# Development of Lifting-Assistive Suit Designs for Patient Caregivers

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**Introduction.** The global population is rapidly aging, leading to an increased prevalence of age-related diseases and conditions such as diabetes, arthritis, and heart diseases (National Council on Aging [NCA], 2023). By 2060, it is projected that there will be around 95 million individuals aged 65 and older, constituting approximately 23% of the United States population (NCA, 2023; Mather et al., 2015). As a result, medical systems often face a shortage of beds, leading to increased economic burden when hospitalization is required. Chronic diseases account for two-thirds of healthcare costs in the U.S. and over 93% of Medicare spending (NCA, 2023). Consequently, nursing services, sanatoriums, and home caregiving have seen a rise in demand. However, moving patients from bed to wheelchair poses risks of injury for both caregivers and nurses. Caregivers face additional challenges when assisting spouses who suffer from musculoskeletal health issues. While assistive tools and products have been developed, there is a scarcity of wearable solutions that adequately fit the wearer. Nurses and caregivers are particularly susceptible to physical burdens. Therefore, the objective of this study was to develop lifting-assistive suits for patient caregivers, and the results of this study have the potential to inform the development of wearable suits, considering fabric mapping and design details.

**Literature Review.** Among various diseases and disorders affecting the elderly, falls are prevalent due to weakened musculoskeletal strength. Over 25% of older adults experience falls annually, resulting in fatal and nonfatal injuries such as hip fractures and head trauma. Falls lead to five times more hospitalizations compared to injuries caused by other factors (Centers for Disease Control and Prevention, 2020; Florence et al., 2018; NCA, 2023). Falls account for 75% of Medicare spending and are associated with physical decline, social isolation, and depression (Gillespie et al., 2012; Houry et al., 2016; NCA, 2022, 2023). Consequently, caregivers are increasingly required to assist or lift patients. When developing lifting-assistive suits, several factors must be considered. Firstly, the suits must be washable for maintaining hygiene, particularly given their use by caregivers. Second, fabric colorfastness to rubbing and pilling is essential due to frequent friction and movement. Additionally, bursting strength is crucial as caregivers exert quick bursts of force while lifting patients. Therefore, these aspects should be thoroughly assessed before prototyping designs.

**Research Method.** During the initial stages of design development, different fabric types and their suitable application locations for the suits were explored. Two candidate fabrics, air mesh (Fabric-F1) and double-layered askin mesh (F2), were subjected to performance testing in accordance with ISO/ASTM standards. These mesh fabrics were selected for their ventilation

and permeability properties, which are crucial for wearable suits. The dimensional stability to washing was evaluated using ISO 5077:2077/ISO 6330:2021, type A, test program 3 N, at a temperature of (30 ± 3) ℃, followed by flat drying. Colorfastness to rubbing was assessed using ISO 105-X12:2016, employing a rubbing finger composed of a cylinder with a force of (9 ± 0.2) N and a wet pick-up of 95~100%. The specimens and rubbing cloth were conditioned for at least 4 hours. Pilling tests were conducted according to ISO 12945-2:2020/ISO 12945-4:2020, utilizing a loading mass of (155 ± 2) g with rubbing action. For assessing bursting strength, the hydraulic method specified in ISO 13938-1:2019 was employed. The test area was 7.3cm2, and the rate of volume increase was set at 150cm3/min. The fabrics underwent rupture testing in both yarn directions to evaluate their bursting behavior. Based on the obtained results, the fabrics were mapped onto the designs, taking into consideration their specific characteristics and intended purposes.

**Results and Discussion.** The results of the study are as follows. First, concerning the dimensional stability to washing, both F1 and F2 exhibited a decrease of -0.5% in length and width. Thus, all four values were identical, indicating that the two fabrics had comparable dimensional stability when subjected to washing. Second, in terms of colorfastness to rubbing, both F1 and F2 achieved a grade of 4-5 for dry and wet conditions in terms of length and width. Similarly, for both fabrics, the wale and course directions attained a grade of 4-5 for dry and wet conditions. Therefore, the colorfastness to rubbing was consistent between the two fabrics. Third, the assessment of fabric pilling revealed that both F1 and F2 obtained grades of 4-5 for pilling, fuzzing, and matting. Thus, F1 and F2 exhibited similar performance in terms of pilling. Lastly, regarding bursting strength, F1 recorded a strength of 707kPa, while F2 displayed a strength of 668kPa. Both fabrics demonstrated high durability against bursting; however, F1 exhibited a higher bursting strength compared to F2.

**Conclusion.** Based on the fabric performance results, it can be concluded that both fabrics exhibited similar dimensional stability to washing, colorfastness to rubbing, and pilling characteristics. However, there was a difference in bursting strength, with F1 demonstrating higher durability. Therefore, it is recommended to utilize F1 fabric in areas such as elbows and where actuators would be attached to ensure enhanced bursting resistance. For future research, thermal mannequin tests and wear-tests involving potential users, specifically patient caregivers, will be conducted to assess their satisfaction with the developed lifting-assistive suits and their overall performance. The findings of this study hold promise in supporting the advancement of wearable suits, ultimately benefiting caregivers and promoting the wellness and well-being of the elderly.

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