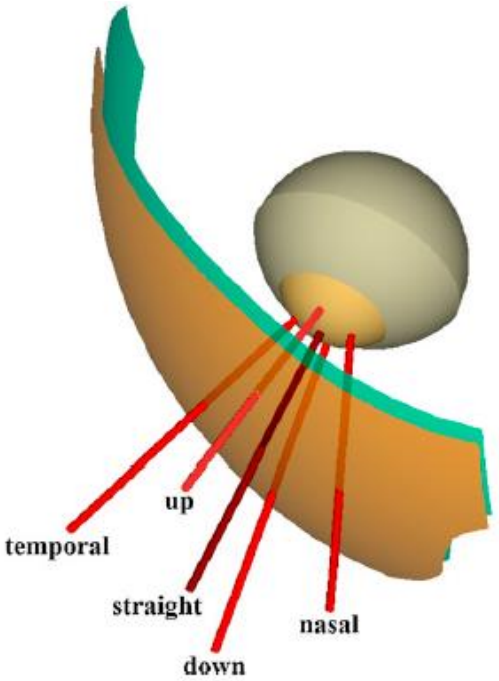


Figure 14. Incident rays.

Literature

2. Physical parameters

Title	Author/s	Preface of Work	Result	Conclusion
The Effect of a Diving Mask on Intraocular Pressure in a Healthy Population.	**Goenadi et al. (2016)**	IOP was measured with and without lenses wearing a diving mask using Tono-Pen AVIA.	IOP with and without lenses was strongly correlated.	➢ Wearing a swimming mask leads to increased IOP. ➢ Distributed and enlarged area of contact reduces IOP.

Figure 15. Experimental diving mask

Figure 16. Tono-Pen AVIA

Literature

3. Psychological parameters

Title	**Author/s**	**Preface of Work**	**Result**	**Conclusion**
Barriers and Benefits of Protective Eyewear Use by Latino Farm Workers	**Forst et al. (2006)**	Determine the perceived benefits and barriers to use of protective eyewear during agricultural work among seasonal farm workers.	Reasons for non-use were perceived no need of protection, discomfort, undesirable appearance, interference with visual acuity, slowing down the work pace, and no mandate from employers.	Functional problems such as falling off, fogging, loss and forgetting glasses, the pace slowdown that reduces production and leads to lower wages for workers should be addressed.

Literature

3. Psychological parameters

Title	Author/s	Preface of Work	Result	Conclusion
Factors influencing worker use of personal protective eyewear	**Lombardi et al. (2009)**	Identify and describe the array of factors that influence a workers' decision to wear personal protective eyewear (PPE) and the barriers that exist in preventing their use.	Lack of comfort/fit, and fogging and scratching of the eyewear were suggested as the most important barriers to PPE usage.	Several potentially modifiable factors identified would lead to an increase in workers' PPE use and encourage supervisors to provide ongoing positive feedback on the continuous use of PPE by workers at risk for an eye injury.

Methodology

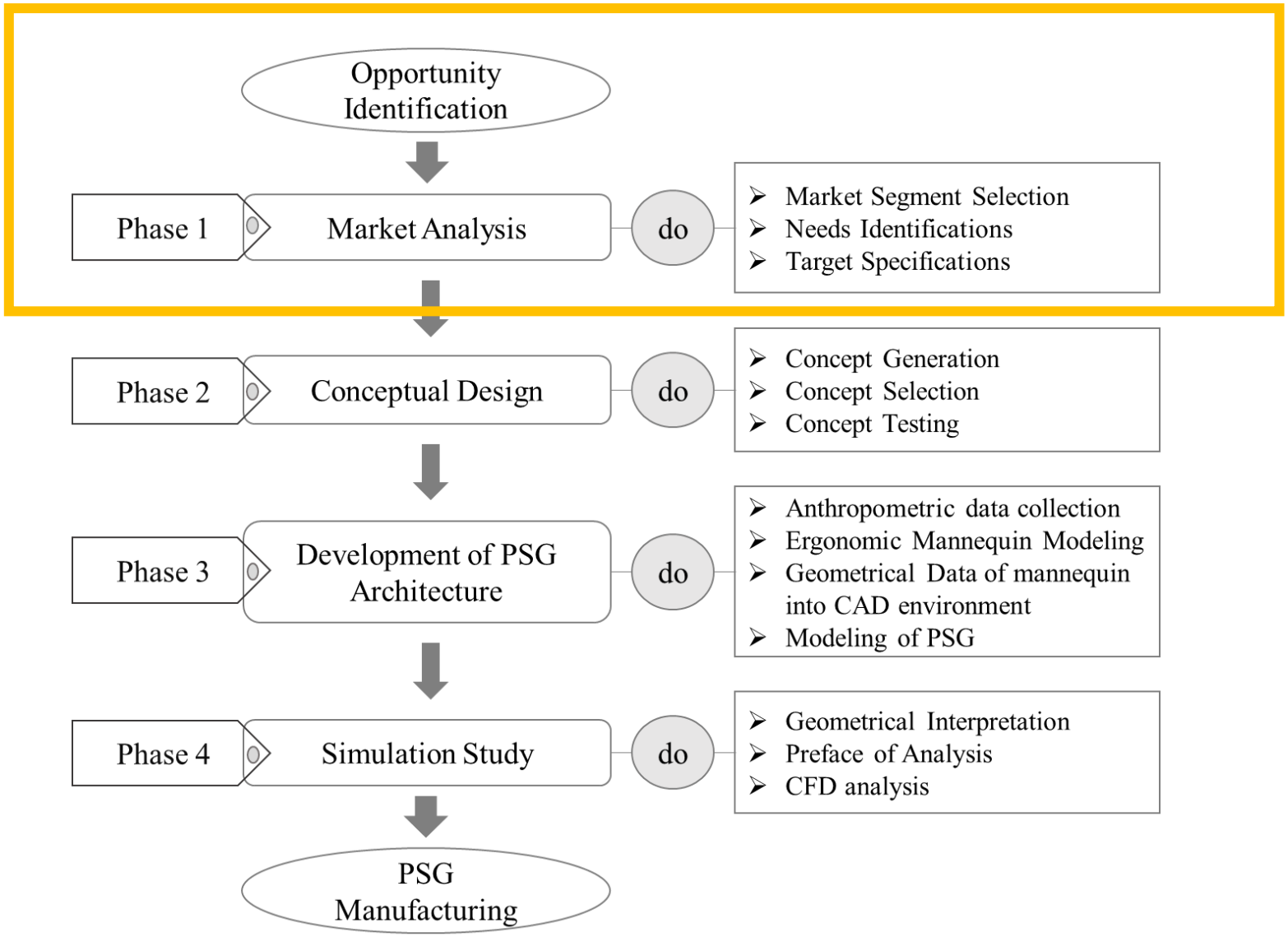


Figure 17. Process flow diagram in order to develop a design protocol for PSG.

Methodology

Market Analysis

1. Prescription Swimming Goggles (PSG) available in the market were studied and their features/specifications documented.
2. Observing and conversing with the swimmers in the Institute swimming pool environment regarding the use of swimming goggles. Problems investigated by taking open-ended surveys from potential users (defective vision).
3. Mean weightage of problems calculated on a scale of 0-5 calculated as

$$Mean\ weight\ of\ each\ problem = \frac{(No.\ of\ users\ who\ reported\ it\ \times 5) + (No.\ of\ users\ who\ DID\ NOT\ report\ it\ \times 0)}{(Total\ No.\ Respondents\ \times 5)}$$

4. Selective market research on solutions available.
5. Those problems identified which are either not available in existing swimming goggles OR do not meet users' expectations.

Results

95 swimmers volunteered to participate in this study.

38 swimmers out of 95 (i.e. 40%) suffer with some kind of visual problems, mostly either affected by Myopia or Hypermetropia.

38 users with defective vision reported -

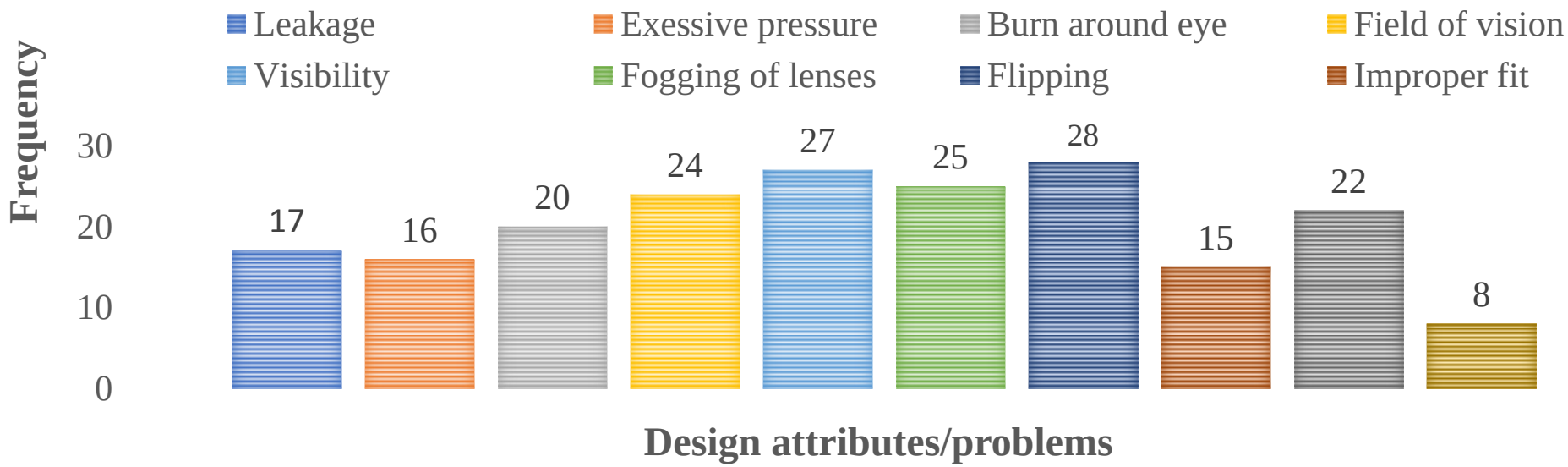


Figure 18. Problem identified and their frequency of reporting.

Results

Hierarchy of the identified problems in the descending order (frequency of reporting):

Flipping (28) > Visibility due to disability (27) > Fogging of lenses (25) > Field of vision (24) > Lens-scratches (22) > Burning-sensation around eyes (20) > Leakage (17) > Pressure excessive on eyes/face (16) > Improper fit (15) > Goggles color dislike (8)

Results

Mapping the reported problems against available market solutions:

Table 3 Market review in order to solve the problems.

Problem priority	Problem title	Availability of Solutions in the Existing PSGs
1	Flipping	Flip proof
2	Visibility	Power lens (fixed or changeable)
3	Fogging of lenses	Anti-fogging liquid and coating
4	Field of vision	Horizontal Range (HR):144°; VR:138° (Maximum)
5	Lens-scratches	Scratch resistant coating
6	Burning around eyes	Extended pads; larger goggles
7	Leakage	Pliable silicone pad
8	Pressure excessiveness	Pliable silicone pad; air compartment within the pad
9	Improper fit	Available sizes; adjustability features; modular design
10	Goggles color	Subjective to preference

Discussion

Table 4. Categorization of the PSG related user problems using broad design categories.

Design parameters	**User problems**
Physiological parameters	Leakage through goggles; ocular area of goggles; visibility; pressure excessiveness; burning around eyes.
Morphological parameters	Leakage through goggles; improper fit to face; flipping of goggles; lens-scratching; fogging of lenses; visibility; field of vision.
Psychological parameters	Goggles color; product architecture; perceived no need of protection; discomfort; no mandate from authorities.

Conclusions

1. Different methods of designing research around design of PSGs have been discussed.
2. Three broad categories of design concerns namely physiological, morphological, and psychological parameters have been formalized and discussed in the context of realizing the scope for design interventions.
3. Intraocular Pressure (IOP) elevation has been recognized as a critical, but often overlooked non-traditional physiological parameter that should be specifically addressed by future PSG designs.
4. Flipping and visibility should be other high priority design concerns.

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Thank You!