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EFFECT OF BRACE TYPE ON KNEE JOINT LAXITIY AND FUNCTIONAL ACHIEVEMENTS FOR PATIENTS WITH ACL RUPTURED KNEES

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Sleeve braces could increase proprioceptive stimulation and hence lead to increased benefits than shell braces in ACL injury rehabilitation. Therefore, the purpose of this study was to investigate the effect of two brace types compared to a non-braced condition on joint laxity and functional achievements (proprioception, stability and strength) in 28 ACL deficient patients. With the sleeve brace a significant reduction of joint laxity and of the medio-lateral deviation when standing on an unstable lateral perturbed surface was achieved. Additionally a significant increase of the rate of force development was shown for the sleeve braced condition compared to the rigid shell and non-braced condition. Sleeve braces might not be needed in simple daily life tasks, but could provide beneficial support in more dynamic settings like sport and physical rehabilitation training.

KEY WORDS: functional bracing, rehabilitation, knee injury.

INTRODUCTION: ACL injury is the most frequent injury at the knee, 70% of which occur during athletic activity (Senter & Hame, 2006). The main goal of ACL injury treatment is to regain functional stability of the knee joint motion and to enable a save return to sportive activity. In assistance of the rehabilitation process functional knee braces can be applied, but the use of them is discussed controversially. Research has shown that the ability of functional braces to reduce tibial displacement is only achieved for low loads but not for high-load conditions, as they may appear in sportive tasks (Beynnon et al., 2003; Wojtys et al., 1996) and brace use might not necessarily lead to superior outcome in rehabilitation in the long term (Risberg et al., 1999). The functional braces studied in the literature are mainly rigid shell functional braces. These braces lead likely to an extension deficit (Mayr et al., 2010) as well as an increased thigh atrophy (e.g. Risberg et al., 1999), alterations in movement pattern (DeVita et al., 1996; Singer & Lamontagne, 2008) and patients often report discomfort while using them (Singer & Lamontagne, 2008; Risberg et al., 1999). Yet, many patients with ACL deficiency or ACL rupture report subjective benefits due to functional braces such as a higher sense of stability or increased performance (Birmingham et al., 2008; Swirtun et al., 2005; Smith et al., 2003). Based on the current discussion on how functional braces can support the rehabilitation of ACL deficient knees, increasing the neuromuscular function by stimulating proprioception appears to be a more favorable aspect over the need to provide just passive mechanical stability (DeVita et al., 1996; Singer & Lamontagne, 2008). Ortheses that support proprioception might equal out detrimental effects of the rigid shell functional braces. Beneficial effects on proprioception have been demonstrated by sleeves in healthy subjects (Jerosch & Prymka, 1996), in subjects with different types of knee disorder (Beynnon et al., 2002). Birmingham et al. (2008) reported that ACL-reconstructed patients provided with a neoprene sleeve had similar outcome in functional tests as patients provided with a rigid functional brace. Mayr et al. (2010) reported a superior effect of a water-filled sleeve brace regarding effusion, swelling, extension deficit and patient compliance over a rigid shell brace. Singer & Lamontagne (2008) found that subjects provided with a sleeve brace showed a gait pattern more alike to that of the non-braced healthy group. Additionally, they reported that due to the elastic material a sleeve brace might distribute the applied force more evenly over the shank and the underlying muscle can expand more freely. This might have positive effects on comfort and may lead to a decreased atrophy of the thigh muscles (Singer & Lamontagne, 2008; Reer et al., 2001). While the reported effects of a sleeve brace seem beneficial, little evidence is available of the effect of the different bracing types on subjects with ACL deficient knees. Therefore, the aim of this study was to investigate the effect of different brace types compared to a non-braced condition on joint laxity and functional achievement for proprioception, stability, strength and daily activity in ACL deficient patients.

METHODS: Twenty-eight subjects (16 female, 12 male; age: 40±13 years), who ruptured ACL between 3 months to 20 years (median: 36 months) ago, participated in this study. All subjects were non-copers defined as having experienced "giving way" episode repeatedly, showing an increase in knee joint laxity compared to the non-injured leg (≥3 mm side difference, KT-1000TM arthrometer) and showing a functional instability based on a single leg hop test. Subjects were provided with a sleeve brace (SofTec Genu, Bauerfeind Germany Inc, Zeulenroda, Fig. 1a) and a rigid shell brace (4Titude Donjoy, ORMED GmbH, Freiburg, Fig. 1b). Both braces were individually fitted by an orthopedic technician. For reducing learning effects all subjects came to the laboratory for two habituation sessions prior to the actual measurements to become familiar with the tests and the entire procedure. All subjects completed two testing sessions. The tests of each session were completed in one condition (sleeve brace, shell brace, non-braced) before the subjects changed to the next condition in a randomized order.

a) b) c) d) e)

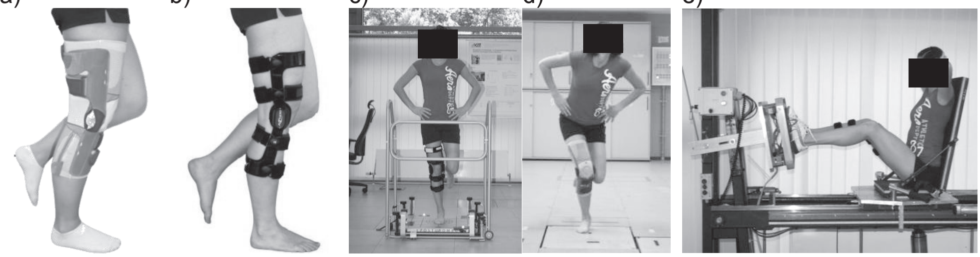

Figure 1: a) Sleeve brace (SofTec Genu, Bauerfeind Germany Inc., Zeulenroda); b) rigid shell brace (4Titude Donjoy, ORMED GmbH, Freiburg), c) single leg stance on instable surface, (d) landing after a 30 cm forward single leg CMJ with a 90° inward turn about the longitudinal axis, e) isometric lower limb extension strength

To define passive knee joint laxity the tibial displacement was measured by the KT-1000TM arthrometer. Postural control was analyzed by testing static and dynamic balance. Static balance was identified by the tests (a) single leg stance on a stable surface (AMTI, BP600900, Watertown, MA, 1000 Hz[a]) with eyes closed, 10 s, (b) single leg stance on an instable surface (Posturomed, Haider Bioswing, Pullenreuth[b]), 15 s, (Fig. 1.c). Dynamic balance was identified by the tests (c) single leg stance on an instable surface with 2.5 cm lateral perturbation (Posturomed[b]), 1 to 5 s after release, (d) landing after a 30 cm forward single leg counter movement jump (CMJ) onto a force plate (AMTI[a]), 5 s, and (e) landing after a 30 cm forward single leg CMJ with a 90° inward turn about the longitudinal axis on a force plate (AMTI[a]) (Fig. 1 d), 5 s. For further analysis the medium 3 out of 5 trials were taken. The path length and the standard deviation of the path in anterior-posterior and medio-lateral direction (of either the center of pressure on the AMTI[a] or of the platform Posturomed[b]) were used as variables.
Maximum isometric lower limb extension strength was tested on an instrumented leg press equipped with a left-right-separated force plate (BioMotion Center, Karlsruhe, 1000 Hz[c], knee angle 120°, 3 s) (Figure 1.e). To analyze dynamic lower limb strength subjects performed a counter movement jump (CMJ) with arms akimbo on a left-right-separated force plates[c]. Force dependent variables were normalized to body mass. The best out of three trials regarding peak force (isometric lower limb extension strength) and maximum jump height

(CMJ) was taken for further analysis. Statistical analysis was performed by a one-way repeated measure ANOVA including a Bonferroni adjustment. The level of significance was set at α = 0.05 in overall significance and was in post-hoc test reduced to α = 0.016, due to the Bonferroni adjustment. For post-hoc test effect sizes based on means were additionally calculated using the corresponding calculation of Cohen's d (Cohen, 1992).

RESULTS: Mean (95%-CI) values and respective p-values and effect sizes of test parameters revealing significant differences are presented in Tab. 1. Subjects wearing a sleeve brace showed a significant reduction of joint laxity by 32% compared to the non-braced condition and by 21% compared to the rigid shell condition. Results for the dynamic balance showed that with a sleeve brace subjects significantly reduced medio-lateral standard deviation of the path length when standing on an unstable lateral perturbed surface by 10%. The dynamic strength tests revealed that subjects wearing a sleeve brace significantly increased the rate of force development of the injured leg by 18% compared to non-braced and 19% compared to shell-braced conditions. All other tests revealed comparable values and non-significant differences between non-braced, sleeve-braced and shell-braced conditions.

Table 1
Mean (95%-CI) values and respective statistics for parameters of the test knee joint laxity (KT 1000), single leg stance on instable platform after perturbation (instable, perturbation) and CMJ

Test	parameter	non-braced (95%-CI)	sleeve (95%-CI)	shell (95%-CI)	p overall	p non-braced-sleeve (d)	p non-braced-shell (d)	p sleeve-shell (d)
KT 1000	98 N [mm]	8.3 (1.3)	5.6 (0.7)	7.1 (1.1)	<0.001	<0.001 (0.94)	0.039 (0.37)	0.001 (0.36)
instable, perturbation	med.-lat._1-5s [mm]	4.11 (0.57)	3.70 (0.64)	3.71 (0.54)	0.011	0.016 (0.83)	0.180 (0.50)	0.656 (0.16)
CMJ	RFD_peak_injured [N/s/kg]	5.98 (0.70)	7.02 (1.11)	5.88 (0.90)	0.003	0.015 (0.42)	1.000 (0.04)	0.016 (0.21)

DISCUSSION: Passive knee joint laxity was significantly reduced only by the sleeve brace. However, the passive situation does not reflect the situation at which a reduction of anterior tibial translation needs to be achieved. Functional braces should provide protection in dynamic weight-bearing situations. Wojtys et al. (1996) report a significant reduce of laxity by 29-39% when the knee was braced and muscles were relaxed, with muscle activation bracing reduced laxity significantly by 70%-85%. Beynnon et al. (2003) complement these findings in reporting that bracing a knee with a chronic ACL tear was effective in reducing abnormal anterior-posterior laxity during non-weight-bearing and weight-bearing tasks. When subjects performed a transit from non-weight-bearing to weight-bearing functional braces were not effective in reducing anterior displacement of the tibia relative to the femur, which was 3.5 times more pronounced in injured than in healthy knees.
Patients with both chronic and symptomatic unilateral ACL deficiency were shown to have a bilateral defect in postural control when body sway was measured during the single limb stance on a force plate (Zätterström et al., 1994), but information if braces can improve postural control in that patient group is limited. Smith et al. (2003) showed that in some subjects brace use indicated a more favorable muscle firing pattern than without brace use in hop tests for maximum distance, of which they concluded functional stability. Others found no difference in maximum distance for the hop test (e.g. Risberg et al., 1999). In the present study no significant difference between sleeve braced, shell braced and non-braced condition were identified for static and most of dynamic stability tasks. This might be due to the fact that patients of this study adapted to the loss of afferent information of the torn ACL and managed to provide stability based on neuromuscular feedback. The only significant difference was identified for the dynamic stability test on an instable platform responding to a lateral perturbation. It seems that for the ability to react under weight-bearing situation on a perturbation impulse the sleeve brace leads to enhanced stabilization in complex situations. It has been suggested that bracing and bandaging stimulates cutaneous receptors around the joint (Fridèn et al., 2001, Jerosh & Prymka, 1996), which might lead to proprioceptive

benefits. In addition to the flexible textile of sleeve braces that allow undisturbed muscle function this might be the cause why only the sleeve brace led to significantly better body stabilization than the shell brace.
The most significant effect of an ACL tear is thigh muscle atrophy (Fridén et al., 2001) leading additionally to a decrease in joint stability. Rigid shell bracing might increase this effect further. Some evidence is provided that sleeve braces do not show detrimental effects on muscle strength after ACL reconstruction. Swirtun et al. (2005) did not find differences between a braced and an unbraced group in isokinetic maximum quadriceps and hamstrings peak torque. Also a study by Reer et al. (2001) showed a 25% lower reduction in circumference of the thigh muscles in patients with ACL deficient knees using a functional sleeve brace of the same type as used in the present study. Additionally, Singer & Lamontagne (2008) suggested that the force applied by this type of brace can be more evenly distributed over the shank and the gastrocnemius due to the elastic material of the brace. The main finding on muscle strength of the present study is a significant increase of peak rate of force development in the injured leg when provided with the sleeve brace compared to the non-braced condition. This indicates that muscle force can be produced significantly faster with a sleeve brace than in the unbraced condition, which might be an important factor in stabilizing the knee joint and preventing further injuries.

CONCLUSION: Compared to the non-braced condition the shell brace showed no significant changes. It is suggested that the sleeve brace enhances the proprioceptive benefit in strength, balance and stabilization tasks. This might be caused by the flexible area of support and the incorporated mechanisms to address proprioceptive aspects. The effects, however, were only observed in complex situations, which might indicate that subjects adjusted partly to the loss of sensory information, usually provided by an unaffected ACL. Sleeve braces might not be needed in simple daily life tasks, but could provide – compared to a shell brace – effective and beneficial support in more dynamic settings like sport and physical training. This is also of special interest in the rehabilitation process of injured athletes, who might be able to set more relevant training stimuli with a sleeve brace in order to return to their sportive activity, especially if the sleeve brace also leads to a decrease in muscle atrophy.

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