



# The Effects of Different Knee Braces on Gait-Related Muscle Activity

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**Abstract**—Knee braces are prescribed to healthy athletes for proprioceptive support and to patients with knee disorders for pain reduction/joint realignment, yet their muscle-level effects lack direct comparison. Using surface EMG on peripatellar muscles in four healthy women (age:  $22.8 \pm 3$  years; height:  $166.0 \pm 3.6$  cm; mass:  $63.5 \pm 7.7$  kg) walking at  $4 \text{ km} \cdot \text{h}^{-1}$ , 5% incline for 30 second sessions, a basic sleeve (Brace-1) and patella-stabilizing brace (Brace-2) were compared. Using nine time-domain features (RMS, Energy, Activity, Mobility, Complexity, Mean, MAD, Skewness, and Peak-to-Peak), a quadratic-kernel SVM distinguished between brace-on and brace-off epochs, obtaining mean accuracies of 87.8% for Brace-1 and 83.9% for Brace-2, and 85.6% for the Brace-1 and Brace-2 comparison. Divergent activation strategies were revealed by violin plots. Whereas Brace-2 displayed upward-shifted, tighter bands indicating steadier activation, Brace-1 produced taller, broader RMS/energy curves indicating variable bursts, meaning Brace-1 amplifies the EMG signals but diversifies, while Brace-2 has a more stabilizing effect on peripatellar muscle activities. Differential neuromuscular signatures were confirmed by machine-learning metrics (low FDR, high sensitivity/specificity). Evidence-based brace selection is informed by the fact that the patella brace allows mechanical realignment with moderate bursts, while the neoprene sleeve enhances proprioceptive drive through diversified recruitment.

**Keywords**—knee braces; electromyography; gait analysis; muscle activity; machine learning, classification.

## I. INTRODUCTION

Knee braces are a great way to prevent injuries, have better proprioception and suppress pain [1]. Recent studies show that the type of knee brace may have different demands on quadriceps and hamstring coactivation during simple activities like walking [2, 3]. Knee braces are therefore applied well beyond everyday fitness: they are fitted after ligament injuries or reconstructive surgery to protect healing tissue and restore proprioceptive acuity [4]; they are prescribed in degenerative conditions such as medial knee osteoarthritis to off-load painful compartments and improve functional stability [5]; and they are often recommended during return-to-sport phases to limit

excessive joint excursions while users rebuild strength and confidence [2]. In each case the brace acts as an external constraint that moderates mechanical load and provides cutaneous feedback and gives the wearer a tangible sense of security, thereby complementing muscle retraining and physiotherapy.

A basic knee sleeve is a lightweight, circumferential compression cuff that supplies constant low-grade pressure and warmth; this continuous cutaneous input heightens joint-position sense and offers mild global support during early rehabilitation or low-impact sport [1, 2]. The patella-stabilizing brace integrates a semi-rigid frame and medial pull-straps that exert a directed force on the patella, guiding it centrically through the trochlear groove; in doing so, it redistributes patellofemoral contact stress and attenuates anterior knee pain [4, 6]. Thus, whereas the basic sleeve principally amplifies sensory feedback and global comfort, the patella-tracking brace delivers targeted biomechanical realignment for patellofemoral control.

Studies on basic sleeves demonstrate both sensory and functional benefits. *Bottoni et al.* reported that wearing a sleeve significantly reduced joint-position error and enhanced proprioception in young, non-professional athletes [1]. In people with knee osteoarthritis, *Cudejko et al.* found that a soft sleeve lowered pain, improved dynamic stability, and thereby lessened activity limitations [2]. During high-volume resistance exercise, *Hatfield et al.* observed higher RMS and energy values—as well as better overall performance—in participants who wore a neoprene sleeve, attributing these gains to improved kinesthetic awareness [7].

Research on patella-tracking braces focuses mainly on patellofemoral pain. *Salarie Sker et al.* showed that an elastic patellar brace reduced pain and significantly modified leg-muscle EMG patterns during stance [4]. Similarly, *Kölle et al.* reported an immediate pain decrease, improved patellar kinematics, and adjusted quadriceps–hamstring co-contraction



after brace application [6]. Collectively, the evidence suggests that sleeves enhance proprioceptive feedback and overall muscle engagement, whereas patella-tracking braces achieve pain relief and mechanical realignment through targeted patellar guidance.

This study aims to determine how two common knee-brace designs differ in the way they modulate activity of the peripatellar muscles. Literature identifies vastus medialis (VM, patellar alignment) and semimembranosus (SM, tibial stabilization) as optimal EMG targets for detecting brace-induced neuromuscular changes. [8, 3].

## II. MATERIALS AND METHODS

The study utilized a BIOPAC MP36 electromyography system (BIOPAC Systems Inc., USA) for surface EMG acquisition, featuring four channels with 24-bit resolution and a sampling rate of 1,000 Hz. Disposable Ag/AgCl electrodes (20 mm diameter) were employed for signal capture.

Two knee brace models were included in the experiments. Brace-1, the basic sleeve (Orthocare 6120 Genucare Basic, Turkiye) provided circumferential compression without rigid components, designed for mild proprioceptive enhancement and thermal retention. Brace-2, the patellofemoral knee brace (Orthocare 6158 Genucare Luxa, Turkiye) brace incorporated a medical-grade polyamide frame with medial straps to correct lateral patellar displacement through controlled medial force application.

Four healthy female volunteers (aged  $22.8 \pm 3$  years; height  $166.0 \pm 3.6$  cm; body mass  $63.5 \pm 7.7$  kg) without any knee disorders participated in this study. The sample size was constrained to four subjects due to scheduling limitations and data quality considerations.

Disposable Ag/AgCl electrodes were placed on both right and left legs' VM and SM, with skin preparation, ensuring electrode-skin impedance  $<5$  k $\Omega$ . Two knee braces were tested, respectively, for experimental tasks. Knee braces were changed after the walking trial of a brace type was finished. Participants performed treadmill walking trials under conditions of a speed of 4 km/h paired with incline of 5% Each 30-second trial was repeated for both brace types 9 times, yielding 18 trials per participant. Between trials, 45-second rest intervals prevented fatigue while maintaining thermal consistency of the braces.

A zero-phase bandpass filter (0.5–500 Hz, 2nd-order Butterworth) was used to remove motion artifacts and high-frequency noise from raw EMG signals. To ensure stationarity, the filtered data were divided into non-overlapping 5-second epochs (5,000 samples per window). MATLAB was then used to extract time-domain features from each epoch. These were the following: Energy (sum of squared samples, reflecting mechanical work) [11], Skewness (asymmetry in amplitude distribution, highlighting burst-like or silent-gap behavior) [10], Mean (average rectified value, indicating overall muscle activation) [9], and Hjorth parameters (Activity as signal variance, Mobility approximating mean frequency, and

Complexity indicating abrupt frequency changes) [10]. Furthermore, calculations were made for Mean-Absolute Deviation (which tracks variability related to fatigue) [12], Root-Mean-Square (RMS), which correlates power-equivalent amplitude with force output [13], and Peak-to-Peak Amplitude, which indicates instantaneous burst strength.

For classification, a quadratic support vector machine (SVM) was selected. Unlike more complicated kernels (such as Gaussian), this kernel offers a moderate amount of flexibility and successfully models the curvature frequently found in EMG datasets without overfitting. The results of trials with other classifiers were comparable to those of *Toledo-Pérez et al.*, who found that quadratic SVM produced better validated accuracy in lower-limb EMG studies with limited time-domain features [14].

*Sokolova & Lapalme's* confusion-matrix-derived metrics were used to assess the model's performance. Precision (positive predictive value), sensitivity (true positive rate), specificity (true negative rate), accuracy (overall correctness), and False Discovery Rate (FDR) (1-precision). Together, these evaluate robustness against false alarms and missed detections [15].

## III. RESULTS

Brace-specific neuromuscular signatures were quantified using SVM classification. Significant brace-induced modulations were found by the quadratic SVM classifier in every condition (Table 1). The most noticeable EMG changes were caused by Brace-1, demonstrated by a lower FDR ( $12.3 \pm 6.2\%$ ) and a higher brace-detection accuracy ( $87.8 \pm 2.6\%$ ) in comparison to Brace-2 ( $83.9 \pm 3.9\%$  accuracy;  $16.0 \pm 4.0\%$  FDR). Importantly, direct brace-to-brace discrimination confirmed essentially distinct activation strategies with an accuracy of  $85.6 \pm 6.4\%$ . The feature distributions in Figs. 1-3 are consistent with these machine-learning metrics.

Table 1 Quadratic SVM classifications: Performance metrics (mean  $\pm$  SD) of 3 conditions: Brace-1, Brace-2, and Brace-1 vs. Brace-2.

| Metrics     | SVM (Quadratic SVM) |                   |                     |
|-------------|---------------------|-------------------|---------------------|
|             | Brace-1             | Brace-2           | Brace-1 vs. Brace-2 |
| Accuracy    | $87.8 \pm 2.6 \%$   | $83.9 \pm 3.9 \%$ | $85.6 \pm 6.4 \%$   |
| Sensitivity | $88.1 \pm 3.4 \%$   | $84.0 \pm 6.5 \%$ | $81.5 \pm 3.5 \%$   |
| Specificity | $87.6 \pm 4.1 \%$   | $83.8 \pm 6.1 \%$ | $81.6 \pm 5.7 \%$   |
| Precision   | $87.7 \pm 3.6 \%$   | $84.0 \pm 4.0 \%$ | $82.1 \pm 3.3\%$    |
| FDR         | $12.3 \pm 6.2 \%$   | $16.0 \pm 4.0 \%$ | $17.9 \pm 3.3 \%$   |

Data from all trials revealed Brace-1 consistently increased EMG amplitude and energy in the braced leg. Median RMS rose by 28% and energy by 34% versus the unbraced leg (Fig. 1), with wider interquartile ranges confirming higher stride variability. Complexity features (Hjorth Activity/Mobility/Complexity) showed similar increases. A quadratic SVM achieved 87.8% accuracy classifying braced/unbraced states. This demonstrates the sleeve induces

machine-detectable EMG modifications without requiring muscle- or task-specific analysis.

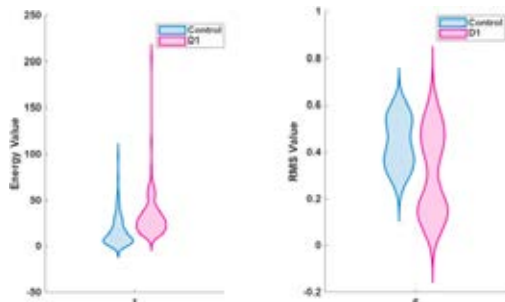


Figure 1: Violin graphs of energy and RMS features, comparing the left (braceless) leg and the right (with brace-1) leg.

Aggregated data showed Brace-2 induced a moderate EMG amplitude increase in the braced leg. Median RMS rose by 22% and energy by 30% versus control (Fig. 2), with wider interquartile ranges confirming heightened variability. Complexity features (skewness, kurtosis, and Hjorth activity) exhibited extended distribution tails. A quadratic SVM achieved 83.9% accuracy classifying braced/unbraced states, indicating the patella brace induces a milder but detectable EMG modification.

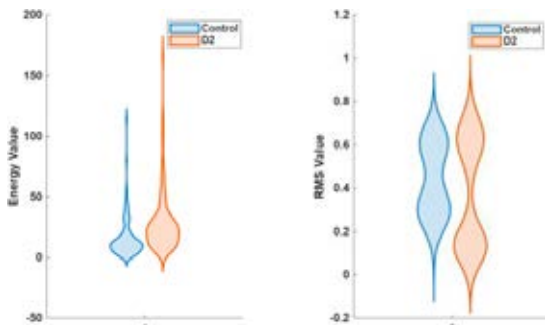


Figure 2: Violin graphs of energy and RMS features, comparing the left (braceless) leg and the right (with brace-2) leg.

A direct brace-to-brace comparison (Fig. 3) clarifies these relative effects. Brace-1 retained the largest median energy and the broadest 90th-percentile tail, signaling occasional high-power bursts; it also yielded higher, more dispersed PTP and Activity values, suggesting a permissive strategy that accentuates peak contractions. By contrast, Brace-2 showed only a modest right-shift in RMS (+3 %) but a conspicuously tighter inter-quartile band, and its Mobility/Complexity metrics clustered around mid-range values, consistent with a levelling effect that raises baseline activation while curbing extremes. These converging patterns—together with the aggregate brace-to-brace classifier performance—explain the hierarchy: Brace-1 leaves the most distinctive spectral-temporal fingerprint, whereas Brace-2 produces a subtler, more homogeneous modulation of neuromuscular output.

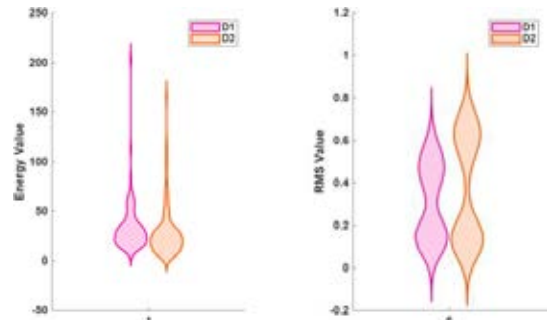


Figure 3: Violin graphs of energy and RMS features, comparing Brace-1 and Brace-2.

Across four healthy females and nine walking conditions, both braces measurably altered the surface-EMG of the braced limb. The basic sleeve elicited the largest rises in RMS and energy and the most distinctive classifier signature; the patella-stabilizing brace produced a more moderate, uniformly distributed activation shift.

#### IV. DISCUSSION

Both braces altered muscle activity differently. Brace-1 increased EMG variability with broader RMS/energy distributions, indicating amplified motor-unit bursts. This matches *Heß et al. (2025)*, where sleeves enhanced proprioceptive drive [16]. Conversely, Brace-2 narrowed distributions by suppressing extremes and shifting activation uniformly—consistent with *Salarie Sker et al.*'s "levelling" effect [3] and *Gülling et al.*'s reduced EMG during extensions [17]. Mechanistically, Brace-1 boosts afferent input for joint sensing, while Brace-2 promotes uniform engagement to offload quadriceps and limit lateral glide.

Unlike single-brace studies, this multi-feature analysis reveals distinct brace "fingerprints" in healthy knees. Clinically, sleeves (e.g., Brace-1) suit mild support/sensory augmentation needs, while patellar-tracking braces (e.g., Brace-2) optimize precise patellar control and energy smoothing.

#### V. CONCLUSION

This study confirms that braces significantly alter peripatellar muscle activity in healthy knees, with effects dictated by design. For general proprioceptive support during low-impact activities, elastic sleeves optimize benefits by diversifying activation. When precise patellar alignment or lateral-motion restraint is critical (e.g., post-patellofemoral pain rehabilitation or mal-tracking-prone knees), patella-stabilizing braces are preferred: they elevate baseline activation within a controlled range while suppressing extremes. Clinically, begin with sleeves for mild instability; if malalignment persists under load, switch to patella-tracking braces for targeted control without excessive muscular strain.



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