

B. Van Gheluwe and B. Nelen
Laboratory of Biomechanics, Vrije Universiteit Brussel, Belgium B1050

6. Plantar foot pressure of lower leg amputees during gait and running

Introduction:

This study investigates the biomechanical characteristics of plantar pressure of 20 lower leg amputees in walking and running. The pressures under the artificial foot are hereby compared with the behavior of the remaining leg and the legs of normal controls.

Review and theory:

Very little biomechanical research has been carried out evaluating the plantar foot pressures or prosthetic gait. Veves, Van Ross and Boulton (1992) presented some data of diabetic leg amputees. They found that prosthetic usage did not increase the pressures under the remaining foot in the non diabetic amputees suggesting that the higher pressures with diabetics are due to neuropathic conditions. Pinzur, Perona, Patwardhan and Havey (1991) found lower pressures on the non-amputated leg of people suffering from vascular insufficiency in comparison with normal controls. The only article found on plantar pressures under the amputated leg comes from Pinzur, Wolf and Havey (1997) compares midfoot with ankle disarticulation amputees, but only a qualitatively. It's therefore the aim of this study to provide quantitative information on the pressure behavior of both the amputated and non-amputated leg, hereby contrasting the non-amputated leg with the prosthetic foot and also with normal controls. Unlike the other studies mentioned, the variable set is not limited to pressure alone but include variables relating to loading rate and the duration of the different phases of ground contact.

Procedures:

The subjects were 19 lower leg amputees (mean age of 34.4 ± 7.0 year and body mass 76 ± 6.9 kg) and a control group of 20 normals (mean age of 30.8 ± 11.2 year and body mass of 69.6 ± 10.2 kg). All subjects lived an active life style and were free of any leg and foot complaint or pathology. There were 4 different types of prostheses used : 12 Flex, 4 SACH, 2 Greisinger and 1 Seattle foot, all fitted with a patella tendon bearing socket. Walking occurred at a self selected pace while running was dictated by a metronome at 132 steps per minute.

Plantar foot pressures were measured using a footscan® pro-XL II pressure plate system at a rate of 300 Hz. The software produced the following biomechanical values for the medial and lateral side of the heel (L and M), the three main metatarsal heads (M1, M3 and M5) and the hallux (T1- being the tip in case of the artificial foot): the percentual contact time compared to the total contact time (% contact), maximal pressure (Pmax), time to reach the maximal pressure relative to sensor contact time (%Load), load rate (being the maximal pressure divided by % load), duration of the heel contact phase (from heel strike to first metatarsal contact), duration of the midstance phase (ending at heel lift) and the propulsion phase (finishing at toe-off).

The pressure plate of the footScan® was calibrated statically by introduction of the exact weight of every subject and also dynamically by putting it on a Kistler force plate. Student t-test were used to compare the non-amputated feet with the prosthetic feet (paired design) and with both feet of the control group (unpaired design) and with both feet of the control group (unpaired design).

Results and discussion:

As expected the pressure patterns of the prosthetic leg differed significantly from the remaining leg for most variables and sensors, during gait as during running (Table 1). It is, however, remarkable that peak heel pressures show no differences during gait. This confirms the results from Veves et al (1992) concerning the peak pressures of non-diabetic amputees for gait. But with increasing speed as during jogging the normal foot seems to accept higher peak loads than the prosthetic foot. Also the build up of pressure (load-rate) is always much higher for the normal heel. This may be due to the dominant presence of the compliant Flex-Foot which is known for its' highly efficient return of store energy during heel impact (Czerniecki, Gitter and Munro, 1991). As for the forefoot and in contrast with the stabilizing thrust of the first metatarsal head in the normal foot, the prosthetic forefoot bears weight centrally. The maximal pressure under the forefoot is about the same for both feet, but the prosthetic forefoot shows a higher loading rate due to its rigid metal structure.

Table 1 : Mean and standard deviations of the plantar pressure variables of the prosthetic (=p) and the normal (n) foot for walking and running (bold figures indicate a significant difference between both means with $p < 0.05$).

As for the differences between the normal leg of the amputees and the right and left leg of the normal control group, only a few spurious differences were found to be significant. This contradicts that the walking and running pattern of the non-amputated leg is not significantly affected by the deviating behavior of the prosthetic leg and as such is presenting a normal walk and running pattern.

References:

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