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Pressure-point-garments: haptic stimulation of the body enabled through a fashionable 3D-textile interface

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ABSTRACT

Developments in textile and fiber engineering have allowed the development of functional clothing such as protective wear, sportswear, and medical clothing. Stimulating pressure points on the skin has a wide range of applications in manual therapy – both to eliminate functional disorders in the musculoskeletal system and to relieve pain. An acupressure-like effect can be achieved when the practitioner or the person pressures the skin with the thumb on specific pressure-points on the body. So far, there have not been any product solutions which combine (full)-body garments with an acupressure-like effect. Understanding textiles as a grid which holds pressure balls in place and making use of fiber and textile technologies for industrial knitting has enabled "trykk." to develop four pressure-point-garments with different textile variables. The purpose of the garment is to substitute the mechanical stimulation of the acupressure-like thumb on the skin through a patent-pending 3-dimensional textile-body interface which consists of a flexible textile grid and small marble-sized semi-precious stone balls. This paper describes a study set-up where the four prototypes in five different haptic use-scenarios are compared to the average force applied in an acupressure-like intervention. Besides, data of the likeability (satisfaction) regarding the four distinctive textiles were obtained. Results demonstrated a comparable performance of the prototypes in four out of five use case scenarios. Textile variables significantly altered users' interest in the garments, yet had no significant effect on the technical performance and the perceived intensity of stimulation.

Keywords
industrial knitting,
biomechanics,
acupressure,
manual therapy,
functional clothing,
textile-body interface

1 Introduction

Therapeutic garments with medical or wellness-effects can either improve a certain condition or contribute to overall greater well-being. Therapeutic, fashionable garments are an underdeveloped niche while having the potential for economic profit [1] and social impact. Since garments are worn every day, at almost all times, they have the potential to initiate continuous therapeutic effects. Most research in the field of garments with a stimulating effect focuses on wearables with high-tech and: or smart functionality [2], requires customization or offers application in generic locations [3]. *trykk.* is the first low-tech wearable, which allows users to target and stimulate individual and specific pressure points on individuals' bodies. Pressure points are defined as specific sensitive areas on the human skin going into deep tissue. They are the crossroads of vessels, nerves, or muscular structures where pain can accumulate [4]. The basis for *trykk*. garments is a specifically developed textile, which is augmented with a non-electrical, 3-dimensional component: semi-precious stone balls. The knitted garment has a flexible grid through which these small stone balls can be moved to any pressure point on the body. Based on negative ease (tight fit), elasticity and: or compression, a functional wearable is created that – besides fulfilling its primary function as clothing (warming, protecting, covering) – can also give some added value to the user. The garments have been designed with the purpose to stimulate specific pain points on the body. In the theory of Traditional Chinese Medicine (TCM), these tender points are referred to as Ah-shi points which show correlations with myofascial trigger points [5]. Acupressure is one effective method to relieve this pain. Like acupuncture, it works with balancing the body's energy system – but unlike acupuncture without the use of needles. Instead, the effect is achieved through applying pressure by fingers or devices [6]. In recent years, science has managed to document the existence and benefits of manual pressure point therapy, while the knowledge has been present since ancient times by demonstrating the existence of meridians as pathways where acu-points are positioned through their conductive qualities [7]. Another possible approach to reducing pain (muscle tension) is the stimulation of soft tissue such as fascia by eliminating myofascial trigger points (MTrPs) [8-11]. MTrPs are nodules of tenderness within taut bands of skeletal muscle [12-13] and are typically associated with injured or overstressed muscles fibers resulting in increased acetylcholine release, involuntary muscle contraction, and sensitization of myofascial pain [13-15].

trykk. garments shall be available to lay public without prescription and the stone balls placed according to own needs (perceived pain points). Perhaps the biggest appeal for individuals is the combination of an innovative concept, a fashionable design, and the idea of a tool fostering mindfulness and relaxation, self-help, and body awareness. This research paper does not investigate any medical or wellness effect which is something that requires further study in the future. Instead, it lays the ground by investigating the intensity of the biomechanical stimulation on the skin through the 3D relief consisting of textile and stone balls to prove whether or not the garment with its stone balls can achieve the same perceived intensity as the average force applied on the skin during an acupressure-like intervention. Each prototype is tested in five distinctive haptic use-scenarios (standing still, self-pressuring a massage ball in the textile, laying down still, laying down and performing Apanasana (knees-to-chest pose from yoga with the modification of rocking on the back from right to left), and sitting on a non-padded chair). A haptic experience is defined as perceptions which are generated through activity. From a neurophysiological point of view, haptic stimulation is distinctive from tactile stimulation which results respectively in a linguistic differentiation. Tactile perceptions occur when our body is deformed or touched by physical stimuli (e.g., when receiving a massage) and remains in a passive state [16]. Besides the predominant research question regarding the prototypes' technical performance, the study also explores the likeability of the different textile variables (thickness, material feel, sensation of compression and elasticity, aesthetics, and overall fit) for the four existing prototypes to create a recipe for *trykk*.'s further product development.

2 Literature review

Systematic literature review suggests a number of inventions in the field of acupressure-like wearables, which are commonly limited to a specific part of the body. The market, however, comprises a range of flexible acupressure devices, most of them with the fundamental design of spiked surfaces (mats, rollers, balls, etc.). The manual mode of operation and the timely investment in achieving the desired relieving effect are hindering their popularity [2]. Rajan *et al.* developed an automated acupressure glove which consists of a dual-layered glove and a programmed electronic module. By making use of the pressure build-up in the chamber between the two layers of gloves, the wearable can provide auto-stimulation of pressure points on the hands-palm and fingers. This research has also looked into existing patents among acupressure devices in the form of a glove and has found inventions such as an acupressure glove device that facilitates self-stimulation of acu-points using direct pressure, a glove attached to a transcutaneous electrical nerve stimulation unit (TENS) used to provide TENS massage or acupressure by a clinician, amongst more [2].

Well-studied acupressure wearables without the need for added technology are Motion Sickness Bands (MSBs, e.g., sea-bands). They apply gentle pressure to a point known as “master of the heart” MH6 on the inner wrist, three-finger widths proximal to the wrist crease [5]. MSBs are approximately one-inch wide, elastic textile strips with a plastic bead on their inner surface which stays in a fixed position. Their medical benefits are controlling nausea and vomiting and have been documented in several studies, e.g., amongst a group of hospice patients [5]. Furthermore, a study investigating the effects of acupressure by sea-bands on nausea and vomiting during pregnancy came to the conclusion that sea-bands with acupressure buttons are a noninvasive, inexpensive, safe, and effective treatment for this scenario [17]. These findings demonstrate the potential of pressure-point garments for health and overall well-being.

Many acupressure-like wearables resemble socks or sole products since stimulation on the feet is an effective approach to improve tiredness and blood circulation. These products are usually not conscious of design and purely focus on functionality. They either stimulate the body through compression such as (Japanese graduated) compression stockings, the way they are engineered, through haptic reliefs consisting of massaging nodules or insoles produced from rubber and magnets which apply light pressure on vital pressure points [1]. All of these products are locally limited to either the feet, the wrists [5,17], or the hands [2] while the massage elements within the tool remain fixed and cannot be moved.

Additional acupressure devices have been developed to apply light-to-medium pressure over points on the abdomen, the waist, and the lower back [18]. Taylor *et al.* developed the Relief Brief, the acupressure panty. The Relief Brief is a cotton lycra panty with non-stretched woven panels filled with nylon net pockets. The front and back panels contain removable latex foam “acupads” against the body which provide pressure in individual and multiple acupressure points on these zones [18]. This type of device is used mainly for the treatment of primary dysmenorrhea in women [18]. Full-body garments which are not limited to a specific body part and are based on the philosophy of Traditional Chinese Medicine are theoretically investigated by Hye Eun Kim who suggests a profound potential while interjecting that further research is required to determine how to create the necessary amount of pressure through the textile [1].

To the authors’ knowledge, there are no studies regarding development of (full)-body low-tech pressure-point garments. The aim of the present study was to explore the potential of the *trykk.* solution to achieve a comparable intensity effect as in an acupressure-like intervention. Beyond, likeability of the different textile parameters used in the distinct prototypes is assessed.

3 Methodology

3.1 Experimental approach

To examine the intensity of the stimulation, a balanced and randomized treatment experimental design was used. The experimental design consisted of four treatments (four different prototypes) and a control tool. The control tool was a Beslands NK-500 Force Gauge Tester Pull/Push Dynamometer with a force of 3.75 kg. Dynamometers are commonly used to measure the force, displacement, and pressure in surfaces [19]. In clinical studies, such as muscle strength measurements, dynamometers are used for more accuracy [20]. In this experiment, a pull/push dynamometer was used to apply the intensity of the pressure on the participant’s skin with the same force a practitioner’s acupressure-like intervention on specific points would have. The force set for the dynamometer was defined through consultation with the TCM expert Nikolaj Munk Nielsen based on his professional experience and the research by Yang, Wu, Ling and Ling [21], which suggests an average force of 3-5 kg. The exact values range between 3.68 kg and 3.82 kg per finger for an intervention with 3 fingers total. Testing the dynamometer on the body with a long sleeve on and comparing it with the intensity of an acupressure thumb, the value was set to 3.75 kg for this specific research [21]. The dynamometer acted as a baseline which was applied on six different pressure-points on the participants' body while wearing normal clothing.

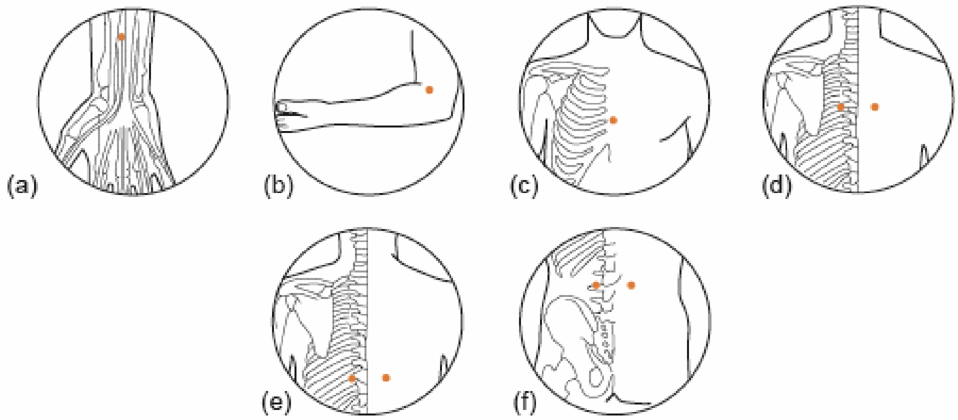

Fig. 1 Tender points used with dynamometer: (a) P6 point; (b) Li11 point; (c) C17 point; (d) BL15 point; (e) BL18 point; (f) BL23 point. Based on [27].

All selected acu-points are common tender points affected by pain and stress. The selected points are shown in Fig. 1 and described in the list below:

- **P6:** located three-finger-widths from wrist crease on middle of inner forearm
- **Li11**: with the elbow flexed, located on the lateral end of the transverse cubital crease
- **C17**: located on the sternum midline, in the depression level with the 4th intercostal space
- **BL15**: located 1.5 cun lateral to the lower border of the spinous process of the 5th thoracic vertebra
- **BL18**: located 1.5 cun lateral to the lower border of the spinous process of the 9th thoracic vertebra
- **BL23**: located 1.5 cun lateral to the lower border of the spinous process of the 2nd lumbar vertebra

A study protocol was designed to measure the intensity of the stimulation, thickness, material feeling on the skin, sensation of compression and elasticity, aesthetics and overall fit through a 7-point Likert scale, which is the most often used scale in usability tests [22]. Once the study protocol was developed, a pilot testing was performed with a sample size of four participants and a TCM practitioner to define the haptic scenarios, front and back pressure points, and the study conditions to reduce experimental variance. The haptic scenarios are described in Fig. 2.

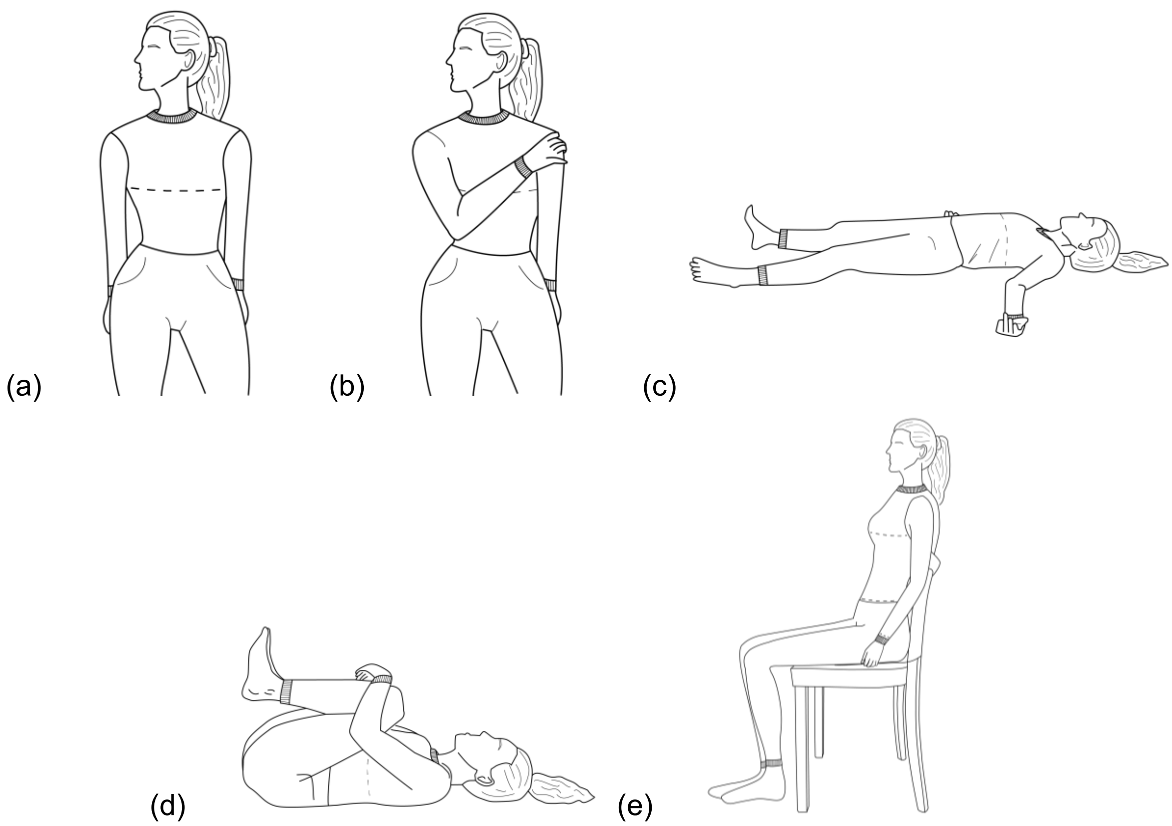

Fig. 2 Haptic use scenarios; (a) standing still; (b) pressing a massage ball; (c) laying down; (d) laying down with movement; (e) sitting down.

3.2 Subjects

By completing a market research study with a sample size of 153 participants it was determined that potential early adopters for *trykk*. products are women in the age of 26 to 41 years. Through a snow-ball sampling method, 13 participants were selected from which only 9 participants' results were taken into consideration. Snowball sampling is based on networking and referral and applied to hard-to-reach populations [23]. When recruiting the participants, it was made sure that all of them were 1.68 m or taller, were wearing size 36-38 in sportswear and had not yet given birth. The participants' characteristics were as follows: women (sample size n=9), age = (27 ± 2.7) years, height = (1.74 ± 0.05) m, mass = (61.67 ± 5.3) kg (mean ± standard deviation (SD)). Each participant had each garment properly fit, assuring that the size requirements were met.

3.3 Prototype development

The four existing *trykk*. prototypes and their corresponding codes are shown in Fig. 3 and Table 1. They are either bodysuits or tight long sleeve shirts. They have been developed through a design research approach defined by the Design Academy Eindhoven. Design research – also: research through design – is a method which usually combines experimentation (with materials, techniques, forms, functions, ideas), intuitive insights, critical reflection, and literature study [24].

Fig. 3 Prototypes from left to right (a) GB15; (b) SL34; (c) BM27; (d) NC89.

Table 1. Prototypes codes and descriptions

Codes	Description
GB15	Knitted bodysuit, color: green-brown, method: industrial knit
SL34	Stitched Lycra leggings and long sleeve, color: beige-black, method: stitching
BM27	Bodysuit with meridians, color: multi-color, method: embroidery
NC89	Nylstar compression long sleeve, color: black-white, method: industrial knit

The basic requirement for the garments is a tight fit which implies the consideration of negative ease in the pattern making to ensure a direct interface between the textile and the body. A guiding principle was wearability, meaning wearing the garment should feel comfortable and even desirable despite its tight fit. The *trykk*. principle, which has been registered as a patent, is a dual-layered textile whose two layers are held together with an octagon-shape grid and an external object – the pressure ball. The pressure ball has a size of 14 mm and the size of the grid depends on the prototype. The grid can be described as an "octagon" that is open on the sides as well as on the top and bottom. By pressing the massage ball, the textile stretches, allowing it to move to the next position on the body through one of the four "octagon" openings. However, it also allows the massage ball to stay static when putting it in a desired point. Instead of producing made-to-measure garments, the *trykk*. innovation allows individual stimulation on correct pressure points through a flexible textile grid and a moveable stimulator.

The development started with SL34 – (grid size horizontal opening: 8 mm, vertical opening: 9 mm) – a prototype which consists of highly-stretchable Lycra yard goods. The pattern was incorporated with a sewing machine, which was a lengthy process but served the purpose of a low-cost prototype to test the initial idea. The size of the pattern was first tested on a sample piece, digitized with the correct measurements, and then printed as a repeat pattern. This served as a template for marking the positions on the garment, which then – once both layers were pinned together – could be traced with the sewing machine. The next prototype in the development process was GB15 – (grid size horizontal opening: 8 mm, vertical opening: 8 mm). It is programmed and then knitted with an industrial knitting machine. Here, the grid pattern is realized through the knit structure. A design vision which guided the development of the knitted suit was the feeling of a cocoon, something that makes the wearer feel salvaged and secure. It was realized through the combination of high elasticity and a natural, soft, and warm feel to the material as the combination of compression and warmth have been found to imitate human touch [25].

BM27 – (grid size horizontal opening: 10 mm, vertical opening: 10 mm) – a bodysuit with a meridian pattern and an embroidered grid – resembled a further exploratory step in the development process. It was created out of a dead-end with the previous industrial knitting method. Since a textile which consisted of at least 14 colors – all representing one of the meridians in the body – was not achievable with the knitting machines available, another solution was found. The meridian pattern was created through a digital print on a specific printable elastic yard good. Then both layers were connected through an electronically controlled embroidery machine, which achieved a result of much higher accuracy and quality compared to SL34. Even though on first consideration, a tight body suit such as GB15 and BM27 are a suitable option as this type of garment allows the majority of spots on the body to be stimulated, the last prototype in the development process so far has been a long sleeve shirt. In addition, pricing, and the vision to wear the *trykk*. garments outside the privacy of one's home led to the decision to focus on a set consisting of a tight top and leggings, starting with a long sleeve shirt. Thus, NC89 – (grid size horizontal opening: 6 mm, vertical opening: 7 mm) – was created out of a high-performance yarn usually employed for sportswear and a compression yarn. This prototype has by far the highest degree of compression.

3.4 Procedures

The study was performed at the Innovation Villa at the Freie Universität Berlin (FU Berlin). The study relied on a signed data privacy statement to voice explicit consent by each participant since relevant anamnesis questions were asked to classify possible effects during the evaluation part. Once the study was explained and clarified, data was compiled. Two researchers were present to the evaluation, one to take notes, and the second one to assure that participants were correctly wearing the garments and that the massage balls were correctly located on the assigned pressure points. Each evaluation was performed in the same space, with the same tools such as the sitting chair to avoid environmental effects.

The evaluation started with the control test. Each participant subjectively evaluated the intensity of the stimulation through a dynamometer in the following points: P6, Li11, CV17, BL15, BL18 and BL23. In the next step, participants received each prototype monodically based on the randomized order criteria to minimize context and order effects [26]. The prototypes were presented once at a time and randomly coded as shown in Table 1. For each prototype, participants were asked about the intensity of stimulation in each of the five haptic scenarios: standing still, self-pressuring a ball in the textile, laying down without movement, laying down with movement, and sitting on a non-padded chair. For each scenario and prototype, the massage balls were positioned in the same pressure points and for scenario (b), participants were asked to self-pressure the same exact point each time. Finally, an effective test (thickness, material feeling, sensation of compression and elasticity, aesthetics and overall fit) was conducted to determine participants likeability of each of the textile variables. Test metrics were based on a 7-point Likert scale (intensity and satisfaction-scale).

3.5 Statistical analysis

The statistical analysis for the sensory evaluation test was performed in Minitab software version 21, using a Mix Model in Fit General Linear Model, where the presentation order and participants were analyzed as blocking variables, and the prototypes as treatments. The results were evaluated using an Analysis of Variance (ANOVA) with a 5% significance level. The ANOVA test was performed to assure that each of the ANOVA assumptions were satisfied. To analyze the fit of the data to the model, it was established a minimum R-squared predicted coefficient of 0.5 based on the study's small sample size. A Tukey test with a 5% significance level was performed in order to determine which prototype had a statistically higher result in each haptic scenario and in each variable. Additionally, for the intensity of the stimulation in each haptic scenario, a Dunnett test (with a 5% significance level) was run to compare the different treatments with the levels of the control.

4 Results

4.1 Intensity of the stimulation

Results from the pre-medical report of participants showed that none of the participants had a broken bone or major muscular problem in the upper part, arms or back of the body. In addition, none of the participants had a record of having given birth. Results related to the intensity of stimulation depending on the haptic scenario are presented in Table 2.

In the scenario “standing still”, none of the prototypes were statistically equal to the control tool (CT42) which was rated with an average of 4.6 or “moderate to intense stimulation”. The intensity of stimulation for the treatments was “not recognizable” for the participants. For the second scenario, where participants were asked to press a massage ball within the garment in one part of their body, the intensity of stimulation between the control CT42 and the other four prototypes (SL34, BM27, NC89, GB15) was statistically the same. The average of stimulation intensity was between 4 and 5 points or “moderate to intense stimulation”. Regarding the laying down scenario, the intensity of stimulation was also the same for the control CT42 and the four prototypes. However, the prototype SL34 and GB15 were statistically different. The SL34 treatment presented a stimulation with an average of 4.9 or (“moderate to intense stimulation”) while the GB15 had an average stimulation of 3.1 or (“mild to moderate stimulation”). Based on observations, the GB15 prototype could have scored lower because of both the thickness of the textile and the wider fit of this specific prototype on the lower and middle back part.

For the laying down with movement (Apanasana pose), the stimulation intensity was the highest for each of the prototypes with an average of 5.1 and 5.3 or (“intense stimulation”). However, the stimulation intensity for all prototypes and the control CT42 were statistically the same. Finally, for the sitting down scenario the four prototypes were statistically equal in the stimulation intensity as the control CT42 with an average score of 3 to 4 points or (“mild to moderate stimulation”).

In general, it could be concluded that the intensity of stimulation is statistically the same between the control (representing an acupressure intervention) and the four *trykk*. prototypes when pressuring a massage ball while wearing the garment, laying down, laying down with movement (Apanasana pose) and sitting on a non-padded chair.

Table 2. Stimulation evaluation results for each prototype

Haptic scenario	Treatment	Average score (mean ± SD)	Grouping
Standing still	CT42	4.6 ± 0.7	A
	SL34	1.6 ± 0.7	B
	BM27	1.7 ± 1.0	B
	NC89	1.4 ± 0.7	B
	GB15	1.7± 0.7	B
Pressing a massage ball	CT42	4.6 ± 0.7	A
	SL34	3.9 ± 1.1	A
	BM27	4.1 ± 1.2	A
	NC89	4.2 ± 1.0	A
	GB15	4.2 ± 0.8	A
Laying down	CT42	4.6 ± 0.7	A/B
	SL34	4.9 ± 1.2	A
	BM27	4.2 ± 1.4	A/B
	NC89	4.2 ± 1.0	A/B
	GB15	3.1 ± 1.5	B
Laying down with movement	CT42	4.6 ± 0.7	A
	SL34	5.3 ± 1.2	A
	BM27	5.3 ± 1.2	A
	NC89	5.1 ± 1.1	A
	GB15	5.3 ± 1.2	A
Sitting down	CT42	4.6 ± 0.7	A
	SL34	3.9 ± 1.5	A
	BM27	4.4 ± 1.5	A
	NC89	3.4 ± 2.0	A
	GB15	3.7 ± 1.7	A

**Different letters are significantly different.*

4.2 Garment's Variables

Results for the following variables: thickness, material feeling on the skin, sensation of compression and elasticity, aesthetics and overall fit are presented in Table 3.

Table 3. Variables evaluation results for each prototype

Variable	Treatment	Average score (mean ± SD)	Grouping
Thickness	SL34	5.8 ± 0.7	A
	BM27	5.8 ± 1.5	A
	NC89	4.9 ± 1.5	A
	GB15	4.9 ± 1.9	A
Material feeling on the skin	SL34	4.4 ± 1.7	B
	BM27	5.2 ± 1.7	A/B
	NC89	5.6 ± 0.9	A/B
	GB15	6.6 ± 0.5	A
Sensation of compression and elasticity	SL34	5.4 ± 1.0	A
	BM27	4.6 ± 1.2	A
	NC89	2.6 ± 1.5	B
	GB15	5.9 ± 1.5	A
Aesthetics	SL34	4.6 ± 1.5	A
	BM27	4.8 ± 1.6	A
	NC89	4.1 ± 1.9	A
	GB15	4.8 ± 0.7	A
Overall fit	SL34	3.2 ± 1.3	A/B
	BM27	3.8 ± 1.9	A/B
	NC89	2.6 ± 1.7	B
	GB15	4.6 ± 1.0	A

**Different letters are significantly different.*

Regarding the thickness of the four treatments, they are not statistically different and have an average score of 5 to 6 or "more or less satisfied to satisfied". The highest scores had the SL34 and BM27 garment. For the material feeling on the skin, prototypes BM27, NC89 and GB15 are statistically the same with an average of 6 to 7 points or "satisfied to extremely satisfied". The SL34 was the one with the lowest score and it is statistically different from the other prototypes. Participants felt discomfort with the feeling of the pattern stitching on their bodies for this specific prototype.

When testing the sensation of compression and elasticity, the treatments SL34, BM27 and GB15 are the ones with the highest score with an average of 5 to 6 points or "more or less satisfied to satisfied". In the case of NC89, which was the prototype with the highest sensation of compression, participants rated it between "dissatisfied to more or less dissatisfied". Participants mentioned that it was very uncomfortable which also affected the identification of the massage balls on their bodies. Regarding the aesthetics evaluation, all treatments are statistically equal with an average score of 4 to 5 points or "neutral to more or less satisfied". During the study, it was noticed that participants considered different parameters to rate the aesthetics, some of them focused mainly on the color, the pattern, only the front look or the fit. For these reasons, further usability tests will be conducted.

For the overall fit, SL34, BM27 and GB15 are statistically equal. The GB15 treatment is the one with the highest average score of 4.5 or "neutral to more or less satisfied". For the SL34 and BM27 the average score was between 3 and 4 or "more or less dissatisfied to neutral". Finally, during the variables analysis it has been found that the NC89 prototype was the one with the lowest scores for the sensation of compression and elasticity and overall fit.

5 Conclusions and Outlook

The stimulation intensity is dependent upon the haptic use scenario. Data shows that participants experience higher stimulation in the following ascending order: standing still without movement (average intensity of the four prototypes: 1.6), sitting (3.9), pressing a massage ball (4.1), laying down without any movement (4.1), laying down with movement (5.3).

For each of the haptic scenarios except standing still, it has been proven that *trykk*. garments achieve a comparable intensity as an acupressure intervention (control). Since this paper is exploring acute mechanical stimulation, all of the scenarios except standing still make up suitable use cases for the product context. However, this finding does not imply that there cannot be any wellness benefits with non-recognizable stimulation intensity – this is something that could be studied within the context of sports medicine in the future.

The study further demonstrates that there are hardly any statistically significant differences between the prototypes regarding the perceived intensity of the stimulation. The few data points that stood out (e.g., SL34 for pressing the massage ball or GB15 for laying down) can most likely be traced back to a non-ideal fit since SL34's fit on the lower arm, and GB15's fit on the middle and lower back were too wide on all participants. A further observation is that more compression in the garment does not imply higher intensity as anticipated when developing the NC89 prototype. However, a further study could focus on more nuanced levels of sensation of compression and the effect of it while wearing a *trykk*. garment.

In addition, based on observations, participants showed preference for the prototypes that were easy to move with and perform activities in. In this study, five haptic scenarios were analyzed, however, this opens the possibility to study the effect of the garments while performing other activities such as yoga or additional sports.

An overarching observation was that participants seem to have a steady perception of stimulation. The control (dynamometer) was applied on six acu-points on participants' bodies – both as a first intervention and after the script for the second prototype had finished to remind the participants of the sensation. Except for one value, people rated the intensity of the control in both interventions the same, which supports the assumption that people have a fairly steady sense of perception regarding the intensity of stimulation on the body. A promising observation that suggests a further positioning on the market is that participants who had a heightened sense of body awareness due to private activities or their profession (athletes and opera singer) were more accurate in the identification of the location of the stone balls. Furthermore, both of them shared that they felt more relaxed after the study. It is therefore to conclude that users with heightened body awareness are more likely prone to recognize the effects. Therefore, the product could be positioned as a "training" intervention that can heighten the mind-body connection. This requires further research. Another interesting observation of the study was the phenomenon of the afterglow. Even after the stimulation had stopped, participants were able to feel stimulation without the presence of the stone ball.

The main constraint of this study is the small sample size of 13 participants, from which four were pilot tests. This resulted in nine participants who were considered for the final data evaluation. The small sample size is justified by limited workforce, the difficulty to find participants who fit the prototype sizes and a lack of funding. This has led to fluctuations in the standard deviation values in the evaluation of the different variables. However, since the data showed clear tendencies and the current goal is to evaluate the subjective perception of participants; the preliminary results are compelling for developing further research. A further limitation is that each haptic scenario was only tested for a few seconds. As a consequence, stimulation over a longer period of time has not been yet assessed. In addition, due to time constraints, the massage balls were placed before the study was run and remained in the same position for all participants. This also implies that the stone balls were not placed precisely on an individual's pressure points.

Since this study aimed to analyze the subjective experience of participants through sensory evaluations of different variables (e.g., sensation of elasticity and compression), no physical phenomena were measured. In addition, the assessment of clinical parameters such as medical or wellness benefits of the garments are kept for further research. For this preliminary study, the current methodology seemed appropriate. For the application of the dynamometer, six specific pressure-points were used as guiding stars – however, the application was done by a researcher who is a non-expert in TCM or physiotherapy, thus the placing might not have been fully accurate, either.

The promising findings recommend further studies that focus on medical applications such as psychosomatic symptoms (e.g., disrupted mind-body connection) or muscular pain and tension. Additional acu-points could also be analyzed in other body parts like the legs, hands, feet, and neck while inserting a massage ball in one of these parts.

Author Contributions

D. Almendariz: conceptualization, methodology, software, validation, formal analysis, writing and editing – original draft preparation; L. Deschl: conceptualization, methodology, investigation, resources, writing – original draft preparation, visualization, images; M. Nielsen: supervision, mentoring. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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