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Evaluation of Problems and Needs of Veteran Lower-Limb Amputees in the San Francisco Bay Area during the Period 1977–1980[a]

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ABSTRACT

From 1977 through 1980, 251 veterans from the San Francisco Bay Area received permanent lower-extremity prostheses at the two local Veterans Administration hospitals. For a survey, 213 of the 251 were contacted and 179 of them (84%) responded to written or telephone questionnaires concerning their prosthetic problems and complaints and their recommendations regarding prosthetic care.

Seventy-four percent of the patients were traumatic amputees and 23 percent were dysvascular amputees. Eighty-six percent of the traumatic amputees said they wore their limbs all day, compared with only 51 percent of the dysvascular group. Seventy-one percent of traumatic and 43 percent of dysvascular amputees engaged in some form of recreational activity. There was a high incidence of complaints of pain in the residual limb: 55 percent among the dysvascular group and 44 percent among the traumatic group. Half of the patients had socket problems.

Fifty-four of the 178 patients received a physical examination, a prosthetic evaluation, and a gait analysis. Among this group, 59 percent of the below-knee prostheses and 78 percent of the above-knee prostheses had inadequate socket fitting. Improper shaping of socket margins was the most frequently observed deficiency. Moreover, 41 percent of below-knee and 22 percent of above-knee amputees had mechanical skin irritation or skin breakdown in the examined residual limbs. Faulty suspension and alignment in addition to improper socket fit and construction contributed to this problem. Excessive stiffness of SACH foot heel cushions was the most common prosthetic foot problem and contributed to gait abnormalities.

INTRODUCTION

At the time that this study was initiated, little information existed in the recent medical literature that defined the current status and prosthetic research needs of veteran lower limb amputees. Observations made during the routine outpatient care of veteran amputees in our institution have brought to light a variety of deficiencies in prosthetic care that warrant further inquiry. In order both to correct these deficiencies and to sharpen the focus of the prosthetics research program of the Veterans Administration Medical Center, San Francisco, a survey of veteran lower-limb amputees in our area was carried out. The primary goal of this survey was to define prosthetic problems and patient needs. This report describes the amputee population surveyed with respect to demographic characteristics, amputation history,

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and current prosthetic status. It proceeds by enumerating and describing those problems in prosthetic care noted by the surveyed amputees themselves. Various subjective complaints are corroborated by individual prosthetic evaluations of a representative group of respondents. These findings are discussed with respect to the prosthetic needs of both traumatic and dysvascular veteran amputees. The recommendations at the conclusion of this report apply specifically to the prosthetic care delivery system within the Veterans Administration.

METHODS

One hundred and forty-seven consecutive lower-limb amputees who received permanent prostheses from local vendors through the San Francisco Veterans Administration Medical Center during the years 1978 and 1979 formed the initial study population. One hundred four additional veterans who received permanent prostheses from the Martinez Veterans Administration Hospital between 1977 and 1980 were surveyed as well, to yield a total initial study population of 251 individuals.

A preliminary questionnaire was sent to a trial group of 10 amputees to determine its acceptance and to identify problems in design. After minor modifications, a revised questionnaire was sent to all 251 amputees. The design of the questions and the specific material covered were based in part on the questionnaire of the National Amputee Foundation and on the survey devised by Kegel, Carpenter, and Burgess (6). Specific questions were asked concerning demographic data, amputation information, activities of daily living, use of the prosthesis, and prosthetic problems, complaints, and needs. Non-respondents were sent a duplicate questionnaire, and urged to participate in the study. Those not responding to the second mailing were contacted by telephone whenever possible and encouraged to respond to the original questionnaire, or to an abbreviated questionnaire, or to a telephone interview.

After the questionnaires had been returned, all respondents were invited to the San Francisco Veterans Administration Medical Center for an evaluation of their prostheses. Those who consented to this evaluation underwent a limited musculoskeletal physical examination and a gait evaluation performed by the research team, comprising an orthopaedic surgeon, prosthetist, and physical therapist. The gait evaluation included measurement of customary walking speed, range of walking speeds, step length and width, a video recording of level walking and ramp performance, and a check sheet of amputee gait deviations during level walking. Each prosthesis was evaluated in concert by the research prosthetist and an additional member of the research team to determine the suitability of the prosthetic prescription for the given amputee, the condition and function of each prosthetic component, and the static and dynamic alignment of the prosthesis. Special care was taken to assess socket fit, as well as general characteristics of workmanship, materials, and wear. A description of each limb was recorded for subsequent analysis.

To determine the extent to which those amputees who agreed to this prosthetic evaluation were representative of the larger group of surveyed veterans, a statistical comparison of the two groups was made. Data from the questionnaire submitted by the amputees in the two groups were entered into a data-sorting program using a PDP 11–03 computer. Additional statistical analysis was provided by Dr. Alan Bostrom, Senior Statistician, University of California, San Francisco Computer Center.

RESULTS

Of the 251 individuals sent questionnaires, 14 had died and 24 were unreachable (repeated questionnaires were returned because of unknown addresses). Of the 213 individuals who were contacted, 179 (84%) participated in the study. One hundred sixteen (65%) of these 179 participants responded to the first questionnaire, 25 (14%) to the second mailing, and 38 (21%) responded following contact by telephone. Fifty-four (30%) of the 179 respondents underwent prosthetic evaluation in the prosthetics research laboratory.

Results from the survey questionnaire were analyzed by dividing the respondents into two groups based on the cause of amputation. The first group consisted of service-connected veterans with lower limb amputations resulting from trauma. The second group comprised those veterans with non-service-connected amputations resulting from dysvascular disease. The few veterans who underwent amputation for tumor were not assessed independently. Percentage calculations in the tables are based on the number of individuals in each group who responded to a particular question. (Not all questionnaire data were obtained in the abbreviated questionnaires and telephone inteviews.)

TABLE 1.
Etiology and level of amputation among 179 surveyed amputees.

Etiology (Number)	Level of amputation											
	BK		AK		BK-BK		AK-BK		AK-AK		Syme		Knee Disart.		Hip Disart.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Dysvascular (42)	21	50%	8	19%	6	14%	4	10%	1	2%	1	2%			1	1%
Trauma (133)	74	56%	38	29%	7	5%	8	6%	2	2%	3	2%	1	1%		
Tumor (4)	3	75%	1	25%												
Total (179)	98	55%	47	26%	13	7%	12	7%	3	2%	4	2%	1	0.6%	1	0.6%

Amputee Survey Results

Demographic Data. Of the 179 respondents in the survey, 133 (74%) sustained their amputations as a result of trauma, 42 (23%) as a result of dysvascular disease, and 4 (2%) as a result of malignant tumors.

Table 1 summarizes the levels of amputation according to cause. Trauma was the most common cause in both above-knee (AK) and below-knee (BK) groups. In the entire population, unilateral BK amputees outnumbered unilateral AK amputees by about two-to-one. There were 28 bilateral lower-limb amputees, 17 of whom had sustained their loss from trauma. For the purpose of analysis, the one hip-disarticulation and one knee-disarticulation amputees were included in the AK group, and the four Syme's amputees in the BK group.

All of the subjects in the study were men who ranged in age from 30 to 90 years. Table 2 lists the mean age and range of ages according to level and bilaterality of amputation. The overall mean age for the traumatic group was 47 years, and for the dysvascular group, 60 years.

Table 3 records the interval between the time of amputation and the present study according to the level of amputation. For the traumatic amputees, the mean interval was 20.7 years, with a range of 1 to 39 years. For the dysvascular group it was 2.3 years, with a range of 1 to 21 years.

The educational background of subjects in the dysvascular group varied from completion of the fourth grade to completion of college. The average maximum level of education for this group was completion of high school. In the traumatic group the average maximum level of education was 2 years past high school, varying from completion of the third grade to 6 years of study after high school.

TABLE 2.
Age of survey respondents.

Etiology	Level	Number	Age range	Mean Age
Dysvascular	AK	8	35-90	60
	BK	21	30-85	58
	Bilat	11	50-80	60
	Total	42	30-90	60
Trauma	AK	38	30-65	48
	BK	74	30-70	50
	Bilat	17	25-65	35
	Total	133	25-70	47

TABLE 3.
Interval since amputation.

Etiology	Level	Number	Range (yrs)	Mean Time (yrs)
Dysvascular	AK	8	1-11	2
	BK	21	1-17	2
	Bilat*	11	1-21	3
	Total	40	1-21	2
Trauma	AK	38	3-38	31
	BK	74	1-39	17
	Bilat*	17	2-27	14
	Total	129	1-39	21
Combined Total		169	1-39	16 yrs

*Time determined since first amputation.

TABLE 4.
Employment status of surveyed veterans.

Etiology (No.)	Employed full time		Student or part time employment		Retired or unemployed		Unable to work due to amputation		Unable to work due to medical illness	
	No.	%	No.	%	No.	%	No.	%	No.	%
Dysvascular (42)	11	26	0	0	15	36	9	21	7	17
Trauma (133)	86	65	9	7	17	13	14	11	7	5
Total (175)	97	55	9	5	32	18	23	13	14	8

Table 4 contains information relating to the current employment status of amputees in each group. Among the dysvascular amputees, 26% were employed full-time and 38% were disabled either because of their amputation or because of medical illness. Sixty-five percent of the traumatic amputees were employed full-time, and only 16% were disabled because of the amputation or concurrent medical illness. Thirty-six percent of dysvascular amputees described their employment status as retired or unemployed; 13% of the traumatic group fell into this category.

Activity Levels and Functional Status. Table 5 indicates the amount of time per day amputees from the two groups wore their prostheses. Eighty-six percent of the traumatic group wore their limbs all day, and 51 percent of the dysvascular group did so. Twenty-four percent of the dysvascular amputees limited their daily use of the prosthesis to 4 hours or less, whereas only 2 percent of the traumatic amputees did so.

Table 6 contains information on the estimated distance walked per day by amputees in the two groups. In the traumatic group 47% reported walking a distance of 6 blocks or more, while 15% of the dysvascu-

TABLE 5.
Time prosthesis worn per day.

Etiology (No.)	All day		5-8 Hours		3-4 Hours		Less than 3 hours	
	No.	%	No.	%	No.	%	No.	%
Dysvascular (41)	21	51%	10	24%	3	7%	7	17%
Trauma (131)	113	86%	15	11%	0	0%	3	2%
Total (172)	134	78%	25	15%	3	2%	10	6%

TABLE 6.
Daily distance walked.

Etiology (No.)	None		Only in home		1-6 Blocks		More than 6 blocks		Unlimited	
	No.	%	No.	%	No.	%	No.	%	No.	%
Dysvascular (42)	4	10%	9	21%	23	55%	4	10%	2	5%
Trauma (132)	4	3%	7	5%	59	45%	30	23%	32	24%
Total (174)	8	5%	16	9%	82	47%	34	20%	34	20%

TABLE 7.
Assistive devices for walking.

Etiology (No.)	Walk without any device		Cane part time		Cane full time		2 Canes part/full time		Wheelchair part/full time	
	No.	%	No.	%	No.	%	No.	%	No.	%
Dysvascular (36)	9	25	11	31	3	8	7	19	6	17
Trauma (113)	69	61	27	24	5	4	6	5	6	5
Total (149)	78	52	38	26	8	5	13	9	12	8

lar amputees fell into this category. Thirty-one percent of the dysvascular amputees were limited to their homes by restrictions in walking, while 8 percent of the traumatic group reported similar severe limitation.

Table 7 records the type of assistive devices required by the respondents. Sixty-one percent of the traumatic amputees required no devices, and 24 percent used a cane part time. Only 5% were confined to a wheelchair full or part time. Twenty-five percent of the dysvascular subjects used no devices, and 31 percent used a cane part time. Seventeen percent of this group required wheelchairs. As demonstrated in Table 8, 72% of the traumatic amputees and 52% of the dysvascular group were able to drive an automobile without adaptive devices, while an additional 23% of the traumatic group and 14% of the dysvascular group were able to drive with such devices.

Patients were queried as to their need for help in the performance of customary daily activities. As demonstrated in Table 9, the greatest need was seen in the bilateral dysvascular group, 64% of whom required assistance, compared with 38% for that group as a whole. Twenty-nine percent of traumatic bilateral am-

TABLE 8.
Driving.

Etiology (No.)	Drive with no device		With assistive device		Do not drive	
	No.	%	No.	%	No.	%
Dysvascular (42)	22	52	6	14	14	33
Trauma (133)	96	72	31	23	6	5
Total (175)	118	67	37	21	20	11

TABLE 9.
Assistance required in daily activities.

Etiology	(No.)	Need for Daily Assistance		Donning		Dressing		Bathing	
		No.	%	No.	%	No.	%	No.	%
Dysvascular									
AK	(8)	4	50	0	0	0	0	3	38
BK	(21)	4	19	0	0	0	0	6	29
Bilat	(11)	7	64	1	9	3	27	4	36
Total	(40)	15	38	1	3	3	8	13	33
Trauma									
AK	(38)	4	11	1	3	2	5	2	5
BK	(74)	7	9	0	0	3	5	8	13
Bilat	(17)	5	29	1	6	1	6	3	18
Total	(129)	16	12	2	2	6	5	13	10
Combined Total	(169)	31	18%	3	2%	9	5%	26	14%

TABLE 10.
Amputees who participate in recreation.

Etiology	(No.)	Did participate	%
Traumatic	(133)	95	71
Dysvascular	(42)	18	43
Tumor	(4)	1	25
Level			
Below-knee	(102)	67	66
Above-knee	(49)	33	67
Bilateral	(28)	14	50
Total	(179)	114	64%

putees required assistance, compared with 12 percent of the entire traumatic group. Assistance with bathing was the most frequently mentioned task requiring help.

Table 10 depicts the incidence of participation in recreational activities among the survey respondents. Seventy-one percent of the traumatic and 43 percent of the dysvascular amputees reported engaging in some form of recreational activity. About two-thirds of the AK and BK amputees participated in such activities, and half of the bilateral group did so. The most popular activities mentioned were fishing (47 subjects), swimming (31), hunting (28), golf (22), bowling (15), walking for exercise (13), gardening (12), dancing (11), hiking (9), bicycling (9), billiards (8), camping (7), water skiing (7), and tennis (5). Subjects were also asked to name activities that were important to them but which they had discontinued following amputation. Many amputees responded that their speed, degree of skill, or endurance in particular activities had been reduced, although they could still participate at a less vigorous or noncompetitive level. Some mentioned activities in a certain social context or stressed the aesthetic quality of a particular activity, such as "playing ball with my kids" and "squeezing sand and fresh mown grass between my toes." The most frequently mentioned activities that amputees could no longer perform were running and jogging (49 subjects), hiking or walking long distances (28), hunting (18), swimming (15), baseball (12), tennis (10), and dancing (9).

Subjective Complaints. Amputees were questioned specifically about the severity and frequency of pain in the amputation stump (residual limb). Table 11 depicts the severity of pain according to cause and level of amputation. About half of the respondents in each group described the presence of moderate or severe pain without a clear relationship to amputation level. The occurence of pain in the residual limb was described as "frequent" or "always" by 55% of the dysvascular group and 44% of the traumatic group. There was no clear-cut relationship between frequency of pain and the level of amputation, although there is a suggestion that those with dysvascular AK amputations suffered more in this respect.

Table 12 depicts the incidence of residual limb pain with respect to weightbearing and prosthesis use. Pain was associated with weightbearing most often in the dysvascular BK amputee. The remainder of amputees in both groups reported pain with about equal frequency while walking and at rest. More than half of the amputees in the traumatic group related pain in the residual limb to use of the prosthesis.

TABLE 11.
Severity and frequency of pain in the residual limb.

			Pain severity						Pain frequency			
Etiology	Level	(No.)	None-Mild		Moderate		Severe		Seldom-Never		Frequent/Always	
			No.	%	No.	%	No.	%	No.	%	No.	%
Dysvascular	AK	(9)	5	56	2	22	2	22	3	33	6	67
	BK	(22)	9	41	12	55	1	5	10	45	12	55
	Bilat	(11)	5	45	3	27	3	27	6	55	5	45
	Total	(42)	19	45	17	40	6	14	19	45	23	55
Trauma	AK	(38)	17	45	14	37	7	18	22	58	16	42
	BK	(77)	37	48	26	34	14	18	44	57	33	43
	Bilat	(17)	7	41	5	29	5	29	8	47	9	53
	Total	(132)	61	46	45	34	26	20	74	56	58	44
Combined total		(174)	80	46%	62	36%	32	18%	93	53%	81	47%

TABLE 12.
Complaints of pain with and without the prostheses, while walking and at rest.

Etiology	Level	No.	Pain with prostheses		Pain without prostheses		Pain with walking		Pain at rest	
			No.	%	No.	%	No.	%	No.	%
Dysvascular	AK	(8)	3	38	2	25	2	25	2	25
	BK	(20)	7	35	7	35	15	75	5	25
	Bilat	(9)	2	22	3	33	4	44	3	33
	Total	(37)	12	32	12	32	21	57	10	27
Trauma	AK	(36)	18	50	17	47	16	44	15	42
	BK	(65)	41	63	22	34	30	46	31	48
	Bilat	(13)	7	54	3	23	6	46	5	38
	Total	(114)	66	58	42	37	52	46	51	45
Combined total		(151)	78	52%	54	36%	73	48%	61	40%

TABLE 13.
Additional pain complaints.

Etiology	Level	No.	Phantom pain		Back pain		Groin pain		Pain in other leg	
			No.	%	No.	%	No.	%	No.	%
Dysvascular	AK	(8)	5	63	2	25	0	0	3	38
	BK	(20)	15	75	7	35	4	20	6	30
	Bilat	(9)	7	78	1	11	2	22	N.A.	
	Total	(37)	27	73	10	27	6	16	9	24
Trauma	AK	(36)	22	61	21	58	8	22	11	31
	BK	(65)	44	68	43	66	3	5	22	34
	Bilat	(13)	10	77	7	54	4	31	N.A.	
	Total	(114)	76	67	71	62	15	13	33	29
Combined Total		(151)	103	68%	81	54%	21	14%	42	29%

Table 13 indicates the incidence of additional pain complaints. Phantom pain occurred in about two-thirds of the amputees in both groups. Back pain occurred in more than half of the traumatic amputees and in less than a third of the dysvascular group.

In addition to pain complaints, amputees were asked specific questions about various prosthetic problems, as detailed in Tables 14 and 15. About one-half of the respondents in both the dysvascular and trauma groups reported "socket problems."* Complaints about the weight of the prosthesis were also common, with 54% of the dysvascular group and 32% of the trauma group stating that their prostheses were "too heavy." Perspiration problems were reported by 70% of the total respondent group. Only 15% of both groups felt that their prosthetic repairs were too frequent.

In terms of adequacy of **prosthetic training,** the dysvascular group as a whole was more satisfied than the trauma group. It should be noted that most dysvascular amputees had undergone amputation more recently, and had received most of their training in Veterans Administration facilities. Individuals in the trauma group had their amputations in a variety of settings following their war-related injuries and received their prosthetic training primarily in military hospitals.

Amputee reports of "tiring easily" were most frequently reported by the dysvascular group (86% of the dysvascular and 50% of the trauma subjects). The

* Table 16 confirms that veteran amputees find socket problems particularly troublesome. The table shows that by far the most common freely made complaint (written in by respondents in reply to a request to list their complaints) was improper fit of the socket and related skin problems.

TABLE 14.
Prosthetic problems reported by respondents in response to specific questioning.

Etiology	Level	Socket problems		Prosthesis heavy		Perspiration problems		Repairs too frequent	
		No.	%	No.	%	No.	%	No.	%
Dysvascular	AK	2	33	3	50	4	80	0	0
	BK	12	55	13	59	9	50	4	22
	Bilat	4	44	5	45	4	44	1	11
	Total	18	49	21	54	17	53	5	15
Trauma	AK	17	45	15	42	24	71	6	17
	BK	36	47	18	24	48	77	11	15
	Bilat	8	53	7	47	8	80	1	7
	Total	61	47	40	32	80	75	18	15
Combined Total		79	47%	61	37%	97	70%	23	15%

TABLE 15.
Problems using prosthesis reported by respondents in response to specific questions.

Etiology	Level	Training inadequate		Tire easily		Limp	
		No.	%	No.	%	No.	%
Dysvascular	AK	2	29	4	67	4	80
	BK	7	33	19	95	13	72
	Bilat	0	0	9	82	7	88
	Total	9	24	32	86	24	77
Trauma	AK	18	50	18	49	24	73
	BK	35	47	33	45	31	48
	Bilat	3	20	11	73	7	70
	Total	56	45	62	50	62	58
Combined Total		65	40%	94	58%	86	62%

TABLE 16.
Amputee suggestions and complaints: responses to the open-ended questions **"What do you not like** about your prosthesis?" and **"What would improve the prosthesis?"**

Complaints	No.	Percent
Improper fit/skin problems*	46	26
Functional deficiencies in limbs	26	15
Suspension problems	14	8
Foot complaints	11	6
Cosmesis	5	3
Noise	5	3
Suggestions for improvement		
Lighter weight prosthesis	39	22
More flexible foot/ankle design	12	7
Development of adjustable sockets	11	6
Better AK knee design	9	5
More research in materials, sensory feedback, powered limbs, etc.	9	5
Development of a cooling system	7	4
Waterproof limb	5	3

*Unlike Table 14, which represents the response to specific questions supplied by the questionnaire, the complaints listed here (TABLE 16) required the patients to enter-in their own complaints without any preselected category from the questionnaire.

dysvascular amputees and both bilateral groups reported this problem with the greatest frequency. "Limping" was also reported more frequently by the dysvascular group (77% of the dysvascular and 58% of the trauma subjects).

Responses to "Open-Ended" Questions. Amputees were asked two open-ended questions concerning what they did not like about their prostheses and what could be done to improve them. The most frequent responses are listed in Table 16, with the percent column referring to percent of the total sample of 179 respondents. While some amputees did not mention any specific problems, most reported one or two things that were particularly troublesome. The large number of complaints about improper socket fit and resultant skin and pain problems make this an important area of concern. The category of "functional deficiencies" includes a variety of complaints such as poor foot function, inadequate AK knee flexion, and inability to perform certain activities such as walking on uneven ground, or running. The most common sug-

gestion for improvement was to reduce the weight of the prosthesis. Some of the amputees suggested the need for development of adjustable sockets, improved suspension, and more naturally functioning components. While a few amputees wanted powered limbs and improved proprioceptive feedback, many others simply complained that their prosthesis was "just not the real thing."

Incidence of Prosthetic Replacement

The frequency of replacement of prostheses for the traumatic, service-connected veterans in the study population was determined by review of the Veterans Administration "Record of Prosthetic Services" forms. Similar data for non-service-connected veterans, mostly the dysvascular amputees, were not obtained since these veterans are usually eligible for only a single initial permanent prosthesis. Among the traumatic amputees it was found that the average number of new prostheses provided per amputated limb over a 10-year period was 4.0, with a range between one and nine. This indicates that the average prosthesis lasted 2.5 years. Above-knee amputees replaced their prostheses after an average of 3.1 years, and BK's after 2.1 years.

Individual Prosthetic Evaluations

Fifty-four subjects (30% of the questionnaire respondents) were seen in the laboratory for a physical examination, gait analysis, and evaluation of their prostheses. By etiology this included 11 dysvascular and 43 traumatic amputees, and by amputation level, 15 unilateral AK, 33 unilateral BK, and 6 bilateral amputees. In all, 57 prostheses were evaluated: 39 BK and 18 AK limbs. (Several bilateral amputees underwent evaluation of only one prosthesis). The 54 subjects who returned for evaluation were compared statistically with the remaining 125 subjects with respect to 45 dependent variables. There were a few statistically significant differences between the two groups. The group that underwent evaluation had more education ($P=0.0538$), needed fewer assistive devices for walking ($P=0.0230$), needed less home care ($P=0.0565$), and reported more pain while wearing their prostheses ($P=0.0188$).* For all other variables there were no statistical differences between the groups. This comparison suggests that patients who did not come in were less able to do so because of their mobility, and that those who did come in experienced more pain associated with use of the prosthesis. In other respects, the 54 amputees who returned for evaluation were found to be statistically representative of the entire sample of 179 who responded to the questionnaire.

The 57 prostheses evaluated had been worn for an average of 23 months. Twenty-two subjects were wearing limbs different from the ones they had received during the questionnaire sample period. Seven of these 22 amputees were wearing even older, "worn out" limbs because they felt their newer limbs were unsatisfactory or inferior. The remaining 15 subjects had obtained an even newer prosthesis more recently because the original limb had deteriorated with wear. Because the average age of the evaluated prostheses was about 2 years, some deterioration in socket fit, suspension, and general condition of the limbs could be expected.

The majority of the examined prostheses (87%) were judged to have been properly prescribed. The use of materials in fabrication of the prosthesis was judged to be correct in all cases, with the general workmanship exhibited by the prosthetist judged "good" in 75%, "fair" in 23%, and "poor" in only 2% of the limbs. Cosmesis was "good" in 78% of the limbs, "fair" in 20%, and "poor" in only 2%. The overall condition of the prostheses with regard to "wear and tear" deterioration was judged "good" in 41%, "fair" in 41%, and "poor" in 18% of the cases.

A significant number of deficiencies were identified in socket fit and construction, limb alignment, suspension, foot and ankle function, and AK knee mechanism function (see Tables 17 and 18). The following findings are based on the 39 BK and 18 AK limbs evaluated.

Below-Knee Prostheses Evaluated

Sockets. Twenty-three of the 39 BK prostheses (59%) were found to have significant socket deficiencies. Two categories of problems were identified: first, those relating to faulty initial socket construction, and second, those caused by amputee limb changes or normal socket and liner wear.

The first category includes sockets whose initial fabrication resulted in areas of excessive pressure or significant skin irritation caused by improper socket size or fit, an improperly shaped brim, or excessively rough surfaces. Fourteen of the 39 examined sockets (36%) fell into this first category, including eight poorly conforming sockets, eight with inadequate flaring of the popliteal brim, and three with improper shaping of the patellar bar. (A number of sockets exhibited multiple deficiencies.)

The lack of a gently curving popliteal flare was a common cause of excess pressure in the popliteal fossa, with consequent skin irritation and breakdown. An adequate popliteal flare should have a radius of curvature at least 0.75 inch (1.9 cm). In some instances

* Ordinal variables such as education and number of assistive devices were compared using a Mann-Whitney test. Nominal variables such as whether home care was needed or whether pain was reported were compared using a chi-square test.

TABLE 17.
Incidence of prosthetic problems in the 39 below-knee prostheses evaluated in the laboratory.

	Prosthetist/manufacturer related problems		Amputee/wear related problems		Total, limbs with problems*	
	No.	%	No.	%	No.	%
Sockets	14	36%	11	28%	23	59%
Alignment	14	36%	—	—	14	36%
Suspension	8	21%	12	31%	19	49%
Feet	19	49%	8	21%	26	67%

*Some prostheses exhibited both prosthetist-related and amputee-related problems.

TABLE 18.
Incidence of prosthetic problems in the 18 above-knee prostheses evaluated in the laboratory.

	Prosthetist/manufacturer related problems		Amputee/wear related problems		Total, limbs with problems*	
	No.	%	No.	%	No.	%
Sockets	10	56%	6	33%	14	78%
Alignment	8	44%	—	—	8	44%
Suspension	2	11%	1	6%	3	17%
Knees	—	—	11	61%	11	61%
Feet	11	61%	2	11%	12	67%

*Some prostheses exhibited both prosthetist-related and amputee-related problems.

in which the amputee had complained of popliteal discomfort, the problem had been compounded by cutting the popliteal area lower, thus leaving a sharp edge and decreasing stabilization of the limb on the patellar shelf.

The second category of BK socket-fit problems resulted from residual limb changes over time, and from socket and liner wear. Eleven of the 39 sockets (28%) fell into this category. Seven sockets fitted poorly as a result of changes in the volume of the residual limb, 5 had worn and misshapen liners, and 1 air-cushion socket had a hole in the distal end, resulting in a skin abrasion. While changes in the prostheses due to wear were expected, it was observed that advanced deterioration in the sockets and liners was the cause of discomfort, gait abnormalities, and skin breakdown in many amputees.

Alignment. Fourteen BK limbs (36%) were found to have faulty alignment, all associated with a resultant gait abnormality. The most common deficiency was inadequate foot outset as gauged by the length of the residual limb. This resulted in excessive lateral excursion of the knee during the prosthetic stance phase. Foot inversion and improper socket alignment were less frequent problems. An additional source of alignment problems for four amputees was the **wearing of shoes with an improper heel height.** Many amputees stated that they were not aware of the changes in stability and limb alignment resulting from the use of shoes with varying heel heights.

Suspension. Suspension problems were found in 19 (49%) of the BK limbs. Eleven of these problems resulted in gait deviations, primarily excessive pistoning of the prosthesis (more than 0.5 inch [1.2 cm]) during the weight acceptance and weight release phases of gait. Eight of these 19 problems were judged to be due to prosthetist error. There were four cases of improperly placed studs for the cuff suspension in patellar-

tendon-bearing prostheses. This resulted in inadequate suspension at varying degrees of knee flexion. Secondary overtightening of the strap caused excessive pressure in the popliteal area during stance. The other four involved improper placement of the medial wedge in those prostheses with supracondylar wedge suspension. The wedge was frequently placed at the level of the medial femoral condyle rather than over the soft tissues more superiorly. This prevented proper suspension since the soft tissues above the condyle were not adequately compressed. Painful pressure on the condyle frequently resulted, and auxiliary suspension was required in a few cases.

There were 12 suspension problems that were judged to be due to usage and wear, most commonly involving loose or worn patellar-tendon-bearing suspension cuff straps. Some cases of loose cuff straps resulted from stretching of the leather suspensory straps, a problem that could have been avoided by the use of reinforcing material with the leather.

Feet. Twenty-six of the 39 (67%) BK feet examined were found to be deficient. Inadequate foot function was the single most prevalent problem in the BK limbs. Sixteen of the 24 SACH feet examined had excessively stiff heel cushions. This was evidenced both by inadequate compression when manually tested and by improper foot function during gait. When a SACH foot is functioning properly during weight acceptance, the forefoot should reach the floor when the shank has attained an angle of 15 deg to the vertical. When the heel cushion is too firm or the shoe too tight to allow adequate heel compression, the amputee may "ride the heel" through much of the stance phase. Forefoot contact occurs later, when the shank has reached a more vertical position. This decreases knee stability, requiring increased muscular effort for knee control. In addition, there is lack of smooth roll-over with the delayed and abrupt transfer of weight to the forefoot.

The majority of the problems with the two-way and multiaxial feet involved bumpers that needed either replacement or adjustment to provide better plantar flexion function.

Above-Knee Prostheses Evaluated

Sockets. Fourteen of the 18 AK sockets (78%) were found to have significant deficiencies. Ten sockets were judged to be deficient as a result of errors in initial fitting or construction by the prosthetist. These included six sockets with inadequate flaring of the medial and anterior brims, five with improper initial socket size, two with very rough surfaces or edges, and two sockets with inadequate adduction of the lateral socket wall for stabilization of the femur during stance.

Six of the AK sockets did not fit properly because of residual limb changes resulting from weight gain or loss.

Alignment. A variety of alignment problems were found, affecting 8 (44%) of the AK limbs examined. These included unstable total knee arthroplasty alignment, improper hip joint, knee, or foot alignment, and various deficiencies in socket aligment. In four cases the faulty alignment resulted in gait deviations such as severe "whip."

Suspension. Suspension problems were relatively infrequent, involving three (17%) of the AK limbs examined. These problems included loss of suction in a poorly fitting suction socket, loosening and wear of a hip joint, and one case in which the addition of auxiliary suspension was required to control medial socket rotation. Two of these cases were associated with gait deviations.

Knees. Eleven of the AK knees (61%) were judged faulty in some respect. However, all of these problems were the result of normal wear and tear. The most common problems were loose and worn bearings in the knee bolt or hydraulic damper and malfunctioning of swing-control mechanism. Three amputees showed significant gait deviations resulting from knee mechanism malfunction.

Feet. Twelve of the AK feet examined (67%) exhibited problems. As with the BK feet, the primary problem was excessive heel cushion stiffness resulting in inadequate plantar flexion function during gait. Eleven out of 13 of the SACH feet showed this deficiency.

Skin Problems in Residual Limbs

As detailed in Table 19, 16 (41%) of the BK and 4 (22%) of the AK residual limbs examined showed significant signs of mechanical skin irritation or breakdown. In most cases, one or more prosthetic deficiencies could be identified as contributing to the residual limb problem. The most prevalent causes in the BK amputees were faulty initial socket fit and construction (11 of 16 cases), deficient suspension (5 of 16 cases), and socket fit problems due to residual limb changes or socket wear (4 of 16 cases).

For the AK amputees, the causes of residual limb breakdown included weight gain or loss, lack of socket relief laterally for the distal femur, and a high, improperly flared medial brim.

Mobility Problems

Three AK and three BK amputees experienced prosthetic problems severe enough to seriously impair

TABLE 19.
Contributory prosthetic causes of residual limb breakdown in sixteen below-knee and four above-knee amputees evaluated in the laboratory.

	BK's (n=39)		AK's (n=18)	
	No.	%	No.	%
Faulty socket fit or construction	11	28%	2	11%
Residual limb changes/ socket wear	4	10%	2	11%
Improper alignment	2	5%	—	—
Suspension problems	5	13%	—	—
Unknown	2	5%	—	—
Total residual limb problems:	16	41%	4	22%

Note: More than one cause may apply to a particular amputee.

their usual mobility and activity level. In the AK amputees the underlying cause was most often a poorly fitting socket, resulting in skin breakdown. Excessive weight of the prostheses and other prosthetic deficiencies also played a role. For the BK's, the usual causative factor was a poorly fabricated socket resulting in residual limb breakdown.

DISCUSSION

The composition of this study population differs from that of many previous amputee studies (1–10) in which dysvascular disease accounts for the majority of amputations. The preponderance of traumatic amputees in our survey is explained by Veterans Administration regulations which determine eligibility for outpatient prosthetics care (11). Those veterans with limb loss due to service-connected causes, usually war-related trauma, are entitled to unlimited outpatient prosthetics care. However, those with amputations secondary to non-service-connected causes (such as dysvascular disease or malignancy) are permitted only a single initial prosthetic fitting. Not all of these newer amputees are able to use a prosthesis. Thus, despite the fact that most new amputations are performed for dysvascular disease in our Veterans Administration facilities, service-connected traumatic amputees receive the large majority of new prosthetic devices in the outpatient departments.

An amputee's functional capabilities and pattern of prosthetic use determine to a significant extent his prosthetic requirements. The survey data suggest that, in most cases, the veteran amputee who sustained his limb loss from trauma in his twenties exhibits different functional capabilities an average of 20 years later than does the one in his fifties or sixties who has undergone a more recent amputation for dysvascular disease. Our study results agree with the observations of Kegel et al. that older amputees and those with more proximal amputations have fewer functional capabilities (6). In the case of the typical traumatic amputee, the treatment goal is to provide a prosthesis that is comfortable, durable, and well suited to his specific employment and recreational needs. Equally as important is the need to provide on-going diagnosis and treatment of new medical or orthopaedic problems which might affect prosthetic function. The primary goal of outpatient prosthetics care for the elderly dysvascular veteran amputee is to provide a single permanent prosthesis that is well-fitted, lightweight, and stable.

The extent to which these treatment goals were being attained was assessed in this study both by surveying a portion of the population treated and by performing individual prosthetic evaluations in a representative group. **The most striking finding from the survey is the high incidence of residual limb discomfort.** Residual limb pain which was moderate to severe in intensity was reported by 54% of both the traumatic and dysvascular amputees. The occurrence of pain was judged to be "frequent" or "always" by 55% of the dysvascular and 44% of the traumatic amputees. The pattern and probable cause of such pain were difficult to discern from the questionnaire responses. Within the dysvascular group, twice as many of the amputees noted pain while walking than when at rest—three-quarters of the dysvascular BK amputees complained of pain while walking. The incidence of pain in the dysvascular group as a whole did not appear to be related directly to whether or not the prosthesis was on or off. Within the traumatic group, residual limb pain occurred with equal frequency when at rest and while walking. However, 58% of these amputees associated pain with wearing of the prosthesis, while 37% noted pain without it.

The unclear relationship between residual limb pain and either walking or simple wearing of the prosthesis may be due to several factors. In some individuals, it is possible that reduced blood flow to the residual limb at rest results in "achiness." In others, local irritation from the socket brim may be accentuated by sitting for extended periods. In BK amputees, for example, local pressure may be caused during sitting by impingement of the popliteal flare of the socket. In AK amputees similar complaints may occur in the groin and

inguinal regions. Pain from other sources, such as phantom sensation or symptomatic neuromata, is known to fluctuate depending both on activity level and on simple wearing of the prostheses.

The frequency of complaints of residual limb pain warrants an explanation. Certainly an ill-fitting socket with resultant high pressure areas and skin irritation will cause increased pain. About half of the amputees in both the dysvascular and traumatic groups reported problems with socket fit. Such problems may result from changes in residual limb size and shape over time or from deterioration of the socket and its liner due to excessive wear. Equally as important, pain and skin breakdown in the residual limb may result from inadequacies in the socket construction due to an improper initial fitting. Lastly, deficiencies in prosthetic suspension, alignment, or foot function may increase shear forces between the skin and the socket, thus adding to pain from improper socket fit.

The individual prosthetic evaluations were carried out to gauge the prevalence and type of prosthetic deficiencies in the surveyed population. **It is important to note** that these evaluations were performed an average of 23 months after the questionnaires were answered. Many of the amputees had obtained new replacement prostheses for one reason or another and thus were wearing limbs different from those at the time of the survey. For this reason, direct statistical correlations were not sought between the individual questionnaire responses and the findings from the prosthetic evaluations.

The prosthetic evaluations produced several noteworthy findings. First, there was a high incidence of improper socket fit. This problem was found in 59% of the BK and 78% of the AK prostheses examined. Most of these problems of poor fit were due to improper initial socket construction. Improper shaping of the socket margins was the most frequently observed deficiency. The remainder of the problems were due to amputee-related factors such as changes in stump size due to weight fluctuations or to deterioration of the socket or liner.

The next finding of note was the frequency of mechanical skin irritation and breakdown in the residual limbs examined. This problem was found in 41% of the BK and 22% of the AK amputees. Faulty socket construction or fit was judged to be directly contributory in more than half of these cases. The remaining problems appeared to arise from amputee weight fluctuations or advanced wear of the socket or liner. Among the BK amputees, faulty suspension and alignment were found to be contributing directly to skin irritation in some cases.

Deficiencies in prosthetic suspension, alignment, and foot function were common in the group as a whole and were often associated with compensatory gait deviations. Suspension problems were found to be due with equal frequency to excessive wear of the suspensory apparatus and to faulty initial adjustment. Malalignment problems were most frequently a result of improper prosthetic construction, although the wearing of shoes with improper heel height occasionally resulted in such problems.

SACH Foot Problem — The frequent finding of excessive stiffness of SACH foot heel cushions in the evaluated limbs deserves special attention. As originally designed, the cushion of the SACH foot extends anteriorly into the mid-arch region (Fig. 1a). The stiffness of the heel cushion is varied according to the weight of the amputee, and plantar flexion alignment of the foot is adjusted according to the height of the

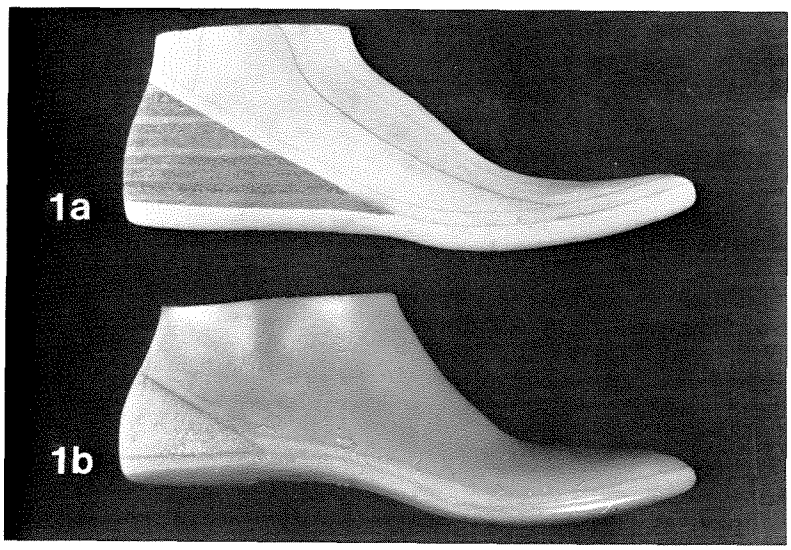

FIGURE 1
Note the difference in the shape of the heel cushion wedge in the SACH foot as originally designed (1a) and in a commercially available model (1b). The cushion in the latter model is inadequate to provide normal roll-over function.

shoe heel. When a SACH foot is functioning properly, there is smooth roll-over of the foot and shank during the stance phase of gait as weight is transferred from the prosthetic hindfoot onto the anterior heel. An excessively stiff SACH heel will cause the amputee to "ride the heel" during stance, with greater muscular effort being required to control stability of the knee upon heel strike. As weight is transferred abruptly from prosthetic hindfoot to forefoot, there is a sudden, jerky hesitation of the knee as a result of a backward force exerted on the shank. (Similar problems occur if the toe lever arm of the prosthetic foot is too long or if the foot is too plantar flexed.) Poor function of the SACH foot heel cushion appears to be due partly to design changes by manufacturers that have resulted in shorter, stiffer cushions (Fig. 1b). The problem is compounded further when heel cushion stiffness is not matched to the amputee by body weight. And occasionally shoes are too snug to permit adequate expansion of the cushion during weight acceptance, resulting in stiffer function.

Most of the amputees whom we interviewed recognized the strong correlation between improper socket fit and mechanical skin breakdown and pain. However, inadequacies in prosthesis suspension, alignment, or foot function frequently were not recognized as such. Rather, they were manifested by compensatory deviations in gait or by changes in type and amount of daily activity. Frequently, amputees indicated their assumption that these problems were unavoidable. However, it was noted that those with greater functional demands, usually the younger and more experienced amputees, tended to judge their prosthetic devices more critically than those who were less active. We made the repeated clinical observation that correction of specific prosthetic deficiencies led to a significant reduction in residual limb discomfort in those amputees with this complaint.

From the results of this study, we conclude that a logical approach to reducing the incidence of residual limb pain complaints in this veteran amputee population would be to reduce the incidence of prosthetic deficiencies. Earlier identification and correction of problems in prosthetic wear and maintenance, both by the amputee and by outpatient personnel, are indicated. Greater emphasis on control of body-weight fluctuations which result in changes in the size or shape of the residual limb would be of benefit. Improvement in the accuracy of the initial fitting of the socket and other aspects of prosthetic fabrication is indicated. Current outpatient treatment protocols in our medical centers do not include a mandatory review of new prostheses[b] to permit routine assessment of function, degree of comfort, and quality of construction. Crowded or inconvenient clinic schedules discourage some amputees from seeking solutions to problems related to newly delivered or aging limbs. There is a clear need for new research to provide more accurate, foolproof techniques for the fitting and fabrication of sockets. The design of a socket system which could be adjusted to compensate for small fluctuations in residual limb volume could prove beneficial in some cases. Research which would lead to greater standardization of SACH foot design and function should be carried out

[b] The contract currently in use between the Veterans Administration Prosthetic and Sensory Aids Service and commercial prosthetic facilities supplying veteran beneficiaries with new limbs or providing major limb-repairs, reads in part as follows:

> 6. MEASUREMENT, FITTING AND DELIVERY:
> A. Measurement and fitting of new limbs will normally be made at the contractor's facility.
> B. Delivery of new limbs or limbs which had major repair will be done in the following manner:
>
> (1) Veterans who are experienced prosthetic wearers may, upon satisfactory fitting, accept the delivery of the prosthesis at the contractor's facility. In these cases, the contractor should have the veteran sign an acceptance receipt, which the contractor will attach to, and forward with, his invoice to support payment. EXAMPLE: ACCEPTANCE RECEIPT:
>
> "The articles/services listed hereon have been received/rendered, as ordered, or as shown by authorized changes indicated below, and are acceptable."
>
> Signature: _____
>
> If the veteran finds that the prosthesis does not fit properly, and further adjustments are required, the contractor will make the necessary changes/adjustments if possible, immediately. When further adjustment cannot be accomplished during the veteran's visit the Contractor will deliver the readjusted prosthesis to the ordering facility for final acceptance and payment.
> (2) Artificial limbs for new veteran amputees who are not experienced wearers will normally be delivered to the ordering VA facility for acceptance. Exceptions may be granted by the Chief, Prosthetic Activity or the prescribing physician if it is believed to be in the best interest of the veteran.

as well. The Veterans Administration is ideally suited to initiate such research studies since it carries a legislative mandate to undertake prosthetics research as well as to provide clinical prosthetics care.

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