THE EFFECT OF FUNCTIONAL KNEE BRACE MIGRATION ON THE KNEE JOINT MOMENT AND POWER PATTERNS DURING WALKING

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The purpose of this investigation was to determine the differences in joint moment and power patterns during walking with and without a functional knee brace and when the brace was deliberately misaligned with the knee axis of rotation. Five participants were asked to walk over a force platform with and without the brace as well as during a condition where the axis of rotation of the brace had been deliberately shifted 1 cm down the leg. Inverse dynamics were used to calculate changes in joint moments and powers at the knee joint. Initial findings indicate that the extensor moment during push-off and its corresponding eccentric power were greatest in the braced and misaligned brace conditions, though the differences in peak joint moments and powers between these two conditions was not large enough to implicate brace migration as an injury mechanism.

KEY WORDS: knee brace, inverse dynamics, locomotion, walking.

INTRODUCTION: Since the 1960s, there has been a deluge of functional knee brace designs appearing on the market in order to resolve the problem of knee instability and ACL insufficiency in the athletically active population. Despite the fact that functional knee braces have been commonly believed to positively affect the performance of individuals with knee instability, there has only recently been a campaign to quantitatively study their effectiveness (Cawley, France, & Paulos, 1991). Moreover, within this research, one will find much disagreement between findings (Vailas & Pink, 1993; Beynnon & Fleming, 1998; Fleming, Renstrom, Beynnon, Engstrom, & Peura, 2000).

Among the athletic community, a common complaint relates to the tendency of the brace to gradually migrate down the leg during activity (France, Cawley, & Paulos, 1990). Regalbuto, Rovick, and Walker (1989) have proposed that brace migration may be due, in part, to the successive contractions of the leg musculature during physical activity, which cause a failure of the brace to adhere to the soft tissues of the leg. As the chief function of the brace is to accept some of the applied force during activity while restricting anterior tibial translation, it is crucial that the axes of rotation of the both the knee and the brace remain aligned during activity in order to maintain the maximum protective benefit from the brace. Lamontagne, Singer and Xu (2003) demonstrated that there was a constant disparity between the kinematics of the knee and the brace during cycling, which persisted throughout the entire testing period. This dissimilarity in kinematics was believed to cause an offset in the optimal placement of the brace hinge with respect to the knee axis of rotation. It has been suggested that mismatch between the axes of rotation of the leg and brace can translate into reduced ability of the brace to control tibial motion, which may lead to increased ACL tension (Walker, Rovick, & Robertson, 1988) and shearing of the soft tissues beneath the brace (Regalbuto, Rovick, & Walker, 1989; Vailas & Pink, 1993).

While there is much known regarding the effects of functional knee bracing on the sagittal plane kinetics during locomotion (DeVita, Torry, Glover, & Speroni, 1996; DeVita, Lassiter, Hortobagyi, & Torry, 1998), there is little known with respect to the effect of brace migration on these variables. With this being the case, the purpose of this investigation was to determine the differences in joint moment and power patterns during walking with and without a functional knee brace and when the brace was deliberately misaligned with the knee axis of rotation. The goal of this research is to shed light on both the efficacy and safety of functional knee bracing. It is hoped that this will ultimately provide information to athletes and medical practitioners so that informed decisions can be made regarding the advantages and drawbacks of functional knee brace use.

METHODS: A group of five healthy participants (mean age: 23.2 yr; mean mass: 72 kg),

having no previous history or current incidence of musculoskeletal disease or injury were recruited from the student population at the University of Ottawa. After informed consent, circumference measures at the upper thigh, knee and lower leg were obtained. Each participant's right leg was subsequently fitted with the brace, according to the manufacturer's specifications. Brace straps were tightened and fastened according to the subjective comfort level of each participant and the participant was asked to wear the brace for half an hour before the commencement of testing.
One Kistler force platform was used to measure vertical, horizontal and mediolateral ground-reaction forces at 240 Hz, while one video camera was used to film the participant in the sagittal plane at 60 Hz. Reflective markers were placed on the lateral side of the shoe at the tip of the great toe, the head of the fifth metatarsal and at the heel, as well as on surface locations over the lateral malleolus, centre of rotation of the knee, greater trochanter and shoulder. Distances between successive markers were measured with an anthropometer and were later used in the verification of data. The protocol consisted of the participant walking at a self-selected speed, impacting the force platform on the second stride, with and without the brace as well as during a condition where the axis of rotation of the brace had been deliberately shifted 1 cm down the leg, with respect to the optimal positioning of the brace. The decision to migrate the brace distally by 1 cm was based on the results of Regalbuto, Rovick and Walker (1989). The order of each of the three experimental conditions was randomly assigned for each participant.
Reflective markers were digitized for one stride, refined by the Biomech System (Robertson, 2004) and filtered using a zero-lag, fourth-order, Butterworth, low-pass filter with a cut-off frequency of 6.0 Hz. After filtering, five frames at the beginning and end of the filming sequence were discarded to improve the accuracy of the data. The lower extremity was modeled as a rigid, linked-segment system; relative and absolute joint angles and joint angular velocities were calculated at the knee. Force platform data were merged and synchronized with the kinematic data at heel-strike. Inverse-dynamics were applied to calculate the joint reaction forces at the hip, knee and ankle joints. Joint moments were expressed as positive values for hip flexion, knee extension and ankle dorsiflexion. Joint powers were calculated as the product of the joint moment and angular velocity, whereby a positive power indicated that the joint moment was produced through concentric contraction. For comparative purposes, joint moments and their powers were normalized to body mass.

RESULTS: Average walking velocities for the unbraced, braced and misaligned brace conditions were 1.451 m/s, 1.123 m/s and 1.123 m/s, respectively. Due to the similarity among ankle and hip moments and powers within the three conditions, only the knee moments and their powers are reported. The joint moment and power curves (Figure 1) show representative patterns throughout stance and swing for gait during the unbraced condition, as well as during aligned and misaligned brace conditions. Preliminary analyses of the results indicate that, at heel contact, the flexor moment in either of the braced conditions was less than in the unbraced condition. Furthermore peak moments were greatest in the misaligned brace condition (Table 1), with the most marked difference being the large extensor moment during the propulsive portion of the stance phase rather than a slight flexor moment, as seen in the unbraced trial. The knee powers for each of the three conditions have a similar pattern to those reported by Winter (1991), with principal differences coming from the fact that in the progression from unbraced to the aligned brace and finally to the unbraced condition, peak joint powers become sequentially larger (Table 1).

Table 1 Peak Joint Moments and Powers in the Unbraced, Braced and Misaligned Brace Conditions.

	Moment of Force			Power		
	Heel Strike	Weight Accpetance	Push Off	K1	K2	K3
Unbraced	-0.54	0.38	0.03	-0.55	0.07	-0.09
Braced	-0.22	0.73	1.00	-0.61	0.23	-3.49
Misaligned	-0.28	1.13	1.16	-1.06	0.54	-3.82

Note: Peak knee joint moments and peak joint moment powers are normalized to body mass and reported in N·m/kg and W/kg, respectively.

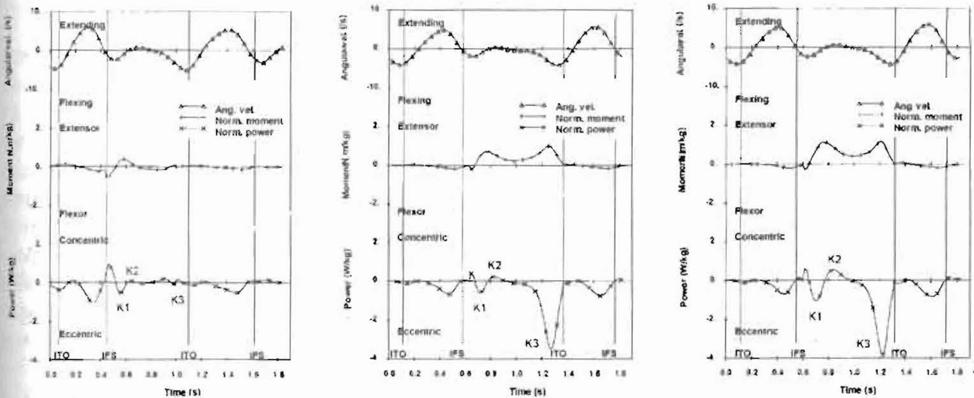

Figure 1: Knee joint angular velocity, moment and power patterns during the unbraced (left), braced (centre) and misaligned brace (right) conditions. Joint moments and their powers are normalized to body mass.

DISCUSSION: Table 1 shows that there was an increase in the magnitude of peak joint moments and powers in the braced and misaligned brace condition in comparison to the unbraced condition, with the misaligned condition producing the highest peak moments and powers. Knee joint moments and powers in the unbraced condition are similar to those reported by Winter (1991). In the braced condition, however, knee moments and powers do not correspond with the findings of DeVita, Torry, Glover and Spencer (1996) or DeVita, Lassiter, Hortobagyi and Torry (1998), who reported a reduced extensor moment as well as reduced power at the knee joint during walking with a functional knee brace. This particular finding was deemed to be a benefit for ACL deficient patients or those with ACL insufficiency, as the reduced extensor moment and its power indicates that less force is generated by the quadriceps, reducing the anterior pull on the tibia and most likely reducing the strain on the ACL. In the current investigation, donning the brace caused an increase in the extensor moment at the knee during both the weight acceptance and push-off phases of the gait cycle. Perhaps the most notable difference between braced and unbraced conditions is the large increase in power during the K3 phase of stance.

The aforementioned dissimilarity in findings between the current study and previous studies may be due to the fact that, in this investigation, the participants were uninjured and were, therefore, still unaccustomed to wearing a functional knee brace, as the acclimatisation period was relatively short. Although the utilization of healthy participants within this study was considered a limitation in terms of its applicability, it was believed to be necessary such that differences in knee joint moments and powers between the conditions could be attributed to the brace itself, rather than the effect of differences in the degree and nature of injury between and within participants. The finding of an increased eccentric extensor moment could also be due to some heretofore unknown mechanical characteristic of the particular brace utilized. Nevertheless, due to the change in joint moments and their powers, it is clear that participants modified their gait pattern in response to the brace. Whether this is due to a mechanical or proprioceptive factor is yet to be determined.

It is also interesting to note that the increase in the extensor moment during push-off and its corresponding power during K3 phase was only slightly accentuated by deliberately misaligning the axis of rotation of the brace from that of the knee. As a consequence of this, it is believed that, for the particular knee brace tested, brace migration is not a cause for concern in terms of increasing the risk of injury to the knee joint. The lack of change in joint moments and powers between the braced and misaligned brace conditions is most likely due to the fact that the leg was essentially free to move within the limits afforded by the elastic material of the brace (Lamontagne, Singer, & Xu, 2003) and thus was not forced to rotate about the axis of the brace hinge.

CONCLUSION: The purpose of the study was to determine the differences in joint moment and power patterns during walking with and without a functional knee brace as well as with the brace axis of rotation deliberately misaligned from that of the knee. There was an increase in the peak extensor moment and its eccentric power during push-off in the braced condition as compared to the unbraced condition. This is most likely due to either a mechanical characteristic of the brace or a proprioceptive factor, which caused participants to alter their gait pattern. Furthermore, the change in peak joint moments and their powers was not substantial when comparing the misaligned brace condition to the braced condition. This small change may be as a result of the fact that the leg could freely move within the confines of the elastic material of the brace, thus, the leg was not forced to rotate about the axis of the hinge. Nonetheless, for the particular brace tested, brace migration does not appear to place the knee joint at further risk of injury.

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