Effects of Wrist Support Types on Grip Strength, Stability, Muscle Fatigue, and Muscle Activity During Static and Dynamic Functional Tasks

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Abstract

Background

Knee orthoses are widely used to provide external support and potentially modify proprioceptive and postural control mechanisms. However, the immediate effects of a figure-of-eight patellar brace on knee muscle strength, joint range of motion, and postural control in healthy adolescents remain unclear. This study investigated the acute effects of a figure-of-eight patellar brace on knee function and postural stability in healthy high school students.

Methods

Six healthy high school students aged 16–18 years, including three males and three females, participated in this study. Knee extension and flexion muscle strength were assessed using a handheld dynamometer, and knee extension and flexion range of motion (ROM) were measured using a digital goniometer. Postural control was evaluated during a 30-second single-leg stance using a pressure-distribution platform. Mediolateral, anteroposterior, and total postural sway were recorded. All measurements were performed before and immediately after application of a figure-of-eight patellar brace. Pre- and post-brace measurements were compared using paired-samples t-tests, and Cohen's d was calculated to estimate the magnitude of the changes.

Results

No statistically significant differences were observed in any outcome following brace application. Knee extension strength decreased from 17.9 ± 3.30 to 16.8 ± 3.43 ($p = 0.578$, $d = 0.33$), whereas knee flexion strength decreased from 17.4 ± 7.26 to 16.8 ± 7.19 ($p = 0.876$, $d = 0.09$). Knee extension ROM decreased from 169.2 ± 13.20° to 166.7 ± 8.16° ($p = 0.701$, $d = 0.23$), while knee flexion ROM increased from 79.2 ± 15.63° to 81.7 ± 12.91° ($p = 0.769$, $d = -0.17$). Mediolateral sway decreased from 174.4 ± 37.72 to 157.1 ± 24.78 ($p = 0.370$, $d = 0.54$), representing the largest effect size among the assessed variables. Anteroposterior sway showed minimal change (218.1 ± 52.97 vs. 217.2 ± 46.81; $p = 0.974$, $d = 0.02$), while total sway decreased from 308.3 ± 64.62 to 294.2 ± 49.88 ($p = 0.680$, $d = 0.25$).

Conclusions

A figure-of-eight patellar brace did not produce statistically significant acute changes in knee muscle strength, knee ROM, or postural sway in healthy high school students. However, the moderate effect size observed for mediolateral sway suggests a potential direction-specific influence of the brace on frontal-plane postural control. Given the small sample size and absence of a control condition, this finding should be considered preliminary. Further studies with larger samples and direct assessments of proprioception and neuromuscular activation are warranted to clarify the sensorimotor effects of figure-of-eight patellar bracing.

Keywords: knee brace; patellar brace; knee joint; muscle strength; range of motion; postural control; postural sway; proprioception; single-leg stance; healthy adolescents.

I. Introduction

The knee joint is a major weight-bearing joint of the lower extremity and plays a fundamental role in standing, walking, stair negotiation, running, jumping, and other functional activities. Because the knee must simultaneously accommodate substantial mechanical loading and permit sufficient movement, its functional integrity depends on an appropriate balance between joint mobility and mechanical stability. Impairments in knee joint stability, muscle strength, range of motion (ROM), proprioception, or postural control may consequently alter lower-extremity movement strategies and negatively affect functional performance. Knee orthoses are commonly used in rehabilitation and sports medicine to provide external support to the knee joint and to modify mechanical and sensory conditions surrounding the joint. The clinical rationale for knee orthosis use includes mechanical stabilization, redistribution of joint loading, reduction of excessive movement, and enhancement of sensorimotor control. However, the magnitude and direction of these effects vary according to orthosis design, material properties, applied pressure, and the functional status of the individual.

Knee orthoses can be broadly classified according to their structural and biomechanical characteristics, including sleeve-type, hinged, unloading, patellofemoral, and functional braces. Sleeve-type orthoses generally provide circumferential compression with relatively little restriction of physiological knee motion, whereas hinged or unloading braces can provide more directional mechanical support. The proposed mechanisms of action include both mechanical and sensorimotor effects. Mechanical support may reduce excessive joint displacement and modify the distribution of external forces acting on the knee. At the same time, compression of the skin and periarticular tissues may stimulate cutaneous and periarticular mechanoreceptors, thereby altering afferent sensory input and potentially influencing proprioception and neuromuscular control. Previous experimental evidence has demonstrated that external elastic support can modify knee proprioception in individuals without knee pathology, suggesting that externally applied compression may influence the sensory information available for joint position control.[1,3]

The relationship between external knee support and proprioception, however, is not straightforward. Van Tiggelen et al. reported that a neoprene knee sleeve could compensate for deficits in knee joint position sense associated with muscular fatigue, indicating that the effect of external compression may become more apparent when the sensorimotor system is challenged.[5] Similarly, studies in healthy individuals have investigated the effects of knee braces and sleeves on proprioception, with findings suggesting that different brace designs may produce different sensory consequences.[6,7] In contrast, other investigations have failed to demonstrate consistent improvements in kinesthetic awareness or balance following knee orthosis application. A study comparing soft elastic and non-elastic jointed orthoses in healthy individuals found no major improvement in joint position sense or balance and suggested that excessive interface pressure could potentially compromise kinesthetic awareness.[8] These findings indicate that the relationship between orthotic compression, proprioceptive input, and functional postural control may not be linear.

A systematic review of knee sleeves further demonstrated the heterogeneity of the existing evidence. Mohd Sharif et al. reviewed 20 studies examining the biomechanical and functional effects of knee sleeves and reported improvements in proprioception in healthy knees and improvements in gait, balance, and functional performance in individuals with knee pathology.[8] However, the authors emphasized substantial heterogeneity among studies and concluded that the biomechanical efficacy of knee sleeves remained inconclusive.[8] Likewise, a systematic review and meta-analysis of joint stabilizers reported that joint stabilization devices could improve proprioceptive outcomes but had more limited effects on postural stability.[9] These findings are clinically important because increased sensory input from an orthosis does not necessarily translate into measurable improvements in functional balance. Therefore, assessment of both proprioception-related mechanisms and objective postural performance is necessary when evaluating the functional effects of external knee support.

Knee muscle strength is another important determinant of functional knee stability. The quadriceps femoris is particularly important for knee extension, weight acceptance, shock attenuation, and dynamic stabilization during functional movement. The hamstrings also contribute to knee stability by controlling knee flexion and regulating tibiofemoral motion. Consequently, changes in the mechanical environment of the knee produced by an orthosis may influence the force-generating behavior of the muscles surrounding the joint. Previous research has specifically investigated whether external knee supports influence quadriceps function. Earl et al. reported that a functional knee brace could alter quadriceps loading in healthy individuals, demonstrating that external bracing may influence lower-extremity muscle mechanics even in the absence of knee pathology.[2] In clinical populations, flexible knee supports have also been investigated with respect to quadriceps strength and arthrogenic muscle inhibition, indicating that the interaction between external support and muscle performance warrants consideration.[10]

The effects of knee orthoses on muscle activation may also depend on the mechanical objective of the brace. For example, valgus knee bracing has been shown to modify lower-extremity muscle activation and co-contraction during gait in individuals with medial knee osteoarthritis.[11] Similarly, systematic biomechanical evidence suggests that unloading braces can modify knee joint loading and other biomechanical parameters.[13] These findings indicate that an orthosis may not simply stabilize the knee passively but may alter the neuromuscular and mechanical environment in which the surrounding musculature operates. Accordingly, assessment of knee extensor and flexor strength is important when determining whether a figure-of-eight patellar brace produces beneficial stabilization or potentially interferes with voluntary force production.

Joint range of motion is also an essential component of normal knee function. Physiological knee flexion and extension are required for efficient gait and functional activities, and restriction of ROM may result in compensatory movement at adjacent joints. Conversely, excessive mobility may increase the demand for active neuromuscular stabilization. The relationship between lower-extremity joint mobility and balance has been demonstrated in rehabilitation research, with reductions in lower-extremity joint mobility being associated with impaired balance performance.[20] Although these findings were obtained in older adults rather than adolescents, they support the broader biomechanical principle that joint mobility is an important component of postural control. Therefore, an orthosis intended to improve stability should ideally provide sufficient external support without unnecessarily restricting physiological knee motion.

The potential interaction between knee ROM and orthotic support is particularly relevant for flexible or semi-rigid knee braces. Unlike rigid immobilization devices, a figure-of-eight patellar brace is intended to provide external compression and directional support while permitting functional knee movement. Nevertheless, increased tension around the knee may alter the mechanical resistance encountered during flexion and extension. Therefore, direct measurement of knee flexion and extension ROM before and after brace application is necessary to determine whether the device produces a clinically relevant restriction of movement.

Postural control represents an integrated outcome of musculoskeletal function, proprioceptive input, and central sensorimotor processing. During single-leg stance, the reduction in the base of support increases the demand placed on the lower-extremity postural control system and requires continuous regulation of the body's center of mass. Center-of-pressure (COP) displacement is commonly used to quantify postural sway and provides objective information regarding the ability to maintain postural stability. In individuals with ACL injury, single-leg postural stability has been shown to be impaired compared with healthy controls, supporting the sensitivity of single-leg stance assessment to knee-related functional deficits.[15] Furthermore, research examining knee proprioception and limits of stability has demonstrated significant associations between knee joint position error and objective postural-control parameters, suggesting that sensory information from the knee may contribute to the regulation of balance.[18]

Importantly, postural control is direction-specific rather than uniform across all planes. During unipedal stance, the neuromuscular system regulates mediolateral and anteroposterior body sway through coordinated contributions from the ankle, knee, and hip. Recent research has demonstrated that lower-limb muscle activity varies according to sway direction during unipedal balance, indicating that different muscular strategies may be recruited for different directions of postural perturbation.[16] Thus, an external support applied specifically to the knee may not necessarily reduce mediolateral and anteroposterior sway to the same extent. This distinction is particularly relevant for a figure-of-eight brace because its directional tension may provide greater mechanical support in the frontal plane than in the sagittal plane.

Previous investigations have reported potential improvements in balance following the use of knee sleeves. Chuang et al. demonstrated improved static and dynamic balance in patients with knee osteoarthritis when wearing a neoprene knee sleeve.[4] However, these findings were obtained in individuals with symptomatic knee pathology, and the underlying mechanisms may differ from those in healthy adolescents. In addition, the use of global balance scores may obscure direction-specific changes in postural sway. Therefore, separate assessment of mediolateral, anteroposterior, and total sway may provide a more precise description of the immediate effects of knee orthosis application.

The evidence regarding knee orthoses remains heterogeneous. Systematic reviews have identified substantial variability in orthosis design, participant characteristics, intervention protocols, and outcome measures.[8,9,12] A systematic review of orthotic devices for knee instability also identified limitations in the existing evidence base, including small sample sizes, single-center studies, heterogeneous methodologies, and limited use of standardized outcome measures.[12] Similarly, biomechanical and clinical reviews have emphasized that the effects of knee bracing cannot be generalized across different brace designs or patient populations.[8,13] These limitations are particularly relevant when considering healthy adolescents, because much of the existing evidence has focused on individuals with osteoarthritis, ligament injury, or other musculoskeletal pathology.

The adolescent population represents an important but relatively understudied group in this context. During adolescence, musculoskeletal structures and neuromuscular control systems continue to develop, while participation in physical education, recreational activity, and organized sports places substantial functional demands on the lower extremities. The immediate effects of external knee support in healthy adolescents may therefore differ from those observed in older adults or patients with knee pathology. In particular, a brace that improves mechanical stability in a pathological knee may have little functional benefit—or may even restrict normal movement—in an asymptomatic knee. Establishing the immediate effects of a knee orthosis in healthy adolescents is therefore necessary before its routine use can be considered from a preventive or performance-oriented perspective.

The figure-of-eight patellar brace examined in the present study is designed to provide directional external compression around the patellar and proximal tibial regions while maintaining functional knee mobility. Its configuration may provide mechanical support around the knee and simultaneously increase cutaneous sensory input. These effects could potentially influence knee muscle performance, joint mobility, and postural control. However, because the brace does not completely immobilize the knee, its effects may be more subtle and direction-specific than those associated with rigid orthoses.

Accordingly, the present study was designed to investigate the immediate effects of a figure-of-eight patellar brace on knee function in healthy Korean high school students aged 16–18 years. Specifically, knee extensor and flexor isometric muscle strength, knee extension and flexion ROM, and postural sway during single-leg stance were assessed before and after brace application. Postural sway was analyzed separately in the mediolateral and anteroposterior directions as well as for total sway. This multidimensional approach was intended to determine whether external knee support produces measurable changes in muscular performance, joint mobility, or postural control.

The primary objective of this study was therefore to compare knee extensor and flexor muscle strength, knee extension and flexion ROM, and mediolateral, anteroposterior, and total postural sway before and after wearing a figure-of-eight patellar brace in healthy male and female high school students. We hypothesized that the application of the brace would influence at least one component of knee function, particularly postural control, while the effects on muscle strength and ROM would depend on the mechanical and sensory characteristics of the brace.

II. Materials and Methods

2.1. Participants

Six healthy high school students, comprising three males and three females, participated in this study. The participants were 16–18 years of age and had no apparent limitations in knee muscle strength or joint range of motion that could interfere with the experimental procedures. Participants were eligible if they had no history of orthopedic or neurological disorders involving the knee or lower back during the preceding 6 months.
Prior to participation, the purpose and procedures of the study were explained to all participants. Written informed consent was obtained from the participants before data collection. The study was conducted in accordance with the principles of research ethics.

2.2. Measurement Instruments

2.2.1. Isometric Muscle Strength

Knee muscle strength was assessed using the microFET2 handheld dynamometer (Hoggan Scientific, LLC, Salt Lake City, UT, USA). The microFET2 is a portable digital force measurement device designed to quantify muscle force during manual muscle testing. During assessment, the examiner positioned the measurement pad against the designated anatomical region and applied resistance against the participant's maximal voluntary isometric contraction (MVIC). The force generated during the contraction was recorded using the device.

2.2.2. Knee Joint Range of Motion

Knee joint ROM was measured using a Baseline® digital goniometer (Fabrication Enterprises Inc., White Plains, NY, USA). The axis of the goniometer was aligned with the anatomical axis of knee rotation, while the stationary and movable arms were aligned with the longitudinal axes of the proximal and distal segments, respectively. The angular displacement displayed on the digital screen was recorded directly.
Knee extension and flexion ROM were assessed to determine whether application of the figure-of-eight patellar brace altered physiological knee joint mobility.

2.2.3. Postural Control

Postural control was assessed using the PhysioSensing platform (Sensing Future Technologies, Lda., Coimbra, Portugal). The platform was connected to a computer via USB, and the appropriate assessment protocol was selected using the associated software. Participants performed the balance assessment barefoot on the platform. During the test, the trajectory of the center of pressure (COP) was recorded.
The assessment provided measures of mediolateral sway, anteroposterior sway, and total postural sway. These parameters were used as objective indicators of postural stability during single-leg stance.

2.3. Experimental Procedures

2.3.1. Application of the Figure-of-Eight Patellar Brace

A figure-of-eight patellar brace was applied to each participant before the post-intervention measurements. The longer portion of the brace was positioned toward the proximal thigh, while the internal cushioning pad was positioned over the tibial tuberosity region below the knee joint. The brace was then stretched appropriately around the knee to provide close contact with the knee region.

The black Velcro fastening strip located on the medial aspect of the brace was attached to the external fabric on the opposite side to maintain the brace in its stretched position. After application, the examiner confirmed that the brace was securely positioned and provided appropriate contact around the knee. Minor positional adjustments were made when necessary to ensure stable application.

2.3.2. Knee Muscle Strength Assessment

Knee muscle strength was assessed in a seated position. For assessment of knee extension strength, participants were seated with the knee positioned at approximately 90° of flexion. The examiner placed the pad of the handheld dynamometer against the anterior aspect of the distal lower leg. Participants were instructed to extend the knee maximally while the examiner provided resistance against the movement. The maximal isometric force generated during a 3-second contraction was recorded.

For assessment of knee flexion strength, the participant's thigh and lower leg were positioned at an internal angle of approximately 120°. The dynamometer pad was positioned against the Achilles tendon region, and participants were instructed to flex the knee maximally against the examiner's resistance. The maximal force generated during the 3-second isometric contraction was recorded.

Knee extension and flexion strength were first measured without the brace. The figure-of-eight patellar brace was then applied, and the same measurements were repeated using identical body positioning and testing procedures.

2.3.3. Knee Range of Motion Assessment

Knee ROM was assessed in the seated position using the digital goniometer. For assessment of knee extension ROM, participants were instructed to actively extend the knee until they perceived a point of stretching or end-range limitation. The angle formed between the thigh and lower leg was then recorded.

For assessment of knee flexion ROM, participants were instructed to actively flex the knee to the maximum comfortable range, and the corresponding angle between the thigh and lower leg was recorded.

Both knee extension and flexion ROM were first assessed without the brace. Following application of the figure-of-eight patellar brace, the measurements were repeated using the same procedure and positioning.

2.3.4. Single-Leg Stance Assessment

Postural stability was assessed using a single-leg stance task on the pressure-distribution platform. Participants stood barefoot on the platform using the right lower extremity, with the knee maintained in an extended position and both arms positioned alongside the trunk. Participants were instructed to maintain the designated posture for 30 seconds.

During the 30-second trial, COP displacement was continuously recorded. The recorded data were used to calculate mediolateral sway, anteroposterior sway, and total sway.

The single-leg stance assessment was initially performed without the figure-of-eight patellar brace. The brace was subsequently applied, and the same assessment was repeated under identical experimental conditions.

2.4. Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics version 23.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for each outcome variable and are presented as mean ± standard deviation (SD).

To compare knee muscle strength, knee ROM, and postural sway before and after application of the figure-of-eight patellar brace, paired-samples t-tests were performed. Effect sizes were calculated using Cohen's effect size formula to quantify the magnitude of the observed changes.

Statistical significance was set at an alpha level of 0.05. Given the within-subject design, comparisons between the pre-brace and post-brace conditions were performed for each outcome variable.

III. Results

3.1. Effects of the Figure-of-Eight Patellar Brace on Knee Muscle Strength

The effects of the figure-of-eight patellar brace on knee muscle strength are presented in Table 1. Knee extension strength decreased from 17.9 ± 3.30 before brace application to 16.8 ± 3.43 after brace application. However, this difference was not statistically significant ($p = 0.578$), with a small-to-moderate effect size (Cohen's $d = 0.33$).

Knee flexion strength also decreased slightly following brace application, from 17.4 ± 7.26 to 16.8 ± 7.19. The difference was not statistically significant ($p = 0.876$), and the effect size was negligible (Cohen's $d = 0.09$).

Overall, application of the figure-of-eight patellar brace did not produce statistically significant changes in either knee extension or knee flexion strength.

Table 1. Effects of figure-of-eight patellar brace application on knee muscle strength, range of motion, and postural sway

Variable	Before brace	After brace	p-value	Effect size (Cohen's d)
Knee extension strength	17.9 ± 3.30	16.8 ± 3.43	0.578	0.33
Knee flexion strength	17.4 ± 7.26	16.8 ± 7.19	0.876	0.09
Knee extension ROM (°)	169.2 ± 13.20	166.7 ± 8.16	0.701	0.23
Knee flexion ROM (°)	79.2 ± 15.63	81.7 ± 12.91	0.769	−0.17
Mediolateral sway	174.4 ± 37.72	157.1 ± 24.78	0.370	0.54
Anteroposterior sway	218.1 ± 52.97	217.2 ± 46.81	0.974	0.02
Total sway	308.3 ± 64.62	294.2 ± 49.88	0.680	0.25

Values are presented as mean ± standard deviation. ROM, range of motion.

3.2. Effects of the Figure-of-Eight Patellar Brace on Knee Range of Motion

The effects of the brace on knee ROM are also presented in Table 1. Knee extension ROM decreased from 169.2 ± 13.20° before brace application to 166.7 ± 8.16° after application. This difference was not statistically significant (p = 0.701), with a small effect size (Cohen's d = 0.23).

In contrast, knee flexion ROM increased slightly from 79.2 ± 15.63° to 81.7 ± 12.91° following brace application. This change was not statistically significant (p = 0.769), and the effect size was negligible (Cohen's d = −0.17).

Thus, the application of the figure-of-eight patellar brace did not significantly alter either knee extension or flexion ROM.

3.3. Effects of the Figure-of-Eight Patellar Brace on Postural Sway

The effects of the figure-of-eight patellar brace on postural sway during single-leg stance are shown in Table 1. Mediolateral sway decreased from 174.4 ± 37.72 before brace application to 157.1 ± 24.78 after application. Although this reduction was not statistically significant (p = 0.370), the corresponding effect size was moderate (Cohen's d = 0.54).

Anteroposterior sway showed virtually no change, decreasing from 218.1 ± 52.97 to 217.2 ± 46.81 following brace application. The difference was not statistically significant (p = 0.974), with a negligible effect size (Cohen's d = 0.02).

Total postural sway decreased from 308.3 ± 64.62 before brace application to 294.2 ± 49.88 after application. However, this difference was not statistically significant (p = 0.680), and the effect size was small (Cohen's d = 0.25).

Taken together, none of the assessed variables demonstrated a statistically significant difference between the pre- and post-brace conditions (p > 0.05). Nevertheless, mediolateral sway demonstrated the largest effect size among the postural control variables, with a moderate effect size (Cohen's d = 0.54), suggesting a potentially meaningful directional change that warrants further investigation in studies with larger sample sizes.

IV. Discussion

The present study investigated the immediate effects of wearing a figure-of-eight patellar brace on knee extensor and flexor muscle strength, knee joint range of motion (ROM), and postural sway during single-leg stance in healthy high school students. The principal finding was that none of the assessed variables demonstrated a statistically significant difference between the pre- and post-brace conditions. Nevertheless, the magnitude of the observed changes was not uniform across variables. In particular, mediolateral postural sway decreased from 174.4 ± 37.72 to 157.1 ± 24.78 following brace application and demonstrated the largest effect size among the assessed outcomes (Cohen's d = 0.54), despite the absence of statistical significance (p = 0.370). In contrast, anteroposterior sway showed virtually no change (Cohen's d = 0.02), while total sway demonstrated only a small effect (Cohen's d = 0.25). These findings suggest that the immediate functional influence of the figure-of-eight patellar brace may be more apparent in the mediolateral component of postural control than in knee muscle strength, knee ROM, or anteroposterior postural control.

In the present study, knee extension strength decreased slightly from 17.9 ± 3.30 to 16.8 ± 3.43 following brace application, whereas knee flexion strength decreased from 17.4 ± 7.26 to 16.8 ± 7.19. Neither change was statistically significant, and the corresponding effect sizes were small ($d = 0.33$) and negligible ($d = 0.09$), respectively. These findings indicate that the figure-of-eight patellar brace did not substantially alter the ability of the participants to generate maximal voluntary isometric force during the testing conditions used in this study.

The absence of a significant reduction in knee muscle strength is clinically relevant because an external orthosis may theoretically interfere with voluntary force production if it restricts joint motion or alters the mechanical relationship between the muscle and joint. However, the present findings suggest that the brace did not produce sufficient mechanical restriction to meaningfully impair either knee extension or flexion force production during short-duration isometric testing. This interpretation is consistent with the broader literature indicating that the biomechanical effects of knee sleeves and braces are heterogeneous and dependent on brace design, loading condition, and participant characteristics. Mohd Sharif et al. reported that knee sleeves produced improvements in some biomechanical and functional outcomes but that eight of the 20 reviewed studies failed to demonstrate significant effects, emphasizing the lack of consistent biomechanical effects across different conditions.[8]

The relatively small effect observed for knee extension strength may nevertheless warrant consideration. The decrease in extension strength following brace application was greater than the decrease in flexion strength, although the difference was not statistically significant. One possible explanation is that external compression around the anterior and peri-patellar region could subtly modify the mechanical environment of the extensor mechanism. However, this interpretation remains speculative because the present study did not directly measure quadriceps activation, patellar tracking, tendon stiffness, or joint torque. Furthermore, the magnitude of the effect was insufficient to establish a clinically meaningful impairment. Therefore, the present findings should be interpreted as evidence that short-term brace application did not substantially compromise maximal knee muscle force in this small healthy sample rather than as evidence that the brace has no effect on neuromuscular function.

The importance of preserving muscle function during brace use has also been emphasized in clinical populations. Mahmoud et al. demonstrated the functional importance of quadriceps strength and hamstring flexibility in individuals with knee osteoarthritis, particularly because quadriceps weakness and altered hamstring length can influence knee joint loading and physical performance.[19] Although the participants in that study had knee osteoarthritis and therefore cannot be directly compared with the healthy adolescents in the present study, the findings provide a biomechanical rationale for monitoring muscle function when evaluating external knee support. The present results indicate that the figure-of-eight brace did not produce a substantial acute deficit in either knee extension or flexion strength.

The present study also demonstrated no statistically significant changes in knee extension or flexion ROM following brace application. Knee extension ROM decreased by approximately 2.5°, whereas knee flexion ROM increased by approximately 2.5°. The corresponding effect sizes were small for extension ($d = 0.23$) and negligible for flexion ($d = -0.17$). These findings suggest that the figure-of-eight patellar brace provided external support without producing a substantial immediate restriction of physiological knee movement.

This finding is important from a functional perspective. An orthosis that increases joint stability but substantially restricts ROM may interfere with normal movement patterns and potentially transfer mechanical demands to adjacent joints. In contrast, the present figure-of-eight brace appears to have maintained relatively similar knee ROM between the two testing conditions. The absence of a consistent directional change in both flexion and extension further suggests that the brace did not systematically impose a mechanical block on sagittal-plane knee motion.

Previous research has demonstrated that lower-extremity joint mobility is associated with postural balance, although the magnitude of this relationship may depend strongly on age and functional status. Woo et al. reported an association between age-related characteristics of lower-extremity joint motion and balance performance in older adults.[20] Because the present participants were healthy adolescents rather than older adults, the absolute ROM characteristics and their contribution to balance cannot be directly extrapolated from that study. Nevertheless, the findings support the importance of considering joint mobility when evaluating interventions intended to modify lower-extremity stability. In the present study, the absence of a substantial ROM restriction suggests that the observed reduction in mediolateral sway was unlikely to have resulted from a generalized limitation of knee motion.

The present results should also be distinguished from studies investigating unloading braces in patients with symptomatic knee osteoarthritis. The ROTOR randomized clinical trial demonstrated clinically meaningful improvements in pain and function after six weeks of unloading brace treatment in patients with medial knee osteoarthritis.[24] However, unloading braces are specifically designed to modify compartmental loading and therefore differ substantially from the figure-of-eight patellar brace used in the present study. Moreover, the ROTOR study evaluated a longer-term therapeutic intervention in symptomatic patients, whereas the present investigation evaluated an immediate response in healthy adolescents. Therefore, the absence of ROM changes in the current study should be interpreted specifically as an acute response to a figure-of-eight patellar brace rather than as evidence regarding the long-term effects of unloading orthoses.

The most notable finding of the present study was observed in mediolateral postural sway. Although the reduction from 174.4 ± 37.72 to 157.1 ± 24.78 did not reach statistical significance ($p = 0.370$), the effect size was moderate ($d = 0.54$), representing the largest effect among all measured variables. In contrast, anteroposterior sway showed almost no change ($d = 0.02$), and total sway showed only a small effect ($d = 0.25$). This pattern suggests that if the figure-of-eight patellar brace exerts an immediate influence on postural control, the effect may be direction-specific rather than a generalized reduction in postural sway.

The direction-specific nature of this finding is biomechanically plausible. During single-leg stance, postural control is maintained through coordinated contributions of the ankle, knee, and hip, and the relative contribution of each joint depends on the direction and magnitude of body sway. Promsri demonstrated that lower-limb muscle activity during unipedal balance is modulated according to sway direction, surface stability, and leg dominance.[16] These findings support the concept that mediolateral and anteroposterior postural control should not necessarily be regarded as identical physiological processes. Consequently, a knee orthosis may influence one component of postural control without producing a comparable effect in another direction.

The present finding is also consistent with evidence demonstrating that mediolateral and anteroposterior postural sway may respond differently to knee-related dysfunction. Lehmann et al. reported that individuals with ACL injury demonstrated significantly greater postural sway than healthy controls during single-leg stance, with significant increases in both anteroposterior and mediolateral sway; however, the standardized effect was larger for mediolateral sway than for anteroposterior sway.[15] Specifically, the reported standardized mean difference was 1.15 for mediolateral sway compared with 0.58 for anteroposterior sway.[15] Although the participants in that systematic review had ACL injury and therefore differ substantially from the healthy adolescents in the present study, the direction-specific pattern provides a plausible biomechanical basis for considering mediolateral sway as a potentially sensitive indicator of knee-related postural control.

A similar interpretation can be made from research examining individuals with combined ACL and anterolateral ligament pathology. Novaes et al. investigated postural control during single-leg stance in individuals with clinical indications for combined ACL and anterolateral ligament reconstruction and emphasized the importance of single-leg postural control assessment in evaluating functional knee stability.[17] The clinical population in that study differs from the present healthy sample, but it supports the use of single-leg stance as a functional task capable of challenging the sensorimotor system associated with knee stability. In the present study, the use of a 30-second single-leg stance condition may therefore have provided sufficient postural demand to reveal a directional response to external knee support, even though the small sample size prevented statistical confirmation.

The relationship between knee proprioception and postural control provides another possible explanation for the observed reduction in mediolateral sway. Raizah et al. reported that knee joint proprioception is related to limits of stability and postural-control performance in individuals with bilateral knee osteoarthritis.[18] Again, the pathological population prevents direct generalization to the present participants, but the study supports the broader concept that sensory information originating from the knee may contribute to the regulation of whole-body stability. A figure-of-eight brace may increase cutaneous and periarticular sensory input through external compression, potentially enhancing the availability of sensory information during single-leg stance. However, because proprioception was not directly measured in the present study, this proposed mechanism remains hypothetical.

In contrast to mediolateral sway, anteroposterior sway was essentially unchanged following brace application. The mean value changed from 218.1 ± 52.97 to 217.2 ± 46.81, corresponding to an effect size of only $d = 0.02$. This finding suggests that the brace did not meaningfully influence the mechanisms responsible for anteroposterior postural regulation under the present experimental conditions.

One possible explanation is that anteroposterior postural control during single-leg stance depends substantially on the ankle strategy and the coordinated activity of the plantar flexor musculature. The direction-dependent muscle activation patterns reported by Promsri support the concept that different lower-limb muscles contribute differentially to postural regulation according to the direction of sway.[16] Because the present intervention was applied specifically around the knee, its ability to modify anteroposterior postural control may have been limited if this component of balance was primarily regulated by distal ankle mechanisms.

This interpretation should nevertheless be regarded cautiously. The present study did not record ankle or hip kinematics, lower-limb muscle activity, or joint moments. Therefore, the relative contributions of the ankle, knee, and hip cannot be directly established from the available data. Future studies incorporating surface electromyography and three-dimensional motion analysis would be useful for determining whether the figure-of-eight brace produces direction-specific changes in lower-extremity neuromuscular coordination.

The present results should be interpreted within the broader context of heterogeneous findings regarding knee orthoses. Collins et al. investigated the effects of a knee sleeve on impulsive loading and muscle co-contraction during gait in individuals with knee osteoarthritis and suggested that changes in proprioceptive input could influence gait-related loading and muscular coordination.[22] Their subsequent kinetic and kinematic analysis further examined the potential biomechanical mechanisms underlying the effects of knee sleeves during gait.[23] These studies were conducted in individuals with knee osteoarthritis and during walking rather than single-leg stance; therefore, direct comparison with the present results is inappropriate. Nevertheless, they support the broader hypothesis that external knee compression may modify neuromechanical behavior without necessarily producing large changes in conventional measures of muscle strength or ROM.

Similarly, Mazzuca et al. reported improvements in pain, stiffness, and functional ability following the use of a heat-retaining knee sleeve in patients with knee osteoarthritis.[21] These effects are likely influenced by mechanisms that are not directly relevant to the present healthy adolescent sample, including symptom modulation and thermal effects. Thus, the current finding of minimal changes in muscle strength and ROM should not be interpreted as inconsistent with clinical benefits reported for knee sleeves in symptomatic populations. Rather, the discrepancy highlights the importance of distinguishing between therapeutic effects in pathological knees and acute biomechanical or sensorimotor effects in healthy knees.

Holden et al. recently emphasized this issue in a scoping review of randomized controlled trials investigating knee braces for knee osteoarthritis. Across 31 trials involving 47 different bracing interventions, substantial variability was identified in brace type, intervention duration, adherence, delivery, and proposed mechanisms of action.[25] This heterogeneity makes it difficult to generalize findings from one brace design to another. The present study further reinforces this point because a figure-of-eight patellar brace cannot be assumed to produce the same mechanical or sensorimotor effects as a valgus/varus unloading brace, hinged brace, or conventional knee sleeve.

The clinical literature also demonstrates that the effectiveness of knee bracing is not universally established. For example, the systematic review by Marois et al. concluded that available evidence was insufficient to support knee bracing as a reliable strategy for preventing ACL reinjury after return to sport.[24] Although injury prevention was not evaluated in the present study, this finding is relevant because it emphasizes that an observed biomechanical or sensory effect should not automatically be interpreted as evidence of improved clinical outcomes. Similarly, the present moderate effect size for mediolateral sway should not be interpreted as evidence that the figure-of-eight brace improves injury prevention, athletic performance, or long-term knee health.

From a clinical perspective, the present results suggest that short-term application of a figure-of-eight patellar brace does not substantially impair knee muscle strength or ROM in healthy high school students. This is relevant because an orthosis that causes excessive restriction of movement or reduction in voluntary muscle force could potentially interfere with functional activity. In the present sample, the changes in knee extension and flexion strength were small and not statistically significant, while knee ROM remained relatively stable.

The reduction in mediolateral sway, although statistically non-significant, may provide a preliminary indication that the figure-of-eight configuration could influence frontal-plane postural control. However, because the sample size was very small and the confidence intervals were not calculated in the original analysis, this observation should be considered hypothesis-generating rather than confirmatory. In particular, the moderate effect size may represent a potentially meaningful signal that could be investigated in a larger controlled study.

The clinical relevance of the finding may be greater in populations characterized by impaired mediolateral knee stability or reduced proprioceptive function. However, the present study did not include individuals with knee instability, ACL injury, patellofemoral pain, or other knee pathology. Therefore, the current results cannot be used to recommend routine brace use for these populations. Instead, they provide preliminary evidence that a figure-of-eight patellar brace may influence a specific component of postural control while preserving knee muscle force and ROM in healthy adolescents.

V. Conclusions

In summary, wearing a figure-of-eight patellar brace did not produce statistically significant changes in knee extension or flexion strength, knee extension or flexion ROM, or postural sway in healthy high school students. Nevertheless, mediolateral sway demonstrated a moderate effect size, whereas anteroposterior sway showed virtually no effect. This pattern suggests that the immediate influence of the figure-of-eight brace, if present, may be direction-specific and potentially related to frontal-plane postural control rather than generalized changes in knee function. Given the small sample size and absence of a control condition, these findings should be regarded as preliminary. Larger randomized controlled studies incorporating direct measures of proprioception, muscle activation, and three-dimensional lower-extremity biomechanics are required to determine whether the observed reduction in mediolateral sway represents a reproducible functional effect of figure-of-eight patellar bracing.

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