

Grading Runners: A Pilot Study to Reverse Engineer Patterns to Understand the Sizing of a Population

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Significance

In the sports product industry, accurate apparel sizing is important for performance, yet traditional pattern grading methods rely on linear regression measurement assumptions that may not reflect real-world body diversity. This research investigates if a dataset of 3D body scans of runners can depict improved approaches to grading and sizing athletic tights for male and female runners.

Background

In the apparel industry, patterning is the process of drafting the blueprint for a product based on a sample size, which serves as the foundation for the first prototype (Datta & Seal, 2018). Once the sample is created, grading is used to expand this blueprint into a full-size run (e.g., women's sizes 0–32) by applying systematic measurement adjustments between sizes (Schofield & LaBat, 2005). While grading follows proportional measurements between sizes, sizing is the broader classification system that organizes body measurements such as chest, waist, and hip dimensions into standardized categories defined by manufacturers or industry regulatory bodies (Sokolowski, Griffin, Wu, McKinney, Morris & Bettencourt, 2022). Despite efforts to standardize these systems, research indicates that traditional grading and sizing methods fail to accommodate the full spectrum of body diversity, particularly in performance apparel (Pisut & Connell, 2007).

The limitations of conventional grading, and sizing approaches are particularly evident in athletic apparel, where poor fit can have physiological, biomechanical and psychological consequences. Studies have shown that garments designed with inadequate fit parameters can contribute to musculoskeletal strain, circulatory restriction, nerve compression, and dermatological injuries, which can compromise overall comfort, confidence and athletic performance (Ashdown & Loker, 2010). As a result, there is a growing need for innovative methods that leverage body scanning and digital patternmaking technologies to enhance precision in fit development.

Methods

Three hundred and ninety-six, 3D body scans of runners dressed in 1:1 fit base layers (e.g., sports bra and boy shorts for women and boxer briefs for men) were collected using a Cyberware scanner (Istook, 2008). Runners were self-identified as individuals who ran at least 1x a week. The scans were then grouped into size buckets using machine learning (ML), with a 6 cm boundary between each bucket. This boundary measurement was selected based on its usage in the sports apparel industry to reflect size differences. The goal was to determine the number of distinct sizes needed to accommodate the variation in body shapes from the scans. Through this process, 36 sizes were identified, each represented by a corresponding group scan.

With the 36 representative 3D body scans, basic running tight patterns were developed using CLO 3D, a software capable of importing 3D scans and generating digital patterns that fit the body contours represented by the scans (CLO Virtual Fashion, 2025). The software enabled the visualization of custom tight patterns fitted on the 3D scan models, offering a depiction of the fit for each of the 36 sizes. With the patterns developed, they were then analyzed using the method outlined by Sokolowski (1999), for analyzing foot shapes. Through this method, each of the 36 patterns were orientated through their geometric center and stacked, using Adobe Illustrator (Adobe Inc., n.d.) (Figure 1). From the stacked patterns, measures in centimeters were taken from each geometric center point to key corners of the pattern (e.g. center front waist, center back waist, front crotch, back crotch, front inseam, back inseam) (Figure 1). With the measures, linear regressions were calculated to see if the patterns follow traditional grading methods used in the industry.

Results and Implications

The findings from this pilot study provided interesting insights into grading methods for running tights. When both female and male patterns were considered together, waist lengths in this study graded linearly, where new grading rules would need to be established for the lower portion of the sized patterns. This is of particular interest for unisex performance products like compression recovery tights where millimeters of mercury measures of compression accuracy is imperative. When patterns were separated out by sex, the female tight patterns exhibited better linear relationships. The only area of the female body that was not linear was the front crotch length. For men, none of the measures were linear at all. This was a surprising finding and for this particular case, men would require the development of a different grading system that does not rely on linearity.

This work also demonstrated that back engineering patterns from 3D body scans that were analyzed by machine learning could be a method used in the future to determine grading rules in the apparel industry. Future work will analyze a larger data set and calculate actual grading rules needed for this population.

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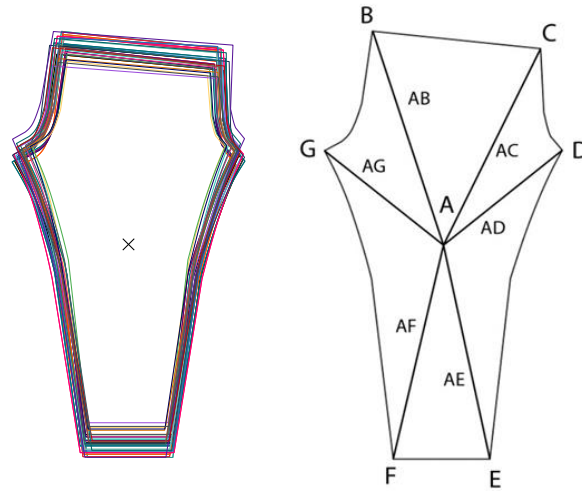


Figure 1: 36 running tight patterns stacked by their geometric center and measurement locations.