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Designing Smart Tech-Couture Wearables for Correcting Teen Posture

Aman Kumar[1], Nitish Kumar[2], Manish Kumar Jangir[3], Mohit[4], Yamya Kumar[5], Dr. Sidharth S Raju[6]

[1,2,3,4,5] *Student Researcher,* [6] *Associate Professor, Vivekananda Global University, Jaipur, India*

***Abstract*-- A time of rapid skeletal growth coupled with unprecedented levels of sitting, screen time. The lifetime prevalence of "text neck" symptoms among children and youth is significantly above 50% in cross-sectional studies, and systematic reviews of the currently available posture corrective technology conclude that these devices are technically feasible, but have low rates of adherence, are designed with an adult focus rather than a youth focus, and fail to take into account the target user's point of view in the design process. This paper presents a design framework for "tech-couture" posture-correcting wearables: clothing incorporating inertial and textile strain sensors, vibrotactile actuators and low-power electronics that is explicitly engineered to serve the identity and self-presentation needs of teens, rather than simply adapted to "medical-brace" silhouettes. The paper relies on literature published over the last 10 years from the fields of spinal-posture wearables, e-textile materials science, and adolescent musculoskeletal epidemiology to characterize the clinical and behavioural case for posture wearable devices aimed at intervening with adolescents; identify the engineering constraints and opportunities that must be addressed to integrate sensing and actuation into soft, washable, fashion-forward textiles; design a system architecture that explicitly incorporates co-design with the population of teenage users (five layers: sensing, actuation, textile-garment, data/personalization, and power layers); and propose an evaluation framework that includes biomechanical accuracy metrics and measures of wearability, adherence, and psychosocial acceptability. The paper concludes with a discussion of privacy, stigma, and body-image issues unique to minors, and makes suggestions for a research agenda on how to take the tech-couture prototypes and make them evaluated interventions.**

***Keywords*-- Smart textiles, e-textiles, posture correction, adolescent health, wearable technology, biofeedback, fashion technology.**

I. INTRODUCTION

As cell phones and tablets have become ubiquitous, and laptops have become more commonplace in the school environment, the way teens use their smartphones to communicate and learn has transformed, as has the way their bodies are positioned for the majority of the day. A combination of repeated forward flexing of the head while looking at handheld screens, prolonged thoracic kyphosis seen in a seated position while at work, and static loading of the cervical and lumbar spine during growth spurts have been combined and attributed to a group of symptoms referred to as 'text neck'. David et al. (2021) document text neck syndrome as cervical spinal strain that occurs when using handheld devices, leading to repeated sustained forward head flexion, especially among adolescents who spend several hours per day hunched over handheld devices. This picture is echoed by independent cross-sectional surveys of school age children, which have found lifetime prevalence of neck-pain of 55 percent or more, and strong relationships between increased scores of neck-disabilities and screen time of more than a few hours per day.

Adolescent postural dysfunctions are clinically relevant because of the fact that the human skeleton is still developing; the musculoskeletal malalignment present during this period may affect the course of the curvature of the spinal column throughout life, as well as cause immediate symptoms, such as headaches, tension in the shoulder girdle, and decreased attention span in school. This has spurred a growing body of engineering research on implements that use either inertial measurement units (IMUs) or strain sensitive textiles or surface electromyography (sEMG) as means to measure departures from a reference posture and provide a corrective signal, often in the form of vibrations.

The general conclusion that can be drawn from these systematic reviews is that, however, the technical aspects of the literature have surpassed the aspects of wearability and user acceptance. In their review of 37 different wearable spinal-posture systems, Simpson et al. (2019) report that there are many wearable devices that use multiple sensors strapped onto the back that require users to wear and remove multiple sensors, and that eventually commercializing these devices is difficult due to the need to balance the accuracy of measurement with ease of wearing. A recent systematic review of wearable posture devices for adolescents also finds the current devices are limited by their lack of consistent methodologies, sensor-attachment issues and a lack of immediate, usable, and potentially clinic-appropriate corrective feedback that could be applied in the real world. In the literature, there has also been nothing particularly focused on the visual and tactile characteristics of a device as a tool for adolescent self-presentation, which determine, in practice, whether or not a teenager would wear a device.

To fill this gap, this paper proposes a design framework for tech-couture posture-correcting wearables, or garments that involve the design of posture sensing and biofeedback into the design of apparel that prioritize the form, silhouette, colour and material language of the garment over the electronics. The word “couture” is used on purpose, not to suggest luxury manufacturing, but to indicate that the fit, aesthetics and expression of identity of the garment is designed as carefully as sensor placement and signal processing. The rest of the paper summarizes the relevant clinical and technical literature (Section 2), outlines the design rationale for the couture-first approach (Section 3), proposes a five-layer system architecture (Section 4), discusses a co-design methodology and evaluation framework (Sections 5–6), and addresses ethical and psychosocial issues that are particular to designing wearable health technology for minors (Section 7).

II. Background And Related Work

2.1 The Case for Posture Intervention in Adolescent Classrooms

The epidemiological studies regarding the association of sedentary behaviour to musculoskeletal symptoms are always consistent in finding that screen directed time corresponds with adolescent neck and back pain. David et al. (2021) place text neck syndrome in the context of the epidemiology of neck pain, which has traditionally been researched in adults, but is now beginning to be explored in children and teens, as device ownership and screen time have grown among the youngest members of society. Cross-sectionally, in school-age populations, most participants report some lifetime history of neck discomfort, and association with hours of daily smartphone and computer use. Combining this literature, two design premises are presented: first, that the target population of posture intervention is not the adult population with diagnosed pathology, but a much larger population of otherwise healthy teenagers, who are acquiring risk due to the use and misuse of their devices in everyday life; and second, that any successful intervention is going to have to work alongside, and not against, the screen-centred activities that are driving the problem, and removing screens from the life of teens is not a realistic design constraint.

2.2 Posture Sensing Systems and Biofeedback for Wear and Use

The postural monitoring problem has been extensively discussed in the engineering literature, both in terms of inertial and textile solutions.

Beyond about three inertial sensors along the spine, additional units don't yield a significant increase in classification accuracy, says Simpson et al. (2019), a result that directly impacts the number of rigid components that a garment-designed system would need to discretely hide or style, particularly for an outfit that would be considered couture. The same review reports on the development of wearable systems specifically for IDS and postural kyphosis with vibrotactile feedback for active postural corrective feedback with measurements errors less than one percent in an angular range of -0° to +70° for at least one of these developed systems which is clinically acceptable for cueing postural correction during use.

Prototypes more recent employ the integration of multiple sensing modalities. Martins et al. (2024) explain how to build an e-textile smart vest that combines surface electromyography signals from the cervical region with the inertial data from an IMU to detect forward head posture, and how they were able to achieve a similar amount of root mean square error to clinical EMG electrodes (made from gels) with the added benefit of increasing the wearability of these devices and eliminating the need to prepare the skin for use of conventional electrodes. Instead of the electronics approach, the authors of Wang, Zhou, Guo, and Sun (2021) take a textile perspective in their work, and embed strain sensors directly into a shirt for data collection in order to determine an adolescent's sitting posture, recognising the need to keep up with increasing sedentary time among teens, who are currently spending more than half their time sitting, and that such technology would be more acceptable to young people than a strap-based, electronics-based solution. This is confirmed by a systematic review of posture wearables for adolescents published in Frontiers in Rehabilitation Sciences (2026) which found limited support for active corrections using vision-based systems or post-hoc analysis systems, while multimodal systems with flexible pressure sensors and in-situ monitoring are emerging in more advanced prototypes, such as an orthosis that integrates both. A larger systematic review of randomized and quasi-experimental posture-correction wearable trials also concludes that smart-garment and vibrotactile interventions are able to achieve measurable improvement in cervical flexion angle and associated biomechanical outcomes, providing initial support of the clinical effectiveness of the overall approach, but raising concern for heterogeneous evidence quality across studies.

Vibrotactile biofeedback is used specifically, and has much more evidence than posture specifically.

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In a randomized crossover design study of 18 patients with chronic stroke, Kim, and Shin (2022) reported that the vibrotactile feedback system significantly improved static balance (shorter postural sway length and slower sway velocity) compared to the visual feedback system or no feedback, suggesting that vibrotactile biofeedback is an effective real-time correction channel for low attentional demands postural tasks, which is the attentional state of a teenager performing school work or engaging in social activities.

2.3 E-Textiles and Fashion-Technology Integration

There is another, parallel, body of materials-science and textile-engineering literature concerning embedding electronic function into soft, comfortable, washable fabric instead of into rigid casings. Younes (2023) gives an overview of smart e-textiles, covering different integration methods to make the circuits more or less invisible in the fabric and applications ranging from health monitoring, safety and fashion. Smart textiles are a neologism for the convergence of electronics and fashion, and as such, must be at the same time garment-like, that is, illuminate, communicate and sense, and at the same time drape and feel good, and have a nice look (Hong, 2023). Abtew, Atalie, Dejene, and McBee-Black (2025) take this analysis a step further and list comfort factors that would make an adaptive apparel smart garment acceptable for daily use: breathability, moisture management, and tactile softness. They also record the use of smart garments in fall detection and vital-sign monitoring, which requires prolonged, comfortable contact with the skin. This literature collectively shows the materials-science challenges to couture-grade smart garments (washability, flexible circuitry, comfort-compatible electrode materials) are actively being addressed, but few published smart garment systems have identified adolescent posture correction as their key use case, and fashion design has been treated as a co-equal requirement.

III. Design Rationale: Why "Tech-Couture"

The pattern observed in the literature above indicates that there is a significant imbalance, with much work on sensor accuracy, and little on the garment as a social object. While a posture-correcting system might theoretically be more accurate, it's actually a lack of adherence — if a teenager wears the device on a typical week of school, sport, and social activity — that will be the limiting factor in the real-world results.

The specifics of the teenage user require that garment aesthetics be a first, not a second design consideration.

Adolescence is a developmental period where clothing plays a central role in identity expression and peer signalling, the former being a device that reads visually like medical equipment, a brace, a strap or a clinical harness, the latter a device that reads as ordinary or desirable streetwear, without any stigma cost. Second, teenagers choose and pay attention to the garments placed on top of the torso and shoulders (t-shirts, hoodies, sports bras, undershirts), with the thoracic and cervical regions being the areas with the most important implications for the posture sensing system; these make it easy to provide a point of natural integration should one be possible where the smart layer is made to replace, and not add on to, a garment already in the daily wear and tear. Third, adolescent bodies are growing, and garments need to be flexible in resizing, providing a different "fit" for each season and sport, and being appropriate for a variety of activity contexts (classroom, PE, sports, sleep).

A tech-couture approach mitigates these constraints by including the following as co-equal design goals in an integrated manner rather than in sequential order: (a) biomechanical measurement validity, (b) garment comfort and washability, (c) visual and stylistic desirability to target age group, and (d) data usability for wearer and, where appropriate, a caregiver/clinician. These goals are translated into an architecture for the layered system proposed in Section 4.

IV. Proposed System Architecture

We suggest breaking up a tech couture posture correction wearable into five interacting layers: sensing, actuation, textile-garment, data and personalization, and power. This layering takes away the coupling of concerns that is often found in previous prototypes and enables the designers of the garment, electrical engineers and behavioural scientists to prototype their respective concerns without sharing any interface specification.

4.1 Sensing Layer

As in the previous study, which found a minimal constellation of three IMUs performing equally well as a denser array, the sensing layer is specified around a minimal constellation: one IMU located at the upper thoracic spine (roughly corresponding to the C7–T1 region), one located at the mid-lumbar region, and, optionally, a textile strain sensor integrated into the shoulder seam to measure independent rounding of the shoulders from spinal flexion.

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If muscle activity in the neck or shoulder is a concern (e.g., monitoring muscle activity of compensation for a forward head posture) a textile dry-electrode sEMG channel validated by Martins et al. (2024) can be applied at the collar without the usage of gel or skin preparation, which is suitable for all-day usage with adolescents. The placement of the sensors should be incorporated into garment seams or an underlying garment, so as to retain the garment's normal shape and silhouette, and to decrease the slippage between the sensor and the garment and the reattachment issues reported as a key limitation in previous strap-based approaches.

4.2 Actuation (Feedback) Layer

The important feedback channel has been found to be vibrotactile, which sometimes outperforms visual if the task requires low level of attention and is performed in real-time; this is accomplished by a small array of flat, flexible vibration motors located at the site of the deviation to be corrected (upper back for thoracic slouching, base of neck for forward head posture). The feedback is "graded" (not all or nothing), with a short and light pulse indicating the beginning of a posture deviation, and only increasing in duration if the deviation remains for more than a user-configurable amount of time, such as eight to twelve seconds – so a transient motion like reaching for an object will not lead to posture deviation feedback. A secondary, non-real time channel (daily and weekly summaries of posture) is also provided to the wearer via an optional companion mobile application which remains separate from the real-time feedback channel (tactile vibration loop) so that the vibrating feedback is not used to correct posture, but rather the mobile application is used to correct posture, which would be counterproductive as a source of bad posture is screen viewing.

4.3 Textile and Garment Layer

This is a layer that separates a tech-couture design from a traditional medical wear. The garment form factor is defined by a base garment (an undershirt, sports bra liner, or compression tank) that is “knit” from moisture-wicking machine-washable knit fabric, with conductive yarns embedded in the surface knit (not surface printed) according to flexible-circuit principles documented in existing e-textile materials research. Electronic modules (battery, microcontroller, radio) are mounted in one small, low-profile pod at the lower back or the side seam that can be removed prior to washing to meet the criterion for washability established as a comfort-critical factor in adaptive-apparel research.

Outwardly, the silhouette, palette and graphic identity of the garment viewed as a design brief may be designed to integrate with the existing streetwear and athleisure categories which teenagers’ favour; the garment may have a seasonal or customizable colour range and be unobtrusive in its branding, with the intent that this piece be worn as a normal base layer rather than as a medical device. These decisions are not made a priori by the designer, but are decided by co-design with teenage users (Section 5).

4.4 Data and Personalization Layer

Because of the variability in natural spinal curvature, and the variability in shoulder alignment both within and across the growth curve of adolescence, the data layer is not a clinical norm, but rather a personalized reference posture. This baseline is periodically (e.g. monthly) updated in a calibration routine, possibly with caregiver or physical-therapist participation, to address the issues stated in the literature of wearables for posture, that fixed thresholds are not well generalizable between people and over time with the wearer's growth. Feedback intensity, correction thresholds and reporting frequency are user adjustable, within clinician set parameters, allowing for adolescent autonomy while maintaining the ability for an adult to set guard rails.

4.5 Power Layer

A low-power microcontroller is specified to allow all-day battery life from a small battery embedded in the garment, with the pod to be removed at night to be charged, and a duty cycled IMU (polling--sampling in bursts rather than continuous) is specified. Not requiring specialized charging hardware, but the pod to be removed at night and charged--the same way that teenagers charge their phones.

V. Design Methodology: Co-Design With Adolescent Users

The central failure mode identified in previous research is not technical failures, but rather failures due to non-adherence caused by aesthetic and social reasons, hence we will not be developing it through an engineering-led approach but rather a participatory and iterative co-design methodology. Standoli et al. (2016) report the development of the PEGASO project wearable activity monitors for adolescents, who deliberately included focus groups with more than four hundred adolescents across various European countries in the requirements-definition stage in order to elicit preferences which the engineering team would not have foreseen. We suggest a similar three-phase approach to tech-couture posture wearables.

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The first phase is the focus group and the generative design workshop, which involve teenagers (with parental consent and institutional review board oversight, as minors) to express their preferences for the category of garments, electronics visibility, colour and pattern language, and feedback modalities before finalizing any hardware. In iterative prototyping (Phase Two), successive prototypes with low fidelity and then with functionality are created, with the garment-design critique sessions and the short-term wear trials (single school day, single athletic session) occurring in an iterative fashion to assess the garment's comfort, sensor stability during movement, and self-reported willingness to wear the garment in front of peers. The near-final prototypes are sent to field evaluation in phase three where they are worn in natural environments (home, school, extracurricular activities) for multiple weeks to evaluate sustained adherence, garment durability with repeated laundry, and the biomechanical and behavioural outcomes outlined in Section 6.

VI. Proposed Evaluation Framework

Considering the outcome measures called for in the systematic-review literature, which go beyond device-level measurement accuracy, we suggest a multi-domain evaluation framework that includes four types of outcomes.

Biomechanical validity measures involve the use of a sensor that, when compared to a gold standard optical or marker-based motion-capture reference, is sampled over a posture range of interest to daily activity of adolescents with a seated desk work, standing, and phone use posture, similar to those previously reported for IMU- or EMG-based posture wearables. The clinical and symptomatic outcomes are patient-reported neck- and back-pain indices (e.g., the Neck Disability Index for adolescent responses); and, when possible, clinician-reported postural angle measures prior to and following a multi-week wear period (as utilized in randomized and quasi-experimental posture-wearable studies). Wearability and adherence measures include subjective wearability ratings and hours worn and days worn per week during the field-evaluation period (wearability); objective wearability ratings (laundering cycle durability of conductive textile components); and self-reported comfort ratings. Psychosocial measures encompassed standardized instruments that had been adapted to the adolescent self-image and stigma associated with devices, peer-visibility concerns and interviews with the adolescents about whether they would recommend the garment to a friend, which serves as a proxy measure of true, rather than compliance-driven, acceptance.

Given this, we suggest that adherence and psychosocial acceptance should be considered as primary, not secondary, outcomes in any future trial of a tech-couture device, as it cannot produce the clinical benefit that accuracy alone would predict, if it is not treated as a primary measure.

VII. Discussion: Ethical, Privacy, And Psychosocial Considerations

In designing wearables for minors, one's attention must be directed to issues different from those that would be considered with an equivalent device for an adult. Because data collected by a posture-sensing garment concerns a minor's body, and because it is the corrective feedback function for which it was collected, it should be collected, stored, and shared only in a way that reflects data-minimization principles: collecting only what is necessary for the corrective feedback function; storing only raw sensor streams for as short a period as necessary; and avoiding default data-sharing arrangements that place continuous body-posture data in the hands of parties other than the wearer and, where appropriate, a treating clinician. Any deployment which includes minors as research participants will require parent/guardian consent as well as age-appropriate adolescent consent and institutional review board (IRB) oversight in the manner indicated in the co-design methodology of Section 5.

The second concern is that a device sold as a body-correction device might make someone worry more about their appearance or body image during adolescence, especially when marketing or in-app messages view posture correction as an aesthetic, instead of a musculoskeletal-health problem. Product and interface language centre framing should focus on functional and comfort aspects, such as “reduce neck strain,” “feel less stiff after study sessions,” and not appearance-based framing, such as “look taller,” “fix your slouch,” as well as its progress reporting: without comparative and competitive aspects regarding other peers, which could open up a very unhealthy social comparison dynamic within what is supposed to be a private health tool.

The third issue is equity of access: since the value proposition of a tech-couture device is partly dependent on fashion desirability, there is a risk that it will be designed mainly for the aesthetics of the more affluent and trendy subgroups of adolescents. To prevent narrow aesthetic assumptions from being encoded into a device that will benefit the general community for public health, the co-design methodology proposed in Section 5 must then involve a sample of participants that is socioeconomically and culturally diverse and not a convenience sample from just one school or community.

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VIII. Limitations And Future Work

This paper is not a built and clinically evaluated device, but rather a design framework and research agenda is presented, which leads to several limitations. First, the framework combines engineering and clinical results obtained from posture-wearable studies, mostly performed with adults or multi-age groups, with a post-adolescent biomechanical validation of the proposed sensing configuration, which is still required. Second, components for textile-based sEMG and strain measurements, as described in the cited papers, have not been tested over repeated laundry processes or multiple seasons, as would be expected with an adolescent wardrobe, and should be tested for durability under these conditions before a real-world trial. Third, the psychosocial and stigma-related outcome scales suggested in Section 6 are taken from the general body-image and technology-acceptance literature and not those validated for use with wearable posture devices, and instrument development or adaptation is necessary as well. Future work should focus on many more garment types and a larger number of sensing configurations, starting with the IMUs in the thoracic and lumbar areas and the shoulder-seam strain sensor, and then moving to a larger number of garments in a co-design and field-evaluation study that is funded and approved by IRB.

IX. Conclusion

The engineering ability to sense and give real-time feedback about the posture of adolescents is well known in the field of wearable sensor and e-textile development. What has not been developed is a systematic incorporation of that ability into clothing that young people will want to wear for all the postures that they will need to assume during their daily activities where bad posture develops. This paper has made the case that the gap needs to be filled by considering the aesthetic, comfort and identity-expression properties of garments as design properties co-equal with sensing accuracy, and has suggested a five-layer system architecture, a participatory co-design methodology and a multi-domain evaluation framework as a way to operationalize that case. Making tech-couture posture correction wearables a reality at scale will depend on continued cooperation among wearable technology engineers, clinicians, behavioural scientists, and — most importantly — the teenagers that would be wearing the device every morning to correct their posture.

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