Visual Characterization of Wheelchair Cushions following Simulated Aging

Noah Bauer[1], Alexandra Delazio[2], Patricia Karg[2], David Brienza[2]

University of Pittsburgh, Department of Mechanical Engineering[1], *Department of Rehabilitation Science and Technology*[2] (Pittsburgh, PA)

INTRODUCTION

Wheelchair cushions are intended to provide body support and prevent pressure injury. Proper performance of wheelchair cushions is critical to these desired outcomes. To better understand and improve the overall performance and longevity of wheelchair cushions, methods to simulate cushion use/aging can be performed. Simulated aging is the process of subjecting a cushion to laboratory stresses and environments to mimic the effects seen in real world use [1].

Sprigle et al. recorded the signs of wear and failure for 202 wheelchair cushions after everyday use for an average of 2.7 years [2]. A large number of cushion covers showed signs of wear, predominantly damage to the material and seams. Foam cushions showed the most signs of wear, including deformation and change in material properties. Fifteen percent of air and viscous fluid cushion bladders had cracks or breaks. Most cushions were clean and in good repair. Linden et al. reported that viscous fluid compartments failed due to accelerated heated aging and cyclic loading procedures [3].

The purpose of this paper was to find the most abundant and significant aging characteristics seen in cushions that have been aged through simulated methods and compare those findings with real world observations to validate and improve cushion testing methods. Various cushions of different structure, material and manufacturer were visually inspected after undergoing simulated aging methods defined by the RESNA seat cushion standard [1] to identify key aging characteristics that can be linked to those seen in the real world. This paper outlines a visual inspection procedure and documents the signs of wear exhibited after two rounds of simulated aging. The wear characteristics found were then compared to observations recorded for cushions after everyday use.

METHODS

A cohort of 21 wheelchair cushions varying in construct and design were aged using the minimum set of simulated aging procedures outlined in ANSI-RESNA Volume 3, Section 6 - Determination of the changes in properties following simulated extended use of seat cushions [1]. This minimum aging protocol includes: disinfection (Clause 26), laundering (Clause 29), accelerated heated aging for half the indicated time period (Clause 22) of 33 days at 50°C for cushions containing materials that degrade at elevated temperatures or 11 days at 70°C otherwise, cyclic loading 0-500N at room temperature for 17,500 cycles (Clause 25), accelerated aging for half the indicated time period (Clause 22), disinfection (Clause 26), laundering (Clause 29). This protocol was repeated twice to simulate two ~18-24 month time periods of real-world cushion use. Cushions were visually inspected before any simulated aging occurred (pre-aging) as well as after the first and second sets of aging procedures were completed.

A methodology for systematically identifying and quantifying the observable effects of aging based on visual inspection was then developed and applied to the 21-cushion cohort. Cushions were inspected first with the covers in place and then the covers removed. Visual Inspection procedures included closely examining the cohort of cushions at each timepoint and identifying evidence of cushion wear per the categories listed in Table 1. Changes pre- and post-aging were noted and the percentages of cushions that experienced each of the defined aging measurements were calculated based on cushion coding (skin protection vs. general use) and construct (air, foam, foam+fluid, honeycomb). Photos of the top and bottom of the cushions with and without covers at each time point were taken to allow for a visual comparison of the primary faces of each cushion. Additional detailed pictures were taken of various aging characteristics identified in the aged cushions.

Table 1. Characterization Properties for Visual Inspection

Wear Characteristic	Definition of Wear Characteristic
Poor Cover Fit	Change in cushion cover fit. Fit deemed to be less conformed compared to a pre-aged condition.
Discoloration	Areas of the cushion have been discolored.
Deformation	Permanent compression of cushion observed along the edges and corners.
Surface Changes	Cracks, holes or abrasions seen directly on the surface of the top or bottom of the cushion.
Cover Damage	Areas on covers where noticeable signs of cover deterioration is seen in the form of snags, tears or holes in material. Wear along the seams where stitching occurred, tears in the stitching, loose fabric/stitching.
Worn Labels	Labels that have been deformed, worn or torn significantly, making the information hard to read.

RESULTS

A visual representation of the total percentage of cushions exhibiting each wear characteristic following aging is shown in Figure 1. The wear after the first aging procedure is indicated by the black bar and additional wear that occurred after the second session of aging is indicated in white.

Figure 1 shows the most prominent aging characteristics after a single round of aging to be those regarding the cover. Over 60% of the cushion covers exhibited a worn cover and 90% poor fitting after only one round of aging. Discoloration and permanent deformation were the most prevalent aging characteristics regarding the cushion. All cushions exhibited worn labels. The second round of aging increased all types of wear, with surface changes almost doubling and nearly all cushions showing cover damage.

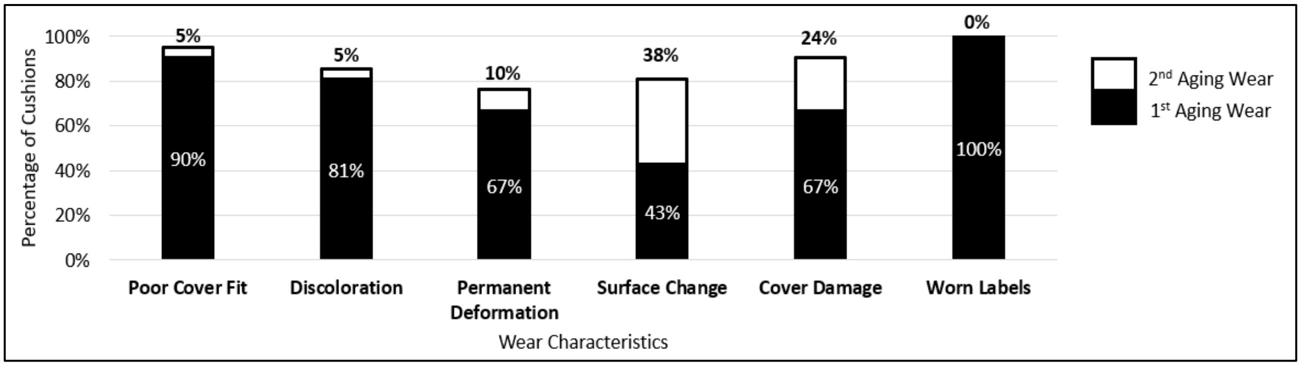


Figure 1. Post-Aging Wear Characteristics by Percentage

Cushions were grouped based upon cushion construct – Air, Honeycomb, Foam and Fluid + Foam – and CMS coding – General Use or Skin Protection (Figure 2). The air group consisted of cushions where the primary support comes from air filled bladders, foam cushions were those that consisted of one or more layers of foam, foam + fluid were cushions that had a base layer of foam with a secondary layer or insert that is fluid, and honeycomb cushions were those made entirely of a cell-like structure in a repeating pattern.

Figure 3 gives the percentage of cushions in each material group exhibiting the wear characteristics. Surface changes and deformation due to the second set of aging occurred in cushions containing foam more than doubled. Of the three air cushions, one had multiple holes in the air bladder.

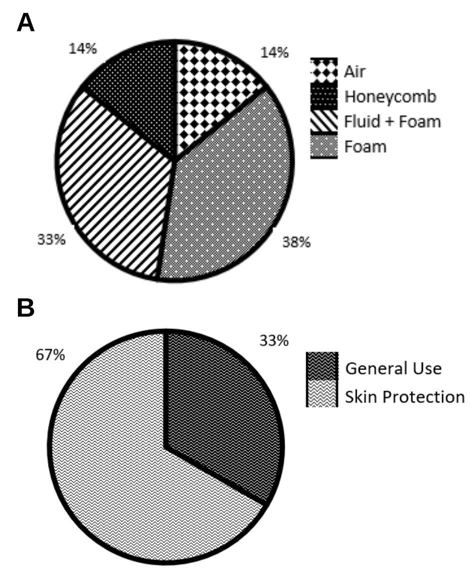


Figure 2. Percentage of the 21 cushion cohort broken down by A: construct, B: code

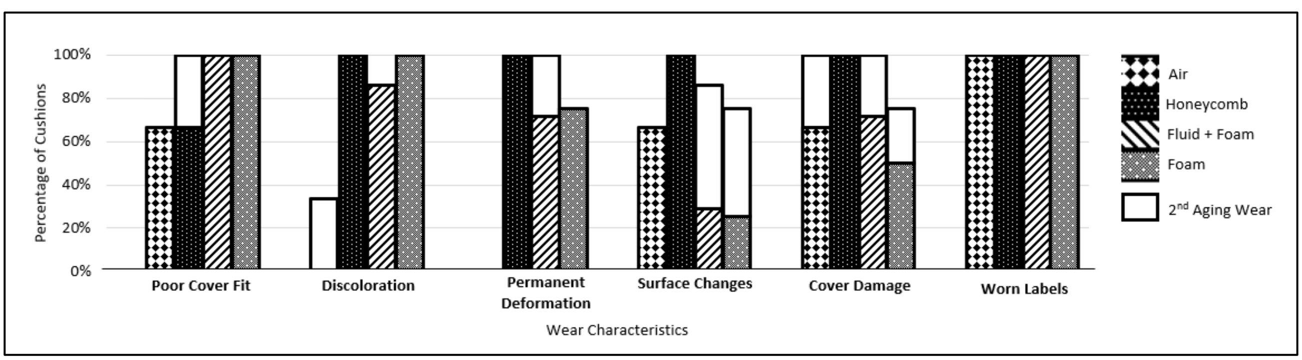


Figure 3. Post-Aging Wear Characteristics by Cushion Construct

Figure 4 shows the percentage of cushions in each code exhibiting the wear characteristics. General Use cushions were more susceptible to wear than Skin Protection after the first round of aging, with more than double the surface changes. Skin Protection cushions had the most signs of additional wear after the second round of aging, especially in surface changes. An observation not noted in the figures was that when adhesives were used to attach hook and loop strips or labels, they became sticky and stained the material. Table 2 provides examples of each type of wear characteristic.

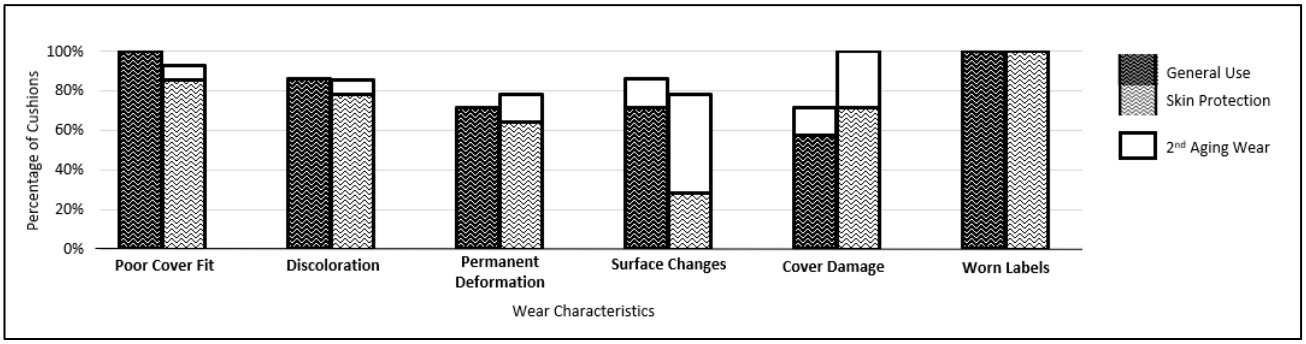
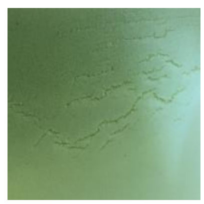


Figure 4. Post-Aging Wear Characteristics by Cushion Code

Table 2. Detailed Wear Characteristic Photos

POOR COVER FIT	DISCOLORATION	PERMANENT DEFORMATION	SURFACE CHANGES	COVER DAMAGE	WORN LABELS
					

DISCUSSION

The study determined and quantified the signs of wear in wheelchair cushions due to standardized procedures for simulated use. Most cushions were found to have similar changes from the simulated aging process, making it feasible to define common wear characteristics. The results identified the most common changes to the cover to be change in ability to conform to the cushion and signs of material damage. Most cushion covers were made of the same or similar material and therefore exhibited common aging effects. Worn labels occurred on every cushion. This can be a significant factor as some of the information on these labels are important to the use and upkeep of the cushions.

After taking off the covers and observing the cushions themselves there were many noticeable changes. The cushions primarily showed signs of discoloration and permanent deformation due to simulated aging. Most aged cushions saw a change in color, primarily small discolorations along the edges, sides and corners. Some cushions saw larger discolorations that changed the whole cushion color or large segments of the cushion. Observing some of the contours of foam cushions it could be seen they had undergone permanent deformations and surface changes, either becoming more smooth or granular from aging. Surface changes also occurred in the honeycomb cushions, observed as deformation of the cells. Primarily in foam and honeycomb cushions, the sides, edges and corners had deformations in the form of creases or wrinkles.

Separating the cushions into their codes and material groups allowed for a more in-depth analysis of which cushions are most likely to exhibit signs of wear and after which cycle of aging. This could be beneficial for improving a certain type or group of cushions to focus and prevent common aging characteristics. Improving the accuracy of simulated aging to that of real-world use is an important aspect of developing a durable well performing cushion. To do this, developing a consistent procedure, criteria and analysis will greatly aid in this process. This study did not find viscous fluid compartment failures as found in the Linden et al. study [3]. This may have been due to the different loading protocols used as this study did two rounds of 17,500 cycles from 0 to 500 N, while Linden et al. did 8,700 (General Use) or 13,000 (Skin Protection) from 0 to 750N. Plus, Linden et al. added a loading protocol that subjected cushions to 35,000 (General Use) or 52,500 cycles (Skin Protection) of 400N to 600N. The higher load and/or additional loading protocol may have resulted in more failure of fluid components.

When comparing the results of simulated testing to what was observed in real use [2], many similarities were found. The prime similarities being discoloration in foam cushions more than any other material, air cushions suffering bladder breaks during testing, noticeable permanent deformations affecting the shape of the cushion, and visibly worn fabric. One striking contrast was the lack of failure or damage to viscous fluid compartments in the simulated aging compared to the 14% breakage occurring in real use [2]. Perhaps higher loads are needed or a loading protocol similar to that in Linden [3] should be added. Another contrast was the condition of the cushion cover in simulated testing to real use. In simulated testing the cover is not treated to the multitude of harsh environments and scenarios as the real use cover is, simulated aging is cleaner and less focused on the cover performance than the cushion itself.

Overall, observations of the simulated aging after the first aging procedure were comparable to that seen in real use. The second aging primarily resulted in surface changes to the cushions containing foam and more cover damage. From visual inspection it is not apparent the second set of aging is needed. Mechanical performance testing of cushions is underway and should shed light on how the second round of aging affects performance. Limitations of the study included a finite set of cushions that may not represent all cushions on the market.

REFERENCES

[1] RESNA (2018). RESNA American National Standard for Wheelchairs - Volume 3: Wheelchair Seating. Rehabilitation Engineering and Assistive Technology Society of North America. Arlington, VA.

[2] Sprigle, S. (2013). Visual Inspections of Wheelchair Cushions after Everyday Use. Assistive Technology, 25(3), 176-180.

[3] Linden M, Sprigle S (2006). Changes in Wheelchair Cushions as a Result of Simulated Use Protocols. *RESNA 2006 Conference Proceedings,* Atlanta, GA.