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Sustainable Fashion for Children's Clothing: Exploring Permanent Pleating for Adaptive Fit and Textile Waste Reduction

Trajnostna moda za otroška oblačila: raziskava trajnega plisiranja za prilagodljivo velikost in zmanjšanje količine tekstilnih odpadkov

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Abstract

Textile waste has become a serious global problem, leading to pollution, resource depletion and overcrowding in landfills. To overcome these problems, sustainable design strategies that reduce resource consumption, minimize waste and maintain ecological balance are needed. Additionally, children's rapid growth demands regular clothes changes, which generates a great deal of fabric waste. This highlights a serious research gap in creative, adaptable and waste-reducing ideas for children's clothing, which affects the sustainability of the textile industry. This study explores the potential of permanent pleating in children's clothing to develop sustainable, innovative designs that minimize waste and improve garment durability. In particular, permanent pleating in both the lengthwise and widthwise directions are investigated, while the durability and fit of pleated garments are assessed, as well as manufacturing limitations and challenges. Permanent pleating was applied to 100% polyester, a polyester-cotton blend, and 100% cotton fabrics using pleating moulds and three distinct methods: oven drying, oven drying with water mugs and steaming. The results revealed that the steaming method yielded the most successful permanent pleats on 100% polyester fabric, outperforming the polyester-cotton blend and 100% cotton fabrics. Permanent pleating reduces frequent clothing replacement by allowing the fabric to expand and fit various body sizes without losing structural integrity. This extends the lifespan of clothing and reduces textile waste.
Keywords: sustainable fashion, textile waste, permanent pleating, adaptive fit, durability

Izvleček

Tekstilni odpadki so postali resen svetovni problem, ki vodi do onesnaževanja, izčrpavanja virov in prenatrpanosti odlagališč. Za premagovanje teh težav so potrebne trajnostne strategije oblikovanja, ki zmanjšujejo porabo virov in količino odpadkov ter ohranjajo ekološko ravnotežje. Hitra rast otrok zahteva redno menjavo

oblačil, kar povzroča veliko odpadkov tkanin. Na tem področju primanjkuje zamisli za zmanjšanje količine odpadkov otroških oblačil, kar vpliva na trajnostno učinkovitost tekstilne industrije. V raziskavi je proučevan potencial plisiranja otroških oblačil, da bi zmanjšali količino odpadkov in podaljšali trajnost oblačil. Proučevani so bili trajno plisiranje v vzdolžni in prečni smeri blaga, obstojnost gub, prileganje plisiranih oblačil, omejitve pri izdelavi in izzivi. Trajno plisirane so bile tkanine iz 100-odstotnega poliestra, mešanice poliestra in bombaža ter 100-odstotnega bombaža. Uporabljeni so bili kalupi za plisiranje in tri metode: sušenje v pečici, sušenje v pečici z vodnimi vrčki in parjenje. Pokazalo se je, da parjenje omogoča trajne gube na tkaninah iz 100-odstotnega poliestra, ki so obstojnejše kot na tkaninah iz mešanice poliestra in bombaža oziroma iz 100-odstotnega bombaža. Plisiranje zmanjšuje pogosto menjavo oblačil, saj omogoča, da se tkanina razširi in prilega različnim velikostim telesa, ne da bi pri tem izgubila strukturno celovitost. Tako se oblačila nosijo dalj časa, s tem pa je tudi tekstilnih odpadkov manj.
Ključne besede: trajnostna moda, tekstilni odpadki, trajno gubanje, prilagodljivo prileganje, vzdržljivost

1 Introduction

The fashion industry has long been identified as a significant contributor to environmental degradation, with textile waste posing a particularly pressing concern [1]. Children's clothing, in particular, exacerbates this issue due to the rapid growth rates of children, leading to frequent garment replacement and substantial waste [2–3]. Innovative design strategies such as permanent pleating have emerged as potential solutions to enhance garment longevity and sustainability [4]. Children's rapid growth necessitates frequent updates to their wardrobes, leading to significant textile waste. Studies have shown that children can outgrow their clothes as quickly as seven sizes within the first two years of life. This rapid turnover contributes to the approximately 92 million tons of textile waste generated on a global scale annually. Addressing this issue requires innovative design approaches that extend the usability of children's garments [5].

Permanent pleating involves creating structured folds in fabric that allow garments to expand and contract, adapting to the wearer's growth [6]. This technique offers a promising solution to the challenges posed by children's rapid growth and the associated textile waste [7]. British designer Ryan Mario Yasin, an aeronautical engineer, drew inspiration from origami folding techniques to develop children's clothing that grows with the child. The garments feature pleated fabrics that stretch horizontally and vertically, accommodating growth from six months to three years of age [2]. The primary advantage of permanent pleating in children's clothing is its ability to maintain a comfortable and adaptive fit as the child grows. The pleated structures enable the garment to expand in response to the child's growth, ensuring that the clothing remains functional and comfortable over an extended period. This adaptability reduces the frequency of garment replacement and enhances the overall user experience for both children and parents [8–9]. For permanent pleating to be a viable solution, the durability of the pleats under regular wear and laundering is crucial. Research indicates that pleated fabrics can maintain structure and functionality over time, provided that appropriate materials and manufacturing processes are employed. The use of high-quality, resilient fabrics and advanced pleating techniques contributes to the longevity of the pleats, ensuring that the garments continue to function as intended throughout their extended use [10–11].

Several initiatives have demonstrated the practical application of permanent pleating in children's clothing. Petit Pli, founded by Ryan Mario Yasin, offers a range of children's clothing that accommodates growth through its pleated designs [2]. Adopting permanent pleating in children's clothing aligns with broader sustainability goals by reducing textile waste and promoting the reuse of garments [12]. Extending the functional lifespan of clothing diminishes the demand for new clothes and lessens the environmental impact associated with textile production and disposal [13]. Furthermore, the potential for reusing garments for multiple children or passing them down within families enhances the circularity of textile products, thereby contributing to a more sustainable fashion ecosystem [14–15].

This research endeavours to mitigate the need for constant replacements by integrating permanent pleats into children's clothing, thus extending its lifespan. This innovation supports sustainable practices, reduces textile waste and offers considerable cost savings for parents while fostering environmentally conscious fashion choices.

2 Experimental

This study aims to ascertain whether permanent pleating in children's clothing is a viable and sustainable strategy to reduce the generation of textile waste.

2.1 Materials and equipment

Focusing on fit retention, pleat durability and production issues, two fabrics from 100% polyester (Table 1) were selected to evaluate the pleating performance and suitability for children's trousers. In preliminary tests, we found that pleats are not stable in the case of cotton and polyester-cotton blend fabrics. All fabrics were sourced from local suppliers and conditioned under standard atmospheric conditions (65% ± 2 % relative humidity and 20 °C ± 2 °C) before pleating and testing.

Table 1: Fabrics

Fabric label	Description
PES-p	100% polyester (recycled), 1/1 plain fabric: lightweight woven fabric with smooth surface and slight sheen (70 g/m^2)
PES-r	100% polyester (recycled), ripstop fabric: reinforced woven fabric with cross-hatch pattern providing enhanced tear resistance (70 g/m^2)

Trims: (1) sewing thread: 100% polyester (count: 27 tex) and (2) Velcro: 100% polyester (white) (white, hook-and-loop type).

Pleating mould: kraft paper: 170 g/m^2 (111.76 cm × 60.96 cm).

Chemicals: (1) detergent: commercial non-ionic detergent; (2) softener: cationic softener; and (3) resin: di-methyl di-hydroxy ethylene urea; cross-linking agent to enhance pleat retention.

Tools: (1) scale, measuring tape, chalk, pencil, eraser and scissors: used for pattern marking and measurement; (2) paper cutter, masking tape and polythene bag: used for pleating mould preparation and sample handling; (3) iron, pan, perforated tray and steel mug: used for resin application and heat treatment, and (4) needle: used for creating micro-perforations beneath pleats.

Equipment: (1) lock stitch sewing machine: used for the assembly of garment panels, (2) overlock sewing machine: used for edge finishing, (3) oven dryer: used for resin curing and pleat setting at controlled temperatures, (4) gas stove and electric plate: used for controlled heating during pleat setting, and (5) universal strength tester: used for fabric tensile strength measurement.

2.2 Methods

Artwork and pattern preparation

A detailed visual representation was meticulously created to visualize the initial and final designs of the garments, which are illustrated in Figure 1. A measurement chart for trousers was then prepared using the measurements taken from a 3-month-old baby and a 2-year-old baby. After that, a trousers pattern was accurately prepared based on precise measurements obtained from a 2-year-old baby, shown in Table 2.

Fabric cutting and sewing: The fabric-cutting process involved the careful handling and precise cutting of the fabrics according to the trousers' pattern to ensure accurate alignment and sizing. The cut fabric pieces were meticulously sewn together using a 3-thread overlock machine for overlock stitch and a plain lock stitch machine to provide a safety stitch. Notably, the waistband and cuffs of most of the trousers were intentionally left unsewn at this stage. The aim of this approach was to prevent excessive thickness in the garment, making it easier to insert into the pleating mould during subsequent steps. However, some samples were prepared with sewn waistbands and cuffs.

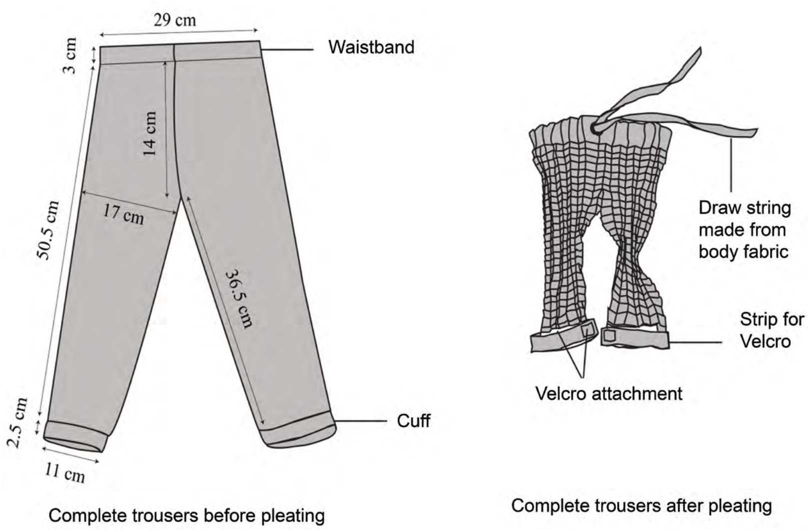


Figure 1: Visual representation of the children's trousers

Table 2: Trousers measurement chart

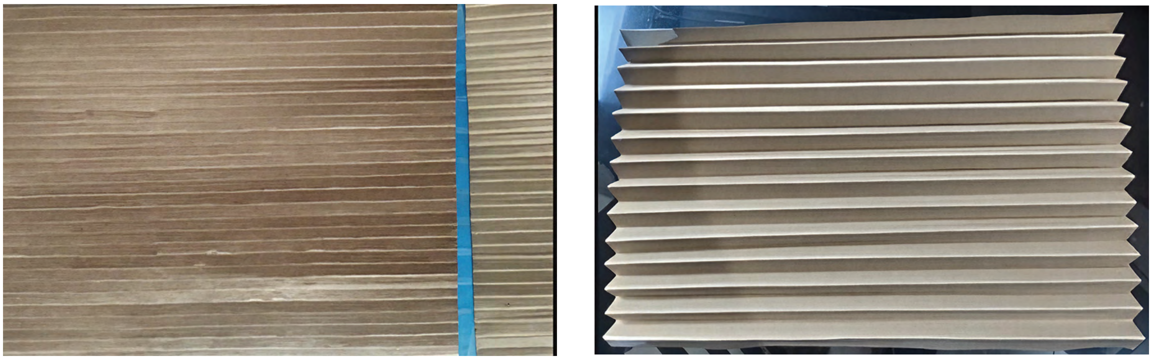
Measurement points	Dimensions of a three month old toddler (cm)	Dimensions of a two year old toddler (cm)	Allowance (cm)
½ waist circumference	20	29	1.5
Waistband depth	3	3	1.5
Front body rise	7.5	14	1.5
½ thigh circumference	8	17	1.5
Inseam leg measurement	15.5	36.5	1.5
Outside leg measurement	23	50.5	1.5
½ cuff circumference	6	11	1.5
Cuff depth	2.5	2.5	1.5

Garment washing and drying: The sewn garments underwent a thorough washing process using appropriate detergents to enhance cleanliness and visual appeal. Softener was also used while washing the garments to enhance their softness. After washing, the garments were carefully air-dried to preserve their original shape and size.

In large-scale manufacturing, the individualized washing and flat drying of garments may not be practical. Omitting this step could slightly affect surface cleanliness and visual uniformity but is not expected to significantly influence the functional performance of pleats, tensile strength, tear strength or breathability, which are primarily determined by the fabric type, pleating method and material properties. The laboratory washing procedure thus serves as a controlled method for assessing material behaviour, while acknowledging that industrial garments may undergo simplified or batch washing processes.

Manufacturers may skip individual washing for mass production, instead relying on fabric pre-treatment and quality control to maintain product performance. Pleat retention and breathability are unlikely to be compromised by the omission of post-sewing washing, although minor variations in appearance may occur.

Pleating mould preparation: (1) flat pleating mould (lengthwise pleating) (Figure 3a); (b) accordion pleating mould (width-wise pleating) (Figure 3b).



a) b)

Figure 2: Preparation of pleating mould: a) flat pleat b) accordion pleat

The flat pleating moulds were created using kraft paper in a sandwich-type structure measuring 58.5 cm × 38 cm. Pleating calculations determined the required overpleat and underpleat sizes to achieve the desired garment pleats. One mould had overpleats of 1.4 cm and underpleats of 0.7 cm, while another had overpleats of 1.3 cm and underpleats of 0.7 cm.

Accordion pleating moulds were painstakingly made for the final product, featuring 1.6 cm overpleats and fixed underpleats. These sandwich-like moulds measured 43 cm × 43 cm.

Pleating calculations

Pants were resized using pleating calculations (Equations 3 and 4).

$$\text{Number of complete pleats in the garment} = \frac{\text{(Outside leg measurement (2 year old child))/(Full pleat)}}{\text{Full pleat}} \quad (1)$$

$$\text{Size of the garment after pleating=1 full overpleat+(Number of full pleats-1)} \times \text{Difference between over and underpleat} \quad (2)$$

According to the distinction between overpleats and underpleats, only one overpleat in flat pleated clothing was completely visible, while the others exhibited partial overpleats. Two types of flat pleating moulds were developed after testing various pleat sizes. The determined full pleat sizes, each consisting of one overpleat and one underpleat, are presented in Table 3.

Table 3: Pleating calculations for resizing trousers from a two-year-old to a three-month-old toddler

Pleating calculations for size adjustment	1st case [a)]	2nd case [b)]
Outside leg measurement (cm)	50.5	23
Full pleat (cm)	2.1	2
Overpleat (cm)	1.4	1.3
Underpleat (cm)	0.7	0.7
Number of complete pleats in the garment	24	25
Size of the garment after pleating (cm)	17.5	15.7

[a)] For trousers of two-year-old toddler; [b)] For trousers of three months old toddler

Accordion pleating

These pleats are primarily used to lock the flat pleats so they do not open up due to weight. The over and underpleats are the same for accordion pleats. For this study, the size of the overpleats and underpleats was 1.6 cm. The accordion pleats also compact the width of the garment, which was necessary in this case. The chosen size of the accordion pleats was stable with the flat pleats and gave the garment the desired effect.

Permanent pleating process

Three methods were used to create permanent pleating. For all cases, garments were first placed in flat pleating moulds. Resin treatment was applied in 100% cotton and polyester-cotton blends before insertion. The moulds were stretched to straighten, garments were laid flat inside, and then folded back into the pleated state and secured with masking tape. The moulds were then ironed for five minutes on each side at the highest temperature possible. These three methods are shown in Figure 3.

First method (oven dryer): The garment in the flat pleating mould was placed in a dryer oven at 180 °C for 30 minutes, then cooled for another 30 minutes before removal. After completing lengthwise pleating, the garment was inserted into an accordion pleating mould, folded, tightly wrapped and subjected to the same oven process. However, the pleats were not stable using this method.

Second method (oven dryer with water mugs): The dryer oven method was repeated with steel water mugs to introduce moisture. However, pleats remained unstable for cotton and polyester-cotton blends. For pure polyester, pleats were also unstable after washing.

Third method (steaming): After ironing, the flat pleating mould was cooled for several hours before transferring the garment to an accordion pleating mould, which was then folded and tightly wrapped. The bottom was left open for steam, while the sides and top were covered with polythene. After setting the mould over a perforated tray filled with boiling water and covering it with a polythene bag, it was steam-cooked at 110 °C for two and a half hours. It was then chilled for at least five to six hours. Pleats were stable for pure polyester even after washing, while they remained unstable for cotton and polyester-cotton mixes.

a) b) c)

Figure 3: Permanent pleating process a) oven drying b) oven drying with water mugs c) steaming

Final finishing

Waistband, cuffs, Velcro and drawstring joining: For most trousers, the waistband and cuffs were joined after the pleating process. This approach was adopted to avoid excessive thickness in the garment, thereby facilitating easier insertion into the pleating mould.

For fitting purposes, drawstring and Velcro were attached to the garment. The joining process involved careful sewing techniques to ensure a secure and aesthetically pleasing finish. Figure 4 shows the final appearance of the trousers.

Figure 4: Final appearance of the trousers after permanent pleating

Adding breathable feature: Manual permanent holes of 0.05 cm in diameter were created in the 100% polyester-made garments using a needle on the underside of the pleats to make the garment more breathable.

In industrial-scale production, such manual perforation would be impractical. Instead, fabric manufacturers could produce fabrics with pre-engineered micro-perforations or controlled mesh structures to achieve similar breathability without compromising fabric integrity. Aligning these micro-perforations precisely beneath pleats in large-scale manufacturing would require specialized design and quality control to maintain consistency, but it could be integrated during fabric weaving or finishing stages. These considerations are important for evaluating the feasibility of applying this method in mass production while maintaining comfort and functional performance in children's garments.

Evaluation

Evaluation after washing: Pleat stability was evaluated based on visual appearance and durability after 5 (five) washes. Garments were hand-washed in cold water with detergent, then rinsed and dried flat in their pleated state.

Washing cycle selection: The evaluation was conducted after 5 washing cycles, representing the typical laundering frequency for children's garments before size outgrowth or replacement. Although studies on washing durability often consider 1, 5 and 10 cycles, the 5-cycle test was selected to balance practical relevance and experimental efficiency, as significant pleat deformation or resin fatigue typically manifests within the first few washes. This approach facilitated the assessment of long-term pleat retention within a realistic user scenario.

Replication: The entire process outlined above was replicated consistently to create multiple permanent pleated garments, thereby ensuring reliability and validating the pleating techniques' repeatability.

2.3 Test methods

Tensile strength test (strip method) (ASTM D5035-11)

To determine the tensile strength of the fabric, a Universal Tensile Strength Tester was used with appropriate sample mounting jaws. The fabric was stretched parallel to the warp and weft directions. Two samples were tested in each direction before and after pleating for every colour. Warp samples (16.5 cm × 6 cm) had 0.5 cm of warp threads removed, while weft samples (6 cm × 16.5 cm) had 0.5 cm of weft threads removed. The top and bottom jaws were correctly positioned, and the instrument was adjusted to the required test settings. Each specimen was placed centrally and securely held across its entire width to avoid any slippage. A consistent load was applied until the specimen ruptured, with the results shown on the computer. The test was conducted again for both warp and weft specimens, and the results were recorded separately for each direction [16].

Tear strength test (EN ISO 13937-3)

Using the tongue tear method, a Universal Tensile Strength Tester was used to measure the fabric's tear strength. Rectangular samples measuring 20 cm × 10 cm (warp direction) and 10 cm × 20 cm (weft direction) were prepared before and after pleating for each colour. A 10 cm cut was made at the centre of each sample to create a two-tongue shape. The upper and lower jaws were set, and each jaw held one tongue. The jaws were separated at a fixed speed, causing the fabric to tear along the pre-cut segment. The results were displayed on the computer after the test [17].

Seam slippage test (ISO 13936-2)

Using the fixed load method, this test evaluates the resilience of woven fabric thread systems to slippage at a stitched seam. Twenty-by-ten-cm examples were cut for each colour, two in the warp direction and two in the weft direction, before and after pleating. After folding the specimens face inward, a seam was sewn 2 cm from the fold, with equal seam allowance on both sides. A 1.2 cm cut was made through both fabric layers. The clamps on the tensile testing apparatus were spaced 100 mm (± 1 mm) apart to ensure correct alignment. The seam was positioned halfway between the clamps to attach the specimens symmetrically. The moving clamp was activated, and when maximum force was reached, the load was reduced to 5 N at a constant extension rate of 50 mm/min ± 5 mm/min. The seam opening at its widest point was measured immediately to the nearest mm, and the procedure was repeated for the remaining specimens [18].

Water vapor transmission rate (water method) (ASTM E-96)

ASTM E-96 was used as a reference for testing with some modifications. Two samples were prepared for each colour: one with holes and the other without. The fabrics were cut into circular shapes. Four bottles were divided into two parts, with the lower section representing one-third of the bottle's original length, and filled with distilled water. The open ends of the bottles were covered with the fabric samples and secured with rubber bands, maintaining a 15 mm distance between the fabric and the water level. Temperature and humidity were controlled in the room. The combined weight of the fabric samples and bottles was measured using an electric balance, and weight loss was recorded at hourly intervals for 8 hours. The weight loss determined the rate of vapour movement through the fabric, with the resulting water vapour transmission rate indicating the fabric's breathability. Higher values represented better breathability [19].

The water vapour transmission rate (WVTR) was calculated according to Equation 1:

$$WVTR = \frac{(W_1 - W_2) \times 24}{A \times t} \quad (3)$$

where, W_1 represents the initial weight of the sample with the water bottle, W_2 represents the final weight of the sample with the water bottle after eight hours, A represents the test area (it was 0.00709 m^2 for fabrics PES-r, PES-p and PES-r with holes and 0.00567 m^2 for fabric PES-p fabric with holes) and t represents the duration of the test (it was eight hours).

Pleat recovery test (BS EN 14704-1)

BS EN 14704-1 was used as a reference to measure the pleat recovery in permanently pleated fabrics, with some modifications. Two strips of fabric measuring 30 cm × 5 cm were sewn for each colour and then permanently pleated. The initial pleated width and length were measured and recorded. The cleaned cloth sample was secured at the top and a 500-gram weight was attached to the bottom for four hours. After the test, the weight was taken off the cloth, which was left to relax naturally for 10 minutes. The length and width of the pleated sample were measured and recorded after the relaxation period using a measuring tape. The pleat recovery percentage was then calculated (Equation 2). A higher pleat recovery percentage indicated better fabric resilience and the ability to retain pleats [20].

$$Pleat\ recovery = \left(1 - \frac{Final\ length\text{-}Initial\ length}{Initial\ length}\right) \times 100\ (\%) \quad (4)$$

3 Results and discussion

Tensile strength test

The results given in Table 4 show that the maximum force required to break the polyester ripstop fabric decreased after pleating in the warp direction, with a mean value of 720.885 N compared to 771.165 N before pleating, indicating a negative effect on the tensile strength of the fabric in the warp direction. The extension percentage increased after pleating, with a mean value of 60.35% compared to 54.595% before pleating. The time to break was longer after pleating, with a mean value of 22 seconds compared to 20 seconds before pleating.

A similar tensile strength loss was seen in the weft direction of the fabric after pleating. The extension percentage also decreased slightly after pleating, with a mean value of 65.31% compared to 65.795% before pleating. The time to break was similar before and after pleating, with a mean value of 28 seconds for both conditions.

It is evident from Table 4 that the maximum force required to break the polyester plain fabric was quite similar before and after pleating, with a mean value of 695.57 N before pleating and 692.275 N after pleating. This indicates that pleating had no significant effect on the tensile strength of the fabric in the warp direction. The extension percentage also remained relatively stable before and after pleating, with a mean value of 51.035% before pleating and 54.035% after pleating. The time to break was slightly longer after pleating, with a mean value of 27 seconds compared to 25 seconds before pleating.

Table 4 shows that the maximum force required to break the fabric decreased after pleating, with a mean value of 343.955 N compared to 396.905 N before pleating. This indicates that pleating had a negative effect on the tensile strength of the fabric in the weft direction. The extension percentage increased slightly after pleating, with a mean value of 33.37% compared to 32.145% before pleating. The time to break was almost identical before and after pleating, with a mean value of 16 seconds before pleating and 17 seconds after pleating.

Pleating reduced the tensile strength of polyester ripstop and plain fabrics, particularly in the weft direction. Ripstop experienced a significant strength loss in the warp, while plain fabric for the most part

Table 4: Fabrics tensile test results

Fabric	Testing direction	Testing	Breaking force (N)			Extension (%)			Average time to break (s)
			Average	SD [c]	CV (%)	Average	SD	CV	
Polyester (ripstop)	Warp	BP [a]	771.165	15.45	2.00	54.595	2.88	5.27	20
		AP [b]	720.885	2.44	0.34	60.35	2.88	4.78	22
	Weft	BP [a]	511.225	53.15	10.39	65.795	0.02	0.03	28
		AP b)	492.92	11.81	2.39	65.31	5.2	7.97	28
Polyester (plain)	Warp	BP a)	695.57	1.48	0.21	51.035	1.58	3.09	25
		AP b)	692.275	3.54	0.51	54.035	0.84	1.56	27
	Weft	BP a)	396.905	0.46	0.12	32.145	0.36	1.12	16
		AP b)	343.955	21.83	6.35	33.37	2.22	6.65	17

[a] Before pleating; [b] after pleating; [c] standard deviation

remained stable. The extension increased in the warp but varied in the weft. The time to break was generally longer after pleating, except for ripstop in the weft, where it remained unchanged. Overall, the polyester plain fabric retained warp strength more effectively, making it a better choice for pleated designs requiring warp durability, while the ripstop fabric demonstrated better performance in the weft direction.

Tear strength

The mean peak force required to tear the polyester ripstop fabric in the warp direction was slightly lower after pleating, with a mean value of 31.84 N compared to 32.46 N before pleating (Table 5). The median peak force was also quite similar before and after pleating, with a mean value of 32.62 N before pleating and 31.435 N after pleating. The maximum peak force was slightly higher after pleating, with a mean value of 49.545 N compared to 44.725 N before pleating. This suggests that pleating may have had a positive effect on the maximum tear strength of the fabric in the warp direction.

It is evident from Table 5 that the mean peak force required to tear the polyester ripstop fabric in the weft direction was slightly lower after pleating, with a mean value of 27.255 N compared to 31.34 N before pleating. This indicates that pleating had a negative effect on the tear strength of the fabric in the weft direction. The median peak force was also slightly lower after pleating, with a mean value of 27.41 N compared to 31.475 N before pleating. The maximum peak force was also lower after pleating, with a mean value of 38.175 N compared to 44.505 N before pleating.

Table 5 shows that the mean peak force required to tear the polyester plain fabric in the warp direction was slightly higher after pleating, with a mean value of 8.52 N compared to 8.21 N before pleating. This indicates that pleating had a positive effect on the tear strength of the fabric in the weft direction. The median peak force was also slightly higher after pleating, with a mean value of 8.59 N compared to 8.36 N before pleating. But the maximum peak force was slightly lower after pleating, with a mean value of 10.5 N compared to 10.915 N before pleating.

It is evident from Table 5 that the mean peak force required to tear the polyester plain fabric in the weft direction was slightly higher after pleating, with a mean value of 5.505 N compared to 5.47 N before pleating. This indicates that pleating had a positive effect on the tear strength of the fabric in the weft direction. However, it is important to note that the difference in mean peak force before and after pleating was relatively small. The median peak force also decreased slightly after pleating, with a median value of 5.495 N compared to 5.50 N before pleating. The maximum peak force required to tear the fabric was also lower after pleating, with a mean value of 6.99 N compared to 7.27 N before pleating.

Pleating had a minimal impact on the warp-wise tear strength of polyester ripstop and plain fabrics, with only slight variations in peak forces. Ripstop experienced a better performance in the warp direction, while tear strength is not consistent in the weft direction, and while plain fabric performs better in the warp direction. Overall, polyester ripstop fabric has higher tear strength than polyester plain fabric, in the warp direction, making it more suitable for pleated designs in the warp direction. However, for consistent tear strength, polyester plain fabric is a better choice.

Seam slippage resistance test results

The seam slippage resistance of polyester fabric (ripstop) and polyester fabric (plain) are shown in Table 6. For polyester (ripstop), the maximum force required for seam slippage stayed nearly the same (80.535 N to 80.52 N). Nevertheless, the seam opening increased from 20.00 mm to 30.00 mm after pleating, indicating a reduction in seam slippage resistance in the weft direction. The standard deviation for ripstop fabric decreased somewhat from 0.64 N to 0.62 N, indicating less variability. The maximum force for polyester (plain) changed slightly from 80.32 N to 80.135 N, while the standard deviation decreased from 0.23 N to 0.04 N, indicating improved consistency. Pleating had little effect on plain fabric but reduced seam slippage resistance in ripstop.

Table 5: Tear strength test

Fabric	Direction	Testing	Mean peak force			Median peak force			Max. peak force		
			Average (N)	SD [c] (N)	CV (%)	Average (N)	SD [c] (N)	CV (%)	Average (N)	SD [c] (N)	CV (%)
Polyester (ripstop)	Warp	BP [a]	32.46	0.92	2.89	32.62	1.81	5.55	44.725	0.64	1.43
	Warp	AP [b]	31.84	1.05	3.33	31.435	1.01	3.21	49.545	0.83	1.67
	Weft	BP [a]	31.34	0.13	0.41	31.475	0.63	2.00	44.505	2.41	5.42
	Weft	AP b)	27.255	2.23	8.18	27.41	2.94	10.73	38.175	2.79	7.31
Polyester (plain)	Warp	BP a)	8.21	0.11	1.38	8.36	0.03	0.36	10.915	0.86	7.88
	Warp	AP b)	8.52	0.18	2.11	8.59	0.18	2.095	10.5	0.34	3.24
	Weft	BP a)	5.47	0.21	3.84	5.50	0.14	2.55	7.27	0.04	0.55
	Weft	AP b)	5.505	0.11	1.998	5.495	0.05	0.91	6.99	0.45	6.44

[a] Before pleating; [b] after pleating; [c] standard deviation

Table 6: Seam slippage resistance

Fabric	Testing	Max. force			Seam opening		
		Average (N)	SD [c] (N)	CV (%)	Average (N)	SD [c] (N)	CV
Polyester (ripstop)	BP [a]	80.535	0.64	0.79	20.00	0.00	0.00
	AP [b]	80.52	0.62	0.77	30.00	0.00	0.00
Polyester (plain)	BP [a]	80.32	0.23	0.29	20.00	0.00	0.00
	AP [b]	80.135	0.04	0.05	20.00	0.00	0.00

[a] Before pleating; [b] after pleating; [c] standard deviation

Water vapor transmission rate

The WVTR (Table 7) varies depending on the type and structure of the fabric, with polyester plain (PES-p) showing better breathability than ripstop (PES-r). Fabrics with holes (PES-r (with holes) and PES-p (with holes)) further increased WVTR, showing that perforations enhance airflow. These insights are essential for sustainable children's apparel, as they help prevent overheating in hot areas and regulate temperature to ensure comfort.

Table 7: Water vapour transmission rate

Fabric	WVTR ($gm^{-2}day^{-1}$)
PES-r	254.1326
PES-r (with holes)	310.7898
PES-p	301.8618
PES-p (with holes)	351.7460

Pleat stability to washing

Children's clothing needs to be washed frequently. In this case, the garment is outerwear, so it must be washed often. So, the garments were washed according to a standard method. After washing the trousers five times and then drying them flat in a pleated state, it was observed that the pleats retained their shapes. It could thus be concluded that the pleats are stable for washing.

Pleat recovery

Polyester plain fabric has better pleat recovery properties than ripstop fabric (Table 8) and is more suitable for this design.

Table 8: Pleat recovery

Fabric	Initial length (cm)	Final length after recovery (cm)	Pleat recovery (%)
PES-r	12	15.5	70.83
PES-p	12.4	14	87.097

The results of tensile strength, tear strength, seam slippage, water vapor transmission, and pleat recovery provide a clear comparison of polyester ripstop and plain fabrics for pleated children's trousers.

Pleating reduced tensile strength, especially in the weft direction, with ripstop showing more loss than plain fabric. Tear strength was largely unaffected, but plain fabric maintained better weft stability. Seam slippage was stable for plain fabric, while ripstop fabric showed a slight increase in seam opening after pleating. Plain fabric exhibited higher water vapor transmission, while the addition of small holes further improved breathability. Both fabrics retained pleats after washing, but plain fabric showed superior pleat recovery (87.1% vs. 70.8%).

4 Conclusion

This research explored permanent pleating as a sustainable option for children's apparel, enabling clothing to grow with kids and reducing textile waste. Among the fabrics tested, permanent pleating with 100% polyester proved the most suitable. The most efficient pleating method was steaming, while pleating directly on garment ensures enhanced durability and alignment. Key elements, such as kraft paper moulds and ideal pleat sizes, improved pleat stability. Fabric testing revealed that pleating generally reduced the tensile strength of both fabrics, particularly in the weft direction, with plain fabric experiencing a greater loss (from 396.905N to 343.955N). However, pleating did not notably affect tear strength, especially for polyester plain fabric, which maintained better performance in this regard. Seam slippage resistance was largely unaffected by pleating in both types of fabric. Moreover, the WVTR revealed that polyester fabric offered better breathability than ripstop fabric, with fabrics perforated by holes further enhancing airflow. This is crucial for designing comfortable children's apparel, as it supports better temperature regulation. The pleats themselves showed good stability when washing, retaining their form after multiple washes, with polyester plain fabric exhibiting superior pleat recovery properties compared to ripstop fabric. Overall, polyester plain demonstrates better strength, comfort, breathability and pleat durability than ripstop fabric. Therefore, polyester plain fabric is the preferred fabric for pleated children's trousers, as it ensures durability, comfort and functional pleats for repeated use. However, obstacles emerged, including limited sample size, temperature fluctuations and restricted access to specialised tools. Future research should focus on improving pleating methods for efficiency and scalability, experimenting with pleating on different materials and integrating modern technologies. By reducing waste and extending the life of clothing, permanent pleating supports sustainable fashion and may make children's apparel more adaptable and durable.

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