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Measurement of maximal end-weight-bearing in lower limb amputees

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Abstract

Modern sockets for lower limb amputees utilize total contact and distribute some weight on the stump end. Its tolerance to bear weight varies but is better after joint disarticulation, however, systematic measures have been missing. Different levels, indications, shapes etc. were analysed with 102 measurements in 69 patients. The maximal-end-weight-bearing of the stump measured on a scale was much lower after transmedullar amputations than after disarticulations. Men had a mean tolerance more than 15 kg but women less than 10 kg. There was a positive correlation to body weight. Diabetics tolerated significantly more end-bearing and patients with phantom pain more than patients with stump pain. Within each category of stumps the range of maximal end-weight-bearing was large. Among all below-knee amputees the tolerance was between 2 to 55 kg or 3 to 79 per cent of body weight. Pointed stumps statistically tolerated about as much as rounded ones and the variability of contact surface was not measured as its sensitivity to pain must be unevenly distributed. It is concluded that this simplified method is helpful to analyse pain and to modify end-weight-bearing more individually.

Introduction

It is well known that knee disarticulation and Syme's amputation create stumps of high functional value. This is ascribed to the long lever arm for the movement of the prosthesis, to the reliable suspension due to the club shape of the stump and to the high end-weight-bearing capacity due to the rounded bone end and its large surface (Hornby and Harris, 1975). To create an increased surface of the bone end at a transmedullary amputation Swanson (1973) has tried a Silastic plug implanted into the marrow cavity to cover the end of bone. Dederich (1963) and others have suggested osteoplasty to bridge between fibula and tibia at below-knee amputation to enlarge and stabilize the end of bone. Foort (1981) has asked for attempts using the femoral condyles or similar bone trimmed and put back at the amputation level to create such an increased breadth of the surface to improve end-weight-bearing.

Older types of artificial limbs were either created for end bearing or for proximal bearing (hanging stumps) but most modern types of sockets distribute weight-bearing over the total stump, however, in spite of that some parts are given extra load. It is therefore not well-known to what extent stumps tolerate end-weight-bearing. Renström (1981) in a series of below-knee amputees, examined maximal end loading capacity using an ordinary weighing scale. Hornby and Harris (1975) examined a series of Syme's amputations also using a scale but combining the recorded total maximal end-weight-bearing with readings from a transducer pad, put into the bottom of the socket and relating to body weight what they called maximal end-weight-bearing capacity.

This paper represents a study of maximal end-weight-bearing capacity of the residual limbs, after lower limb amputation at different levels, with the intention of finding out how such values differ and how if possible this can be used in future for the design of the total contact socket or in analysis of pain.

Material and method

During 1981 102 measurements were taken of 69 patients, nine of whom were bilateral. Repeated measurements were made in 24 cases following an interval of between 1 and 9 months.

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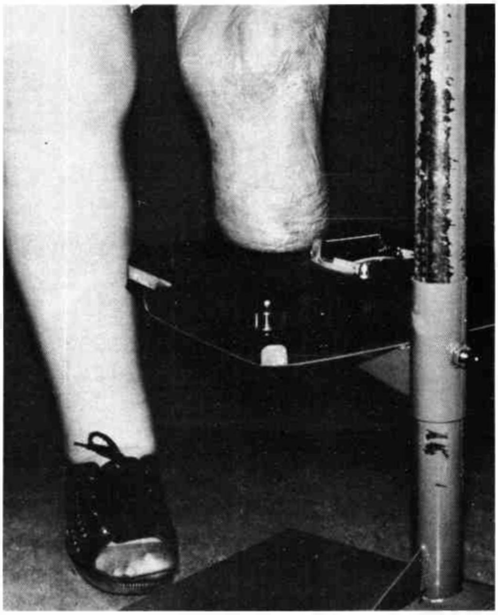

Fig. 1. Weighing scale mounted on adjustable table to measure maximal end-weight-bearing capacity of amputation stumps.

The method of measuring the maximal end-weight-bearing capacity is shown in Figure 1. A weighing scale of spring type (EKS, 0-120 kg, Holland) constructed for ordinary body weight measurements was mounted on a table. This was adjusted to a height to suit the individual when standing, allowing comfortable pressure with the stump on the scale. The patient watched the scale to see how much weight he could put on gradually for a few seconds. This was repeated two or three times and the maximum reading which the patient had been able to reproduce was recorded. The top of the scale had a cover of a soft plastic material 3 mm thick, however, when the measurements for 10 below-knee amputees were repeated with a hard wooden surface, there was no change in tolerance. At the same time basic notes were collected concerning age, sex, body weight, reason for amputation including diabetes level, date of amputation, general activity, shape of stump and phantom and stump pain problems.

Results

The mean age of the examined group was 67 years, the below-knee male group was 68 (SD 15) and the below-knee female group 76 (SD 11) years. The mean body weight was 64 kilograms, the below-knee males 70 (SD 10·6) and the below-knee female 57 (SD 11·4). The mean maximal end-weight-bearing capacity (MEW) of the entire population was 13 (SD 12·0), for the below-knee male group 13.3 (SD 10·7) and the below-knee female 7·9 (SD 5.3) kilograms.

Separated into different levels of amputation Figures 2-3 show the recorded end-weight-bearing capacities. Amputation through joints (hip, knee and ankle) had a much higher end-weight-bearing tolerance than transmedullary (AK and BK) amputations. Above-knee amputees tolerated 13·7 compared to below-knee 11 kilograms. Ischaemic below-knee amputees had a mean of 10·7 (SD 9·0) compared to other indications 13·9 (SD 10·9) kilograms.

There was a significantly higher MEW-value in patients with a higher body weight (Fig. 4). Tested on the entire group there was no increase by time following amputation ($p=0{\cdot}45$). When looking at the below-knee level only there was still an increased MEW-value with increasing body weight ($p=0{\cdot}01$) but none with increasing postoperative time ($p=0{\cdot}47$). The male group had a significantly higher value than the female, (15·7 versus 9·4 kilograms). Among below-knee amputees active walkers tolerated more than less active walkers.

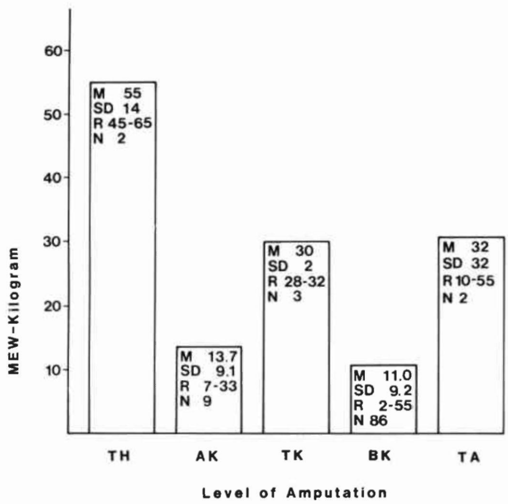

Fig. 2. Maximal end-weight-bearing (MEW) and level of amputation: TH=through hip, AK=above knee, TK=through knee, BK=below knee and TA=through ankle. M=mean, SD=standard deviation, R=range, N=number.

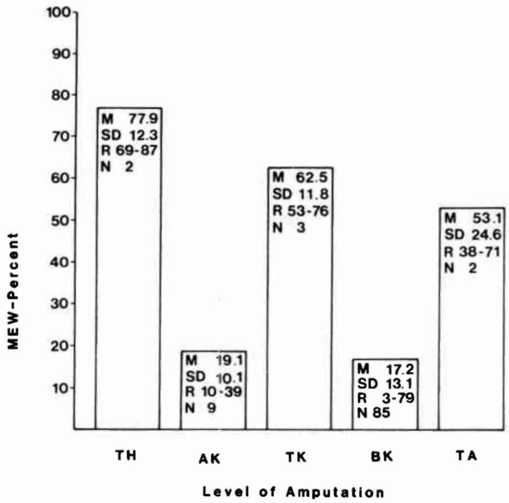

Fig. 3. Maximal end-weight-bearing (MEW) as a percentage of body weight and level of amputation.

It was noted that some patients with very high MEW-values after below-knee amputations were diabetic and when tested for this correlation it was found to be, for the below-knee level among diabetics, 21·5 (SD 17·5) and non-diabetics 14·3 (SD 8·5) kilograms (Fig. 5). This difference was the same when tested as absolute values (MEW-kilograms) or in relation to body weight (MEW-per cent). The lack of protective sensibility of diabetic patients could be expected to cause an increased number of patients with skin damage. In this material, however, there was no such difference with a quarter of the patients in both groups having skin damage. In addition, there was no correlation to diabetes with stump pain and phantom pain.

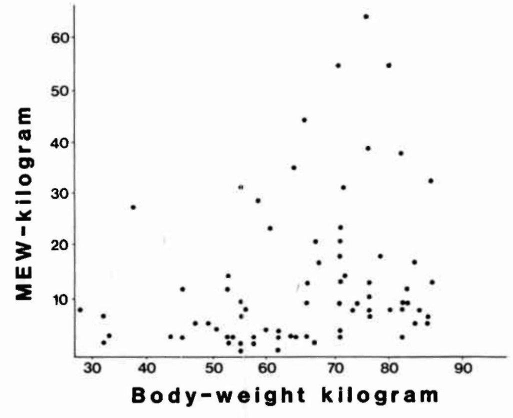

Fig. 4. Maximal end-weight-bearing (MEW) and body weight in BK. N=101, p=0·01, y=0·3+0·2x.

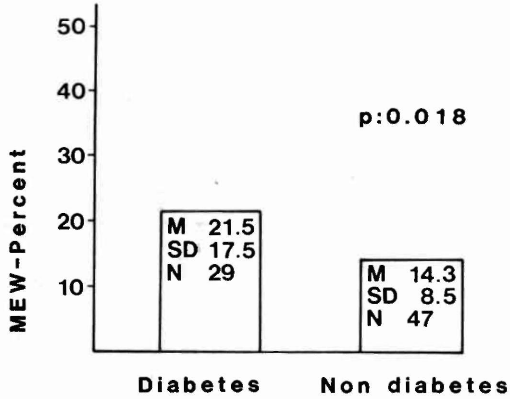

Fig. 5. Maximal end-weight-bearing (MEW) as a percentage of body weight among BK amputees for ischaemia with and without diabetes.

The maximal end-weight-bearing (MEW) is limited by tolerance of pain during the procedure. Patients with stump pain or phantom pain were separately analysed. Stump pain was correlated to significantly lower MEW-value (Fig. 6) but phantom pain was not (Fig. 7). To a certain extent the shape of the stump end could be correlated to perception of pain when testing MEW-values. There was no such difference between pointed and rounded stumps when analysed on all (Fig. 8) but when tested on stumps older than one year there was such a tendency but it was not statistically significant.

Discussion

Measurements of mechanical loading of stumps after amputation has not been used often according to the literature although weight-bearing capacity is critical for function with a

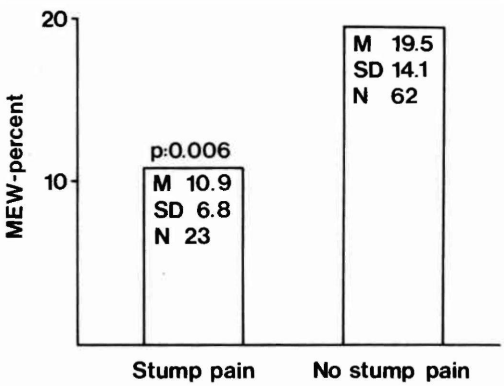

Fig. 6. Maximal end-weight-bearing (MEW) and stump pain in BK amputees.

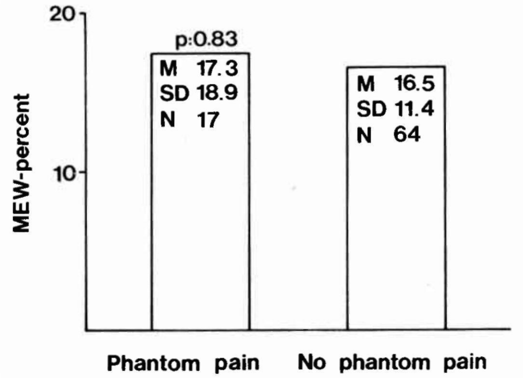

Fig. 7. Maximal end-weight-bearing (MEW) and phantom pain.

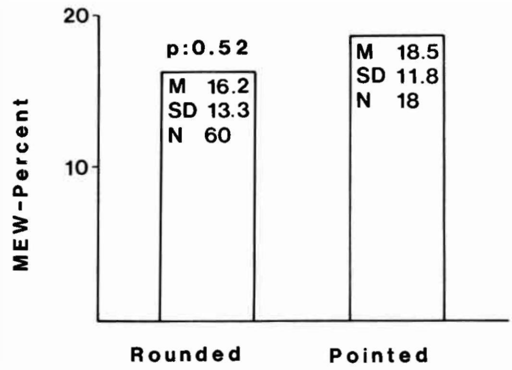

Fig. 8. Maximal end-weight-bearing (MEW) in per cent of body weight in BK amputees with rounded and pointed stump ends.

prosthesis and for construction of the socket. Baker and Stableforth (1969) found only five out of 67 Syme amputees unable to bear full weight on their stumps when standing, and Hornby and Harris (1975) found 19 out of 68 traumatic Syme patients unable to stand on their bare stump. They recorded "end-weight-bearing values" between 28 and 100 per cent of the body weight with a mean value around 75 per cent and noted that "those who could tolerate full end bearing on their bare stumps did well no matter what type of prosthesis they used".

The positive correlation between increased body-weight and end-weight-bearing capacity makes it reasonable to use MEW-values as a percentage body weight (MEW-per cent) rather than absolute values (MEW-kilograms), but both units have been used in this study because it is believed that it is easier to measure in kilograms. Newton is the correct SI-unit for force but when comparing to body weight it is pragmatic to retain kilogram for end-weight-bearing.

It seems possible that an enlarged series would prove the findings that through-knee amputations tolerate more than Syme and that through-hip tolerate more than through-knee and that these joint disarticulations as a group tolerate several times higher end-weight-bearing values than transmedullary levels do (Figs. 2 and 3).

It is highly interesting that diabetics had higher MEW-values though they did not have a higher proportion of skin damage. It was known that they have a better healing potential at below-knee level (Persson 1974) and that they might have a polyneuropathy which can explain their higher MEW-value. There is no information about how they manage with their prosthesis as a group compared to non-diabetic ischaemic patients but it is known that they are about 4 years younger. It is possible that longstanding diabetes gives higher MEW-values than old-age diabetes but the material did not allow that distinction.

An increase in the MEW-value with time following amputation was expected. There was such a tendency but it was insignificant. The study was not, however, designed to study this as it would have needed a series of patients individually followed at regular intervals. Hornby and Harris (1975) state that: "With the passage of time the Syme stumps toughened and became less sensitive". Renström (1981) examined 21 below-knee stumps (19 men, 2 women) 6-90 months postoperatively before and after 10 weeks of muscular training and observed that the loading capacity of the bare stump end increased from 11·9 ±2·9 (3-35) to 14·5±2·2 (3-40) kilograms as measured on a weighing scale. He did not compare this to any control group without training and the group contained amputees of traumatic, tumorous and ischaemic types with and without diabetes. Therefore detailed comparison with the present study is not possible.

Except for Syme and below-knee levels as cited above no reports of maximal end-weight-bearing tolerance have been found in literature. Analysing pain Weiss et al. (1971) measured surface pain and deep pressure sensitivity around the circumference of stumps and found very significant correlation with psychological self-rating criteria. Their findings probably correspond to the low ratings found in this study of maximal end-weight-bearing (MEW) in patients with stump pain. They measured around one circumference 2·5 cm below the medial tibial plateau or perineum in 44 below— and 56 above-knee amputees respectively and compared the findings to the unamputated side. The readings were taken by using a piston rod spring, with the tip one quarter inch square. Deep cutaneous pressure tolerance per square centimeter could thus be recorded ranging from 0 to 20 kg/cm^2, and was between 5 and 20 in the best rehabilitated cases. Deep pressure sensitivity had a mean of 4·3 kg/cm^2 in above-knee patients and 5·7 kg/cm^2 in below-knee patients (p 0·05). For the entire sample the below-knee stumps were less sensitive but deep sensitivity was the same in below— and above-knee stumps among diabetics. No reports are given concerning difference of sensitivity between diabetics and non-diabetics as found in the present study. The difference found between above— and below-knee levels in this study was not significant and is contradicted by the finding that below-knee stumps had a higher tolerance of load per square inch around a distal circumference in the above mentioned study (Weiss et al. 1971).

Older stumps become more pointed by atrophy at the same time as they may become toughened by training. Differences in MEW-values between rounded and pointed below-knee amputees could not be demonstrated. Extremely pointed stumps of course must tolerate less total end loading due to the small surface. Theoretically maximal end-weight-bearing should be analysed with account taken of the area of contact but this would make a more elaborate method necessary as it can not be assumed that the tolerance is evenly distributed at all. The most sensitive part limits the load irrespective of the total contact surface. The lack of correlation between shape of end and MEW-value illustrates this and simple measurement of the maximal end-weight-bearing disregarding the contact area is thus preferred.

The difference found between patients with stump pain and phantom pain seems highly interesting as an objective method to differentiate pain problems and to refine the socket distribution of pressure during casting for the prosthetic socket. The total contact socket should distribute weight-bearing differently in different individuals allowing the patient to put at least his body-weight on the artificial limb with a minimum of pain and adverse skin reactions.

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