

SELECTION AND EVALUATION OF TEXTILE MATERIALS FOR ADAPTIVE CLOTHING FOR CHILDREN WITH CEREBRAL PALSY

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Abstract

The development of adaptive clothing for children with cerebral palsy (CP) is particularly relevant due to the need to simultaneously address functional limitations, impaired motor control, comfort, and the development of greater independence in dressing. The aim of this study was to justify the selection of textile materials for the design of adaptive clothing, including a rehabilitation suit with the potential integration of myostimulation elements. A total of 13 textile material samples were examined, including seven denim fabrics and six knitted fabrics with different fiber compositions. The materials were evaluated in terms of surface density, thickness, electrostatic properties, tensile strength, elongation at break, and stretchability under a 6 N load. The results showed that denim

fabrics demonstrated higher strength and dimensional stability, whereas elastic knitted fabrics, particularly the biflex sample, exhibited substantially greater deformability. These findings indicate that a combination of different materials may be an appropriate solution: elastic knitted fabrics can be used in functionally active areas, while stronger denim materials can be applied to structurally loaded sections of the garment. This approach makes it possible to combine freedom of movement, supportive properties, durability, and manufacturability. In addition, the potential for reusing denim materials was considered as part of an environmentally oriented approach to adaptive clothing design.

Keywords: Adaptive clothing, cerebral palsy, Lycra, biflex, denim, knitted fabrics, textile materials, physical and mechanical properties, rehabilitation clothing, sustainable design.

Introduction

Childhood disability is a significant medical, social, and design-related issue. According to UNICEF, nearly 240 million children worldwide live with disabilities, representing approximately one in ten children. Functional limitations may affect various aspects of a child's daily activities and participation in social life [1].

Cerebral palsy (CP) comprises a group of conditions associated with disturbances in the development of movement and maintenance of posture resulting from damage to the developing brain. Clinical manifestations vary considerably in type and severity, and consequently, the clothing needs of children with CP are also diverse. Spasticity, involuntary movements, impaired balance, and limitations in voluntary movement may make independent dressing, maintaining a comfortable body position, and performing personal care more difficult [2].

Adaptive clothing is considered an important component of an accessible and inclusive environment. Unlike conventional garments, it is designed to address the specific functional limitations of the user. Such clothing may incorporate easy-to-use fasteners, improved access to specific areas of the garment, adjustable components, elastic materials, and construction features that facilitate dressing and personal care. Recent studies emphasize that dressing difficulties among children with developmental disabilities may affect not only their independence

but also their participation in social and recreational activities, while simultaneously increasing the caregiving burden [3].

Particular attention has been given to elastic materials containing Lycra and other elastomeric fibers. Clinical studies have reported potential beneficial effects of Lycra garments on certain aspects of postural control, balance, and motor function in children with CP. However, the findings across studies have been inconsistent, and prolonged use may present practical challenges, including difficulties with toileting and putting on the garment [4–6]. Therefore, textile materials intended for adaptive clothing should be evaluated not solely on their stretchability but also on a combination of functional and performance characteristics.

Another important aspect is sustainable design. The reuse of denim can extend the life cycle of already manufactured textiles while incorporating a durable material into adaptive garments. However, the environmental benefits of denim reuse should be considered within a life-cycle perspective, as the production and processing of cotton denim are associated with substantial water and resource consumption [7,8].

2. Aim and Objectives of the Study

The aim of this study was to scientifically substantiate the selection of textile materials for the design of adaptive clothing for children with cerebral palsy (CP), based on their physical and mechanical properties and the functional requirements of the garments.

To achieve this aim, the following objectives were established:

- to analyze the requirements for materials used in adaptive and rehabilitation clothing for children with motor impairments;
- to investigate the physical and mechanical properties of denim and knitted fabrics with different fiber compositions;
- to compare the strength and deformation characteristics of the materials studied;
- to identify the most promising groups of materials for different functional zones of adaptive clothing;
- to develop recommendations for the combined use of denim and elastic knitted fabrics.

3. Materials and Methods

The study examined 13 textile material samples intended for clothing production, including seven denim fabrics and six knitted fabrics. The fiber composition, surface density, and other characteristics of the samples are presented in Table 1. The denim samples contained 60–80% cotton fibers and 20–40% polyester fibers, with surface densities ranging from 156.1 to 240.9 g/m². The knitted materials included polyester, cotton, and viscose fabrics, as well as a biflex sample. Their surface densities ranged from 153 to 326.3 g/m².

The physical and mechanical properties of the materials were evaluated at the testing laboratories of the Tashkent Institute of Textile and Light Industry (Uz-COR), Sentex-Uz, and the Department of Materials Science. The following characteristics were determined: surface density, electrostatic properties, thickness, breaking force in the warp and weft directions, elongation at break in the warp and weft directions, and stretchability under a 6 N load.

The determination of the maximum force and elongation of the textile materials was performed with reference to the international standard ISO 13934-1:2013, which is applicable to woven fabrics, including materials containing elastomeric components [9].

The interpretation of the results took into account the specific functional requirements of adaptive clothing. For functionally active areas of a garment, priority was given to stretchability and the ability of the material to conform to body movements without excessively restricting mobility. In contrast, structurally loaded areas require sufficient strength, dimensional stability, and resistance to mechanical and operational stresses.

4. Results

Table 1. Structural Characteristics of the Materials Studied

No	Material / Fiber Composition	Group	Surface Density (g/m ²)
1	70% cotton + 30% Polyester	Denim	210,1
2	65% cotton + 35% ПЭ	Denim	191,0
3	80% cotton + 20% Polyester	Denim	156,1
4	60% cotton + 40% Polyester	Denim	240,9
5	70% cotton + 30% Polyester	Denim	210,0
6	75% cotton + 25% Polyester	Denim	200,4
7	65% cotton + 35% Polyester	Denim	188,8
8	100% cotton, biflex	Knitted Fabric	211,5
9	100% Polyester	Knitted Fabric	206,2
10	100% cotton	Knitted Fabric	205,9
11	100% cotton	Knitted Fabric	153,0
12	100% Viscose (Bamboo)	Knitted Fabric	194,0
13	100% Polyester	Knitted Fabric	326,3

Among the materials investigated, Sample 11 (100% cotton) had the lowest surface density, at 153 g/m², whereas Sample 13 (100% polyester) had the highest, at 326.3 g/m². For adaptive clothing, surface density alone cannot be considered a sufficient criterion for material selection; thickness, strength, stretchability, and the specific functional requirements of each garment zone should be considered simultaneously.

Table 2. Physical and Mechanical Properties of the Materials

No	Surface Density (g/m ²)	Electrostatic Charge (V)	Thickness (mm)	Breaking Force, Weft (N)	Breaking Force, Warp (N)	Elongation at Break, Warp (%)	Elongation at Break, Weft (%)	Stretchability at 6 N, Warp/Weft (%)
1	210.1	161	0.5	784	430	13	47	6 / 5
2	191.0	193	0.3	630	477	16	57	4 / 8
3	156.1	416	0.2	329	403	17	102	7 / 29
4	240.9	114	0.35	293	503	18	55	8 / 16
5	210.0	168	0.3	453	286	14	54	8 / 7
6	200.4	297	0.3	743	386	22	44	8 / 16
7	188.8	326	0.25	603	204	95	18	7 / 4
8	211.5	1018	0.5	283	196	353	254	34 / 37
9	206.2	1110	0.35	253	199	281	28	46 / 59
10	205.9	159	0.5	190	154	170	227	52 / 59
11	153.0	114	0.2	188	103	78	140	21 / 38
12	194.0	218	0.25	111	134	144	158	59 / 49
13	326.3	1230	0.4	336	249	241	398	27 / 42

Note: The values presented in the table were reproduced from the original experimental data. In the original table, the final pair of columns was labeled “stretch ability upon heating at 6 N.” For consistency, the present text refers to this parameter as “stretch ability at 6 N,” without altering the numerical values.

Comparative Analysis

Overall, the denim fabrics demonstrated higher breaking force values than most of the knitted fabric samples. Among the denim materials, the highest breaking force in the warp direction was recorded for Sample 1 (784 N), followed by Sample 6 (743 N). These results indicate the high mechanical strength of denim and its suitability for garment areas exposed to considerable operational loads.

At the same time, denim generally exhibited lower elongation at break than the elastic knitted fabrics. An exception was Sample 7, which showed an elongation at break of 95% in the warp direction and 18% in the weft direction. This pronounced anisotropy indicates that the direction of fabric placement should be considered during pattern development and garment construction.

The highest deformation capacity was observed for Sample 8, a 100% polyester biflex fabric. Its elongation at break reached 353% in the warp direction and 254% in the weft direction, while stretchability under a 6 N load was 34% and 37%, respectively. Sample 9 also demonstrated a high deformation capacity, particularly in the warp direction, with an elongation at break of 281%. These characteristics make elastic knitted fabrics promising for garment areas requiring close body conformity, freedom of movement, and controlled supportive action.

The cotton knitted fabrics represented by Samples 10 and 11 also demonstrated considerable deformation capacity, although their properties differed substantially between the warp and weft directions. Sample 10 showed elongation at break of 170% in the warp direction and 227% in the weft direction, whereas Sample 11 demonstrated values of 78% and 140%, respectively. The bamboo-based viscose fabric (Sample 12) exhibited elongation at break of 144% and 158% and stretchability under a 6 N load of 59% and 49% in the warp and weft directions, respectively.

4. Discussion

The results obtained are consistent with previously published studies on therapeutic garments. In a study by Scrutton et al., the use of Lycra garments in children with different forms of cerebral palsy was associated with improvements in selected measures of functional activity and proximal stability, although the authors also reported practical difficulties associated with the use of such garments [4]. Another clinical study involving a small group of children found improvements in static balance following the use of a Lycra suit; however, the authors emphasized the need for further research involving larger samples [5]. A systematic review also reported potential improvements in postural alignment and gait associated with certain types of therapeutic garments, while characterizing the overall quality of evidence as limited [6].

These findings have direct implications for garment design. The material should not be regarded as an independent therapeutic intervention. Rather, its role in adaptive clothing is to create controlled mechanical conditions that support comfort, freedom of movement, and, where appropriate, a supportive effect. Garment construction, the degree of compression, and the placement of seams, fasteners, and functional zones should therefore be developed in an integrated manner, taking into account both medical and ergonomic requirements.

From an ergonomic perspective, elastic knitted fabrics are preferable in areas where the garment needs to conform closely to the body and deform during movement. The high stretchability of biflex and other elastic fabrics makes them suitable for functional inserts and areas requiring a high degree of mobility. However, excessive stretchability may reduce dimensional stability and increase the demands placed on garment construction and manufacturing technology. Therefore, the use of highly elastic fabrics should be localized and functionally justified.

In contrast, denim provides high strength and durability, which are particularly important for garments intended for intensive daily use. It can be effectively used in components that need to maintain their shape, withstand loads from fasteners and assistive devices, and protect the garment against mechanical wear. At the same time, the use of rigid denim directly in areas involving active limb flexion may restrict movement. Therefore, combining denim with elastic fabrics appears more appropriate than constructing the entire garment from a single material.

The environmental aspect also deserves particular attention. Life-cycle studies of denim have demonstrated the substantial influence of cotton cultivation, processing, finishing, and laundering on the water and environmental footprint of the garment [7,8]. In this context, the reuse of suitable denim in adaptive clothing may form part of a strategy aimed at extending the service life of textile materials. However, the environmental benefits should be confirmed through a separate life-cycle assessment and should not be presented as a quantitatively established outcome of the present study.

Highly stretchable knitted materials are appropriate for zones that require freedom of movement and controlled conformity to the body. Biflex and similar highly elastic fabrics may be used in functional inserts and supportive components; however, the degree of fabric tension should be determined by the garment construction and the individual needs of the child. Denim materials with high breaking force are suitable for structurally loaded areas, fastening components, pockets, and zones exposed to increased wear. When combining denim and knitted fabrics, differences in their deformation behavior should be taken into account to prevent localized seam tension and discomfort.

For children's clothing, rigid or protruding elements in areas of skin contact should be minimized, while fasteners should be positioned so that they are readily accessible to the parent and, where possible, to the child. When developing a rehabilitation suit, provision should be made for medical supervision and individualized adjustment of the garment construction. Textile clothing should not be positioned as an independent therapeutic intervention.

5. Conclusion

The study of 13 textile material samples demonstrated substantial differences between denim and knitted fabrics in terms of strength and deformation characteristics. Within the sample set investigated, denim fabrics were generally characterized by higher breaking force, indicating their potential suitability for structural and wear-resistant components of adaptive clothing. Knitted fabrics, particularly biflex, demonstrated substantially greater stretchability and elongation, making them promising for functional zones associated with movement and changes in body position.

For the design of adaptive clothing for children with cerebral palsy, the most appropriate approach is not the selection of a single universal material but the functional combination of textiles with different performance characteristics. Such an approach makes it possible to simultaneously address strength, deformation capacity, freedom of movement, and dimensional stability of the garment. The findings of this study can serve as a materials-science basis for the development and prototyping of adaptive clothing and rehabilitation suits.

However, the results should be interpreted as a materials-science basis for garment design rather than as evidence of the clinical effectiveness of the resulting garments. Further clinical and ergonomic studies involving the target user population are required to confirm the functional benefits and practical effectiveness of the developed garments.

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