C-Brace

Biomechanics – Gait analysis

Major Findings

With C-Brace:

→ Gait pattern becomes more natural

Knee flexion while swing phase approximates normal physiological level of 65° (vs. 0° with locked KAFO and 74° with SCO) (Schmalz et al. 2016).

Compensatory movements are reduced (external hip moment) (Schmalz et al. 2016).

Step length and single leg support time : the difference between the affected and healthy leg decreased (Hobusch et al. 2018).

Opposite foot off: occurred earlier in gait cycle (GC) and decreased for the affected leg (Hobusch et al. 2018).

→ Controlled knee flexion while stance phase is possible

83 % of the subjects used the unique knee flexion function of C-Brace in the stance phase (Schmalz et al. 2016).

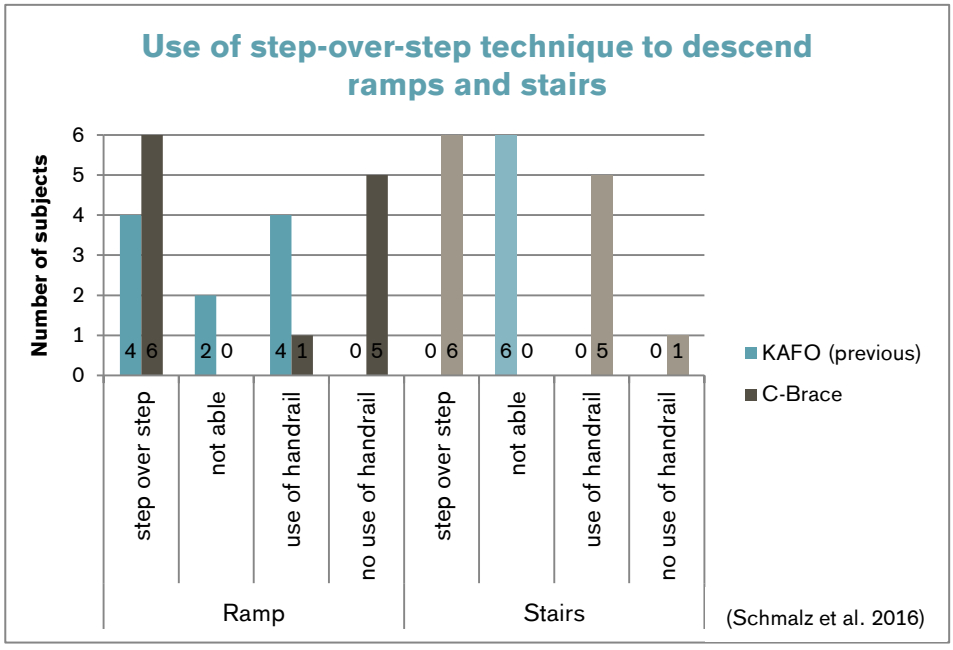
→ Safer gait

The gait pattern changed from an unstable, asymmetrical gait with crutches to a stable and more symmetrical gait without crutches (Hobusch et al. 2018).

→ Descending stairs and ramps more natural

All subjects that could not walk down stairs and ramps with a step-over-step pattern with the conventional orthosis could do so with C-Brace (Schmalz et al. 2016).

Only 17% of subjects needed the handrail when walking down a ramp while 100% needed it with the conventional orthosis (Schmalz et al. 2016).



(Schmalz et al. 2016)

Clinical Relevance

The main aim of C-Brace is the restoration of independent ambulation. It has influence on the mobility, the participation and, therefore, general quality of life. Furthermore, a natural gait pattern is pursued since it prevents the sound side from

higher or inappropriate loads due to compensatory movements. Overloading of the sound limb can result in secondary diseases such as osteoarthritis.

Stair ambulation is an important activity since it is a requirement to participate in daily life. Just like negotiating ramps and hills. Biomechanical assessment is conducted to determine joint angles, moments and load on the joints. It was additionally recorded how many subjects need support from handrail while doing activity. With C-Brace it is aimed to allow for a nearly natural gait pattern, which includes symmetrical gait characteristics and a loading distributed between the two limbs as even as possible.

Summary

Many patients with lower limb paresis or paralysis can re-establish mobility only using a KAFO with locked knee joints. This ensures safety while walking, but is associated with proven biomechanical and metabolic disadvantages (Kerrigan et al. 1995, Mattson et al. 1990, Schmalz et al. 2005). These disadvantages have been partially reduced with the development of stance control orthoses (SCOs), in which the knee joint is locked in the stance phase, but is released for a free swing phase (Zacharias et al. 2012). However, only a relatively small percentage of patients can benefit from these systems because a minimum level of residual motor function in the affected limb is required. The C-Brace has been developed to overcome those functional limitations. Its technology involves the use of a microprocessor-controlled hydraulic unit that controls the movement resistance of the orthotic knee joint in all routine motor function situations, both with and without loading the orthosis, what leads to a reduction in the risk of falling.

Results for level walking:

There were no differences in walking velocity, stride length and step length asymmetry between the previous KAFO and C-Brace (Schmalz et al. 2016). In contrast, Hobusch et al. (2018) found in their case study an enhanced walking speed, cadence and stride length. Furthermore the gait was more symmetrical. This was shown by an decreased difference between the orthotic and healthy limb for the step length (difference decreased from 39% to 8%) and the single support (difference decreased from 81% to 12%).

For all patients, the stance knee flexion angle on the orthotic side clearly approaches a more physiological pattern (mean flexion angle of 11.0°) with C-Brace compared to the previous orthoses (0°). (Schmalz et al. 2016)

In the swing phase, a mean maximum knee flexion angle of 74° was measured with the SCO system in contrast to 67° with the C-Brace, what is close to the physiological level of approximately 65°. All subjects used the swing phase flexion with all orthotic limbs. (Schmalz et al. 2016)

The hip moments on the orthotic side are consistently high during stance phase compared to healthy individuals. They are an indicator for necessary compensatory movements. The extension moment has an abnormally increased value in locked KAFOs and is clearly reduced with C-Brace. (Schmalz et al. 2016)

The load on the unaffected joints is drastically increased only for the locked KAFO. No such increased load was determined for SCOs or C-Brace. (Schmalz et al. 2016)

The use of walking aids was reduced. While the subject was unable to walk without crutches before, with C-Brace she was able to walk, ascend and descend slopes and stairs without crutches (Hobusch et al. 2018).

Results for descending stairs:

With previous orthosis, no subject was able to descent stairs step-over-step, but with C-Brace all patients were. For ambulating stairs step over step, the C-Brace mechanism requires a specific movement technique to utilize knee flexion during weight bearing. It is possible that this necessary movement technique sometimes

results in higher joint moments on the unaffected limb. Despite this unavoidable compensatory mechanism, the clearest functional benefit for patients compared to KAFOs and SCOs was found in the step-over-step descent of stairs. (Schmalz et al. 2016)

Results for descending ramps:

All six subjects were able to descend a ramp with a step-over-step technique with C-Brace while only four of them could do this with their previous orthosis and the use of a handrail. Only one subject needed the handrail with C-Brace. Additionally, the technique on the ramp observed in four patients with the previous orthosis requires extreme compensatory movements, which leads to excessive loads to the locomotor system. The C-Brace allows for a nearly natural downward movement of the body's center of gravity. (Schmalz et al. 2016)

The peak values of the joint moments measured on the unaffected side are considered a reliable indication that the locomotor system is subjected to nearly physiological loads when ambulating ramps with the C-Brace. (Schmalz et al. 2016)

Compared with the movement patterns of healthy persons, altered hip moments were measured during single leg stance on the orthotic side. However, the peak values of the altered hip moments also do not exceed those of healthy persons. (Schmalz et al. 2016)

References of summarized studies

Schmalz, T., Pröbsting, E., Auberger, R., Siewert, G. (2016). A functional comparison of conventional knee–ankle–foot orthoses and a microprocessor-controlled leg orthosis system based on biomechanical parameters. Prosthetics and Orthotics International, 40(2), 277-286. DOI: 10.1177/0309364614546524

Hobusch, G. M., Hasenöhrl, K., Pieber, K., Schmalz, T., Dana, S., Ambrozy, C., Pohlig, K., Dietl, H., Crevenna, R., von Skrbensky, G., Hofer, C., Auberger, R., Windhager, R.(2018) A novel mechanotronic orthosis enables symmetrical gait kinematics in a patient with a femoral nerve palsy – a case study. Disability and Rehabilitation: Assistive Technology, 13:2, 201-205.

Other References

Kerrigan, C., Viraontes, B., Corcoran, P., et al. (1995). Measured versus predicted vertical displacement of the sacrum as a tool to measure biomechanical gait performance. Am J Phys Med Rehabil, 74(1): 3–7.

Mattson, E. & Broström, L. (1990). The increase in energy cost of walking with an immobilized knee or an unstable ankle. Scand J Rehabil Med, 22: 51–53.

Schmalz, T., Blumentritt, S., Drewitz, H. (2005). Gangphasenabhängig entriegelnde versus gesperrte Beinorthesen – Biomechanische und metabolische Untersuchungen. Medizinisch Orthopädische Technik, 125(3): 67–74.

Zacharias, B. & Kannenberg, A. (2012). Clinical benefits of stance control orthosis systems: an analysis of the scientific literature. Journal of Prosthetics and Orthotics, 24(1): 2–7.