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RESEARCH ARTICLE

Impact of the Prophylactic Brace on Knee Kinematics and Stability in Dynamic Situations

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Introduction

Prophylactic braces are commonly utilized protective devices in sports to reduce the risk of knee injuries. Despite their widespread use, there exists a divergence of opinions regarding their effectiveness. Several studies have investigated the efficacy of prophylactic brace in athletes, revealing enhancements in biomechanical factors linked to the risk of anterior cruciate ligament injuries, such as knee range of motion, flexion angles, or angular velocity [1]. Individuals with knee pathology exhibited a reduction in relative internal/external knee range of motion and reported a "subjective" preference for wearing the brace [2]. Furthermore, improvements in neuromuscular control during dynamic movements have been noted [3], along with reductions in kinesiophobia, which refers to the fear associated with specific movements [4].

In contrast, studies have demonstrated that prophylactic brace do not have a significant impact on biomechanical parameters associated with knee injuries in athletes, including proprioception [2]. Moreover, poorly designed prophylactic orthosis, such as those with excessive compression around the knee joint, can impede athlete performance [5]. The design of the prophylactic orthosis in this study is crucial, emphasizing the need to explore biomechanical factors linked to stability during dynamic situations.

The impact of knee orthoses on stability in dynamic situations generates divergent outcomes in the literature. Studies indicate enhanced stability during dynamic situations, especially in subjects suffering from osteoarthritis [6] or reductions in the knee joint loads [7,8]. However, some research shows no improvement over the long term compared to a non-orthotic condition [9] or even a negative impact on balance (Khan, et al., 2018).

Hanzlíková, et al. [10] conducted a detailed examination of the effect of a prophylactic brace on knee control during 3 dynamic tasks on subjects with a history of cruciate ligament rupture. The tasks were assessed using an optoelectronic system with flexion/extension, abduction/adduction and internal/external rotation movements. The prophylactic brace reduced maximum external knee rotation angle and range of motion in the transverse plane during the pivot-rotation jump task. Importantly, it is noteworthy that the majority of participants found the tasks easier to perform with the prophylactic orthosis than without. This specific protocol and the measurements conducted emphasized the influence of prophylactic braces on knee kinematics during dynamic tasks.

Functional orthoses are likely to exert a more substantial impact on stability compared to prophylactic orthoses, due to their rigid frames which enable them to restrict the knee joint. However, this type of brace is not permitted for use in competitive physical activity. Consequently, our focus in the subsequent sections will be exclusively on prophylactic braces. In this study, the brace utilized is based on a patented selective compression technology by BV SPORT, enabling precise targeting of areas and levels of pressure applied around the knee joint. The objective is to enhance stability in dynamic situations.

The objective of this study was to gain deeper insights into enhancing stability in dynamic situations through the utilization of a prophylactic orthosis. Our

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hypothesis posited that the prophylactic brace could enhance the biomechanical factors that influence dynamic stability.

Methods

Population

The study involved 22 sportsmen and women (regional level with at least 3 training sessions per week; 21.3 ± 2.3, 63.5 ± 11.4 kg; 1.71 ± 0.1 (m)), including 7 women and 15 men (Table 1). A history of clinical ankle sprain was an exclusion criterion for participation in the study.

Materials

The equipment used for this test includes:

- Force platform AMTI (OR6.7.2000)

The AMTI force platform enables measurement of ground reaction forces. It measures the 3 orthogonal force components along the X, Y and Z axes, as well as the 3 moment components.

- An optoelectronic system (Optitrack):

The "Optitrack" system is a 3D motion measurement system. We'll be using 6 infrared cameras (Flex 3, NaturalPoint, Inc. DBA Optitrack) set up in a motion analysis room in the STAPS laboratory (EA7507/PSMS).

This optoelectronic system captures the movement of reflective markers placed on the skin, based on standardized anatomical landmarks. The movement of these markers will be analyzed to determine their location in space.

The chosen sampling frequency is 120 Hz [11]. Motive Body software will be used to collect motion captures. The variables obtained by Optitrack will be Cartesian data of lower limb positions in 3D space. These Cartesian data will be processed with SciLab software to determine the angular variables of the lower limb (Lacouture and Junqua, 1991).

Protocol

The aim of this test is to analyze knee joint kinematics and knee stability in a dynamic situation.

Subjects are randomly assigned to 2 conditions:

- COMP: with a selective compression-based prophylactic knee brace

Table 1: Anthropological measurements of test subjects.

Thigh length (cm)	Leg length (cm)	Calf circumference (cm)	Thigh circumference (cm)	Knee circumference (cm)
49 ± 2.4	48.2 ± 2.4	36 ± 3.3	51.8 ± 5.1	36.2 ± 2.4

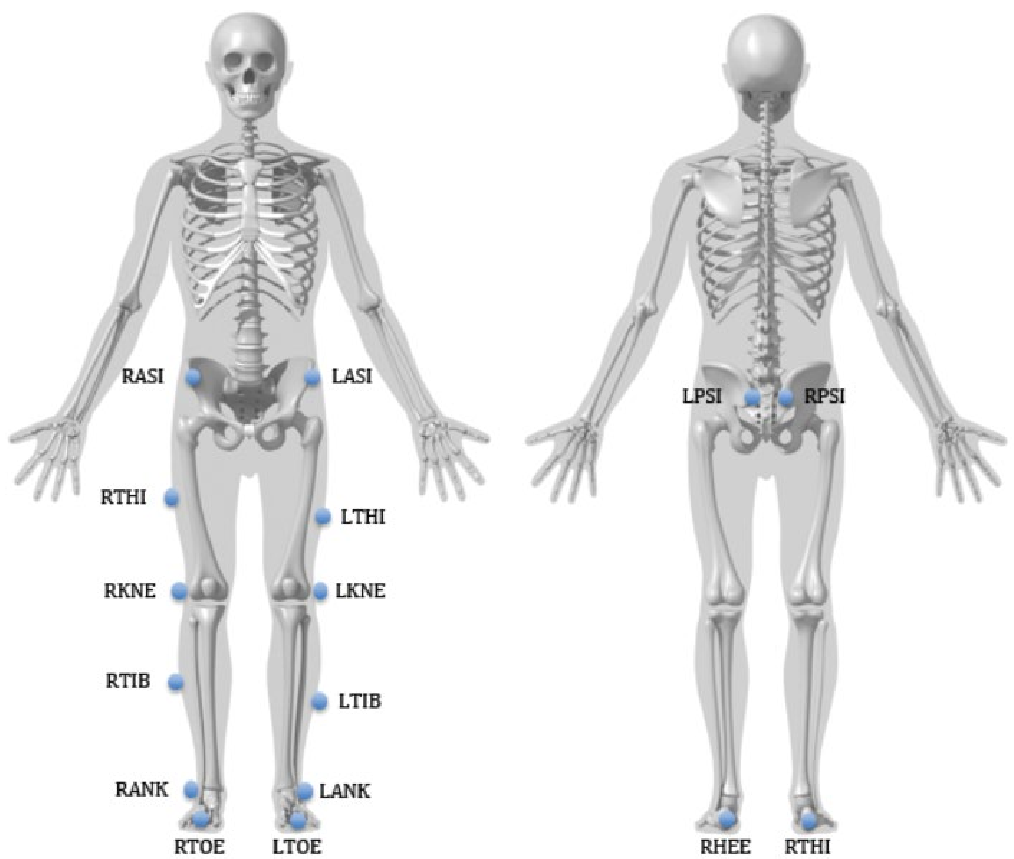

Figure 1: Placing passive markers with the Lower Conventional Body.

- WITHOUT: Without orthosis (control)

For the next two tests, subjects will be fitted with reflective markers placed on the skin in the Conventional Lower Body model (Figure 1). Each sensor must be viewed by at least 2 cameras throughout the movement.

Before each experiment, a calibration phase was carried out to obtain the initial positions of the 3D markers and all the trajectories.

A standardized warm-up was performed before the start of the tests (40 squats followed by 20 alternating forward lunges). Each subject completed a habituation measurement beforehand. Tests were cross-over, controlled and randomized.

The test consisted in performing a downward jump from a height of 0.40 m. Reception was made on the AMTI force platform (200 Hz). Following landing, subjects performed a vertical jump as high as possible in 3 randomized directions:

- Drop Jump (front),
- Drop Jump Right (DJR): After landing on the bench, a jump was made to the right,
- Drop Jump Left (DJL): After landing on the bench, a jump was made to the left.

The hands were placed on the hips throughout the movement. The test was performed 3 times in bare feet, with a one-minute pause between each pass. The best performance was retained.

Measured variables

About the kinematics, the variables measured were:

- Mean knee flexion angle (°)
- Mean Valgus/Varus angle (°)
- Knee translations
    - o Medio-lateral (mm) (T ML)
    - o Anteroposterior (mm) (T AP) (Benoît, et al., 2006)

Knee joint translations are obtained as the distance between point KNE (knee) and KNE at t + 1, which corresponds to the norm of the vector in the associated planes. To measure these variables, two types of equations were determined, using Al Kashi's equation and the scalar product equation to validate flexion and valgus/varus angle calculations (McLean, et al., 2005; DiMattia, et al., 2005). The markers selected for this measurement are, depending on the dominant leg, THI (thigh), KNE (knee) and ANK (ankle).

Each of these variables was measured over 2 periods:

- Reception 1: 1st landing of the Drop Jump from the starting platform onto the force platform
- Reception 2: 2nd landing after the Drop Jump on the force platform

About the biomechanical analysis, the entire Drop Jump was measured:

- Index of Global Stability (OSI): An indicator of equilibrium [12]
- Impulse (N.s)
- Flying time (s)
- Vertical jump(m)

Statistics

Study data were analyzed using tests for normality (Shapiro-Wilks) and homogeneity of variances (Levene). Depending on normality, parametric (Student's t-test) or non-parametric (Wilcoxon) analyses were performed to compare COMP and WITHOUT conditions per movement. Then an ANOVA (Friedman) was performed to study the effects of movements (DJ, DJR and DJL) and compression. The confidence index was set at 95%. Statistical analyses were performed using Statsoft's Statistica 12.

Results

Kinematic analysis

The first results were obtained using an optoelectronic system. They enabled us to study the kinematics of the knee joint during a dynamic phase, a Drop Jump.

These results (Table 2) showed significant reductions in mean knee joint angle during Drop Jump flexion for the 1st and 2nd landings ($p < 0.01$) with COMP versus WITHOUT. We also observe that for the 1st landing, medio-lateral and antero-posterior translations are significantly reduced with COMP compared to WITHOUT for each movement (DJ, DJR and DJL). For the 2nd reception, the significant reductions in ML and AP translations of COMP over SANS appear only for DJ and DJL. Valgus/Varus is also significantly reduced for the 1st landing with the DJR movement ($p < 0.01$) and for the 2nd landing with the DJ and DJL movements ($p < 0.01$).

Biomechanical analysis

Results on the biomechanical analysis (Table 3) showed no significant differences between COMP and WITHOUT conditions on each parameter, apart from a significant improvement in flight time on DJ ($p = 0.02$) with COMP compared with WHITOUT.

Discussion

The objective of this study was to enhance the understanding of improving stability in dynamic situations through the application of a prophylactic orthosis. Kinematic analysis using an optoelectronic system and postural analysis using a force platform were carried out on 22 sports subjects. The hypotheses put forward were an improvement in biomechanical factors

Table 2: Drop Jump measurements according to orthosis wear for kinematic analysis.

Reception	Movements	Measures	COMP	WITHOUT	Difference	Size effect
Reception 1	DJ	Flexion (°)	**104.3 ± 14.2****	**109.5 ± 17.9**	**-5%**	**0.08**
		Valgus/Varus (°)	162.5 ± 12.4	162.2 ± 13.8	0%	0.01
		T ML (mm)	**5.5 ± 2.5****	**6.0 ± 2.9**	**-8%**	**0.04**
		T AP (mm)	**6.6 ± 3.0****	**7.0 ± 3.4**	**-7%**	**0.03**
	DJD	Flexion (°)	**112.7 ± 12.2****	**124.5 ± 7.1**	**-9%**	**0.21**
		Valgus/Varus (°)	**141.3 ± 14.8****	**151.7 ± 5.3**	**-7%**	**0.15**
		T ML (mm)	**5.7 ± 2.5***	**6.0 ± 3.6**	**-5%**	**0.02**
		T AP (mm)	**6.9 ± 2.1***	**7.3 ± 1.7**	**-5%**	**0.03**
	DJG	Flexion (°)	**110.4 ± 24.9****	**122.1 ± 12.9**	**-10%**	**0.10**
		Valgus/Varus (°)	139.7 ± 25.7	147.4 ± 14.8	-5%	0.07
		T ML (mm)	**5.3 ± 2.5****	**6.0 ± 2.2**	**-12%**	**0.05**
		T AP (mm)	**6.2 ± 2.7****	**7.0 ± 2.5**	**-11%**	**0.06**
Reception 2	DJ	Flexion (°)	**90.6 ± 16.0****	**96.6 ± 13.7**	**-6%**	**0.08**
		Valgus/Varus (°)	**153.3 ± 11.7****	**165.6 ± 11.1**	**-7%**	**0.23**
		T ML (mm)	**1.8 ± 2.0****	**2.2 ± 2.1**	**-18%**	**0.03**
		T AP (mm)	**2.0 ± 2.2****	**2.4 ± 2.4**	**-17%**	**0.03**
	DJR	Flexion (°)	**95.6 ± 8.0****	**92.7 ± 7.2**	**+3%**	**0.08**
		Valgus/Varus (°)	165.7 ± 15.3	175.6 ± 7.9	-3%	0.09
		T ML (mm)	1.8 ± 2.6	1.8 ± 2.1	0%	0
		T AP (mm)	2.0 ± 2.2	2.1 ± 2.4	-5%	0.01
	DJL	Flexion (°)	**110.4 ± 24.9****	**122.1 ± 12.9**	**-10%**	**0.10**
		Valgus/Varus (°)	**141.6 ± 12.0****	**165.9 ± 7.0**	**-15%**	**0.44**
		T ML (mm)	**1.8 ± 2.0****	**2.6 ± 1.5**	**-31%**	**0.07**
		T AP (mm)	**2.0 ± 2.2****	**2.8 ± 1.6**	**-29%**	**0.06**

*p < 0.05; **p < 0.01; DJ: Drop Jump; DJR: Drop Jump Right; DJL: Drop Jump Left

Table 3: Drop Jump measurements according to orthosis wear for biomechanical analysis.

	Movements	Measures	COMP	WITHOUT	Difference
Total Jump	DJ	Impulsion (N.s)	2279.1 ± 397.4	2229.5 ± 385.8	+2%
		Flying time (s)	**1.48 ± 0.17***	**1.46 ± 0.18**	**+1%**
		Vertical jump (m)	0.2 ± 0.4	0.2 ± 0.1	+0%
		OSI	7.7 ± 0.7	7.5 ± 0.8	+3%
	DJR	Impulsion (N.s)	2223.6 ± 422.6	2193 ± 407.9	+1%
		Flying time (s)	1.41 ± 0.15	1.40 ± 0.17	+1%
		Vertical jump (m)	0.2 ± 0.5	0.2 ± 0.1	0%
		OSI	7.7 ± 1	7.9 ± 1.1	-3%
	DJL	Impulsion (N.s)	2189.5 ± 457.1	2191.8 ± 375.6	0%
		Flying time (s)	1.39 ± 0.18	1.40 ± 0.17	-1%
		Vertical jump (m)	0.2 ± 0.1	0.2 ± 0.1	+2%
		OSI	7.8 ± 1.1	7.8 ± 1	0%

*p = 0.02; DJ: Drop Jump; DJR: Drop Jump Right; DJL: Drop Jump Left

related to dynamic stability, and a reduction in the confidence ellipse surface with the use of a prophylactic orthosis compared with no orthosis at all.

The kinematic analysis revealed a significant decrease in mean knee joint flexion angles during both Drop Jump landings and in all directions ($p < 0.001$). The results are in accordance with a portion of the existing literature, which also reported significant decreases in flexion angles during dynamic movements [13,14]. It is important to note that while most studies demonstrating these reductions employed functional knee orthoses with reinforcements, not solely compression, our study specifically focused on a prophylactic orthosis. Functional orthoses, typically incorporating reinforcements, have been shown to be more effective in reducing pain than prophylactic orthoses [15]. Therefore, comparing our prophylactic orthosis directly with functional orthoses is limited due to inherent differences in their capacities. However, our study allows for a comparison with a more effective product in the context of reduced knee flexion angles during dynamic movements.

The results also showed a significant reduction in ML and AP translations for the 1st landing of the Drop Jump and for each direction ($p < 0.05$) and for the 2nd landing ($p < 0.01$) except for the DJR. These smaller movements, combined with reductions in flexion angles during stance phases, show that the prophylactic brace provides a degree of control over the knee joint in dynamic situations. This control limits the knee joint's range of motion, thereby improving stability in dynamic situations. Restricting mobility with the orthosis provides prophylactic protection for athletes returning to sport after injury [14].

In addition, for valgus-varus, significant reductions were reported for the 2 receptions ($p < 0.001$), but not 2 times in the same direction. The brace is therefore considered to have little impact on valgus-varus.

For the kinematics, no significant difference was observed apart from an improvement in flight time on COMP DJ compared with WITHOUT ($p = 0.02$). These results are questionable when compared with those obtained with the optoelectronic system. At the very least, we would have expected the OSI to be significantly lower with COMP than WITHOUT.

However, these results can be interpreted in another way. It can be assumed that the prophylactic brace provides a gain in control of the knee joint, thanks to the limitations it imposes. But this gain in control does not sufficiently improve stability in dynamic situations. The effects of the orthosis are certainly limited and need to be accentuated, particularly in terms of the pressure exerted.

However, it should be remembered that we studied the effects of the orthosis on the biomechanics of the knee joint immediately after the orthosis was put on. The subjects had not worn it beforehand, nor had they worn any other type of orthosis during the year. It might therefore be interesting to study whether the effects of training with a prophylactic orthosis and its habituation to exercise have an influence on stability in dynamic situations. It should also be noted that the subjects performed the tasks barefoot and not in shoes, which is not very representative of reality [1]. These parameters offer the prospect of studies to assess the impact of compression-based prophylactic orthoses on knee joint biomechanics.

Conclusion

The aim of this study was to evaluate the impact of a prophylactic orthosis based on selective compression on knee kinematics and stability in dynamic activities. Our findings demonstrate that the prophylactic orthosis provides control of the knee joint in dynamic situations, including Drop Jumps in 3 directions (front, right and left). This control offers prophylactic protection for athletes resuming sports activities post-injury. However, biomechanical variables indicated no enhancement in stability with the prophylactic orthosis.

The outcomes acquired contribute significantly to advancing scientific understanding regarding prophylactic orthoses. The contribution is particularly noteworthy due to the application of an innovative methodology, sparsely explored in existing literature. Additionally, conducting prolonged training with the orthosis is essential to determine its potential impact, if any, on stability during dynamic activities.

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