Bending and torsional moments acting on prosthetic feet – a pilot study

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Introduction

Gait analysis of patients with lower leg amputations is often performed by the comparison of prosthetic and contralateral sides using kinematic and kinetic measurement devices like camera systems and force platforms. This study used a new insole measurement system (vebitoSCIENCE, vebitosolution GmbH, Steinfurt, Germany), which provides bending and torsional moments acting under the foot in shoes. The insole contains 5 measuring locations on a forked carrier out of stainless steel. Because of the shape it is possible to examine the medial and lateral forefoot separately. In comparison to pressure measurement it is possible to measure multidimensional with the vebito system.

In this study the bending and torsional moments acting on both sides when wearing prosthetic feet are recorded and evaluated. Additionally, this paper focuses on the effect of the same foot used by different subjects. The aim was to find out, if the results can be of benefit for e.g. a prosthetist concerning the choice and adjustment of prosthetic feet for patients.

Methods

Six subjects (4 f, 60 ± 10 years) participated in the pilot study. They were able to walk the distance of 10 m in a self-selected speed. During the measurements the subjects wore a neutral shoe (Adidas® Samba). Two measurements were recorded. In the first trial the subjects used their own prosthetic foot, in the second one they received a new foot, which they have never worn before. The new foot was chosen and adapted by an experienced prosthetist (UKM ProTec Orthopädische Werkstätten GmbH, Münster, Germany) considering the activity level of each subject.

The vebitoSCIENCE insole (125Hz, Bluetooth data transmission) was used to obtain bending and torsional moments at the heel, MTP I, MTP V, DIP I, and DIP V. Data analysis considered 7-8 strides out of every measurement. For these strides the bending and torsional moments were normalized to 100% gait cycle (GC) and averaged. The results presented in this paper deal exclusively with the heel with focus on (i) a description of the general shape of the bending moment curves and (ii) the ranges of both bending and torsional moments.

Results

The curves of the bending moment show similar shapes for all subjects, both feet and both sides. After initial ground contact the bending moment increases strongly up to 5-10% of GC. At 70% of GC the data reaches the same level compared to the initial ground contact and then remains almost constant during the swing phase. The torsional moments mostly also show these shapes, except the maximum occurs a little later, at 10-20% of GC. In general, the prosthetic feet show higher maxima compared to the contralateral side.

The bending and torsional moments of one subject are very similar at both sides, independent from the two different prosthetic feet. The bending moment ranges within this subject are 88 and 105 Nmm on the contralateral side, whereas the prosthetic side shows ranges of 400 and 459 Nmm. The torsional moments' ranges on the contralateral side are 135 and 145 Nmm and on the prosthetic side 228 and 276 Nmm. The moments of all 6 subjects indicate more similarities concerning shape and range on the contralateral side. Moreover in most cases it is noticeable which 2 curves belong to 1 subject, when comparing all measurements. On the prosthetic side there is more deviation. This appears mainly in the range, which differs from 33 to 462 Nmm (bending) and from 31 to 438 Nmm (torsion).

One type of prosthetic feet (Quantum, Ortho Reha Neuhof) was worn by 3 subjects during the second measurement. The bending moment curves of the prosthetic side show a very similar trend for all these subjects. However, one curve reveals a maximum which is about 50% lower compared to the other 2 subjects. In general the corresponding data of the contralateral side have lower maxima and less mean variation compared to the prosthetic side.

There were two more prosthetic feet that were worn by two different subjects each, which provide similar results. Again the difference appears in the range. However, the phases of increase, decrease and return to the initial position within the GC are mostly congruent within the remaining data of this measuring location.

Conclusion

Although each subject wore a new foot in the second measurement the general shape of the bending curves for the heel region are almost similar between the own prosthetic foot and the new one. This result indicates a subject specific gait characteristic which remains dominant even if a remarkable intervention is provided by the new foot. Particularly the moments of the contralateral side seem to be not (or only slightly) affected by the different feet.

Despite this effect it seems that there is also a foot specific gait characteristic indicated by the similar shapes of the bending curves for the Quantum (Ortho Reha Neuhof). Further studies are required to analyze which of the both characteristics might have a stronger impact on the results. What can be stated is, that bending and torsional moments make the differences of prosthetic feet, and their influence on the contralateral side as well as on the gait pattern, visible. This opens a new perspective for the choice and modification of prosthetic feet next to the evaluation with kinematic e.g. camera systems and other kinetic measurement devices like force platforms. Bending and torsional moments therefore can be helpful for daily practice because they make stress at certain locations of the foot visible. More data and a further study could help to establish guidelines for the practical benefit of bending and torsional stress detection for e.g. surgeons, prosthetists and orthopedist.